Table A-1. HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access and stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May affect juvenile survival, growth, and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect adult spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered sediment transport	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability as a result of beach erosion from altered sediment supply.	Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous	Juveniles	Juveniles: Sediment supply and substrate composition are core ecosystem characteristics that compose the nearshore ecosystem. Alteration in these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile Chinook salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effects of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. **Risk of take = H**
	Altered substrate composition		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of longitudinal (i.e., upstream-downstream) habitat connectivity; change in habitat structure, availability, and suitability.	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Dams can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types if the dam presents a barrier to fish passage. Even when passage is provided, limitations on upstream migration may lead to decreased survival and spawning productivity due to delayed migration, increased exposure to predation and poaching, and other related stressors. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Minimize severing upstream-downstream connectivity by installing fish passage.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dam placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible. Encourage spillway design to promote moderation of stream temperatures in downstream reaches.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species.	Year-round	Permanent	Continuous	Juveniles	Juveniles: Dams create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased incubation success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of project in areas with spring, seeps, or other source of significant groundwater recharge. Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, as well as adult spawning productivity.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modification								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses for altered dissolved oxygen under Water Quality Modification.		See effects for related stressors of altered dissolved oxygen under Water Quality Modification.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Provide sufficient streamflows to avoid temperature effects in reaches downstream of the impoundment. Promote dam designs that limit impoundment effects on downstream temperatures (e.g., draw streamflows from impoundment below the stratification layer in summer).	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.	Avoid large sediment pulses during construction and dam removal where practicable.	May affect juvenile survival, growth and fitness as well as adult survival and spawning productivity.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All exposes life history stages: Dam removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to dam removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increases may result form decreased nutrient cycling from loss of riparian, aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Dam construction and operation may lead to introductions of toxic substances through accidental spills or other pathways. Impoundments may attract increased recreational vessel activity, creating a pathway for chronic exposure to hydrocarbons and other contaminants. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Require a spill control and containment plan for dam operations if appropriate. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access and stranding (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.

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Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability.	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Weirs can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Upstream migration is limited causing reduced and delayed migration, increased predation. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Minimize severing upstream-downstream connectivity by installing fish passage.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage weir placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species	Year-round	Permanent	Continuous	Juveniles	Juveniles: Weirs may create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased incubation success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, as well as adult spawning productivity.
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses for altered dissolved oxygen under Water Quality Modification.		See effects for related stressors of altered dissolved oxygen under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. <u>Juveniles and adults</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. <u>Adults</u>: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>All exposed life history stages:</u> Weir removal may lead to rapid release of contaminated sediments accumulated upstream of weirs creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to weir removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and productivity of juveniles and adults.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increases may result form decreased nutrient cycling from loss of riparian, aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Weir construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Dikes/Levees									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Flow Bypass, Fish Handling, and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. <u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. <u>Juveniles</u>: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. <u>Adults</u>: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	<u>Eggs and alevins, juveniles</u>: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Potential redd scour and/or sedimentation, resulting in decreased incubation success. <u>Juveniles</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. <u>Adults</u>: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>Juveniles</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. <u>Adults</u>: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. <u>Juveniles</u>: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. <u>Adults</u>: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	<u>Juveniles</u>: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	Egg and alevin mortality or injury is highly likely if exposure occurs. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile Chinook salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effects of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns.	May affect survival, growth, and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult Chinook salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. Adult Chinook will generally be less sensitive to these stressors. However, increased stress and delayed migration in the migratory corridor may reduce fitness and ultimately reduce spawning success.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns.	May affect survival, growth, and fitness at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: Dikes and levees can force channel incision, or directly sever connection leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Reduced availability of thermal refuge and decreased intragravel DO, nutrient cycling effects	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Decreased hyporheic exchange may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. <u>Adults and juveniles</u>: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. <u>Adults</u>: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dike/levee placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	<u>All exposed life-history stages</u>: Dikes and levees in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Lacustrine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	<u>All exposed life-history stages</u>: Dikes and Levees permanently fragment lacustrine habitats. For salmonids, loss of nearshore habitats may result. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles and adults: Decreased availability of thermal refuge habitat, limiting juvenile survival, growth, and fitness. May limit adult survival and spawning productivity. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other source of significant groundwater recharge. Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.
	Marine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round, (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Chinook dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, Chinook are known to utilize terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile survival, growth, and fitness.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Chinook dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of current patterns, wind conditions, and other factors. However, juveniles trapped in isolated habitats by such as artificial embayments with narrow outlets may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth and fitness.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs	Year-round (stressor exposure occurs predominantly during spring outmigration period through lakes)	Permanent	Continuous	Juveniles	Juveniles: Chinook are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during predominantly during spring outmigration period through lakes)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile survival, growth, and fitness.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during predominantly during spring outmigration period through lakes)	Permanent	Continuous	Juveniles	Juveniles: Chinook dependence on groundwater inflow to nearshore lacustrine habitats is currently a data gap.	Avoid disturbance of vegetation along the shoreline.	Effects of the action resulting from this impact mechanism are unknown.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile survival, growth, and fitness, as well as adult spawning productivity.
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity.		May affect juvenile survival. May affect adult growth and spawning fitness.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Outfalls									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Flow Bypass, Fish Handling and Channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile Chinook salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effects of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult Chinook salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. Adult Chinook will generally be less sensitive to these stressors. However, increased stress and delayed migration in the migratory corridor may reduce fitness and ultimately reduce spawning success.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns.	May affect survival, growth, and fitness at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of longitudinal connectivity may result from water quality barrier when high effluent discharge causes chemical barrier to migration. If constructed parallel to the channel, side channel and floodplain habitat may become fragmented. These actions will result in changes in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: High flow outfalls can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Marine and Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Outfalls in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	The degree to which outfalls affect riparian vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine environments.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults		Avoid disturbance of vegetation along stream.	
	Marine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round, (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth and fitness.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Chinook dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, Chinook are known to utilize terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and fitness.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles	The degree to which outfalls affect riparian vegetation conditions in lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in lacustrine environments.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs	Year-round (stressor exposure occurs predominantly during spring outmigration period through lakes)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during predominantly during spring outmigration period through lakes)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of habitat features.	

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses for altered dissolved oxygen concentrations under Water Quality Modification.		See effects for related stressors for altered dissolved oxygen concentrations under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity.		May affect juvenile survival. May affect adult growth and spawning productivity.
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which outfalls affect aquatic vegetation conditions in riverine and lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine and lacustrine environments.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Water Quality Modification								
		Altered thermal regime (i.e., increased summer temperatures due to elevated effluent temperatures relative to receiving body)	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect juvenile survival and fitness. May affect adult survival and spawning productivity.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered nutrient cycling (due to effects of effluent discharge)	During and following discharge events	Long-term to permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: nutrient increases may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate effluent potential to adversely affect eutrophication. Require or encourage use of upstream treatment measures prior to discharge.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.
Water Intakes /Diversion Structures									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile Chinook salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effects of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching])	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult Chinook salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. Adult Chinook will generally be less sensitive to these stressors. However, increased stress and delayed migration in the migratory corridor may reduce fitness and ultimately reduce spawning success.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns.	May affect survival, growth and fitness at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability.	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Intakes and diversions can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Upstream migration is limited causing reduced and delayed migration, increased predation. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Minimize severing upstream-downstream connectivity by installing fish passage.	May affect survival, growth, and fitness at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered groundwater-surface water exchange	Accumulation of fines will reduce hyporheic exchange, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. <u>Adults and juveniles</u>: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. <u>Adults</u>: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage intakes and diversions placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Marine and Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	<u>All exposed life-history stages</u>: Intakes and diversions in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Loss of LWD recruitment	Reduced availability of LWD from drift. Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival, growth, and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Direct mortality due to winter ice formation and scour. <u>Juveniles</u>: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. <u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. <u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile survival, growth and fitness, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased incubation success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, as well as adult spawning productivity.
	Marine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round, (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth and fitness.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Chinook dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, Chinook are known to utilize terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile survival, growth, and fitness.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Chinook dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.
	Lacustrine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by lake currents may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs	Year-round (stressor exposure occurs predominantly during spring outmigration period through lakes)	Permanent	Continuous	Juveniles	Juveniles: Chinook are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during predominantly during spring outmigration period through lakes)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile survival, growth, and fitness.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during predominantly during spring outmigration period through lakes)	Permanent	Continuous	Juveniles	Juveniles: Chinook dependence on groundwater inflow to nearshore lacustrine habitats is currently a data gap.	Avoid disturbance of vegetation along the shoreline.	Effects of the action resulting from this impact mechanism are unknown.
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles;	Juveniles: See related stressor responses for altered dissolved oxygen under Water Quality Modification.		See effects for related stressors of altered dissolved oxygen under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile growth, and fitness.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses for altered dissolved oxygen concentrations under Water Quality Modification.		See effects for related stressors for altered dissolved oxygen concentrations under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity.		May affect juvenile survival, growth, and fitness.
	Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses for altered dissolved oxygen concentrations under Water Quality Modification.		See effects for related stressors for altered dissolved oxygen concentrations under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile growth, and fitness.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Ensure that appropriate instream flows necessary to regulate temperature and other habitat parameters are maintained.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Avoid nutrient inputs when possible.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. Physiological injury may affect survival, growth and fitness of juveniles. May affect adult survival and spawning productivity.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Tide Gates									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May cause direct mortality to eggs and alevins. May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
		Loss of habitat, stranding from dewatering (during construction, maintenance, and removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and tidal exchange are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile Chinook salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effects of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities and tidal exchange		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time	Permanent	Continuous				
	Altered channel geometry		Year-round	Permanent	Continuous				

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation of habitat	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Juveniles; Adults	<u>All exposed life-history stages</u>: Tide gates can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Upstream and downstream migrations are limited causing reduced and delayed migration and increased predation. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Limit length of time tide gates are closed as much as possible.	May affect survival at juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit length of time tide gates are closed as much as possible. No additional specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Marine								
	Lateral and longitudinal fragmentation of habitat	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	<u>All exposed life-history stages</u>: Tide gates in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. Limit length of time tide gates are closed as much as possible.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Loss of LWD recruitment	Reduced availability of LWD from drift. Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit length of time tide gates are closed as much as possible. Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival, growth, and fitness.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tidegates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults		Avoid disturbance of vegetation along stream.	

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Marine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round, (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tidegates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of habitat features.	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid disturbance of vegetation along shoreline.	

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile growth, and fitness.
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. May affect eventual spawning productivity.		May affect juvenile survival. May affect adult growth and ultimate spawning productivity.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect juvenile growth and fitness and adult productivity and spawning success. May cause direct mortality in acute events.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. Intermediate-term effluent effects on receiving body pH may alter habitat suitability.	Avoid curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered salinity	Year-round	Long-term to permanent	Intermittent (daily)	Juveniles	Juveniles: Altered salinity patterns may limit habitat suitability for juvenile rearing in nearshore marine environments. This in turn may increase competition for available habitats, limiting survival, growth, and fitness.	Limit closure time of tide gate to maximize natural tidal exchange.	May affect juvenile survival, growth, and fitness.

Table A-1 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chinook Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect juvenile and adult survival, growth, and fitness.
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Juveniles	Tidegate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent. Exposure to toxic substances may lead to behavioral avoidance in adults. For juveniles, limitations in the availability of suitable juvenile rearing habitat, or potential physiological injury may affect survival, growth, and fitness.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect adult behavior. May affect juvenile survival, growth, and fitness.

Table A-2. HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. May cause direct mortality or injury.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lateral and Longitudinal habitat Fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of longitudinal (i.e., upstream-downstream) habitat connectivity; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Dams can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types if the dam presents a barrier to fish passage. Even when passage is provided, limitations on upstream migration may lead to decreased survival and spawning productivity due to delayed migration, increased exposure to predation, poaching, and other related stressors. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Minimize severing upstream-downstream connectivity by installing fish passage.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dam placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible. Encourage spillway design to promote moderation of stream temperatures in downstream reaches.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered Community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species.	Year-round	Permanent	Continuous	Juveniles	Juveniles: Dams create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Direct mortality due to winter ice formation and scour. <u>Juveniles</u>: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. <u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. <u>Adults:</u> Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	<u>Eggs/alevins:</u> Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. <u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. <u>Adults:</u> Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	<u>Juveniles:</u> Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	<u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. <u>Adults:</u> Increased mortality, decreased fitness, and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity.
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize alteration and shading of native aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Altered thermal regime	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Provide sufficient streamflows to avoid temperature effects in reaches downstream of the impoundment. Promote dam designs that limit impoundment effects on downstream temperatures (e.g., draw streamflows from impoundment below the stratification layer in summer).	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats	Avoid large sediment pulses during construction and dam removal where practicable. Promote use of dam designs that maintain stream temperatures within desirable limits to limit DO effects.	May affect juvenile survival, growth and fitness as well as adult survival and spawning productivity.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Dam removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to dam removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Dam construction and operation may lead to introductions of toxic substances through accidental spills or other pathways. Impoundments may attract increased recreational vessel activity, creating a pathway for chronic exposure to hydrocarbons and other contaminants. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Require a spill control and containment plan for dam operations if appropriate. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources	May affect survival, growth and fitness at all exposed life history stages.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	Should exposure occur, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	Should exposure occur, decreased survival is likely. May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. Should exposure occur, direct mortality or injury is probable.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access and stranding (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Weirs can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage weir placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species	Year-round	Permanent	Continuous	Juveniles	Juveniles: Weirs may create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. Adults: Increased mortality, decreased fitness, and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Decreased incubation success. <u>Juveniles</u>: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. <u>Adults</u>: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity.
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	<u>Juveniles</u>: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	<u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	<u>Juveniles and adults</u>: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	<u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Altered thermal regime (i.e., increased summer temperatures)\	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	<u>Juveniles</u>: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. <u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. <u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers.	Provide sufficient streamflows to avoid temperature effects in reaches downstream of the impoundment. Promote weir designs that limit impoundment effects on downstream temperatures (e.g., draw streamflows from impoundment below the stratification layer in summer).	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. <u>Juveniles and adults</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. <u>Adults</u>: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>All expose life history stages:</u> Weir removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to weir removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages. **Risk of take = M to H** (depending on contaminants, exposure parameters, and sensitivity of exposed life history stages)
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs and no direct waste discharge. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>All expose life history stages:</u> Weir construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dikes/Levees									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling, and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile coho. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns.	May affect juvenile survival, growth, and fitness.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory coho salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns.	May affect juvenile survival, growth, and fitness.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat, change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Dikes and levees can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Reduced availability of thermal refuge and decreased intragravel DO, nutrient cycling effects	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dike/levee placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Dikes and levees in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Lacustrine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Dikes and levees in lacustrine environments can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. Adults: Increased mortality, decreased fitness, and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity.
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. This effect may be limited in magnitude, however, as juvenile coho use of littoral habitats is relatively limited.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and growth.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as juvenile coho use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Coho dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, coho are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Coho dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival growth and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Coho dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. However, coho are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth, fitness, and survival.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and fitness.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Coho dependence on groundwater inflow to littoral lacustrine habitats is currently a data gap. However, loss of groundwater may lead to reduction in shallow water thermal refuge, increased competition, and decreased foraging opportunity.	Avoid disturbance of vegetation along shoreline.	May affect juvenile survival, growth, and fitness.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.		May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Outfalls									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and Alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling, and Channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. <u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation. <u>Juveniles</u>: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. <u>Adults</u>: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. May cause direct mortality or injury.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile coho. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect juvenile survival, growth, and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history stage.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory coho salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns. Profile characteristics where impacts are unavoidable.	May affect juvenile survival, growth, and fitness at the juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of longitudinal connectivity may result from water quality barrier when high effluent discharge causes chemical barrier to migration. If constructed parallel to the channel, side channel and floodplain habitat may become fragmented. These actions will result in changes in habitat structure, availability, and suitability; reduced food web complexity.	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: High flow outfalls can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Marine and Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Outfalls in the marine and lacustrine environments can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	The degree to which outfalls affect riparian vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine environments.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. This effect may be limited in magnitude, however, as juvenile coho use of littoral habitats is relatively limited.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and growth.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as juvenile coho use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Coho dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, coho are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The degree to which outfalls affect riparian vegetation conditions in lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in lacustrine environments.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses for altered dissolved oxygen levels under Water Quality Alteration.	Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	See effects for related stressors for altered dissolved oxygen levels under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.		May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which outfalls affect aquatic vegetation conditions in riverine and lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from aquatic vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine and lacustrine environments.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Water Quality Modification								
		Altered thermal regime (i.e., increased summer temperatures due to elevated effluent temperatures relative to receiving body)	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling (due to effects of effluent discharge)	During and following discharge events	Long-term to permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increases may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate effluent potential to adversely affect eutrophication. Require or encourage use of upstream treatment measures prior to discharge.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect juvenile growth and fitness, may affect adult spawning productivity.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	<u>Juveniles</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile coho. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles	<u>Juveniles</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory coho salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. Profile characteristics where impacts are unavoidable.	May affect juvenile survival, growth, and fitness.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition and stability		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Intakes and diversions can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fines will reduce hyporheic exchange, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage intakes and diversions placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Marine and Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Intakes and diversions in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Loss of LWD recruitment	Reduced availability of LWD from drift. Reduced availability of LWD from drift. Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. Adults: Increased mortality, decreased fitness, and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity.
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. This effect may be limited in magnitude, however, as juvenile coho use of littoral habitats is relatively limited.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and growth.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as juvenile coho use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and fitness.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Coho dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, coho are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Coho dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival growth and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Coho dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. However, coho are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth, fitness, and survival.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and fitness.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Coho dependence on groundwater inflow to littoral lacustrine habitats is currently a data gap. However, loss of groundwater may lead to reduction in shallow water thermal refuge, increased competition, and decreased foraging opportunity.	Avoid disturbance of vegetation along shoreline.	May affect juvenile survival, growth, and fitness.
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.		May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity.
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Ensure that appropriate instream flows necessary to regulate temperature and other habitat parameters are maintained.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Avoid nutrient inputs when possible.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>All expose life history stages:</u> Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Tide Gates									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane (flood gates only) ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow Bypass, fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins (flood gates only) and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins(flood gates only): Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins(flood gates only): Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; mMay affect adult fitness and spawning productivity. Should exposure occur, direct mortality or injury is probable.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat, stranding from dewatering (during construction, maintenance, and removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins(flood gates only): Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins(flood gates only): Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile coho. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect juvenile survival, growth, and fitness. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities and tidal exchange		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered channel geometry		Year-round	Permanent	Continuous				

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation of habitat	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: Tide gates can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Upstream and downstream migrations are limited causing reduced and delayed migration and increased predation. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Limit the length of time that tide gates are closed as much as possible.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit the length of time that tide gates are closed as much as possible. No additional specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Marine								
	Lateral and longitudinal fragmentation of habitat	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	<u>All exposed life-history stages</u>: Tide gates in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Loss of LWD recruitment	Reduced availability of LWD from drift Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit the length of time that tide gates are closed as much as possible. Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival, growth and fitness.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tide gates is considered to be a component of the effects of dikes and levees. The incremental effects of the tide gate are negligible in comparison.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Marine and Lacustrine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tidegates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid disturbance of vegetation along shoreline.	
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.	Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. May affect eventual spawning productivity		May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Allow inundation to occur in areas where temperature fluctuations imposed by reduced exchange may affect aquatic life.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.

Table A-2 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coho Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins(flood gates only): Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered salinity	Year-round	Long-term to permanent	Intermittent (daily)	Juveniles	Juveniles: Altered salinity patterns may limit habitat suitability for juvenile rearing in nearshore marine environments. This in turn may increase competition for available habitats, limiting survival, growth, and fitness.	Limit closure time of tide gate to maximize natural tidal exchange.	May affect juvenile survival, growth, and fitness.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect juvenile and adult survival, growth, and fitness.
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Juveniles	Tide gate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent. Exposure to toxic substances may lead to behavioral avoidance in adults. For juveniles, limitations in the availability of suitable juvenile rearing habitat, or potential physiological injury may affect survival, growth, and fitness.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect adult behavior. May affect juvenile survival, growth, and fitness.

Table A-3. HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Potential redd scour and/or sedimentation, resulting in decreased incubation success. <u>Juveniles</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. <u>Adults</u>: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. <u>Juveniles</u>: Migration delay, and increased predation risk. <u>Adults</u>: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. May cause direct mortality or injury.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	<u>Juveniles</u>: Effects on chum salmon will be relatively minimal due to limited dependence on freshwater foraging.	Limit area of dewatering to the greatest extent practicable.	Temporary localized reductions in invertebrate abundance would not be expected to adversely affect juvenile chum salmon.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Potential decreased egg incubation success and alevin survival due to water loss and stranding. <u>Juveniles</u>: Barrier to migration, loss of habitat accessibility, stranding, migration delay, increased predation risk. Stranding may lead to direct mortality. <u>Adults</u>: Potential migration barrier and delay, leading to reduced spawning productivity., Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	<u>Juveniles and adults</u>: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Mortality or injury from entrainment. <u>Juveniles</u>: Altered migratory behavior. Decreased growth and fitness. <u>All life-history stages</u>: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Marine								
	Altered sediment transport	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability as a result of beach erosion from altered sediment supply.	Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous	Juveniles	Juveniles: Sediment supply and substrate composition are core ecosystem characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile chum. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply to marine environments.	May affect juvenile survival, growth, and fitness. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered substrate composition		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Lateral and Longitudinal habitat Fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of longitudinal (i.e., upstream-downstream) habitat connectivity; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Dams can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types if the dam presents a barrier to fish passage. Even when passage is provided, limitations on upstream migration may lead to decreased survival and spawning productivity due to delayed migration, increased exposure to predation, poaching, and other related stressors. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Minimize severing upstream-downstream connectivity by installing fish passage.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dam placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible. Encourage spillway design to promote moderation of stream temperatures in downstream reaches.	May affect egg and alevin survival, May affect adult spawning productivity.
	Altered Community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species.	Year-round	Permanent	Continuous	Juveniles	Juveniles: Dams create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: : Limited effects from food web alteration due to minimal dependence on freshwater forage resources.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Unlikely to affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Increased predation exposure. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased incubation success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect adult spawning productivity.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Chum dependence on autochthonous inputs from aquatic vegetation is limited, as this species does not forage in riverine and lacustrine environments. Therefore, effects on juvenile chum growth and fitness will be limited.	Design: Limit project structural footprint to minimize alteration and shading of native aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Impact mechanism is unlikely to affect chum salmon.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability, potentially leading to altered migratory behavior and increased predation exposure.		May affect juvenile survival.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Provide sufficient streamflows to avoid temperature effects in reaches downstream of the impoundment. Promote dam designs that limit impoundment effects on downstream temperatures (e.g., draw streamflows from impoundment below the stratification layer in summer).	May affect survival of eggs, alevins and juveniles. May affect adult spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats	Avoid large sediment pulses during construction and dam removal where practicable.	May affect juvenile survival, growth and fitness as well as adult survival and spawning productivity.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Dam removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to dam removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Dam construction and operation may lead to introductions of toxic substances through accidental spills or other pathways. Impoundments may attract increased recreational vessel activity, creating a pathway for chronic exposure to hydrocarbons and other contaminants. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Require a spill control and containment plan for dam operations if appropriate. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources	May affect survival, growth and fitness at all exposed life history stages.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	Should exposure occur, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	Should exposure occur, decreased survival is likely. May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. Should exposure occur, direct mortality or injury is probable.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Effects on chum salmon will be relatively minimal due to limited dependence on freshwater foraging.	Limit area of dewatering to the greatest extent practicable.	Temporary localized reductions in invertebrate abundance would not be expected to adversely affect juvenile chum salmon.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access and stranding (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, stranding, migration delay, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect survival at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Weirs can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation)	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage weir placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival,. May affect adult spawning productivity.
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species	Year-round	Permanent	Continuous	Juveniles	Juveniles: Weirs may create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased predation, leading to decreased survival.	No specific recommendations	May affect juvenile survival.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Potential injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Limited effects from food web alteration due to minimal dependence on freshwater forage resources.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Unlikely to affect juvenile rearing.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat, increased predation exposure. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect adult spawning productivity.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Chum dependence on autochthonous inputs from aquatic vegetation is limited, as this species does not forage in riverine and lacustrine environments. Therefore, effects on juvenile chum growth and fitness will be limited.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Impact mechanism is unlikely to affect chum salmon.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability, potentially leading to altered migratory behavior and increased predation exposure.		May affect juvenile survival.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult survival and spawning productivity.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs .	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Weir removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to weir removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs and no direct waste discharge. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Weir construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Dikes/Levees									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Flow Bypass, Fish Handling, and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Effects on chum salmon will be relatively minimal due to limited dependence on freshwater foraging.	Limit area of dewatering to the greatest extent practicable.	Temporary localized reductions in invertebrate abundance would not be expected to adversely affect juvenile chum salmon.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>Juveniles</u>: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. <u>Adults</u>: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	<u>Juveniles and adults</u>: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Mortality or injury from entrainment. <u>Juveniles</u>: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. <u>All life-history stages</u>: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Adults	<u>Eggs and alevins</u>: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. <u>Adults</u>: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile chum. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns.	May affect survival, growth, and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory chum salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns.	May affect juvenile survival, growth, and fitness.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat, change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Dikes and levees can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success,.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Reduced availability of thermal refuge and decreased intragravel DO, nutrient cycling effects	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased hyporheic exchange may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dike/levee placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival. May affect adult survival and spawning productivity.
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Dikes and levees in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Lacustrine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Dikes and levees in lacustrine environments can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Limited effects from food web alteration due to minimal dependence on freshwater forage resources.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Unlikely to affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat, increased predation exposure. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect adult spawning productivity.
	Marine								

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. This effect may be limited in magnitude, however, as juvenile chum use of littoral habitats is relatively limited.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and growth.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as juvenile chum use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Chum dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, chum are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Chum dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Chum dependence on autochthonous inputs from aquatic vegetation is limited, as this species does not forage in riverine and lacustrine environments. Therefore, effects on juvenile chum growth and fitness will be limited.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Impact mechanism is unlikely to affect chum salmon.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability, potentially leading to altered migratory behavior and increased predation exposure.		May affect juvenile survival.
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.		May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Outfalls									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and Alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling, and Channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. May cause direct mortality or injury.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Effects on chum salmon will be relatively minimal due to limited dependence on freshwater foraging.	Limit area of dewatering to the greatest extent practicable.	Temporary localized reductions in invertebrate abundance would not be expected to adversely affect juvenile chum salmon.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile chum. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect juvenile survival, growth, and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history stage.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory chum salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns. Profile characteristics where impacts are unavoidable.	May affect juvenile survival, growth, and fitness at the juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of longitudinal connectivity may result from water quality barrier when high effluent discharge causes chemical barrier to migration. If constructed parallel to the channel, side channel and floodplain habitat may become fragmented. These actions will result in changes in habitat structure, availability, and suitability; reduced food web complexity.	Year-round	Permanent	Continuous	Eggs and alevins; Adults	All exposed life-history stages: High flow outfalls can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, life-history stages. May affect spawning productivity.
	Marine and Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Outfalls in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Adults	The degree to which outfalls affect riparian vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine environments.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and growth.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as juvenile chum use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Chum dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, chum are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The degree to which outfalls affect riparian vegetation conditions in lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in lacustrine environments.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness, potentially limiting subadult survival during ocean migration.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses for altered dissolved oxygen levels under Water Quality Alteration.		See effects for related stressors for altered dissolved oxygen levels under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.		May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which outfalls affect aquatic vegetation conditions in riverine and lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine and lacustrine environments.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Water Quality Modification								
		Altered thermal regime (i.e., increased summer temperatures due to elevated effluent temperatures relative to receiving body)	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling (due to effects of effluent discharge)	During and following discharge events	Long-term to permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increases may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate effluent potential to adversely affect eutrophication. Require or encourage use of upstream treatment measures prior to discharge.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect juvenile growth and fitness, may affect adult spawning productivity.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Effects on chum salmon will be relatively minimal due to limited dependence on freshwater foraging.	Limit area of dewatering to the greatest extent practicable.	Temporary localized reductions in invertebrate abundance would not be expected to adversely affect juvenile chum salmon.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile chum. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory chum salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. Profile characteristics where impacts are unavoidable.	May affect juvenile survival, growth, and fitness.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition and stability		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Adults	All exposed life-history stages: Intakes and diversions can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fines will reduce hyporheic exchange, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage intakes and diversions placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival. May affect adult survival and spawning productivity.
	Marine and Lacustrine								

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Intakes and diversions in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Loss of LWD recruitment	Reduced availability of LWD from drift. Reduced availability of LWD from drift. Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult survival and spawning productivity.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Limited effects from food web alteration due to minimal dependence on freshwater forage resources.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Unlikely to affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat, increased predation exposure. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased incubation success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect adult spawning productivity.
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. This effect may be limited in magnitude, however, as juvenile chum use of littoral habitats is relatively limited.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and growth.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as juvenile chum use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Chum dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, chum are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Chum dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival growth and fitness.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Chum dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. However, chum are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth, fitness, and survival.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and fitness.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Chum dependence on groundwater inflow to littoral lacustrine habitats is currently a data gap. However, loss of groundwater may lead to reduction in shallow water thermal refuge, increased competition, and decreased foraging opportunity.	Avoid disturbance of vegetation along shoreline.	May affect juvenile survival, growth, and fitness.
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.		May affect juvenile survival. May affect adult growth and spawning productivity.
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Chum dependence on autochthonous inputs from aquatic vegetation is limited, as this species does not forage in riverine and lacustrine environments. Therefore, effects on juvenile chum growth and fitness will be limited.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Impact mechanism is unlikely to affect chum salmon.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability, potentially leading to altered migratory behavior and increased predation exposure.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Ensure that appropriate instream flows necessary to regulate temperature and other habitat parameters are maintained.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Avoid nutrient inputs when possible.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Tide Gates									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane (flood gates only) ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins (flood gates only), and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. Should exposure occur, direct mortality or injury is probable.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Effects on chum salmon will be relatively minimal due to limited dependence on freshwater foraging.	Limit area of dewatering to the greatest extent practicable.	Temporary localized reductions in invertebrate abundance would not be expected to adversely affect juvenile chum salmon.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat, stranding from dewatering (during construction, maintenance, and removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin life-history stages. May affect spawning productivity
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile chum. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect juvenile survival, growth, and fitness. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities and tidal exchange		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered channel geometry		Year-round	Permanent	Continuous				

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation of habitat	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Tide gates can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Upstream and downstream migrations are limited causing reduced and delayed migration and increased predation. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Limit the length of time that tide gates are closed as much as possible.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit the length of time that tide gates are closed as much as possible. No additional specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Marine								
	Lateral and longitudinal fragmentation of habitat	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Tide gates in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Loss of LWD recruitment	Reduced availability of LWD from drift Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit the length of time that tide gates are closed as much as possible. Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival, growth and fitness.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tide gates is considered to be a component of the effects of dikes and levees. The incremental effects of the tide gate are negligible in comparison.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Marine and Lacustrine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tidegates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid disturbance of vegetation along shoreline.	

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Chum dependence on autochthonous inputs from aquatic vegetation is limited, as this species does not forage in riverine and lacustrine environments. Therefore, effects on juvenile chum growth and fitness will be limited.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Impact mechanism is unlikely to affect chum salmon.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability, potentially leading to altered migratory behavior and increased predation exposure.		May affect juvenile survival, growth, and fitness.
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. May affect eventual spawning productivity		May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered salinity	Year-round	Long-term to permanent	Intermittent (daily)	Juveniles	Juveniles: Altered salinity patterns may limit habitat suitability for juvenile rearing in nearshore marine environments. This in turn may increase competition for available habitats, limiting survival, growth, and fitness.	Limit closure time of tide gate to maximize natural tidal exchange.	May affect juvenile survival, growth, and fitness.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect juvenile and adult survival, growth, and fitness.

Table A-3 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Chum Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Juveniles	Tide gate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent. Exposure to toxic substances may lead to behavioral avoidance in adults. For juveniles, limitations in the availability of suitable juvenile rearing habitat, or potential physiological injury may affect survival, growth, and fitness.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect adult behavior. May affect juvenile survival, growth, and fitness.

Table A-4. HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

<table>
<tr><th rowspan="2">Sub-activity Type</th><th rowspan="2">Mechanism of Impact</th><th colspan="5">Exposure</th><th rowspan="2">Response to Stressor</th><th rowspan="2">Minimization Measures</th><th rowspan="2">Resulting Effects of the Submechanism</th></tr>
<tr><th>Stressor</th><th>When</th><th>Duration</th><th>Frequency</th><th>Life-history Form</th></tr>
<tr><td colspan="10">Dams</td></tr>
<tr><td></td><td colspan="9">Construction and Maintenance Activities</td></tr>
<tr><td></td><td>Construction equipment operation and materials placement</td><td>Increased underwater noise levels</td><td>During project construction and maintenance activities</td><td>Temporary (auditory masking) to short-term (hearing threshold effects)</td><td>Interannual to decadal (during project construction and maintenance)</td><td>Eggs and alevins;
Juveniles;
Adults</td><td><u>All exposed life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from:
Rupture of egg membrane.
Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival.
Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey.
Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.</td><td>Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.</td><td>May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.</td></tr>
<tr><td></td><td></td><td>Altered ambient noise levels</td><td>During project construction and maintenance activities</td><td>Temporary (auditory masking) to short-term (hearing threshold effects)</td><td>Interannual to decadal (during project construction and maintenance)</td><td>Juveniles;
Adults</td><td><u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.</td><td>Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.</td><td>May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.</td></tr>
<tr><td></td><td></td><td>Bank/shoreline/channel disturbance, resulting in increased sediments</td><td>During project construction and maintenance activities</td><td>Short-term</td><td>Interannual to decadal (during project construction and maintenance)</td><td>Eggs and alevins;
Juveniles;
Adults</td><td><u>All exposed life-history stages</u>: See responses to related stressors under Water Quality Modification.</td><td>Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.</td><td>See effects for related stressors under Water Quality Modification.</td></tr>
<tr><td></td><td></td><td>Exposure to toxic chemicals from accidental spills</td><td>During project construction and maintenance activities</td><td>Short-term</td><td>Interannual to decadal (during project construction and maintenance)</td><td>Eggs and alevins;
Juveniles;
Adults</td><td><u>All exposed life-history stages</u>: See responses to related stressors under Water Quality Modification.</td><td>Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.</td><td>See effects for related stressors under Water Quality Modification.</td></tr>
<tr><td></td><td>Flow Bypass, Fish Handling and Channel Rewatering</td><td>Fish removal, relocation, and exclusion</td><td>During project construction and maintenance activities</td><td>Short-term</td><td>Interannual to decadal (depending on activity frequency)</td><td>Eggs and alevins;
Juveniles;
Adults</td><td><u>Eggs and alevins</u>: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality.
<u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully.
<u>Juveniles</u>: Increased competition once relocated, reduced growth and fitness, and increased predation exposure.
<u>Adults</u>: Delayed migration resulting in decreased fitness and spawning success.</td><td>Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.</td><td>May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.</td></tr>
<tr><td></td><td></td><td>Entrainment in pumps or impingement on pump screens</td><td>During project construction and maintenance activities</td><td>Short-term</td><td>Interannual to decadal (depending on activity frequency)</td><td>Eggs and alevins;
Juveniles</td><td><u>Eggs, alevins, and juveniles</u>: Injury or mortality from entrainment or impingement.</td><td>Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.</td><td>May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.</td></tr>
</table>

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. May cause direct mortality or injury.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Effects on pink salmon will be relatively minimal due to limited dependence on freshwater foraging.	Limit area of dewatering to the greatest extent practicable.	Temporary localized reductions in invertebrate abundance would not be expected to adversely affect juvenile pink salmon.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity,. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Marine								
	Altered sediment transport	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability as a result of beach erosion from altered sediment supply.	Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous	Juveniles	Juveniles: Sediment supply and substrate composition are core ecosystem characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile pink salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply to marine environments.	May affect juvenile survival, growth, and fitness. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered substrate composition		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lateral and Longitudinal habitat Fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of longitudinal (i.e., upstream-downstream) habitat connectivity; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Dams can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types if the dam presents a barrier to fish passage. Even when passage is provided, limitations on upstream migration may lead to decreased survival and spawning productivity due to delayed migration, increased exposure to predation, poaching, and other related stressors. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Minimize severing upstream-downstream connectivity by installing fish passage.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness.. Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dam placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible. Encourage spillway design to promote moderation of stream temperatures in downstream reaches.	May affect egg and alevin survival. May affect adult survival and spawning productivity.
	Altered Community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species	Year-round	Permanent	Continuous	Juveniles	Juveniles: Dams create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: : Limited effects from food web alteration due to minimal dependence on freshwater forage resources.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Unlikely to affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat, increased predation exposure. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased incubation success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect adult spawning productivity.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Pink salmon dependence on autochthonous inputs from aquatic vegetation is limited, as this species does not forage in riverine and lacustrine environments. Therefore, effects on juvenile pink salmon growth and fitness will be limited.	Design: Limit project structural footprint to minimize alteration and shading of native aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Impact mechanism is unlikely to affect pink salmon.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability, potentially leading to altered migratory behavior and increased predation exposure.		May affect juvenile survival.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Provide sufficient streamflows to avoid temperature effects in reaches downstream of the impoundment. Promote dam designs that limit impoundment effects on downstream temperatures (e.g., draw streamflows from impoundment below the stratification layer in summer).	May affect survival, of eggs, alevins and juveniles. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats	Avoid large sediment pulses during construction and dam removal where practicable.	May affect juvenile survival, growth and fitness as well as adult survival and spawning productivity.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. <u>Juveniles and adults</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. <u>Adults</u>: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>All exposed life history stages:</u> Dam removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to dam removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>All exposed life history stages:</u> Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>All exposed life history stages:</u> Dam construction and operation may lead to introductions of toxic substances through accidental spills or other pathways. Impoundments may attract increased recreational vessel activity, creating a pathway for chronic exposure to hydrocarbons and other contaminants. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Require a spill control and containment plan for dam operations if appropriate. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources	May affect survival, growth and fitness at all exposed life history stages.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Juveniles: Increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	Should exposure occur, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	Should exposure occur, decreased survival is likely. May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Migration delay, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. Should exposure occur, direct mortality or injury is probable.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Effects on pink salmon will be relatively minimal due to limited dependence on freshwater foraging.	Limit area of dewatering to the greatest extent practicable.	Temporary localized reductions in invertebrate abundance would not be expected to adversely affect juvenile pink salmon.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access and stranding (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, stranding, migration delay, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Weirs can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage weir placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival. May affect adult survival and spawning productivity.
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species	Year-round	Permanent	Continuous	Juveniles	Juveniles: Weirs may create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased predation, leading to decreased survival.	No specific recommendations	May affect juvenile survival,.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Limited effects from food web alteration due to minimal dependence on freshwater forage resources.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Unlikely to affect juvenile rearing.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat, increased predation exposure. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect adult spawning productivity.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Pink salmon dependence on autochthonous inputs from aquatic vegetation is limited, as this species does not forage in riverine and lacustrine environments. Therefore, effects on juvenile pink salmon growth and fitness will be limited.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Impact mechanism is unlikely to affect pink salmon.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability, potentially leading to altered migratory behavior and increased predation exposure.		May affect juvenile survival.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult survival and spawning productivity.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs .	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. <u>Juveniles and adults</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading increased predation exposure, and altered migration behavior. <u>Adults</u>: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>All expose life history stages:</u> Weir removal may lead to rapid release of contaminated sediments accumulated upstream of weirs creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to weir removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs and no direct waste discharge. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>All exposed life history stages:</u> Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Weir construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Dikes/Levees									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow Bypass, Fish Handling, and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Effects on pink salmon will be relatively minimal due to limited dependence on freshwater foraging.	Limit area of dewatering to the greatest extent practicable.	Temporary localized reductions in invertebrate abundance would not be expected to adversely affect juvenile pink salmon.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile pink salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns.	May affect survival, growth, and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory pink salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns.	May affect juvenile survival, growth, and fitness.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat, change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Dikes and levees can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning successs.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Reduced availability of thermal refuge and decreased intragravel DO, nutrient cycling effects	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased hyporheic exchange may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dike/levee placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival.. May affect adult survival and spawning productivity.
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Dikes and levees in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Lacustrine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Dikes and levees in lacustrine environments can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Limited effects from food web alteration due to minimal dependence on freshwater forage resources.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Unlikely to affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat, increased predation exposure. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect adult spawning productivity.
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. This effect may be limited in magnitude, however, as juvenile pink salmon use of littoral habitats is relatively limited.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and growth.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as juvenile pink salmon use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Pink salmon dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, pink salmon are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Pink salmon dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Pink salmon dependence on autochthonous inputs from aquatic vegetation is limited, as this species does not forage in riverine and lacustrine environments. Therefore, effects on juvenile pink salmon growth and fitness will be limited.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Impact mechanism is unlikely to affect pink salmon.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability, potentially leading to altered migratory behavior and increased predation exposure.		May affect juvenile survival.
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.		May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. <u>Juveniles and adults</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. <u>Adults</u>: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>All exposed life history stages:</u> Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>All expose life history stages:</u> Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Outfalls									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and Alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling, and Channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. <u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation. <u>Juveniles</u>: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. <u>Adults</u>: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. May cause direct mortality or injury.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Effects on pink salmon will be relatively minimal due to limited dependence on freshwater foraging.	Limit area of dewatering to the greatest extent practicable.	Temporary localized reductions in invertebrate abundance would not be expected to adversely affect juvenile pink salmon.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile pink salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect juvenile survival, growth, and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history stage.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory pink salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns. Profile characteristics where impacts are unavoidable.	May affect juvenile survival, growth, and fitness at the juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of longitudinal connectivity may result from water quality barrier when high effluent discharge causes chemical barrier to migration. If constructed parallel to the channel, side channel and floodplain habitat may become fragmented. These actions will result in changes in habitat structure, availability, and suitability; reduced food web complexity.	Year-round	Permanent	Continuous	Eggs and alevins; Adults	All exposed life-history stages: High flow outfalls can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, life-history stages. May affect spawning productivity.
	Marine and Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Outfalls in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	The degree to which outfalls affect riparian vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine environments.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and growth.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as juvenile pink salmon use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Pink salmon dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, pink salmon are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The degree to which outfalls affect riparian vegetation conditions in lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in lacustrine environments.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness, potentially limiting subadult survival during ocean migration.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses for altered dissolved oxygen levels under Water Quality Alteration.		See effects for related stressors for altered dissolved oxygen levels under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.		May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which outfalls affect aquatic vegetation conditions in riverine and lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine and lacustrine environments.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Water Quality Modification								
		Altered thermal regime (i.e., increased summer temperatures due to elevated effluent temperatures relative to receiving body)	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling (due to effects of effluent discharge)	During and following discharge events	Long-term to permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate effluent potential to adversely affect eutrophication. Require or encourage use of upstream treatment measures prior to discharge.	May affect survival, growth and fitness at all exposed life history stages. **Risk of take = M to H** (depending on magnitude and extent of stressor and sensitivity of exposed life history stages)
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. <u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation. <u>Juveniles</u>: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. <u>Adults</u>: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect juvenile growth and fitness, may affect adult spawning productivity.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Effects on pink salmon will be relatively minimal due to limited dependence on freshwater foraging.	Limit area of dewatering to the greatest extent practicable.	Temporary localized reductions in invertebrate abundance would not be expected to adversely affect juvenile pink salmon.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile pink salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory pink salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. Profile characteristics where impacts are unavoidable.	May affect juvenile survival, growth, and fitness.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition and stability		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Intakes and diversions can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fines will reduce hyporheic exchange, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage intakes and diversions placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival. May affect adult survival and spawning productivity.
	Marine and Lacustrine								

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Intakes and diversions in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Loss of LWD recruitment	Reduced availability of LWD from drift. Reduced availability of LWD from drift. Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult survival and spawning productivity.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Limited effects from food web alteration due to minimal dependence on freshwater forage resources.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Unlikely to affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat, increased predation exposure. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity.
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. This effect may be limited in magnitude, however, as juvenile pink salmon use of littoral habitats is relatively limited.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and growth.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as juvenile pink salmon use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Pink salmon dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, pink salmon are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Pink salmon dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival growth and fitness.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Pink salmon dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. However, pink salmon are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth, fitness, and survival.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and fitness.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Pink salmon dependence on groundwater inflow to littoral lacustrine habitats is currently a data gap. However, loss of groundwater may lead to reduction in shallow water thermal refuge, increased competition, and decreased foraging opportunity.	Avoid disturbance of vegetation along shoreline.	May affect juvenile survival, growth, and fitness.
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.		May affect juvenile survival. May affect adult growth and spawning productivity.
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Pink salmon dependence on autochthonous inputs from aquatic vegetation is limited, as this species does not forage in riverine and lacustrine environments. Therefore, effects on juvenile pink salmon growth and fitness will be limited.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Impact mechanism is unlikely to affect pink salmon.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability, potentially leading to altered migratory behavior and increased predation exposure.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Ensure that appropriate instream flows necessary to regulate temperature and other habitat parameters are maintained.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Avoid nutrient inputs when possible.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Tide Gates									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane (flood gates only) ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. Should exposure occur, direct mortality or injury is probable.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Effects on pink salmon will be relatively minimal due to limited dependence on freshwater foraging.	Limit area of dewatering to the greatest extent practicable.	Temporary localized reductions in invertebrate abundance would not be expected to adversely affect juvenile pink salmon.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat, stranding from dewatering (during construction, maintenance, and removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Adults	<u>Eggs and alevins</u>: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. <u>Adults</u>: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin life-history stages. May affect spawning productivity
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	<u>Juveniles</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile pink salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect juvenile survival, growth, and fitness. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities and tidal exchange		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered channel geometry		Year-round	Permanent	Continuous				

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation of habitat	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: Tide gates can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Upstream and downstream migrations are limited causing reduced and delayed migration and increased predation. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Limit the length of time that tide gates are closed as much as possible.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit the length of time that tide gates are closed as much as possible. No additional specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Marine								
	Lateral and longitudinal fragmentation of habitat	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	<u>All exposed life-history stages</u>: Tide gates in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Loss of LWD recruitment	Reduced availability of LWD from drift Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit the length of time that tide gates are closed as much as possible. Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival, growth and fitness.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tide gates is considered to be a component of the effects of dikes and levees. The incremental effects of the tide gate are negligible in comparison.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	
	Marine and Lacustrine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tidegates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid disturbance of vegetation along shoreline.	
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Pink salmon dependence on autochthonous inputs from aquatic vegetation is limited, as this species does not forage in riverine and lacustrine environments. Therefore, effects on juvenile pink salmon growth and fitness will be limited.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Impact mechanism is unlikely to affect pink salmon.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability, potentially leading to altered migratory behavior and increased predation exposure.		May affect juvenile survival, growth, and fitness.
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. May affect eventual spawning productivity		May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered salinity	Year-round	Long-term to permanent	Intermittent (daily)	Juveniles	Juveniles: Altered salinity patterns may limit habitat suitability for juvenile rearing in nearshore marine environments. This in turn may increase competition for available habitats, limiting survival, growth, and fitness.	Limit closure time of tide gate to maximize natural tidal exchange.	May affect juvenile survival, growth, and fitness.

Table A-4 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pink Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect juvenile and adult survival, growth, and fitness.
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Juveniles	Tide gate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent. Exposure to toxic substances may lead to behavioral avoidance in adults. For juveniles, limitations in the availability of suitable juvenile rearing habitat, or potential physiological injury may affect survival, growth, and fitness.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect adult behavior. May affect juvenile survival, growth, and fitness.

Table A-5. HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage (river rearing sockeye). May affect adult fitness and spawning productivity
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access and stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and Alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May affect juvenile survival, growth, and fitness. See effects for related stressors on all life-history stages under Water Quality Modification
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased refuge habitat during migration to lacustrine rearing environments, and increased predation exposure. Juvenile river rearing sockeye may also experience decreased foraging opportunity, leading to increased competition and decreased growth and fitness. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg, alevin, and juvenile life-history stages (river rearing sockeye). May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered sediment transport	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability as a result of beach erosion from altered sediment supply.	Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous	Juveniles	Juveniles: Sediment supply and substrate composition are core ecosystem characteristics that compose the nearshore ecosystem. Alteration in these parameters can fundamentally alter marine littoral habitats. Juvenile sockeye have relatively limited dependence on nearshore marine habitats. However, alteration of habitat productivity in the nearshore may lead to alteration of food web dynamics in offshore environments, potentially affecting foraging opportunities, leading to decreased growth and productivity. Adults: Alteration of nearshore habitat characteristics can demonstrably affect the productivity of forage species preyed upon by returning adult sockeye. Decreased foraging opportunity may lead to decreased growth and productivity.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase. May affect adult growth and productivity.
	Altered substrate composition		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of longitudinal (i.e., upstream-downstream) habitat connectivity; change in habitat structure, availability, and suitability.	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Dams can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types if the dam presents a barrier to fish passage. Even when passage is provided, limitations on upstream migration may lead to decreased survival and spawning productivity due to delayed migration, increased exposure to predation and poaching, and other related stressors. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Minimize severing upstream-downstream connectivity by installing fish passage.	May affect survival at egg, alevin, and juvenile life-history stages . May affect spawning productivity (river rearing sockeye).
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dam placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible. Encourage spillway design to promote moderation of stream temperatures in downstream reaches.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species.	Year-round	Permanent	Continuous	Juveniles	Juveniles: Dams create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity (river rearing sockeye).

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress and increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, as well as adult spawning productivity.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile productivity.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses for altered dissolved oxygen under Water Quality Modification.		See effects for related stressors of altered dissolved oxygen under Water Quality Modification.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Provide sufficient streamflows to avoid temperature effects in reaches downstream of the impoundment. Promote dam designs that limit impoundment effects on downstream temperatures (e.g., draw streamflows from impoundment below the stratification layer in summer).	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.	Avoid large sediment pulses during construction and dam removal where practicable.	May affect juvenile survival, growth and fitness as well as adult survival and spawning productivity.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Dam removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to dam removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increases may result from changes in nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Dam construction and operation may lead to introductions of toxic substances through accidental spills or other pathways. Impoundments may attract increased recreational vessel activity, creating a pathway for chronic exposure to hydrocarbons and other contaminants. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Require a spill control and containment plan for dam operations if appropriate. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity..

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness..
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity (river rearing sockeye)..
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect egg and alevin incubation success and survival; may affect growth and fitness at juvenile life-history stage; may affect adult spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage..
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity (river rearing sockeye).
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stage. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity (river rearing sockeye).
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability.	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Weirs can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Upstream migration is limited causing reduced and delayed migration, increased predation. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Minimize severing upstream-downstream connectivity by installing fish passage.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity (river rearing sockeye).
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage weir placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species	Year-round	Permanent	Continuous	Juveniles	Juveniles: Weirs may create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Direct mortality due to winter ice formation and scour. <u>Juveniles</u>: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. <u>Adults and juveniles:</u> Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. <u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	<u>Eggs/alevins:</u> Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. <u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. <u>Adults:</u> Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	<u>Juveniles:</u> Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	<u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. <u>Adults:</u> Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress and increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile productivity.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses for altered dissolved oxygen under Water Quality Modification.		See effects for related stressors of altered dissolved oxygen under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs .	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Weir removal may lead to rapid release of contaminated sediments accumulated upstream of weirs creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to weir removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and productivity of juveniles and adults.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Nutrient increases may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Weir construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Dikes/Levees									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Flow Bypass, Fish Handling, and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity (river rearing sockeye).
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	Egg and alevin mortality or injury is highly likely if exposure occurs. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased refuge habitat during migration to lacustrine rearing environments, and increased predation exposure. Juvenile river rearing sockeye may also experience decreased foraging opportunity, leading to increased competition and decreased growth and fitness. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg, alevin, and juvenile life-history stages (river rearing sockeye). May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile sockeye salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effects of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time [e.g., due to accumulation of shell hash, sediment settling due to altered wave and/or current regime, routine grounding, anchor trenching])	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult sockeye salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. Adult sockeye will generally be less sensitive to these stressors. However, increased stress and delayed migration in the migratory corridor may reduce fitness and ultimately reduce spawning success.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Dikes and levees can force channel incision, or directly sever connection leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity (river rearing sockeye).
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater-surface water exchange	Reduced availability of thermal refuge and decreased intragravel DO, nutrient cycling effects	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dike and levee placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Dikes and levees in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Lacustrine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Dikes and Levees permanently fragment lacustrine habitats. For sockeye, loss of nearshore habitats may result. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity (river rearing sockeye).

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles and adults: Decreased availability of thermal refuge habitat, limiting juvenile survival, growth, and fitness. May limit adult survival and spawning productivity. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round, (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	<u>Juveniles</u>: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. Juvenile sockeye dependence on the nearshore marine environment is relatively limited. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and growth.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	<u>Juveniles</u>: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	<u>Juveniles</u>: Sockeye dependence on allochthonous inputs from marine riparian vegetation is a data gap but is likely limited due to the lesser dependence of this species on the nearshore marine environment.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Potential effects resulting from this impact mechanism are unknown.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	<u>Juveniles:</u> Sockeye dependence on nearshore marine habitats is limited in comparison to other salmonids. Sockeye response to alteration of nearshore habitat complexity is currently a data gap. <u>Adults</u>: Reduction in nearshore habitat complexity may affect availability of forage for returning adult sockeye, affecting growth and productivity during spawning.	Encourage project designs that limit permanent alteration of habitat features.	Potential effects on juvenile sockeye resulting from this impact mechanism are unknown. May affect adult growth and productivity.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	<u>Juveniles</u>: Sockeye dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure. Eggs and alevins: Potential reduction in egg survival and incubation success (for beach spawning sockeye) due to increased sedimentation and turbidity, as described under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: May affect spawning habitat suitability, leading to decreased spawning productivity as described under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness. May affect egg and alevin survival. May affect juvenile survival and productivity. May affect adult spawning productivity.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Sockeye dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. Sockeye are primarily planktonic feeders in the photic zone, so direct dependence on allochthonous inputs for prey is likely limited.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Potential effects resulting from this impact mechanism are unknown.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs	Year-round (stressor exposure occurs predominantly during spring outmigration period through lakes)	Permanent	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival, growth, and fitness.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during predominantly during spring outmigration period through lakes)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	<u>Eggs and alevins</u>: Decreased egg and alevin survival (beach-spawning sockeyes) due to lower dissolved oxygen levels in spawning substrate. <u>Juveniles</u>: Sockeye dependence on groundwater inflow to nearshore habitats is currently a data gap. <u>Adults</u>: Decreased suitable spawning habitat, leading to decreased spawning productivity.	Avoid disturbance of vegetation along shoreline.	May affect egg and alevin survival. May affect adult spawning productivity. Effects on juveniles are unknown.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during predominantly during spring outmigration period through lakes)	Permanent	Continuous	Juveniles	<u>Juveniles</u>: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	<u>Juveniles</u>: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	<u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile productivity.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	<u>Juveniles and adults</u>: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	<u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Sockeye dependence on autochthonous inputs from marine littoral vegetation is a data gap but is likely limited due to the lesser dependence of this species on the nearshore marine environment.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Potential effects resulting from this impact mechanism are unknown.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Sockeye dependence on nearshore marine habitats is limited in comparison to other salmonids. Sockeye response to alteration of nearshore habitat complexity is currently a data gap. Adults: Reduction in nearshore habitat complexity may affect availability of forage for returning adult sockeye, affecting growth and productivity during spawning.		Potential effects on juvenile sockeye resulting from this impact mechanism are unknown. May affect adult growth and productivity.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	**When**	**Duration**	**Frequency**	**Life-history Form**			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. <u>Juveniles and adults</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. <u>Adults</u>: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>All expose life history stages:</u> Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Outfalls									
	Construction and Maintenance Activities								
	Pile driving	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction equipment operation	Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased refuge habitat during migration to lacustrine rearing environments, and increased predation exposure. Juvenile river rearing sockeye may also experience decreased foraging opportunity, leading to increased competition and decreased growth and fitness. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg, alevin, and juvenile life-history stages (river rearing sockeye). May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Juvenile sockeye have relatively limited dependence on nearshore marine habitats. However, alteration of habitat productivity in the nearshore may lead to alteration of food web dynamics in offshore environments, potentially affecting foraging opportunities, leading to decreased growth and productivity. Adults: Alteration of nearshore habitat characteristics can demonstrably affect the productivity of forage species preyed upon by returning adult sockeye. Decreased foraging opportunity may lead to decreased growth and productivity.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles; Adults	Juveniles and Adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult sockeye salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect growth and fitness at juvenile and adult life-history stages. May affect adult spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous		patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. Adult sockeye will generally be less sensitive to these stressors. However, increased stress and delayed migration in the migratory corridor may reduce fitness and ultimately reduce spawning success.		
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of longitudinal connectivity may result from water quality barrier when high effluent discharge causes chemical barrier to migration. If constructed parallel to the channel, side channel and floodplain habitat may become fragmented. These actions will result in changes in habitat structure, availability, and suitability; reduced food web complexity.	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: High flow outfalls can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Marine and Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	<u>All exposed life-history stages</u>: Outfalls in the marine and lacustrine environments can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	The degree to which outfalls affect riparian vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine environments.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults		Avoid disturbance of vegetation along stream.	
	Marine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round, (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. Juvenile sockeye dependence on the nearshore marine environment is relatively limited. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and growth.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Sockeye dependence on allochthonous inputs from marine riparian vegetation is a data gap but is likely limited due to the lesser dependence of this species on the nearshore marine environment.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Potential effects resulting from this impact mechanism are unknown.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Sockeye dependence on nearshore marine habitats is limited in comparison to other salmonids. Sockeye response to alteration of nearshore habitat complexity is currently a data gap. Adults: Reduction in nearshore habitat complexity may affect availability of forage for returning adult sockeye, affecting growth and productivity during spawning.	Encourage project designs that limit permanent alteration of high-quality habitat features.	Potential effects on juvenile sockeye resulting from this impact mechanism are unknown. May affect adult growth and productivity.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Lacustrine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles	The degree to which outfalls affect riparian vegetation conditions in lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in lacustrine environments.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs	Year-round (stressor exposure occurs predominantly during spring outmigration period through lakes)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during predominantly during spring outmigration period through lakes)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of habitat features.	

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Sockeye dependence on autochthonous inputs from marine littoral vegetation is a data gap but is likely limited due to the lesser dependence of this species on the nearshore marine environment.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Potential effects resulting from this impact mechanism are unknown.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Sockeye dependence on nearshore marine habitats is limited in comparison to other salmonids. Sockeye response to alteration of nearshore habitat complexity is currently a data gap. Adults: Reduction in nearshore habitat complexity may affect availability of forage for returning adult sockeye, affecting growth and productivity during spawning.		Potential effects on juvenile sockeye resulting from this impact mechanism are unknown. May affect adult growth and productivity.
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which outfalls affect aquatic vegetation conditions in riverine and lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine and lacustrine environments.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Water Quality Modification								
		Altered thermal regime (i.e., increased summer temperatures due to elevated effluent temperatures relative to receiving body)	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect juvenile survival and fitness. May affect adult survival and spawning productivity.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered nutrient cycling (due to effects of effluent discharge)	During and following discharge events	Long-term to permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate effluent potential to adversely affect eutrophication. Require or encourage use of upstream treatment measures prior to discharge.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.
Water Intakes /Diversion Structures									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased refuge habitat during migration to lacustrine rearing environments, and increased predation exposure. Juvenile river rearing sockeye may also experience decreased foraging opportunity, leading to increased competition and decreased growth and fitness. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity (river rearing sockeye).
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	<u>Juveniles</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Juvenile sockeye have relatively limited dependence on nearshore marine habitats. However, alteration of habitat productivity in the nearshore may lead to alteration of food web dynamics in offshore environments, potentially affecting foraging opportunities, leading to decreased growth and productivity. <u>Adults</u>: Alteration of nearshore habitat characteristics can demonstrably affect the productivity of forage species preyed upon by returning adult sockeye. Decreased foraging opportunity may lead to decreased growth and productivity.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered sediment transport		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered substrate composition		Year-round (beginning with project installation and becoming more pronounced over time	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles; Adults	Juveniles and Adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult sockeye salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. Adult sockeye will generally be less sensitive to these stressors. However, increased stress and delayed migration in the migratory corridor may reduce fitness and ultimately reduce spawning success.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth and fitness at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability.	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Intakes and diversions can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Upstream migration is limited causing reduced and delayed migration, increased predation. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Minimize severing upstream-downstream connectivity by installing fish passage.	May affect survival, growth, and fitness at egg, alevin, and juvenile life-history stages. May affect spawning productivity (river rearing sockeye).
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered groundwater-surface water exchange	Accumulation of fines will reduce hyporheic exchange, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. <u>Adults and juveniles</u>: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. <u>Adults</u>: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage intakes and diversions placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Marine and Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	<u>All exposed life-history stages</u>: Intakes and diversions in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Loss of LWD recruitment	Reduced availability of LWD from drift. Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival, growth, and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Direct mortality due to winter ice formation and scour. <u>Juveniles</u>: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. <u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. <u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity (river rearing sockeye).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile survival, growth and fitness, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress and increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins, as well as adult spawning productivity.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round, (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. Juvenile sockeye dependence on the nearshore marine environment is relatively limited. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and growth.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Sockeye dependence on allochthonous inputs from marine riparian vegetation is a data gap but is likely limited due to the lesser dependence of this species on the nearshore marine environment.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Potential effects resulting from this impact mechanism are unknown.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Sockeye dependence on nearshore marine habitats is limited in comparison to other salmonids. Sockeye response to alteration of nearshore habitat complexity is currently a data gap. Adults: Reduction in nearshore habitat complexity may affect availability of forage for returning adult sockeye, affecting growth and productivity during spawning.	Encourage project designs that limit permanent alteration of high-quality habitat features.	Potential effects on juvenile sockeye resulting from this impact mechanism are unknown. May affect adult growth and productivity.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Sockeye dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Lacustrine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure. Eggs and alevins: Potential reduction in egg survival and incubation success (for beach spawning sockeye) due to increased sedimentation and turbidity, as described under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: May affect spawning habitat suitability, leading to decreased spawning productivity as described under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness. May affect egg and alevin survival. May affect juvenile survival and productivity. May affect adult spawning productivity.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Sockeye dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. Sockeye are primarily planktonic feeders in the photic zone, so direct dependence on allochthonous inputs for prey is likely limited.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Potential effects resulting from this impact mechanism are unknown.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs	Year-round (stressor exposure occurs predominantly during spring outmigration period through lakes)	Permanent	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival, growth, and fitness.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during predominantly during spring outmigration period through lakes)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Eggs and alevins: Decreased egg and alevin survival (beach-spawning sockeyes) due to lower dissolved oxygen levels in spawning substrate. Juveniles: Sockeye dependence on groundwater inflow to nearshore habitats is currently a data gap. Adults: Decreased suitable spawning habitat, leading to decreased spawning productivity.	Avoid disturbance of vegetation along shoreline.	May affect egg and alevin survival. May affect adult spawning productivity. Effects on juveniles are unknown.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during predominantly during spring outmigration period through lakes)	Permanent	Continuous	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Alteration of aquatic vegetation may indirectly affect food web dynamics, potentially leading to decreased foraging opportunities.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile productivity.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Alteration of aquatic vegetation may indirectly affect food web dynamics, potentially leading to decreased foraging opportunities.		May affect juvenile survival.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Sockeye dependence on autochthonous inputs from marine littoral vegetation is a data gap but is likely limited due to the lesser dependence of this species on the nearshore marine environment.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Potential effects resulting from this impact mechanism are unknown.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Sockeye dependence on nearshore marine habitats is limited in comparison to other salmonids. Sockeye response to alteration of nearshore habitat complexity is currently a data gap. Adults: Reduction in nearshore habitat complexity may affect availability of forage for returning adult sockeye, affecting growth and productivity during spawning.		Potential effects on juvenile sockeye resulting from this impact mechanism are unknown. May affect adult growth and productivity.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Ensure that appropriate instream flows necessary to regulate temperature and other habitat parameters are maintained.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Avoid nutrient inputs when possible.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. Physiological injury may affect survival, growth and fitness of juveniles. May affect adult survival and spawning productivity.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Tide Gates									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May cause direct mortality to eggs and alevins. May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Loss of habitat, stranding from dewatering (during construction, maintenance, and removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased refuge habitat during migration to lacustrine rearing environments, and increased predation exposure. Juvenile river rearing sockeye may also experience decreased foraging opportunity, leading to increased competition and decreased growth and fitness. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg, alevin, and juvenile life-history stages (river rearing sockeye). May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and tidal exchange are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile sockeye salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effects of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities and tidal exchange		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered channel geometry		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation of habitat	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Tide gates can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Upstream and downstream migrations are limited causing reduced and delayed migration and increased predation. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Limit length of time tide gates are closed as much as possible.	May affect survival at juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit length of time tide gates are closed as much as possible. No additional specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Marine								
	Lateral and longitudinal fragmentation of habitat	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	<u>All exposed life-history stages</u>: Tide gates in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. Limit length of time tide gates are closed as much as possible.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Loss of LWD recruitment	Reduced availability of LWD from drift. Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit length of time tide gates are closed as much as possible. Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival, growth, and fitness.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tide gates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults		Avoid disturbance of vegetation along stream.	

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Marine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round, (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tidegates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of habitat features.	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid disturbance of vegetation along shoreline.	
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	<u>Juveniles</u>: Alteration of aquatic vegetation may indirectly affect food web dynamics, potentially leading to decreased foraging opportunities.	<u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile productivity.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	<u>Juveniles and adults</u>: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	<u>Juveniles</u>: Alteration of aquatic vegetation may indirectly affect food web dynamics, potentially leading to decreased foraging opportunities.		May affect juvenile survival.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Sockeye dependence on autochthonous inputs from marine littoral vegetation is a data gap but is likely limited due to the lesser dependence of this species on the nearshore marine environment.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Potential effects resulting from this impact mechanism are unknown.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Sockeye dependence on nearshore marine habitats is limited in comparison to other salmonids. Sockeye response to alteration of nearshore habitat complexity is currently a data gap. Adults: Reduction in nearshore habitat complexity may affect availability of forage for returning adult sockeye, affecting growth and productivity during spawning.		Potential effects on juvenile sockeye resulting from this impact mechanism are unknown. May affect adult growth and productivity.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.

Table A-5 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Sockeye Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect juvenile growth and fitness and adult productivity and spawning success. May cause direct mortality in acute events.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. Intermediate-term effluent effects on receiving body pH may alter habitat suitability.	Avoid curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered salinity	Year-round	Long-term to permanent	Intermittent (daily)	Juveniles	Juveniles: Altered salinity patterns may limit habitat suitability for juvenile rearing in nearshore marine environments. This in turn may increase competition for available habitats, limiting survival, growth, and fitness.	Limit closure time of tide gate to maximize natural tidal exchange.	May affect juvenile survival, growth, and fitness.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect juvenile and adult survival, growth, and fitness.
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Juveniles	Tidegate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent. Exposure to toxic substances may lead to behavioral avoidance in adults. For juveniles, limitations in the availability of suitable juvenile rearing habitat, or potential physiological injury may affect survival, growth, and fitness.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect adult behavior. May affect juvenile survival, growth, and fitness.

Table A-6. HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May affect juvenile survival, growth, and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect adult spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered sediment transport	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability as a result of beach erosion from altered sediment supply.	Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous	Juveniles	Juveniles: Sediment supply and substrate composition are core ecosystem characteristics that compose the nearshore ecosystem. Alteration in these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile steelhead. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effects of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. Adults: Subadult and returning adult steelhead forage in nearshore environments. Alteration in nearshore ecosystem processes may decrease foraging opportunity, affecting growth and fitness.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered substrate composition		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of longitudinal (i.e., upstream-downstream) habitat connectivity; change in habitat structure, availability, and suitability.	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Dams can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types if the dam presents a barrier to fish passage. Even when passage is provided, limitations on upstream migration may lead to decreased survival and spawning productivity due to delayed migration, increased exposure to predation and poaching, and other related stressors. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Minimize severing upstream-downstream connectivity by installing fish passage.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dam placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible. Encourage spillway design to promote moderation of stream temperatures in downstream reaches.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species	Year-round	Permanent	Continuous	Juveniles	Juveniles: Dams create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, as well as adult spawning productivity.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Altered food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit structural and impoundment footprint to avoid alteration of native vegetation community to the extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile productivity.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses for altered dissolved oxygen under Water Quality Modification.		See effects for related stressors of altered dissolved oxygen under Water Quality Modification.
	Altered habitat complexity	Altered food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Provide sufficient streamflows to avoid temperature effects in reaches downstream of the impoundment. Promote dam designs that limit impoundment effects on downstream temperatures (e.g., draw streamflows from impoundment below the stratification layer in summer).	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats. May affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.	Avoid large sediment pulses during construction and dam removal where practicable.	May affect juvenile survival, growth and fitness as well as adult survival and spawning productivity.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Dam removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to dam removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Nutrient increases may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Dam construction and operation may lead to introductions of toxic substances through accidental spills or other pathways. Impoundments may attract increased recreational vessel activity, creating a pathway for chronic exposure to hydrocarbons and other contaminants. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Require a spill control and containment plan for dam operations if appropriate. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity..

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness..
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity..
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage..
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability.	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Weirs can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Upstream migration is limited causing reduced and delayed migration, increased predation. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Minimize severing upstream-downstream connectivity by installing fish passage.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage weir placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species	Year-round	Permanent	Continuous	Juveniles	Juveniles: Weirs may create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, as well as adult spawning productivity.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile productivity.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses for altered dissolved oxygen under Water Quality Modification.		See effects for related stressors of altered dissolved oxygen under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs .	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. <u>Juveniles and adults</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. <u>Adults</u>: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>All expose life history stages:</u> Weir removal may lead to rapid release of contaminated sediments accumulated upstream of weirs creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to weir removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and productivity of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Weir construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Dikes/Levees									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Flow Bypass, Fish Handling, and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	Egg and alevin mortality or injury is highly likely if exposure occurs. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile steelhead salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effects of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles; Adults	<u>Juveniles and adults</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult steelhead salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. Adult steelhead will generally be less sensitive to these stressors. However, increased stress and delayed migration in the migratory corridor may reduce fitness and ultimately reduce spawning success.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: Dikes and levees can force channel incision, or directly sever connection leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered groundwater-surface water exchange	Reduced availability of thermal refuge and decreased intragravel DO, nutrient cycling effects	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dike/levee placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Dikes and levees in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Lacustrine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Dikes and Levees permanently fragment lacustrine habitats. For salmonids, loss of nearshore habitats may result. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles and adults: Decreased availability of thermal refuge habitat, limiting juvenile survival, growth, and fitness. May limit adult survival and spawning productivity. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, juvenile survival, growth, and fitness, and adult survival and spawning productivity.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round, (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. The extent of nearshore habitat use by juvenile steelhead is currently a data gap. However, juveniles trapped by tidal exchange in specific habitats, such as pocket estuaries, may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The potential effects of this mechanism on juvenile steelhead are generally unknown. However, may affect juvenile survival and growth.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as juvenile steelhead use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The potential effects of this mechanism on juvenile steelhead are generally unknown. However, may affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Steelhead dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, steelhead are known to use terrestrial insect resources recruited from the riparian zone in freshwater environments, so exploitation of these resources in marine environments is possible.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The potential effects of this mechanism on juvenile steelhead are generally unknown. However, may affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Steelhead dependence on nearshore habitat complexity is currently a data gap. Altered habitat complexity may lead to decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	The potential effects of this mechanism on juvenile steelhead are generally unknown. However, may affect juvenile survival, growth, and fitness.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Steelhead dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs	Year-round (stressor exposure occurs predominantly during spring outmigration period through lakes)	Permanent	Continuous	Juveniles	Juveniles: Steelhead dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. However, steelhead are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth, fitness, and productivity.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during predominantly during spring outmigration period through lakes)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival and fitness, spawning success, and overall population productivity.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during predominantly during spring outmigration period through lakes)	Permanent	Continuous	Juveniles	Juveniles: Steelhead dependence on groundwater inflow to littoral lacustrine habitats is currently a data gap. However, loss of groundwater may lead to reduction in shallow water thermal refuge, increased competition, and decreased foraging opportunity.	Avoid disturbance of vegetation along shoreline.	May affect juvenile survival and fitness.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile productivity.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile survival, growth, and fitness, as well as adult spawning productivity.
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity.		May affect juvenile survival. May affect adult growth and spawning fitness.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Outfalls									
	Construction and Maintenance Activities								
	Pile driving	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
	Construction equipment operation	Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow Bypass, Fish Handling and Channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile steelhead. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effects of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. Adults: Subadult and returning adult steelhead forage in nearshore environments. Alteration in nearshore ecosystem processes may decrease foraging opportunity, affecting growth and fitness.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult steelhead salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. Adult Steelhead will generally be less sensitive to these stressors. However, increased stress and delayed migration in the migratory corridor may reduce fitness and ultimately reduce spawning success.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of longitudinal connectivity may result from water quality barrier when high effluent discharge causes chemical barrier to migration. If constructed parallel to the channel, side channel and floodplain habitat may become fragmented. These actions will result in changes in habitat structure, availability, and suitability; reduced food web complexity.	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: High flow outfalls can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity. (depending on specific water quality effects)
	Marine and Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Outfalls in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	The degree to which outfalls affect riparian vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine environments.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults		Avoid disturbance of vegetation along stream.	
	Marine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round, (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. The extent of nearshore habitat use by juvenile steelhead is currently a data gap. However, juveniles trapped by tidal exchange in specific habitats, such as pocket estuaries, may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The potential effects of this mechanism on juvenile steelhead are generally unknown. However, may affect juvenile survival and growth.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as juvenile steelhead use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The potential effects of this mechanism on juvenile steelhead are generally unknown. However, may affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Steelhead dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, steelhead are known to use terrestrial insect resources recruited from the riparian zone in freshwater environments, so exploitation of these resources in marine environments is possible.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The potential effects of this mechanism on juvenile steelhead are generally unknown. However, may affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Steelhead dependence on nearshore habitat complexity is currently a data gap. Altered habitat complexity may lead to decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	The potential effects of this mechanism on juvenile steelhead are generally unknown. However, may affect juvenile survival, growth, and fitness.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Lacustrine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles	The degree to which outfalls affect riparian vegetation conditions in lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in lacustrine environments.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs	Year-round (stressor exposure occurs predominantly during spring outmigration period through lakes)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during predominantly during spring outmigration period through lakes)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of habitat features.	

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses for altered dissolved oxygen concentrations under Water Quality Modification.		See effects for related stressors for altered dissolved oxygen concentrations under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity.		May affect juvenile survival. May affect adult growth and spawning productivity.
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which outfalls affect aquatic vegetation conditions in riverine and lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine and lacustrine environments.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults			

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Water Quality Modification								
		Altered thermal regime (i.e., increased summer temperatures due to elevated effluent temperatures relative to receiving body)	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect juvenile survival and fitness. May affect adult survival and spawning productivity.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered nutrient cycling (due to effects of effluent discharge)	During and following discharge events	Long-term to permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Nutrient increases may result from decreased nutrient cycling from the loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate effluent potential to adversely affect eutrophication. Require or encourage use of upstream treatment measures prior to discharge.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.
Water Intakes /Diversion Structures									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. <u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation. <u>Juveniles</u>: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. <u>Adults</u>: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	<u>Eggs and alevins, juveniles</u>: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Potential redd scour and/or sedimentation, resulting in decreased incubation success. <u>Juveniles</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. <u>Adults</u>: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>Juveniles</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. <u>Adults</u>: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. <u>Juveniles</u>: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. <u>Adults</u>: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	<u>Juveniles</u>: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile steelhead. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effects of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. Adults: Subadult and returning adult steelhead forage in nearshore environments. Alteration in nearshore ecosystem processes may decrease foraging opportunity, affecting growth and fitness.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory habitat for adult steelhead. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality. Adult Steelhead will generally be less sensitive to these stressors. However, increased stress and delayed migration in the migratory corridor may reduce fitness and ultimately reduce spawning success.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth and fitness at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater-surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability.	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Intakes and diversions can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Upstream migration is limited causing reduced and delayed migration, increased predation. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Minimize severing upstream-downstream connectivity by installing fish passage.	May affect survival, growth, and fitness at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater-surface water exchange	Accumulation of fines will reduce hyporheic exchange, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage intakes and diversions placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Marine and Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Intakes and diversions in the marine and lacustrine environments can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Loss of LWD recruitment	Reduced availability of LWD from drift. Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival, growth, and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival. May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile survival, growth and fitness, as well as spawning success and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid disturbance of vegetation along stream.	May affect survival of eggs and alevins, as well as adult spawning productivity.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round, (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. The extent of nearshore habitat use by juvenile steelhead is currently a data gap. However, juveniles trapped by tidal exchange in specific habitats, such as pocket estuaries, may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The potential effects of this mechanism on juvenile steelhead are generally unknown. However, may affect juvenile survival and growth.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as juvenile steelhead use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The potential effects of this mechanism on juvenile steelhead are generally unknown. However, may affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Steelhead dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, steelhead are known to use terrestrial insect resources recruited from the riparian zone in freshwater environments, so exploitation of these resources in marine environments is possible.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The potential effects of this mechanism on juvenile steelhead are generally unknown. However, may affect juvenile survival, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Steelhead dependence on nearshore habitat complexity is currently a data gap. Altered habitat complexity may lead to decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	The potential effects of this mechanism on juvenile steelhead are generally unknown. However, may affect juvenile survival, growth, and fitness.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Steelhead dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction of organic matter inputs	Year-round (stressor exposure occurs predominantly during spring outmigration period through lakes)	Permanent	Continuous	Juveniles	Juveniles: Steelhead dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. However, steelhead are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth, fitness, and productivity.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during predominantly during spring outmigration period through lakes)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival and fitness, spawning success, and overall population productivity.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during predominantly during spring outmigration period through lakes)	Permanent	Continuous	Juveniles	Juveniles: Steelhead dependence on groundwater inflow to littoral lacustrine habitats is currently a data gap. However, loss of groundwater may lead to reduction in shallow water thermal refuge, increased competition, and decreased foraging opportunity.	Avoid disturbance of vegetation along shoreline.	May affect juvenile survival and fitness.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile productivity.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles;	Juveniles: See related stressor responses for altered dissolved oxygen under Water Quality Modification.		See effects for related stressors of altered dissolved oxygen under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile growth, and fitness.
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses for altered dissolved oxygen concentrations under Water Quality Modification.		See effects for related stressors for altered dissolved oxygen concentrations under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity.		May affect juvenile survival, growth, and fitness.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses for altered dissolved oxygen concentrations under Water Quality Modification.		See effects for related stressors for altered dissolved oxygen concentrations under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Ensure that appropriate instream flows necessary to regulate temperature and other habitat parameters are maintained.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Avoid nutrient inputs when possible.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. Physiological injury may affect survival, growth and fitness of juveniles. May affect adult survival and spawning productivity.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Tide Gates									
	Construction and Maintenance Activities								
	Equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth and fitness, and adult spawning productivity.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs and alevins (flood gates only), juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness; may affect adult spawning productivity.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May cause direct mortality to eggs and alevins. May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat, stranding from dewatering (during construction, maintenance, and removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Mortality or injury from entrainment. Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater-surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous		decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.		
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability; reduced food web complexity, habitat availability, and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and tidal exchange are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile steelhead. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effects of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities and tidal exchange		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered channel geometry		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lateral and longitudinal fragmentation of habitat	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Tide gates can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Upstream and downstream migrations are limited causing reduced and delayed migration and increased predation. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Limit length of time tide gates are closed as much as possible.	May affect survival at juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit length of time tide gates are closed as much as possible. No additional specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Marine								
	Lateral and longitudinal fragmentation of habitat	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Tide gates in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent. Limit length of time tide gates are closed as much as possible.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Loss of LWD recruitment	Reduced availability of LWD from drift. Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit length of time tide gates are closed as much as possible. Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival, growth, and fitness.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tide gates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate. Reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Adults		Avoid disturbance of vegetation along stream.	

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round, (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tidegates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of habitat features.	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid disturbance of vegetation along shoreline.	
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile productivity.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile growth, and fitness.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity and decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. May affect eventual spawning productivity.		May affect juvenile survival. May affect adult growth and ultimate spawning productivity.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.

Table A-6 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Steelhead Salmon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect juvenile growth and fitness and adult productivity and spawning success. May cause direct mortality in acute events.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. Intermediate-term effluent effects on receiving body pH may alter habitat suitability.	Avoid curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered salinity	Year-round	Long-term to permanent	Intermittent (daily)	Juveniles	Juveniles: Altered salinity patterns may limit habitat suitability for juvenile rearing in nearshore marine environments. This in turn may increase competition for available habitats, limiting survival, growth, and fitness.	Limit closure time of tide gate to maximize natural tidal exchange.	May affect juvenile survival, growth, and fitness.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect juvenile and adult survival, growth, and fitness.
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Juveniles	Tidegate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent. Exposure to toxic substances may lead to behavioral avoidance in adults. For juveniles, limitations in the availability of suitable juvenile rearing habitat, or potential physiological injury may affect survival, growth, and fitness.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect adult behavior. May affect juvenile survival, growth, and fitness.

Table A-7. HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout .

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. <u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. <u>Juveniles</u>: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. <u>Adults</u>: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	<u>Eggs, alevins, and juveniles</u>: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. May cause direct mortality or injury.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered sediment transport	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability as a result of beach erosion from altered sediment supply.	Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous	Juveniles	Juveniles: Sediment supply and substrate composition are core ecosystem characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile coastal cutthroat trout. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply to marine environments.	May affect juvenile survival, growth, and fitness.
	Altered substrate composition		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and Longitudinal habitat Fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of longitudinal (i.e., upstream-downstream) habitat connectivity; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Dams can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types if the dam presents a barrier to fish passage. Even when passage is provided, limitations on upstream migration may lead to decreased survival and spawning productivity due to delayed migration, increased exposure to predation, poaching, and other related stressors. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Minimize severing upstream-downstream connectivity by installing fish passage.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. <u>Adults and juveniles</u>: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. <u>Adults</u>: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dam placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible. Encourage spillway design to promote moderation of stream temperatures in downstream reaches.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered Community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species.	Year-round	Permanent	Continuous	Juveniles	<u>Juveniles</u>: Dams create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Direct mortality due to winter ice formation and scour. <u>Juveniles</u>: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. <u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. <u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. Adults: Increased mortality, decreased fitness, and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation codification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize alteration and shading of native aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Provide sufficient streamflows to avoid temperature effects in reaches downstream of the impoundment. Promote dam designs that limit impoundment effects on downstream temperatures (e.g., draw streamflows from impoundment below the stratification layer in summer).	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats	Avoid large sediment pulses during construction and dam removal where practicable.	May affect juvenile survival, growth and fitness as well as adult survival and spawning productivity.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. <u>Juveniles and adults</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. <u>Adults</u>: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Dam removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to dam removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults. Reduced adult fitness may affect spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>All exposed life history stages:</u> Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>All exposed life history stages:</u> Dam construction and operation may lead to introductions of toxic substances through accidental spills or other pathways. Impoundments may attract increased recreational vessel activity, creating a pathway for chronic exposure to hydrocarbons and other contaminants. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Require a spill control and containment plan for dam operations if appropriate. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources	May affect survival, growth and fitness at all exposed life history stages.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	Should exposure occur, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	Should exposure occur, decreased survival is likely. May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. Should exposure occur, direct mortality or injury is probable.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access and stranding (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.

Table A-7 (continued).   HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Weirs can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage weir placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species	Year-round	Permanent	Continuous	Juveniles	Juveniles: Weirs may create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. Adults: Increased mortality, decreased fitness, and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation codification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs .	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Weir removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to weir removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs and no direct waste discharge. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults. Reduced adult fitness may affect spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Weir construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dikes/Levees									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling, and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile coastal cutthroat trout. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns.	May affect juvenile survival, growth, and fitness. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory coastal cutthroat trout salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns.	May affect juvenile survival, growth, and fitness. May affect spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat, change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Dikes and levees can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Reduced availability of thermal refuge and decreased intragravel DO, nutrient cycling effects	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dike/levee placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Dikes and levees in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Lacustrine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Dikes and levees in lacustrine environments can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. Adults: Increased mortality, decreased fitness, and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity.
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. This effect may be limited in magnitude, however, as juvenile cutthroat trout use of littoral habitats is relatively limited.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and growth.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as juvenile cutthroat trout use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Coastal cutthroat trout dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, cutthroat trout are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Cutthroat trout dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival growth and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Cutthroat trout dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. However, cutthroat trout are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth, fitness, and survival.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and fitness.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Cutthroat trout dependence on groundwater inflow to littoral lacustrine habitats is currently a data gap. However, loss of groundwater may lead to reduction in shallow water thermal refuge, increased competition, and decreased foraging opportunity.	Avoid disturbance of vegetation along shoreline.	May affect juvenile survival, growth, and fitness.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	**When**	**Duration**	**Frequency**	**Life-history Form**			
	Aquatic Vegetation codification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	<u>Juveniles</u>: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	<u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	<u>Juveniles and adults</u>: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	<u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	<u>Juveniles</u>: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	<u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	<u>Juveniles and adults</u>: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	<u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. <u>Adults</u>: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.		May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Direct mortality due to winter ice formation and scour. <u>Juveniles</u>: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. <u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. <u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Outfalls									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and Alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling, and Channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. May cause direct mortality or injury.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile cutthroat trout. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect juvenile survival, growth, and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history stage.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory cutthroat trout salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns. Profile characteristics where impacts are unavoidable.	May affect juvenile survival, growth, and fitness at the juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of longitudinal connectivity may result from water quality barrier when high effluent discharge causes chemical barrier to migration. If constructed parallel to the channel, side channel and floodplain habitat may become fragmented. These actions will result in changes in habitat structure, availability, and suitability; reduced food web complexity.	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: High flow outfalls can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Marine and Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Outfalls in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	The degree to which outfalls affect riparian vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine environments.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	<u>Juveniles</u>: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. This effect may be limited in magnitude, however, as juvenile cutthroat trout use of littoral habitats is relatively limited.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and growth.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as juvenile cutthroat trout use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Cutthroat trout dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, cutthroat trout are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The degree to which outfalls affect riparian vegetation conditions in lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in lacustrine environments.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation codification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses for altered dissolved oxygen levels under Water Quality Alteration.		See effects for related stressors for altered dissolved oxygen levels under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.		May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity.
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which outfalls affect aquatic vegetation conditions in riverine and lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine and lacustrine environments.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Water Quality Modification								
		Altered thermal regime (i.e., increased summer temperatures due to elevated effluent temperatures relative to receiving body)	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling (due to effects of effluent discharge)	During and following discharge events	Long-term to permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increases may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate effluent potential to adversely affect eutrophication. Require or encourage use of upstream treatment measures prior to discharge.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect juvenile growth and fitness, may affect adult spawning productivity.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile cutthroat trout. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory cutthroat trout salmon. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. Profile characteristics where impacts are unavoidable.	May affect juvenile survival, growth, and fitness.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition and stability		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Intakes and diversions can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fines will reduce hyporheic exchange, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage intakes and diversions placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Marine and Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Intakes and diversions in the marine and lacustrine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Loss of LWD recruitment	Reduced availability of LWD from drift. Reduced availability of LWD from drift. Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. Adults: Increased mortality, decreased fitness, and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity.
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. This effect may be limited in magnitude, however, as juvenile cutthroat trout use of littoral habitats is relatively limited.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and growth.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as juvenile cutthroat trout use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Cutthroat trout dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, cutthroat trout are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Cutthroat trout dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival growth and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Cutthroat trout dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. However, cutthroat trout are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth, fitness, and survival.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and fitness.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Cutthroat trout dependence on groundwater inflow to littoral lacustrine habitats is currently a data gap. However, loss of groundwater may lead to reduction in shallow water thermal refuge, increased competition, and decreased foraging opportunity.	Avoid disturbance of vegetation along shoreline.	May affect juvenile survival, growth, and fitness.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation codification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.		May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity.
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Ensure that appropriate instream flows necessary to regulate temperature and other habitat parameters are maintained.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Avoid nutrient inputs when possible.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults. Reduced adult fitness may affect spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Tide Gates									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins (flood gates only):, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only):: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only):: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. Should exposure occur, direct mortality or injury is probable.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat, stranding from dewatering (during construction, maintenance, and removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only):: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	<u>Juveniles and adults</u>: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins (flood gates only)</u>:: Mortality or injury from entrainment. <u>Juveniles</u>: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. <u>All life-history stages</u>: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	<u>Eggs and alevins</u>: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. <u>Juveniles</u>: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. <u>Adults</u>: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile cutthroat trout. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect juvenile survival, growth, and fitness. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities and tidal exchange		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered channel geometry		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation of habitat	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Tide gates can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Upstream and downstream migrations are limited causing reduced and delayed migration and increased predation. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Limit the length of time that tide gates are closed as much as possible.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit the length of time that tide gates are closed as much as possible. No additional specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Marine								
	Lateral and longitudinal fragmentation of habitat	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Tide gates in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Loss of LWD recruitment	Reduced availability of LWD from drift Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit the length of time that tide gates are closed as much as possible. Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tide gates is considered to be a component of the effects of dikes and levees. The incremental effects of the tide gate are negligible in comparison.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine and Lacustrine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tidegates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid disturbance of vegetation along shoreline.	
	Aquatic Vegetation codification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.	Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. May affect eventual spawning productivity		May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.

Table A-7 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Coastal Cutthroat Trout.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults. Reduced adult fitness may affect spawning success.
		Altered salinity	Year-round	Long-term to permanent	Intermittent (daily)	Juveniles	Juveniles: Altered salinity patterns may limit habitat suitability for juvenile rearing in nearshore marine environments. This in turn may increase competition for available habitats, limiting survival, growth, and fitness.	Limit closure time of tide gate to maximize natural tidal exchange.	May affect juvenile survival, growth, and fitness.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect juvenile and adult survival, growth, and fitness.
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Juveniles	Tide gate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent. Exposure to toxic substances may lead to behavioral avoidance in adults. For juveniles, limitations in the availability of suitable juvenile rearing habitat, or potential physiological injury may affect survival, growth, and fitness.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect adult behavior. May affect juvenile survival, growth, and fitness.

Table A-8. HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. <u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. <u>Juveniles</u>: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. <u>Adults</u>: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	<u>Eggs, alevins, and juveniles</u>: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. May cause direct mortality or injury.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Riverine								
	Lateral and Longitudinal habitat Fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of longitudinal (i.e., upstream-downstream) habitat connectivity; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Dams can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types if the dam presents a barrier to fish passage. Even when passage is provided, limitations on upstream migration may lead to decreased survival and spawning productivity due to delayed migration, increased exposure to predation, poaching, and other related stressors. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Minimize severing upstream-downstream connectivity by installing fish passage.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dam placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible. Encourage spillway design to promote moderation of stream temperatures in downstream reaches.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered Community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species.	Year-round	Permanent	Continuous	Juveniles	Juveniles: Dams create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. Adults: Increased mortality, decreased fitness, and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize alteration and shading of native aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Provide sufficient streamflows to avoid temperature effects in reaches downstream of the impoundment. Promote dam designs that limit impoundment effects on downstream temperatures (e.g., draw streamflows from impoundment below the stratification layer in summer).	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats	Avoid large sediment pulses during construction and dam removal where practicable.	May affect juvenile survival, growth and fitness as well as adult survival and spawning productivity.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Dam removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to dam removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Dam construction and operation may lead to introductions of toxic substances through accidental spills or other pathways. Impoundments may attract increased recreational vessel activity, creating a pathway for chronic exposure to hydrocarbons and other contaminants. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Require a spill control and containment plan for dam operations if appropriate. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources	May affect survival, growth and fitness at all exposed life history stages.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	Should exposure occur, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	Should exposure occur, decreased survival is likely. May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. Should exposure occur, direct mortality or injury is probable.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access and stranding (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Weirs can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage weir placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species	Year-round	Permanent	Continuous	Juveniles	Juveniles: Weirs may create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. Adults: Increased mortality, decreased fitness, and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs .	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Weir removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to weir removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs and no direct waste discharge. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Weir construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dikes/Levees									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling, and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Altered current and circulation conditions (lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	**When**	**Duration**	**Frequency**	**Life-history Form**			
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory native trout. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for lacustrine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns.	May affect juvenile survival, growth, and fitness.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat, change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Dikes and levees can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Reduced availability of thermal refuge and decreased intragravel DO, nutrient cycling effects	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dike/levee placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	<u>All exposed life-history stages</u>: Dikes and levees in lacustrine environments can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Direct mortality due to winter ice formation and scour. <u>Juveniles</u>: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. <u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. <u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	<u>Eggs/alevins:</u> Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. <u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. <u>Adults:</u> Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	<u>Juveniles:</u> Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. Adults: Increased mortality, decreased fitness, and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival growth and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Native trout dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. However, native trout are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth, fitness, and survival.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and fitness.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Native trout dependence on groundwater inflow to littoral lacustrine habitats is currently a data gap. However, loss of groundwater may lead to reduction in shallow water thermal refuge, increased competition, and decreased foraging opportunity.	Avoid disturbance of vegetation along shoreline.	May affect juvenile survival, growth, and fitness.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Outfalls									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and Alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling, and Channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. <u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation. <u>Juveniles</u>: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. <u>Adults</u>: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	**When**	**Duration**	**Frequency**	**Life-history Form**			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity; may affect adult spawning productivity.
		Altered current and circulation conditions (lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. May cause direct mortality or injury.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory native trout. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for lacustrine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns. Profile characteristics where impacts are unavoidable.	May affect juvenile survival, growth, and fitness at the juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of longitudinal connectivity may result from water quality barrier when high effluent discharge causes chemical barrier to migration. If constructed parallel to the channel, side channel and floodplain habitat may become fragmented. These actions will result in changes in habitat structure, availability, and suitability; reduced food web complexity.	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: High flow outfalls can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Outfalls in the lacustrine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	The degree to which outfalls affect riparian vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine environments.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The degree to which outfalls affect riparian vegetation conditions in lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in lacustrine environments.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which outfalls affect aquatic vegetation conditions in riverine and lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine and lacustrine environments.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Water Quality Modification								
		Altered thermal regime (i.e., increased summer temperatures due to elevated effluent temperatures relative to receiving body)	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling (due to effects of effluent discharge)	During and following discharge events	Long-term to permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increases may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate effluent potential to adversely affect eutrophication. Require or encourage use of upstream treatment measures prior to discharge.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	**When**	**Duration**	**Frequency**	**Life-history Form**			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	<u>Eggs, alevins, and juveniles</u>: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Potential redd scour and/or sedimentation, resulting in decreased incubation success. <u>Juveniles</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. <u>Adults</u>: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect juvenile growth and fitness, may affect adult spawning productivity.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>Juveniles</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. <u>Adults</u>: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. <u>Juveniles</u>: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. <u>Adults</u>: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	<u>Juveniles</u>: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	<u>Juveniles and adults</u>: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory native trout. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. Profile characteristics where impacts are unavoidable.	May affect juvenile survival, growth, and fitness.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition and stability		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Intakes and diversions can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fines will reduce hyporheic exchange, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage intakes and diversions placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Intakes and diversions in the lacustrine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Loss of LWD recruitment	Reduced availability of LWD from drift. Reduced availability of LWD from drift. Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. Adults: Increased mortality, decreased fitness, and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival growth and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Native trout dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. However, native trout are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will therefore result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth, fitness, and survival.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and fitness.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Native trout dependence on groundwater inflow to littoral lacustrine habitats is currently a data gap. However, loss of groundwater may lead to reduction in shallow water thermal refuge, increased competition, and decreased foraging opportunity.	Avoid disturbance of vegetation along shoreline.	May affect juvenile survival, growth, and fitness.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.	Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Ensure that appropriate instream flows necessary to regulate temperature and other habitat parameters are maintained.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Avoid nutrient inputs when possible.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Tide Gates									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane (flood gates only) ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Flow Bypass, fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins (flood gates only), and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Altered current and circulation conditions (lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. Should exposure occur, direct mortality or injury is probable.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Loss of habitat, stranding from dewatering (during construction, maintenance, and removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation of habitat	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Tide gates can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Upstream and downstream migrations are limited causing reduced and delayed migration and increased predation. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Limit the length of time that tide gates are closed as much as possible.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit the length of time that tide gates are closed as much as possible. No additional specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tide gates is considered to be a component of the effects of dikes and levees. The incremental effects of the tide gate are negligible in comparison.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The effects of tide gates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tide gates is considered to be a component of the effects of dikes and levees. The incremental effects of the tide gate are negligible in comparison.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid disturbance of vegetation along shoreline.	
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.	Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect juvenile and adult survival, growth, and fitness.

Table A-8 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Native Trout (Westslope Cutthroat and Redband Trout).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Juveniles	Tide gate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent. Exposure to toxic substances may lead to behavioral avoidance in adults. For juveniles, limitations in the availability of suitable juvenile rearing habitat, or potential physiological injury may affect survival, growth, and fitness.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect adult behavior. May affect juvenile survival, growth, and fitness.

Table A-9. HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. May cause direct mortality or injury.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Marine								
	Altered sediment transport	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability as a result of beach erosion from altered sediment supply.	Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous	Juveniles	Juveniles and adults: Sediment supply and substrate composition are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of foraging habitats for adult char. This may occur through a number of specific stressors, including change in current and wave energy patterns, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and fitness, and potentially decreased survival due to predation exposure.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply to marine environments.	May affect juvenile survival, growth, and fitness.
	Altered substrate composition		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Riverine								
	Lateral and Longitudinal habitat Fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of longitudinal (i.e., upstream-downstream) habitat connectivity; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: Dams can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types if the dam presents a barrier to fish passage. Even when passage is provided, limitations on upstream migration may lead to decreased survival and spawning productivity due to delayed migration, increased exposure to predation, poaching, and other related stressors. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Minimize severing upstream-downstream connectivity by installing fish passage.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. <u>Adults and juveniles</u>: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. <u>Adults</u>: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dam placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible. Encourage spillway design to promote moderation of stream temperatures in downstream reaches.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered Community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species.	Year-round	Permanent	Continuous	Juveniles	<u>Juveniles</u>: Dams create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. Adults: Increased mortality, decreased fitness, and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Char dependence on littoral lacustrine vegetation is relatively limited as this species tends to occupy cold water river habitats and deepwater lacustrine habitats in the photic or profundal zone where aquatic vegetation is limited or non-existent. Therefore, modification of aquatic vegetation may have limited direct effects on this species. However, such alterations may limit the productivity of prey species for native char, leading to decreased foraging opportunity and decreased growth and fitness.	Design: Limit project structural footprint to minimize alteration and shading of native aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Provide sufficient streamflows to avoid temperature effects in reaches downstream of the impoundment. Promote dam designs that limit impoundment effects on downstream temperatures (e.g., draw streamflows from impoundment below the stratification layer in summer).	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats	Avoid large sediment pulses during construction and dam removal where practicable.	May affect juvenile survival, growth and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Dam removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to dam removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect survival, growth and fitness at all exposed life history stages.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Dam construction and operation may lead to introductions of toxic substances through accidental spills or other pathways. Impoundments may attract increased recreational vessel activity, creating a pathway for chronic exposure to hydrocarbons and other contaminants. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Require a spill control and containment plan for dam operations if appropriate. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources	May affect survival, growth and fitness at all exposed life history stages.
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	Should exposure occur, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	Should exposure occur, decreased survival is likely. May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. Should exposure occur, direct mortality or injury is probable.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Loss of habitat access and stranding (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Weirs can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage weir placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species	Year-round	Permanent	Continuous	Juveniles	Juveniles: Weirs may create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. Adults: Increased mortality, decreased fitness, and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Char dependence on littoral lacustrine vegetation is relatively limited as this species tends to occupy cold water river habitats and deepwater lacustrine habitats in the photic or profundal zone where aquatic vegetation is limited or non-existent. Therefore, modification of aquatic vegetation may have limited direct effects on this species. However, such alterations may limit the productivity of prey species for native char, leading to decreased foraging opportunity and decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs .	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Weir removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to weir removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs and no direct waste discharge. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Weir construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dikes/Levees									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling, and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of foraging habitats for adult char. This may occur through a number of specific stressors, including change in current and wave energy patterns, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and fitness, and potentially decreased survival due to predation exposure.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns.	May affect juvenile survival, growth, and fitness.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats. Use of these habitats by adult char is limited, as these species tend to utilize cold, deepwater habitats in the photic and profundal zone. However, reduction in nearshore habitat productivity may affect abundance of potential prey species, reducing adult foraging opportunity and leading to decreased growth and fitness.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns.	May affect juvenile survival, growth, and fitness.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat, change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Dikes and levees can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered groundwater-surface water exchange	Reduced availability of thermal refuge and decreased intragravel DO, nutrient cycling effects	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dike/levee placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Dikes and levees in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Lacustrine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Dikes and levees in lacustrine environments can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. Adults: Increased mortality, decreased fitness, and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles; Adults	Juveniles and adults: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, adult char trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. This effect may be limited in magnitude, however, as adult char use of littoral habitats is relatively limited.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and growth.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults	Juveniles and adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as adult char use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Char dependence on autochthonous inputs from marine riparian vegetation is a data gap. However, the dependence on terrestrial insect fall as a food source may be limited as adult char are primarily piscivorous. Indirect effects on food web productivity may decrease foraging opportunities, leading to decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Char dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles; Adults	Juvenile and adults: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions, and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade, leading to decreased availability of refuge and forage habitat, increased competition, and increased predation exposure.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults	Juveniles and adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival growth and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Char dependence on autochthonous inputs from lacustrine riparian vegetation is a data gap. However, the dependence on terrestrial insect fall as a food source may be limited as adult char are primarily piscivorous. Indirect effects on food web productivity may decrease foraging opportunities, leading to decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and fitness.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Char dependence on groundwater inflow to littoral lacustrine habitats is currently a data gap. However, loss of groundwater may lead to reduction in shallow water thermal refuge, increased competition, and decreased foraging opportunity.	Avoid disturbance of vegetation along shoreline.	May affect juvenile survival, growth, and fitness.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Char dependence on littoral riverine and lacustrine vegetation is relatively limited as this species tends to occupy cold water river habitats and deepwater lacustrine habitats in the photic or profundal zone where aquatic vegetation is limited or non-existent. Therefore, modification of aquatic vegetation may have limited direct effects on this species. However, such alterations may limit the productivity of prey species for native char, leading to decreased foraging opportunity and decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.		May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Outfalls									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and Alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Flow Bypass, Fish handling, and Channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. <u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation. <u>Juveniles</u>: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. <u>Adults</u>: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	<u>Eggs, alevins, and juveniles</u>: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Potential redd scour and/or sedimentation, resulting in decreased incubation success. <u>Juveniles</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. <u>Adults</u>: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity; may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>Juveniles</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. <u>Adults</u>: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins</u>: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. <u>Juveniles</u>: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. <u>Adults</u>: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. May cause direct mortality or injury.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	<u>Juveniles</u>: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles; Adults	<u>Juveniles and adults</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of foraging habitats for adult char. This may occur through a number of specific stressors, including change in current and wave energy patterns, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and fitness, and potentially decreased survival due to predation exposure.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect juvenile survival, growth, and fitness at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history stage.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles	<u>Juveniles</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and migratory char. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for lacustrine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns. Profile characteristics where impacts are unavoidable.	May affect juvenile survival, growth, and fitness at the juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of longitudinal connectivity may result from water quality barrier when high effluent discharge causes chemical barrier to migration. If constructed parallel to the channel, side channel and floodplain habitat may become fragmented. These actions will result in changes in habitat structure, availability, and suitability; reduced food web complexity.	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	<u>All exposed life-history stages</u>: High flow outfalls can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine and Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Outfalls in the marine and lacustrine environments can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	The degree to which outfalls affect riparian vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine environments.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles; Adults	Juveniles and adults: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, adult char trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness. This effect may be limited in magnitude, however, as adult char use of littoral habitats is relatively limited.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and growth.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults	Juveniles and adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as adult char use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Char dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, the dependence on terrestrial insect fall as a food source may be limited as adult char are primarily piscivorous. Indirect effects on food web productivity may decrease foraging opportunities, leading to decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The degree to which outfalls affect riparian vegetation conditions in lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in lacustrine environments.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses for altered dissolved oxygen levels under Water Quality Alteration.		See effects for related stressors for altered dissolved oxygen levels under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.		May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which outfalls affect aquatic vegetation conditions in riverine and lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine and lacustrine environments.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Water Quality Modification								
		Altered thermal regime (i.e., increased summer temperatures due to elevated effluent temperatures relative to receiving body)	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	<u>Eggs and alevins:</u> Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. <u>Juveniles and adults</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. <u>Adults</u>: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling (due to effects of effluent discharge)	During and following discharge events	Long-term to permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life history stages: Nutrient increases may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate effluent potential to adversely affect eutrophication. Require or encourage use of upstream treatment measures prior to discharge.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Eggs and alevins; Juveniles; Adults	<u>All exposed life history stages</u>: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect juvenile growth and fitness, may affect adult spawning productivity.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	Eggs and alevins: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of foraging habitats for adult char. This may occur through a number of specific stressors, including change in current and wave energy patterns, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and fitness, and potentially decreased survival due to predation exposure.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect juvenile and adult survival and growth.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles	Juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of foraging habitat for adult char. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for lacustrine migration, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. Profile characteristics where impacts are unavoidable.	May affect juvenile survival, growth, and fitness.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition and stability		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Intakes and diversions can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fines will reduce hyporheic exchange, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage intakes and diversions placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and alevin survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine and Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Intakes and diversions in the marine and lacustrine environments can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Loss of LWD recruitment	Reduced availability of LWD from drift. Reduced availability of LWD from drift. Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults	Eggs/alevins: Decreased incubation success due to decreased redd dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, and resulting effects on growth and fitness. Adults: Increased mortality, decreased fitness, and spawning success due to decreased availability of suitable migratory and spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Decreased incubation success. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and alevins. May affect juvenile survival and growth. May affect adult spawning productivity.
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles; Adults	Adults and juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, adult char trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence have been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible.	May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults	Adults and juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Char dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, the dependence on terrestrial insect fall as a food source may be limited as adult char are primarily piscivorous. Indirect effects on food web productivity may decrease foraging opportunities, leading to decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles; Adults	Juveniles: Char dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles; Adults	Adults and juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of lacustrine current patterns, wind conditions, and other factors. However, adult char trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence have been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible.	May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults	Adults and juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles; Adults	<u>Adults and juveniles</u>: Char dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. However, the dependence on terrestrial insect fall as a food source may be limited as adult char are primarily piscivorous. Indirect effects on food web productivity may decrease foraging opportunities, leading to decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	<u>Adults</u>: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles; Adults	<u>Juveniles</u>: Char dependence on groundwater inflow to nearshore lacustrine habitats is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	<u>Juveniles</u>: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	<u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	<u>Juveniles</u>: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	<u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. <u>Adults</u>: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.		May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity.
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	<u>Adults and juveniles</u>: Char dependence on littoral riverine and lacustrine vegetation is relatively limited as this species tends to occupy cold water river habitats and deepwater lacustrine habitats in the photic or profundal zone where aquatic vegetation is limited or non-existent. Therefore, modification of aquatic vegetation may have limited direct effects on this species. However, such alterations may limit the productivity of prey species for native char, leading to decreased foraging opportunity and decreased growth and fitness.	<u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Ensure that appropriate instream flows necessary to regulate temperature and other habitat parameters are maintained.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Avoid nutrient inputs when possible.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All expose life history stages: Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Tide Gates									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles	Eggs, alevins, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only): Potential redd scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and alevin life-history stage, may affect adult spawning productivity.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only):: Potential decreased egg incubation success and alevin survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and alevin life-history stages; may affect adult fitness and spawning productivity. Should exposure occur, direct mortality or injury is probable.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat, stranding from dewatering (during construction, maintenance, and removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only):: Potential decreased egg incubation success and alevin survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and alevins; Juveniles; Adults	Eggs and alevins (flood gates only):: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and alevin life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles Adults	<u>Eggs and alevins</u>: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and alevin survival. <u>Juveniles</u>: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. <u>Adults</u>: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of redds) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and alevin and juvenile life-history stages. May affect spawning productivity
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles; Adults	<u>Juveniles and adults</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of foraging habitats for adult char. This may occur through a number of specific stressors, including change in current and wave energy patterns, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and fitness, and potentially decreased survival due to predation exposure.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect juvenile survival, growth, and fitness. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Altered current velocities and tidal exchange		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered channel geometry		Year-round	Permanent	Continuous				

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation of habitat	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults	All exposed life-history stages: Tide gates can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and juvenile rearing habitat for salmonid species dependent on these habitat types. Upstream and downstream migrations are limited causing reduced and delayed migration and increased predation. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Limit the length of time that tide gates are closed as much as possible.	May affect survival at egg, alevin, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit the length of time that tide gates are closed as much as possible. No additional specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Marine								
	Lateral and longitudinal fragmentation of habitat	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Tide gates in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging salmonids to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Loss of LWD recruitment	Reduced availability of LWD from drift Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit the length of time that tide gates are closed as much as possible. Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival, growth and fitness.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and alevins; Juveniles; Adults	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tide gates is considered to be a component of the effects of dikes and levees. The incremental effects of the tide gate are negligible in comparison.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased redd dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and alevins; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and alevins; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Marine and Lacustrine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tidegates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid disturbance of vegetation along shoreline.	
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Char dependence on littoral riverine vegetation is relatively limited as this species tends to occupy cold water river habitats and deepwater lacustrine habitats in the photic or profundal zone where aquatic vegetation is limited or non-existent. Therefore, modification of aquatic vegetation may have limited direct effects on this species. However, such alterations may limit the productivity of prey species for native char, leading to decreased foraging opportunity and decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect growth and fitness of juveniles and adults. Reduced adult fitness may lead to decreased spawning success.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.		May affect juvenile survival, growth, and fitness.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival, growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles	Juveniles: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness. May affect eventual spawning productivity		May affect juvenile survival, growth, and fitness. May affect adult growth and spawning productivity.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.

Table A-9 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Bull Trout and Dolly Varden (Native Char).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and alevins; Juveniles; Adults	Eggs and alevins: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and alevins through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and alevins. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered salinity	Year-round	Long-term to permanent	Intermittent (daily)	Juveniles	Juveniles: Altered salinity patterns may limit habitat suitability for juvenile rearing in nearshore marine environments. This in turn may increase competition for available habitats, limiting survival, growth, and fitness.	Limit closure time of tide gate to maximize natural tidal exchange.	May affect juvenile survival, growth, and fitness.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect juvenile and adult survival, growth, and fitness.
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Juveniles	Tide gate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent. Exposure to toxic substances may lead to behavioral avoidance in adults. For juveniles, limitations in the availability of suitable juvenile rearing habitat, or potential physiological injury may affect survival, growth, and fitness.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect adult behavior. May affect juvenile survival, growth, and fitness.

Table A-10. HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed local migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs, larvae, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential ~~redd~~ scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration to spawning stream, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and larvae life-history stage, may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larvae survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and larvae life-history stages; may affect adult fitness and spawning productivity. May cause direct mortality or injury.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larvae survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and larvae life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles Adults	Eggs-larvae: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased egg incubation success and survival. Pygmy whitefish dependence on groundwater inflow for incubation success is currently a data gap. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of spawning areas) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and larvae and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and Longitudinal habitat Fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of longitudinal (i.e., upstream-downstream) habitat connectivity; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Larvae and adults: Dams can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor is unlikely to significantly affect pygmy whitefish, which spawn in the mainstems of small, swift rivers and the larvae are transported to oligotrophic lakes for rearing to adulthood.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Minimize severing upstream-downstream connectivity by installing fish passage.	Stressor may affect larval and adult pygmy whitefish, but is unlikely to adversely affect these species.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dam placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible. Encourage spillway design to promote moderation of stream temperatures in downstream reaches.	May affect egg and larvae survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered Community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species.	Year-round	Permanent	Continuous	Juveniles	Juveniles: Dams create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs-larvae; Juveniles; Adults	Eggs-larvae: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns (optimal range 50°F or less). Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect larval, juvenile, and adult growth and fitness.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults	Eggs-larvae: Decreased incubation success due to decreased dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival during incubation, rearing, and spawning.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Pygmy whitefish dependency upon allochthonous input is a data gap. However, Pygmy whitefish feed on zooplankton and aquatic insects that could be associated with terrestrial riparian inputs. Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Decreased foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased pool availability and availability of suitable spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect larval and juvenile survival, growth, and productivity. May affect adult spawning productivity
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and larvae; Adults	Eggs-larvae: Decreased incubation success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs-larvae and adult spawning productivity.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize alteration and shading of native aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Provide sufficient streamflows to avoid temperature effects in reaches downstream of the impoundment. Promote dam designs that limit impoundment effects on downstream temperatures (e.g., draw streamflows from impoundment below the stratification layer in summer).	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. (dissolved oxygen should be > 5ppm) Juveniles and adults: behavioral avoidance of habitats affected by acute low DO events, increasing stress, predation exposure, and competition for suitable habitats	Avoid large sediment pulses during construction and dam removal where practicable.	May affect juvenile survival, growth and fitness as well as adult survival and spawning productivity.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and larvae through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Dam removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to dam removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Dam construction and operation may lead to introductions of toxic substances through accidental spills or other pathways. Impoundments may attract increased recreational vessel activity, creating a pathway for chronic exposure to hydrocarbons and other contaminants. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Require a spill control and containment plan for dam operations if appropriate. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources	May affect survival, growth and fitness at all exposed life history stages.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	<u>All exposed life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae</u>: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. <u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish are not captured and relocated successfully. <u>Juveniles</u>: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. <u>Adults</u>: Delayed local migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs, larvae, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	Should exposure occur, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential ~~redd~~ scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration to spawning stream, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	Should exposure occur, decreased survival is likely. May affect survival during egg and larvae life-history stage, may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larvae survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and larvae life-history stages; may affect adult fitness and spawning productivity. Should exposure occur, direct mortality or injury is probable.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access and stranding (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larvae survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and larvae life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles Adults	Eggs-larvae: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased egg incubation success and survival. Pygmy whitefish dependence on groundwater inflow for incubation success is currently a data gap. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of spawning areas) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and larvae and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Larvae and adults: Weirs can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor is unlikely to significantly affect pygmy whitefish, which spawn in the mainstems of small, swift rivers and the larvae are transported to oligotrophic lakes for rearing to adulthood.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, larvae, and juvenile life-history stages. May affect spawning productivity.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Eggs and larvae: . Pygmy whitefish dependence on groundwater inflow for incubation success is currently a data gap. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage weir placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and larvae survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species	Year-round	Permanent	Continuous	Juveniles	Juveniles: Weirs may create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs-larvae: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns (optimal range 50°F or less). Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect larval, juvenile, and adult growth and fitness.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults	Eggs-larvae: Decreased incubation success due to decreased dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Pygmy whitefish dependency upon allochthonous input is a data gap. However, Pygmy whitefish feed on zooplankton and aquatic insects that could be associated with terrestrial riparian inputs. Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing, growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Eggs and larvae; Juveniles; Adults	Larvae and juveniles: Decreased foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased pool availability and availability of suitable spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and larvae; Adults	Eggs-larvae: . Pygmy whitefish dependence on groundwater inflow for incubation success is currently a data gap. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and larvae. May affect juvenile survival and growth. May affect adult spawning productivity.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile and adult survival, growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. (dissolved oxygen should be > 5.0 ppm) Juveniles and adults: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality.	Avoid sediment pulses. Limit nutrient inputs .	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and larvae through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All expose life history stages: Weir removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to weir removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs and no direct waste discharge. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All expose life history stages: Weir construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dikes/Levees									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	<u>All exposed life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling, and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae</u>: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. <u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation. Failure to capture and relocate fish may lead to mortality from stranding. <u>Juveniles</u>: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. <u>Adults</u>: Delayed local migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	<u>Eggs, larvae, and juveniles</u>: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae</u>: Potential ~~redd~~ scour and/or sedimentation, resulting in decreased incubation success. <u>Juveniles</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. <u>Adults</u>: Delayed migration to spawning stream, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and larvae life-history stage, may affect adult spawning productivity.
		Altered current and circulation conditions (lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>Juveniles</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. <u>Adults</u>: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae</u>: Potential decreased egg incubation success and larvae survival due to turbidity exposure and substrate disturbance. <u>Juveniles</u>: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. <u>Adults</u>: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and larvae life-history stages; may affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	<u>Juveniles</u>: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>Juveniles</u>: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. <u>Adults</u>: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and larvae; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May affect survival during egg and larvae life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles Adults	Eggs-larvae: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased egg incubation success and survival. Pygmy whitefish dependence on groundwater inflow for incubation success is currently a data gap. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of spawning areas) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival and productivity at egg, larvae, and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and adult whitefish. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, fitness, and productivity, as well as direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns.	May affect juvenile survival, growth, and fitness.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat, change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Larvae and adults: Dikes and levees can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor is unlikely to significantly affect pygmy whitefish, which spawn in the mainstems of small, swift rivers and the larvae are transported to oligotrophic lakes for rearing to adulthood.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	Stressor may affect larval and adult pygmy whitefish, but is unlikely to adversely affect these species.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Reduced availability of thermal refuge and decreased intragravel DO, nutrient cycling effects	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Decreased hyporheic exchange may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dike/levee placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and larvae survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles	Juveniles: Dikes and levees can fragment nearshore lacustrine habitats. Larval and juvenile pygmy whitefish are known to occur in these habitat types, but knowledge of dependence on these habitats is limited. Given prevalence in these habitat types, however, stressor exposure may affect juvenile survival, growth, and fitness if habitat access is impaired.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs-larvae: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns (optimal range 50°F or less). Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect larval, juvenile, and adult growth and fitness.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults	Eggs-larvae: Decreased incubation success due to decreased dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival during incubation, rearing, and spawning.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Pygmy whitefish dependency upon allochthonous input is a data gap. However, Pygmy whitefish feed on zooplankton and aquatic insects that could be associated with terrestrial riparian inputs. Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing growth and fitness.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Decreased foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased pool availability and availability of suitable spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect larval and juvenile survival, growth, and productivity. May affect adult spawning productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Eggs and larvae: . Pygmy whitefish dependence on groundwater inflow for incubation success is currently a data gap. Juveniles: Decreased availability of thermal refuge habitat, resulting in increased thermal stress, increased competition for suitable habitats. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and larvae. May affect juvenile survival and growth. May affect adult spawning productivity.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of currents, wind conditions, and other factors. However, juveniles trapped in habitats with isolated water level changes may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival growth and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Pygmy whitefish are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth, fitness, and survival.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and fitness.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Whitefish dependence upon groundwater inflow is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.(dissolved oxygen levels should be >5 ppm). Juveniles and adults: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival, growth, and fitness as well as adult survival and spawning productivity.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and larvae through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All expose life history stages: Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Outfalls									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and Larvae; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling, and Channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed local migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	**When**	**Duration**	**Frequency**	**Life-history Form**			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs, larvae, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential ~~redd~~ scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration to spawning stream, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and larvae life-history stage, may affect adult spawning productivity; may affect adult spawning productivity.
		Altered current and circulation conditions (lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larvae survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and larvae life-history stages; may affect adult fitness and spawning productivity. May cause direct mortality or injury.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and larvae life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles Adults	Eggs-larvae: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased egg incubation success and survival. Pygmy whitefish dependence on groundwater inflow for incubation success is currently a data gap. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of spawning areas) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and larvae and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and adult whitefish. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, fitness, and productivity, as well as direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, wave energy, and current patterns. Profile characteristics where impacts are unavoidable.	May affect juvenile survival, growth, and fitness at the juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of longitudinal connectivity may result from water quality barrier when high effluent discharge causes chemical barrier to migration. If constructed parallel to the channel, side channel and floodplain habitat may become fragmented. These actions will result in changes in habitat structure, availability, and suitability; reduced food web complexity.	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: High flow outfalls can force channel incision, leading to disconnection of side channel and floodplain habitats during lower flow periods. This stressor is unlikely to significantly affect pygmy whitefish, which spawn in the mainstems of small, swift rivers and the larvae are transported to oligotrophic lakes for rearing to adulthood.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	Stressor may affect larval and adult pygmy whitefish, but is unlikely to adversely affect these species.
	Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Outfalls in the lacustrine environment can fragment nearshore rearing habitat. Larval and juvenile pygmy whitefish are known to occur in these habitat types, but knowledge of dependence on these habitats is limited. Given prevalence in these habitat types, however, stressor exposure may affect juvenile survival, growth, and fitness if habitat access is impaired.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and larvae; Juveniles; Adults	The degree to which outfalls affect riparian vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine environments.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The degree to which outfalls affect riparian vegetation conditions in lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in lacustrine environments.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which outfalls affect aquatic vegetation conditions in riverine and lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine and lacustrine environments.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Water Quality Modification								
		Altered thermal regime (i.e., increased summer temperatures due to elevated effluent temperatures relative to receiving body)	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.(dissolved oxygen levels should be >5 ppm). Juveniles and adults: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality.	Avoid sediment pulses. Limit nutrient inputs.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and larvae through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect survival and fitness of juveniles and adults.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered nutrient cycling (due to effects of effluent discharge)	During and following discharge events	Long-term to permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Nutrient increases may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate effluent potential to adversely affect eutrophication. Require or encourage use of upstream treatment measures prior to discharge.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow Bypass, Fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed local migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs, larvae, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential ~~redd~~ scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration to spawning stream, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and larvae life-history stage, may affect juvenile growth and fitness, may affect adult spawning productivity.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larvae survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and larvae life-history stages; may affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and larvae life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles Adults	Eggs-larvae: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased egg incubation success and survival. Pygmy whitefish dependence on groundwater inflow for incubation success is currently a data gap. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of spawning areas) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and larvae and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juvenile and adult whitefish. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, fitness, and productivity, as well as direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns. Profile characteristics where impacts are unavoidable.	May affect survival and productivity at juvenile life-history stage. Decreased adult fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition and stability		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Intakes and diversions can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor is unlikely to significantly affect pygmy whitefish, which spawn in the mainstems of small, swift rivers and the larvae are transported to oligotrophic lakes for rearing to adulthood.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	Stressor may affect larval and adult pygmy whitefish, but is unlikely to adversely affect these species.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fines will reduce hyporheic exchange, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage intakes and diversions placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and larvae survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Intakes and diversions in the lacustrine environment can fragment nearshore littoral habitat. Larval and juvenile pygmy whitefish are known to occur in these habitat types, but knowledge of dependence on these habitats is limited. Given prevalence in these habitat types, however, stressor exposure may affect juvenile survival, growth, and fitness if habitat access is impaired.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect juvenile survival, growth, and fitness.
	Loss of LWD recruitment	Reduced availability of LWD from drift. Reduced availability of LWD from drift. Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs-larvae: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns (optimal range 50°F or less). Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect larval, juvenile, and adult growth and fitness.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults	Eggs-larvae: Decreased incubation success due to decreased dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival during incubation, rearing, and spawning.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Pygmy whitefish dependency upon allochthonous input is a data gap. However, Pygmy whitefish feed on zooplankton and aquatic insects that could be associated with terrestrial riparian inputs. Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile rearing, growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Decreased foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased pool availability and availability of suitable spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and larvae; Adults	Eggs-larvae: Decreased incubation success. Adults: Decrease in suitable spawning habitat, increased competition, decreased spawning fitness and success.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs-larvae and adult spawning productivity
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of currents, wind conditions, and other factors. However, juveniles trapped in habitats with isolated water level changes may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival, growth, and fitness.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival growth and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Pygmy whitefish are known to use terrestrial insect resources recruited from the riparian zone. Alteration of vegetation will result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth, fitness, and survival.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival and productivity, spawning success, and overall population productivity.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Whitefish dependence upon groundwater inflow is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile survival, growth, and fitness.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Ensure that appropriate instream flows necessary to regulate temperature and other habitat parameters are maintained.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.(dissolved oxygen levels should be >5 ppm). Juveniles and adults: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality.	Avoid sediment pulses. Avoid nutrient inputs when possible.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and larvae through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All expose life history stages: Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Tide Gates									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow Bypass, fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed local migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs, larvae, and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential ~~redd~~ scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration to spawning stream, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and larvae life-history stage, may affect adult spawning productivity.
		Altered current and circulation conditions (lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	May affect juvenile growth and fitness, potentially limiting survival during ocean migration; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larvae survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses, potential migration delay leading to reduced spawning productivity, reduced foraging opportunities, and increased predation risk.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg and larvae life-history stages; may affect adult fitness and spawning productivity. Should exposure occur, direct mortality or injury is probable.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Loss of habitat, stranding from dewatering (during construction, maintenance, and removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larvae survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg and larvae life-history stages. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles Adults	Eggs-larvae: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased egg incubation success and survival. Pygmy whitefish dependence on groundwater inflow for incubation success is currently a data gap. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation of spawning areas) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and larvae and juvenile life-history stages. May affect spawning productivity
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation of habitat	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Tide gates can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor is unlikely to significantly affect pygmy whitefish, which spawn in the mainstems of small, swift rivers and the larvae are transported to oligotrophic lakes for rearing to adulthood. Upstream and downstream migrations are limited causing reduced and delayed migration and increased predation. Decreased habitat availability may lead to density-dependent effects on adult spawning success, as well as juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Limit the length of time that tide gates are closed as much as possible.	May affect survival at egg, larvae, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit the length of time that tide gates are closed as much as possible. No additional specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and larvae; Juveniles; Adults	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tide gates is considered to be a component of the effects of dikes and levees. The incremental effects of the tide gate are negligible in comparison.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tidegates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid disturbance of vegetation along shoreline.	
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	<u>Juveniles</u>: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	<u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	<u>Juveniles and adults</u>: See related stressor responses under Water Quality Modification.	<u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	<u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. <u>Adults:</u> Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat.		May affect juvenile survival, growth, and fitness.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.(dissolved oxygen levels should be >5 ppm). Juveniles and adults: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality.	Avoid sediment pulses. Limit nutrient inputs.	May affect juvenile survival and productivity as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and decreased survival of eggs and larvae through reduction in substrate dissolved oxygen. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness, as well as adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect juvenile and adult survival, growth, and fitness.

Table A-10 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pygmy Whitefish.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Juveniles	Tide gate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent. Exposure to toxic substances may lead to behavioral avoidance in adults. For juveniles, limitations in the availability of suitable juvenile rearing habitat, or potential physiological injury may affect survival, growth, and fitness.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect adult behavior. May affect juvenile survival, growth, and fitness.

Table A-11. HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane. ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs and larvae, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential egg scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and larval life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larvae survival due to water loss and stranding. Juveniles and adults: Loss of habitat access, stranding may lead to injury or mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Juveniles; Adults	Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May affect juvenile survival, growth, and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles Adults	All exposed life history stages: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. Mudminnow are dependent on habitats with low or zero flow velocity, loose silt substrate, and abundant aquatic vegetation for survival. Any alterations in hydraulic and geomorphic conditions that affect flow and substrate characteristics are likely to affect habitat suitability for this species. This in turn is likely to affect survival, growth, and fitness at all life history stages, spawning productivity, and distribution and abundance.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at all life history stages, spawning productivity. May affect distribution and abundance.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and Longitudinal habitat Fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of longitudinal (i.e., upstream-downstream) habitat connectivity; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Dams can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. If these conditions lead to loss of suitable habitats for mudminnow, population loss could occur.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Minimize severing upstream-downstream connectivity by installing fish passage.	May affect survival at egg, larval, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Alteration of hyporheic exchange may alter or affect habitat suitability for this species by affecting the extent and quality of wetland habitats.	Encourage dam placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible. Encourage spillway design to promote moderation of stream temperatures in downstream reaches.	May affect egg and larvae survival, may affect juvenile survival, growth, and fitness. May affect adult survival growth and fitness.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered Community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species.	Year-round	Permanent	Continuous	Juveniles	Juveniles: Dams create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality or impaired survival due to temperature effects. Adults and juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Decreased fitness, physiological injury or mortality from exposure to temperatures in excess of tolerance thresholds (noting that mudminnow are relatively tolerant of high water temperatures.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Decreased habitat suitability, leading to population loss.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles; Adults	Juveniles and adudlts: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult and juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	All exposed life history stages: Decreased habitat suitability, leading to population loss.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced habitat productivity.	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Decreased habitat suitability, leading to population loss.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and larvae. May affect juvenile survival and growth. May affect adult spawning productivity.
	Aquatic Vegetation Modification								

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juveniles. This is particularly true for mudminnow, which are dependent on aquatic vegetation for habitat.	<u>Design</u>: Limit project structural footprint to minimize alteration and shading of native aquatic vegetation to the greatest extent practicable. <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile and adult survival, growth, and fitness. May affect spawning productivity, abundance and distribution.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	<u>All exposed life history stages:</u> Decreased habitat suitability, leading to population loss.		May affect juvenile growth and survival, spawning success, and overall population productivity.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Juveniles; Adults	<u>Juveniles and adults</u>: This species has a wide temperature tolerance range. May result in behavioral alteration.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult behavior.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by impoundment draining), dependent on contributing mechanism of impact	Intermittent to intermediate-term (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae</u>: Mortality in acute low dissolved oxygen events due to asphyxiation. <u>Juveniles and adults</u>: Behavioral alteration resulting in increased predation exposure (mudminnows are tolerant of wide variations in DO levels due to the ability to absorb atmospheric oxygen).	Avoid large sediment pulses or dewatering of culvert induced impoundments where practicable.	May affect egg and larval survival. May affect juvenile and adult behavior.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae:</u> Turbidity of sufficient magnitude may decrease egg and larval survival. <u>Juveniles and adults</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure etc.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness and adult productivity and spawning success.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane. ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness..	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs and larvae, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential egg scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and larval life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae</u>: Potential decreased egg incubation success and larvae survival due to water loss and stranding. <u>Juveniles</u>: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. <u>Adults</u>: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	<u>Juveniles and adults</u>: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	<u>Juveniles and adults</u>: See responses described under Aquatic Vegetation Modifications.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Juveniles; Adults	<u>Juveniles</u>: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. <u>All life-history stages</u>: See responses described for related stressors under Water Quality Modifications.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May affect juvenile survival, growth, and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles Adults	<u>All exposed life history stages</u>: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. Mudminnow are dependent on habitats with low or zero flow velocity, loose silt substrate, and abundant aquatic vegetation for survival. Any alterations in hydraulic and geomorphic conditions that affect flow and substrate characteristics are likely to affect habitat suitability for this species. This in turn is likely to affect survival, growth, and fitness at all life history stages, spawning productivity, and distribution and abundance.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at all life history stages, spawning productivity. May affect distribution and abundance.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Dams can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. If these conditions lead to loss of suitable habitats for mudminnow, population loss could occur.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, larvae, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Alteration of hyporheic exchange may alter or affect habitat suitability for this species by affecting the extent and quality of wetland habitats.	Encourage weir placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and larva survival, may affect juvenile survival, growth, and fitness. May affect adult survival, growth and fitness
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species	Year-round	Permanent	Continuous	Juveniles	Juveniles: Weirs may create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality or impaired survival due to temperature effects. Adults and juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Decreased fitness, physiological injury or mortality from exposure to temperatures in excess of tolerance thresholds (noting that mudminnow are relatively tolerant of high water temperatures.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Decreased habitat suitability, leading to population loss.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles ; Adults	Juveniles and adults: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult and juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	All exposed life history stages: Decreased habitat suitability, leading to population loss.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced habitat productivity.	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Decreased habitat suitability, leading to population loss.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and larvae. May affect juvenile survival and growth. May affect adult spawning productivity.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juveniles. This is particularly true for mudminnow, which are dependent on aquatic vegetation for habitat.	Design: Limit project structural footprint to minimize alteration and shading of native aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile and adult survival, growth, and fitness. May affect spawning productivity, abundance and distribution. .
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	All exposed life history stages: Decreased habitat suitability, leading to population loss.		May affect juvenile growth and survival, spawning success, and overall population productivity.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Juveniles; Adults	Juveniles and adults: This species has a wide temperature tolerance range. May result in behavioral alteration.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult behavior.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by impoundment draining), dependent on contributing mechanism of impact	Intermittent to intermediate-term (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae</u>: Mortality in acute low dissolved oxygen events due to asphyxiation. <u>Juveniles and adults</u>: Behavioral alteration resulting in increased predation exposure (mudminnows are tolerant of wide variations in DO levels due to the ability to absorb atmospheric oxygen).	Avoid large sediment pulses or dewatering of culvert induced impoundments where practicable.	May affect egg and larval survival. May affect juvenile and adult behavior.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae:</u> Turbidity sufficient to cause fine sediment embeddedness may lead to decreased survival of eggs and larvae. <u>Juveniles and adults</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. <u>Adults</u>: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>All expose life-history stages:</u> Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
Dikes/Levees									
	Construction and Maintenance Activities								

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane. ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness..	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs and larvae, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential egg scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and larval life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larvae survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Juveniles; Adults	Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May affect juvenile survival, growth, and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles Adults	All exposed life history stages: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. Mudminnow are dependent on habitats with low or zero flow velocity, loose silt substrate, and abundant aquatic vegetation for survival. Any alterations in hydraulic and geomorphic conditions that affect flow and substrate characteristics are likely to affect habitat suitability for this species. This in turn is likely to affect survival, growth, and fitness at all life history stages, spawning productivity, and distribution and abundance.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at all life history stages, spawning productivity. May affect distribution and abundance.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat, change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Dams can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. If these conditions lead to loss of suitable habitats for mudminnow, population loss could occur.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, larvae, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Reduced availability of thermal refuge and decreased intragravel DO, nutrient cycling effects	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Alteration of hyporheic exchange may alter or affect habitat suitability for this species by affecting the extent and quality of wetland habitats.	Encourage dike/levee placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and larvae survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Riparian Vegetation Modification								

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae:</u> Mortality or impaired survival due to temperature effects. <u>Adults and juveniles</u>: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns._Decreased fitness, physiological injury or mortality from exposure to temperatures in excess of tolerance thresholds (noting that mudminnow are relatively tolerant of high water temperatures.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~<u>benthic</u> dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults	<u>All exposed life history stages:</u> Decreased habitat suitability, leading to population loss.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles; Adults	<u>Juveniles and adudlts:</u> Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult and juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	<u>All exposed life history stages:</u> Decreased habitat suitability, leading to population loss.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	<u>All exposed life history stages:</u> Decreased habitat suitability, leading to population loss.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and larvae. May affect juvenile survival and growth. May affect adult spawning productivity.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juveniles. This is particularly true for mudminnow, which are dependent on aquatic vegetation for habitat.	<u>Design</u>: Limit project structural footprint to minimize alteration and shading of native aquatic vegetation to the greatest extent practicable. <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile and adult survival, growth, and fitness. May affect spawning productivity, abundance and distribution. .
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Juveniles; Adults	Juveniles and adults: This species has a wide temperature tolerance range. May result in behavioral alteration.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult behavior.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by impoundment draining), dependent on contributing mechanism of impact	Intermittent to intermediate-term (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Behavioral alteration resulting in increased predation exposure (mudminnows are tolerant of wide variations in DO levels due to the ability to absorb atmospheric oxygen).	Avoid large sediment pulses or dewatering of culvert induced impoundments where practicable.	May affect egg and larval survival. May affect juvenile and adult behavior.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to decreased survival of eggs and larvae. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Outfalls									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	<u>All exposed life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane. ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	<u>All expose life-history stages:</u> Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness..	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs and larvae, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential egg scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and larval life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larvae survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Juveniles; Adults	Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May affect juvenile survival, growth, and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles Adults	All exposed life history stages: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. Mudminnow are dependent on habitats with low or zero flow velocity, loose silt substrate, and abundant aquatic vegetation for survival. Any alterations in hydraulic and geomorphic conditions that affect flow and substrate characteristics are likely to affect habitat suitability for this species. This in turn is likely to affect survival, growth, and fitness at all life history stages, spawning productivity, and distribution and abundance.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at all life history stages, spawning productivity. May affect distribution and abundance.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lateral and longitudinal habitat fragmentation	Fragmentation of longitudinal connectivity may result from water quality barrier when high effluent discharge causes chemical barrier to migration. If constructed parallel to the channel, side channel and floodplain habitat may become fragmented. These actions will result in changes in habitat structure, availability, and suitability; reduced food web complexity.	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: High flow outfalls can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. . If these conditions lead to loss of suitable habitats for mudminnow, population loss could occur.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, larva, and juvenile life-history stages. May affect spawning productivity.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs larvae; Juveniles; Adults	The degree to which outfalls affect riparian vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine environments.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs larvae; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs larvae; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	
	Aquatic Vegetation Modification								

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juveniles. This is particularly true for mudminnow, which are dependent on aquatic vegetation for habitat.	Design: Limit project structural footprint to minimize alteration and shading of native aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile and adult survival, growth, and fitness. May affect spawning productivity, abundance and distribution. .
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Juveniles; Adults	Juveniles and adults: This species has a wide temperature tolerance range. May result in behavioral alteration.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult behavior.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by impoundment draining), dependent on contributing mechanism of impact	Intermittent to intermediate-term (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Behavioral alteration resulting in increased predation exposure (mudminnows are tolerant of wide variations in DO levels due to the ability to absorb atmospheric oxygen).	Avoid large sediment pulses or dewatering of culvert induced impoundments where practicable.	May affect egg and larval survival. May affect juvenile and adult behavior.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to decreased survival of eggs and larvae. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane. ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness..	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. Juveniles: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs and larvae, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential egg scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and larval life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larvae survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Juveniles; Adults	Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May affect juvenile survival, growth, and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles Adults	All exposed life history stages: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. Mudminnow are dependent on habitats with low or zero flow velocity, loose silt substrate, and abundant aquatic vegetation for survival. Any alterations in hydraulic and geomorphic conditions that affect flow and substrate characteristics are likely to affect habitat suitability for this species. This in turn is likely to affect survival, growth, and fitness at all life history stages, spawning productivity, and distribution and abundance.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at all life history stages, spawning productivity. May affect distribution and abundance.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Intakes and diversions can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. If these conditions lead to loss of suitable habitats for mudminnow, population loss could occur.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, larva, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered groundwater-surface water exchange	Accumulation of fines will reduce hyporheic exchange, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage intakes and diversions placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and larvae survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality or impaired survival due to temperature effects. Adults and juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Decreased fitness, physiological injury or mortality from exposure to temperatures in excess of tolerance thresholds (noting that mudminnow are relatively tolerant of high water temperatures.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Decreased habitat suitability, leading to population loss.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles ; Adults	Juveniles and adults: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect adult and juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	All exposed life history stages: Decreased habitat suitability, leading to population loss.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and survival, spawning success, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced habitat productivity.	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Decreased habitat suitability, leading to population loss.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	May affect survival of eggs and larvae. May affect juvenile survival and growth. May affect adult spawning productivity.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juveniles. This is particularly true for mudminnow, which are dependent on aquatic vegetation for habitat.	<u>Design</u>: Limit project structural footprint to minimize alteration and shading of native aquatic vegetation to the greatest extent practicable. <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile and adult survival, growth, and fitness. May affect spawning productivity, abundance and distribution.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Juveniles; Adults	<u>Juveniles and adults</u>: This species has a wide temperature tolerance range. May result in behavioral alteration.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult behavior.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by impoundment draining), dependent on contributing mechanism of impact	Intermittent to intermediate-term (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae</u>: Mortality in acute low dissolved oxygen events due to asphyxiation. <u>Juveniles and adults</u>: Behavioral alteration resulting in increased predation exposure (mudminnows are tolerant of wide variations in DO levels due to the ability to absorb atmospheric oxygen).	Avoid large sediment pulses or dewatering of culvert induced impoundments where practicable.	May affect egg and larval survival. May affect juvenile and adult behavior.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to decreased survival of eggs and larvae. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
Tide Gates									
	Construction and Maintenance Activities								

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	<u>All exposed life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane. ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Employ appropriate BMPs to insulate surface waters from equipment noise and vibration occurring over extended periods.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	<u>All expose life-history stages:</u> Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness..	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae</u>: Mortality, injury, or stress from capture, handling, and relocation. Egg relocation is impractical, likely leading to mortality. <u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation. Risk of mortality from stranding if fish cannot be captured and relocated successfully. <u>Juveniles</u>: Increased competition once relocated, reduced growth and fitness, and increased predation exposure. <u>Adults</u>: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness, and adult spawning productivity.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles	Eggs and larvae, juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Injury and stress may affect survival, growth, and fitness.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential egg scour and/or sedimentation, resulting in decreased incubation success. Juveniles: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and larval life-history stages; may affect juvenile growth and fitness; may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: Stress and behavioral modifications by adults exposed to sediment pulses. Potential migration delay, leading to reduced spawning productivity.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at juvenile life-history stage. May affect adult fitness and spawning productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modifications.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modifications.
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larvae survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modifications.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Juveniles; Adults	Juveniles: Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modifications.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May affect juvenile survival, growth, and fitness. See effects for related stressors on all life-history stages under Water Quality Modifications.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles Adults	All exposed life history stages: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, and changes in food web complexity. Mudminnow are dependent on habitats with low or zero flow velocity, loose silt substrate, and abundant aquatic vegetation for survival. Any alterations in hydraulic and geomorphic conditions that affect flow and substrate characteristics are likely to affect habitat suitability for this species. This in turn is likely to affect survival, growth, and fitness at all life history stages, spawning productivity, and distribution and abundance.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at all life history stages, spawning productivity. May affect distribution and abundance.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation of habitat	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Tide gates can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. If these conditions lead to loss of suitable habitats for mudminnow, population loss could occur.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Limit the length of time that tide gates are closed as much as possible.	May affect survival at egg, larva, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit the length of time that tide gates are closed as much as possible. No additional specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Riparian Vegetation Modification								
	Riverine								

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and larvae; Juveniles; Adults	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tide gates is considered to be a component of the effects of dikes and levees. The incremental effects of the tide gate are negligible in comparison.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Extensive modification of aquatic vegetation can alter habitat complexity and food web productivity, which may in turn affect survival growth, and fitness of juveniles. This is particularly true for mudminnow, which are dependent on aquatic vegetation for habitat.	Design: Limit project structural footprint to minimize alteration and shading of native aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile and adult survival, growth, and fitness. May affect spawning productivity, abundance and distribution. .
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Juveniles; Adults	Juveniles and adults: This species has a wide temperature tolerance range. May result in behavioral alteration.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult behavior.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by impoundment draining), dependent on contributing mechanism of impact	Intermittent to intermediate-term (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Behavioral alteration resulting in increased predation exposure (mudminnows are tolerant of wide variations in DO levels due to the ability to absorb atmospheric oxygen).	Avoid large sediment pulses or dewatering of culvert induced impoundments where practicable.	May affect egg and larval survival. May affect juvenile and adult behavior.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause fine sediment embeddedness may lead to decreased survival of eggs and larvae. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and larvae. May affect juvenile growth and fitness and adult productivity and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth, and fitness at all exposed life-history stages.

Table A-11 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympic Mudminnow.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Introduction of toxic substances	During construction and maintenance	Short-term	Interannual–decadal (dependent on activity frequency)	Eggs and larvae; Juveniles; Adults	All expose life-history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth, and fitness.	Require TESC plan for all construction and maintenance activities.	May affect survival, growth, and fitness at all exposed life-history stages.
		Altered salinity	Year-round	Long-term to permanent	Intermittent (daily)	Juveniles	Juveniles: Altered salinity patterns may limit habitat suitability for juvenile rearing in nearshore marine environments. This in turn may increase competition for available habitats, limiting survival, growth, and fitness.	Limit closure time of tide gate to maximize natural tidal exchange.	May affect juvenile survival, growth, and fitness.

Table A-12. HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs ; Juveniles; Adults	<u>All exposed life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: Rupture of egg membrane. Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs ; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs ; Juveniles; Adults	<u>All exposed life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	<u>Eggs:</u> Mortality due to dewatering. <u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation. Small juvenile dace may be difficult to capture and relocate, leading to higher incidence of mortality. Increased competition once relocated, and reduced growth and fitness; increased predation exposure.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles	<u>Eggs, and juveniles</u>: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	<u>Eggs</u> : Potential ~~redd~~ scour and/or sedimentation, resulting in decreased incubation success. <u>Juveniles and adults</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg life-history stage, may affect adult spawning productivity.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	Eggs: Potential decreased survival due to turbidity exposure and substrate disturbance. Juveniles and adults: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, reduced foraging opportunities, and increased predation risk, leading to decreased survival, growth, and fitness. See responses to related stressors under Water Quality Modification.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect growth and fitness at egg life-history stage; may affect adult fitness and spawning productivity. May cause direct mortality or injury.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	Eggs : Potential decreased egg incubation success and survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs ; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs ; Juveniles; Adults	Eggs and juveniles: Eggs and immobile juveniles entrained during dredging may experience direct mortality or injury. Juveniles and adults: Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May affect juvenile productivity and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs ; Juveniles Adults	<u>Eggs</u>: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased egg incubation success and survival. <u>Juveniles</u>: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. Dace are associated with low to moderate flows, which may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. <u>Adults</u>: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations, egg burial, etc.) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Lateral and Longitudinal habitat Fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of longitudinal (i.e., upstream-downstream) habitat connectivity; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs (dace); Juveniles; Adults	<u>Eggs</u>: Adult dace spawning habitat availability may be limited by the structural footprint of dams, and by limitations on movement in the nearshore zone. Increased egg density may in turn increase potential egg losses from predation, localized water quality impacts, or other mechanisms, limiting egg survival and/or incubation success. <u>Juveniles</u>: Disconnection of floodplain habitats can lead to decreased availability and suitability of rearing habitat, and changes in food web complexity. Moderate gradient stream systems preferred by sculpins may limit the extent of suitable habitat area. Disconnection of sloughs and similar slow-flowing floodplain habitats in lower gradient systems may limit habitat area preferred by dace and juvenile suckers. These stressors may thereby result in decreased foraging opportunities and increased competition for suitable habitats, affecting survival, growth, and fitness. <u>Adults</u>: Disconnection of sloughs and similar slow-water rearing habitats may limit the availability of suitable foraging and spawning habitat for dace. In moderate gradient habitats, disconnection of floodplain habitats may limit the availability and suitability of spawning habitat for mountain sucker, and foraging and spawning habitat for margined sculpins. These stressors may thereby result in decreased foraging opportunities, and increased competition for suitable habitats, affecting survival, growth, fitness, and by extension, spawning productivity.	Require assessment of the hydraulic effects of the project before permitting and avoid permitting designs that lead to disconnection of floodplain habitat.	May affect egg survival. May affect juvenile and adult survival, growth, and fitness. May affect adult spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs ; Juveniles; Adults	<u>Eggs</u> : Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. <u>Adults and juveniles</u>: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. <u>Adults</u>: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dam placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible. Encourage spillway design to promote moderation of stream temperatures in downstream reaches.	May affect egg survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered Community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species.	Year-round	Permanent	Continuous	Juveniles	Juveniles: Dams create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs ; Juveniles; Adults	Eggs: High water temperatures may decrease egg survival. Juveniles: Reduced growth and fitness caused by temperatures outside optimal growth range, and alteration of food web patterns. Adults and juveniles: May reduce the availability of suitable refuge and foraging habitat, leading to reduced survival, growth, and fitness. Adults: Spawning is temperature dependent; alteration of nearshore temperature may affect spawning success and productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness at all life-history stages. Mountain sucker prefer deeper water environments and are likely to be less sensitive to these effects.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs; Juveniles; Adults	Eggs: Decreased incubation success due to turbidity effects as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness at all life-history stages
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Dace feed on terrestrial insects. While less dependent, suckers are opportunistic feeders dependent on overall food web productivity. Reduced allochthonous inputs may affect food web productivity, leading to decreased foraging opportunities and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect growth and fitness at juvenile and adult life-history stages.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased availability of suitable foraging and refuge habitat, leading to decreased foraging opportunities, increased competition, increased predation exposure, collectively affecting survival, growth, and fitness. Reduction in suitable spawning habitat area may affect spawning productivity.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile and adult survival, growth, and fitness. May affect adult spawning productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs; Juveniles; Adults	All exposed life-history stages: Dace and sucker dependency on groundwater is currently a data gap. However, decreased availability of thermal refuge may affect survival during temperature extremes.	Avoid disturbance of vegetation along stream.	Effects resulting from this impact mechanism are uncertain, as dace and sucker sensitivity to stressor exposure is currently a data gap. However, lack of suitable thermal refuge habitat may affect dace survival.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Reduced foraging opportunities due to decreased food web productivity, leading to decreased growth and fitness. Primary forage for suckers includes algae and aquatic invertebrates, which may be affected by decreased autochthonous production.	Design: Limit project structural footprint to minimize alteration and shading of native aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect survival, growth, and productivity of juvenile and adult life-history stages.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, increased predation exposure, and resulting effects on survival, growth, and fitness.		May affect survival, growth, and productivity of juvenile and adult life-history stages.
	Water Quality Modification								

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen and temperature levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs; Juveniles; Adults	All exposed life-history stages: Alteration of water temperatures leading to increases or decreases beyond optimal ranges may affect growth and fitness of dace and sucker. Optimal temperatures range from 59–64°F for dace and 55–70°F for mountain sucker. Exposure to higher temperatures may lead to direct mortality or sufficient stress to affect survival. Acute low dissolved oxygen events may cause direct mortality of eggs, juveniles, and adults by asphyxiation. Juveniles and adults may exhibit temporary avoidance behavior, increased stress, increased predation exposure, and decreased foraging opportunities.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs. May affect juvenile and adult survival, growth, and fitness.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs ; Juveniles; Adults	Eggs: Turbidity sufficient to cause fine sediment embeddedness may lead to egg burial, causing decreased survival. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses), leading to increased territoriality, reduced foraging opportunity, increased predation exposure.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs. May affect juvenile and adult survival, growth, and fitness.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs ; Juveniles; Adults	All exposed life history stages: Dam removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to dam removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Juveniles; Adults	All exposed life-history stages: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. Mobile juveniles and adults may exhibit temporary avoidance behavior, increased stress, increased predation exposure, and decreased foraging opportunities.	Avoid curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality or physiological injury in acute events. May affect survival of eggs and immobile juveniles. May affect juvenile and adult growth and fitness.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs ; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect survival, growth and fitness at all exposed life history stages.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs ; Juveniles; Adults	All exposed life history stages: Dam construction and operation may lead to introductions of toxic substances through accidental spills or other pathways. Impoundments may attract increased recreational vessel activity, creating a pathway for chronic exposure to hydrocarbons and other contaminants. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Require a spill control and containment plan for dam operations if appropriate. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources	May affect survival, growth and fitness at all exposed life history stages.
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs ; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. May cause direct mortality or injury.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	Eggs: Mortality due to dewatering. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Small juvenile dace may be difficult to capture and relocate, leading to higher incidence of mortality. Increased competition once relocated, and reduced growth and fitness; increased predation exposure.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct injury or mortality of juveniles and adults. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles	Eggs and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	Should exposure occur, direct mortality or injury is probable. May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	Eggs: Potential substrate scour/or sedimentation, resulting in decreased incubation success. Juveniles and adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.	Limit alteration of flow conditions to minimal area.	Should exposure occur, decreased survival is likely. May affect survival during egg life-history stage, may affect adult spawning productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	Eggs: Potential decreased survival due to turbidity exposure and substrate disturbance. Juveniles and adults: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, reduced foraging opportunities, and increased predation risk, leading to decreased survival, growth, and fitness. See responses to related stressors under Water Quality Modification.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect egg survival. May affect juvenile and adult survival, growth, and fitness. See effects of related stressor exposure under Water Quality Modification.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access and stranding (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	Eggs : Potential decreased egg incubation success survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs ; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs ; Juveniles; Adults	Eggs and juveniles: Eggs and immobile juveniles entrained during dredging may experience direct mortality or injury. Juveniles and adults: Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May affect juvenile productivity and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs ; Juveniles Adults	Eggs: Changes in channel morphology, flow velocity, and substrate composition and stability can alter substrate composition and stability, leading to decreased egg incubation success and survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. Dace are associated with low to moderate flows, which may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations, egg burial, etc.) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs (dace); Juveniles; Adults	Eggs: Adult dace spawning habitat availability may be limited by the structural footprint of weirs, and by limitations on movement in the nearshore zone. Increased egg density may in turn increase potential egg losses from predation, localized water quality impacts, or other mechanisms, limiting egg survival and/or incubation success. Juveniles: Disconnection of floodplain habitats can lead to decreased availability and suitability of rearing habitat, and changes in food web complexity. Moderate gradient stream systems preferred by sculpins may limit the extent of suitable habitat area. Disconnection of sloughs and similar slow-flowing floodplain habitats in lower gradient systems may limit habitat area preferred by dace and juvenile suckers. These stressors may thereby result in decreased foraging opportunities and increased competition for suitable habitats, affecting survival, growth, and fitness. Adults: Disconnection of sloughs and similar slow-water rearing habitats may limit the availability of suitable foraging and spawning habitat for dace. In moderate gradient habitats, disconnection of floodplain habitats may limit the availability and suitability of spawning habitat for mountain sucker, and foraging and spawning habitat for margined sculpins. These stressors may thereby result in decreased foraging opportunities, and increased competition for suitable habitats, affecting survival, growth, fitness, and by extension, spawning productivity.	Require assessment of the hydraulic effects of the project before permitting and avoid permitting designs that lead to disconnection of floodplain habitat.	May affect egg survival. May affect juvenile and adult survival, growth, and fitness. May affect adult spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs ; Juveniles; Adults	Eggs : Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage weir placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species	Year-round	Permanent	Continuous	Juveniles	Juveniles: Weirs may create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs; Juveniles; Adults	Eggs: High water temperatures may decrease egg survival. Juveniles: Reduced growth and fitness caused by temperatures outside optimal growth range, and alteration of food web patterns. Adults and juveniles: May reduce the availability of suitable refuge and foraging habitat, leading to reduced survival, growth, and fitness. Adults: Spawning is temperature dependent; alteration of nearshore temperature may affect spawning success and productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness at all life-history stages. Mountain sucker prefer deeper water environments and are likely to be less sensitive to these effects.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs; Juveniles; Adults	Eggs: Decreased incubation success due to turbidity effects as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness at all life-history stages
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Dace feed on terrestrial insects. While less dependent, suckers are opportunistic feeders dependent on overall food web productivity. Reduced allochthonous inputs may affect food web productivity, leading to decreased foraging opportunities and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect growth and fitness at juvenile and adult life-history stages.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased availability of suitable foraging and refuge habitat, leading to decreased foraging opportunities, increased competition, increased predation exposure, collectively affecting survival, growth, and fitness. Reduction in suitable spawning habitat area may affect spawning productivity.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile and adult survival, growth, and fitness. May affect adult spawning productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs; Juveniles; Adults	All exposed life-history stages: Dace and sucker dependency on groundwater is currently a data gap. However, decreased availability of thermal refuge may affect survival during temperature extremes.	Avoid disturbance of vegetation along stream.	Effects resulting from this impact mechanism are uncertain, as dace and sucker sensitivity to stressor exposure is currently a data gap. However, lack of suitable thermal refuge habitat may affect dace survival.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Reduced foraging opportunities due to decreased food web productivity, leading to decreased growth and fitness. Primary forage for suckers includes algae and aquatic invertebrates, which may be affected by decreased autochthonous production.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect survival, growth, and productivity of juvenile and adult life-history stages.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, increased predation exposure, and resulting effects on survival, growth, and fitness.		May affect survival, growth, and productivity of juvenile and adult life-history stages.
	Water Quality Modification								
		Altered dissolved oxygen and temperature levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs; Juveniles; Adults	All exposed life-history stages: Alteration of water temperatures leading to increases or decreases beyond optimal ranges may affect growth and fitness of dace and sucker. Optimal temperatures range from 59–64°F for dace and 55–70°F for mountain sucker. Exposure to higher temperatures may lead to direct mortality or sufficient stress to affect survival. Acute low dissolved oxygen events may cause direct mortality of eggs, juveniles, and adults by asphyxiation. Juveniles and adults may exhibit temporary avoidance behavior, increased stress, increased predation exposure, and decreased foraging opportunities.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs. May affect juvenile and adult survival, growth, and fitness.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs ; Juveniles; Adults	Eggs: Turbidity sufficient to cause fine sediment embeddedness may lead to egg burial, causing decreased survival. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses), leading to increased territoriality, reduced foraging opportunity, increased predation exposure.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs. May affect juvenile and adult survival, growth, and fitness.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs ; Juveniles; Adults	All expose life history stages: Weir removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to weir removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	All exposed life-history stages: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. Mobile juveniles and adults may exhibit temporary avoidance behavior, increased stress, increased predation exposure, and decreased foraging opportunities.	Avoid curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality or physiological injury in acute events. May affect survival of eggs and immobile juveniles. May affect juvenile and adult growth and fitness.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs ; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs ; Juveniles; Adults	All expose life history stages: Weir construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Dikes/Levees									
	Construction and Maintenance Activities								

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs ; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling, and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	Eggs: Mortality due to dewatering. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Small juvenile dace may be difficult to capture and relocate, leading to higher incidence of mortality. Increased competition once relocated, and reduced growth and fitness; increased predation exposure.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct mortality and injury. May affect survival, growth, and fitness at juvenile and adult life-history stages.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles	Eggs and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	Eggs: Potential substrate scour/or sedimentation, resulting in decreased incubation success. Juveniles and adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.	Limit alteration of flow conditions to minimal area.	May affect survival, growth, and fitness during egg and juvenile life-history stages. May affect adult spawning growth and fitness.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered current and circulation conditions (lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juvenile and adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.	To greatest extent practicable, limit alteration of current and circulation patterns to minimal area.	May affect juvenile and adult survival, growth, and productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	Eggs: Potential decreased survival due to turbidity exposure and substrate disturbance. Juveniles and adults: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, reduced foraging opportunities, and increased predation risk, leading to decreased survival, growth, and fitness. See responses to related stressors under Water Quality Modification.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect egg survival. May affect juvenile and adult survival, growth, and fitness. See effects of related stressor exposure under Water Quality Modification.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and productivity at juvenile and adult life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs ; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs ; Juveniles; Adults	Eggs : Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May affect survival during egg life-history stage. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning	Year-round	Permanent	Continuous	Eggs ; Juveniles	Eggs: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the	May affect survival, growth, and fitness at egg and juvenile life-history stages. May affect spawning

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered flow regime	and rearing habitat availability and suitability	Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal	Adults	decreased egg incubation success and survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. Dace are associated with low to moderate flows, which may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations, egg burial, etc.) if potential spawning habitat is affected.	project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	productivity.
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Juveniles	All exposed life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juveniles and adults. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness, or mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at all exposed life-history stages. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lateral and longitudinal fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat, change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs (dace); Juveniles; Adults	Eggs: Adult dace spawning habitat availability may be limited by the structural footprint of dikes and levees, and by limitations on movement in the nearshore zone. Increased egg density may in turn increase potential egg losses from predation, localized water quality impacts, or other mechanisms, limiting egg survival and/or incubation success. Juveniles: Disconnection of floodplain habitats can lead to decreased availability and suitability of rearing habitat, and changes in food web complexity. Moderate gradient stream systems preferred by sculpins may limit the extent of suitable habitat area. Disconnection of sloughs and similar slow-flowing floodplain habitats in lower gradient systems may limit habitat area preferred by dace and juvenile suckers. These stressors may thereby result in decreased foraging opportunities and increased competition for suitable habitats, affecting survival, growth, and fitness. Adults: Disconnection of sloughs and similar slow-water rearing habitats may limit the availability of suitable foraging and spawning habitat for dace. In moderate gradient habitats, disconnection of floodplain habitats may limit the availability and suitability of spawning habitat for mountain sucker, and foraging and spawning habitat for margined sculpins. These stressors may thereby result in decreased foraging opportunities, and increased competition for suitable habitats, affecting survival, growth, fitness, and by extension, spawning productivity.	Require assessment of the hydraulic effects of the project before permitting and avoid permitting designs that lead to disconnection of floodplain habitat.	May affect egg survival. May affect juvenile and adult survival, growth, and fitness. May affect adult spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Reduced availability of thermal refuge and decreased intragravel DO, nutrient cycling effects	Year-round	Permanent	Continuous	Eggs ; Juveniles; Adults	Eggs : Decreased hyporheic exchange may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dike/levee placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Lacustrine								

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability	Year-round	Permanent	Continuous	Eggs (dace); Juveniles (dace and mountain suckers); Adults (dace and mountain suckers)	Eggs: Adult dace spawning habitat availability may be limited by the structural footprint of dikes and levees, and by limitations on movement in the nearshore zone. Increased egg density may in turn increase potential egg losses from predation, localized water quality impacts, or other mechanisms, limiting egg survival and/or incubation success. Juveniles and adults: dikes and levees can fragment nearshore habitats, forcing juvenile fish moving along the shoreline to migrate into deeper water. Dace, which prefer shallow water habitats, would experience increased predation exposure and increased stress and exertion as a result. Concentration in nearshore habitats due to restricted movement may limit foraging opportunities. Exposure to these stressors may limit survival, growth, and fitness. Reduced adult fitness may affect spawning productivity. Juvenile and adult suckers will experience similar stressor exposure but are less prone to the resulting effects due to their benthic orientation. Margined sculpins are found predominantly in small rivers and streams in the Tucannon and Walla Walla River drainages. The likelihood of occurrence in lakes is limited, which in turn limits the potential for stressor exposure in lacustrine environments.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect juvenile and adult survival, growth, and fitness. May affect egg survival and/or incubation success.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs; Juveniles; Adults	Eggs: High water temperatures may decrease egg survival. Juveniles: Reduced growth and fitness caused by temperatures outside optimal growth range, and alteration of food web patterns. Adults and juveniles: May reduce the availability of suitable refuge and foraging habitat, leading to reduced survival, growth, and fitness. Adults: Spawning is temperature dependent; alteration of nearshore temperature may affect spawning success and productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness at all life-history stages. Mountain sucker prefer deeper water environments and are likely to be less sensitive to these effects.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs; Juveniles; Adults	Eggs: Decreased incubation success due to turbidity effects as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness at all life-history stages
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Dace feed on terrestrial insects. While less dependent, suckers are opportunistic feeders dependent on overall food web productivity. Reduced allochthonous inputs may affect food web productivity, leading to decreased foraging opportunities and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect growth and fitness at juvenile and adult life-history stages.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased availability of suitable foraging and refuge habitat, leading to decreased foraging opportunities, increased competition, increased predation exposure, collectively affecting survival, growth, and fitness. Reduction in suitable spawning habitat area may affect spawning productivity.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile and adult survival, growth, and fitness. May affect adult spawning productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs; Juveniles; Adults	All exposed life-history stages: Dace and sucker dependency on groundwater is currently a data gap. However, decreased availability of thermal refuge may affect survival during temperature extremes.	Avoid disturbance of vegetation along stream.	Effects resulting from this impact mechanism are uncertain, as dace and sucker sensitivity to stressor exposure is currently a data gap. However, lack of suitable thermal refuge habitat may affect dace survival.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a relatively minor effect on deep lacustrine water temperatures relative to the dominant influence of currents, wind conditions, and other factors. However, protected nearshore habitats favored by dace may be sensitive to temperature extremes. Lack of suitable thermal refuge habitat may lead to decreased survival.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness at all life-history stages. Mountain sucker prefer deeper water environments and are likely to be less sensitive to these effects.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs (dace); Juveniles; Adults	Eggs: Dace may experience decreased egg survival in lacustrine spawning environments due to turbidity effects. Juveniles and adults: Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect dace egg survival. See effects for related stressors under Water Quality Modification.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Dace and suckers prey upon terrestrial insects recruited from riparian zone. Alteration of vegetation will result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect growth, fitness, and productivity.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Alteration of habitat complexity may affect the suitability of spawning, rearing, and refuge habitat for dace and suckers, leading to reduced survival, growth, and fitness. Reduced habitat complexity may affect the availability of suitable spawning habitats for dace. Likelihood of effects on sucker spawning habitat is more limited due to preference for shallow riffle habitats unsuitable for dikes and levees.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect survival, growth, and fitness during juvenile and adult life-history stages. Reduced habitat complexity may affect spawning productivity.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Dependence on groundwater–surface water exchange by these fish species is a data gap. However, lack of suitable thermal refuge habitat may lead to decreased survival during temperature extremes.	Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible.	Effects resulting from this impact mechanism are uncertain, as dace and sucker sensitivity to stressor exposure is currently a data gap. However, lack of suitable thermal refuge habitat may affect dace survival.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Reduced foraging opportunities due to decreased food web productivity, leading to decreased growth and fitness. Primary forage for suckers includes algae and aquatic invertebrates, which may be affected by decreased autochthonous production.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect survival, growth, and productivity of juvenile and adult life-history stages.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, increased predation exposure, and resulting effects on survival, growth, and fitness.		May affect survival, growth, and productivity of juvenile and adult life-history stages.
	Water Quality Modification								

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen and temperature levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs; Juveniles; Adults	All exposed life-history stages: Alteration of water temperatures leading to increases or decreases beyond optimal ranges may affect growth and fitness of dace and sucker. Optimal temperatures range from 59–64°F for dace and 55–70°F for mountain sucker. Exposure to higher temperatures may lead to direct mortality or sufficient stress to affect survival. Acute low dissolved oxygen events may cause direct mortality of eggs, juveniles, and adults by asphyxiation. Juveniles and adults may exhibit temporary avoidance behavior, increased stress, increased predation exposure, and decreased foraging opportunities.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs. May affect juvenile and adult survival, growth, and fitness.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs ; Juveniles; Adults	Eggs: Turbidity sufficient to cause fine sediment embeddedness may lead to egg burial, causing decreased survival. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses), leading to increased territoriality, reduced foraging opportunity, increased predation exposure.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs. May affect juvenile and adult survival, growth, and fitness.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs ; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs ; Juveniles; Adults	All expose life history stages: Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Outfalls									
	Construction and Maintenance Activities								

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs ; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury from barotrauma or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling, and Channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	Eggs: Mortality due to dewatering. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Small juvenile dace may be difficult to capture and relocate, leading to higher incidence of mortality. Increased competition once relocated, and reduced growth and fitness; increased predation exposure.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct mortality and injury. May affect survival, growth, and fitness at juvenile and adult life-history stages.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles	Eggs and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	Eggs: Potential substrate scour/or sedimentation, resulting in decreased incubation success. Juveniles and adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.	Limit alteration of flow conditions to minimal area.	May affect survival, growth, and fitness during egg and juvenile life-history stages. May affect adult spawning growth and fitness.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered current and circulation conditions (lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juvenile and adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.	To greatest extent practicable, limit alteration of current and circulation patterns to minimal area.	May affect juvenile and adult survival, growth, and productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	Eggs: Potential decreased survival due to turbidity exposure and substrate disturbance. Juveniles and adults: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, reduced foraging opportunities, and increased predation risk, leading to decreased survival, growth, and fitness. See responses to related stressors under Water Quality Modification.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect egg survival. May affect juvenile and adult survival, growth, and fitness. See effects of related stressor exposure under Water Quality Modification.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect juvenile and adult growth and fitness.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs ; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs ; Juveniles; Adults	Eggs and juveniles: Eggs and immobile juveniles entrained during dredging may experience direct mortality or injury. Juveniles and adults: Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid dredging in shallow water margin areas preferred by these species.	May affect juvenile productivity and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs ; Juveniles Adults	Eggs: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased egg incubation success and survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and	May affect survival, growth, and fitness at egg and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered substrate composition and stability		Year round	Permanent	Continuous		in decreased rearing habitat suitability and changes in food web complexity. Dace are associated with low to moderate flows, which may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. <u>Adults</u>: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations, egg burial, etc.) if potential spawning habitat is affected.	groundwater exchange to the greatest extent practicable.	
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Eggs (dace); Juveniles; Adults	<u>All exposed life-history stages</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juveniles and adults. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness, or mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at all exposed life-history stages. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lateral and longitudinal habitat fragmentation	Fragmentation of longitudinal connectivity may result from water quality barrier when high effluent discharge causes chemical barrier to migration. If constructed parallel to the channel, side channel and floodplain habitat may become fragmented. These actions will result in changes in habitat structure, availability, and suitability; reduced food web complexity.	Year-round	Permanent	Continuous	Eggs (dace); Juveniles; Adults	Eggs: Adult dace spawning habitat availability may be limited by the structural footprint of outfalls, and by limitations on movement in the nearshore zone. Increased egg density may in turn increase potential egg losses from predation, localized water quality impacts, or other mechanisms, limiting egg survival and/or incubation success. Juveniles: Disconnection of floodplain habitats can lead to decreased availability and suitability of rearing habitat, and changes in food web complexity. Moderate gradient stream systems preferred by sculpins may limit the extent of suitable habitat area. Disconnection of sloughs and similar slow-flowing floodplain habitats in lower gradient systems may limit habitat area preferred by dace and juvenile suckers. These stressors may thereby result in decreased foraging opportunities and increased competition for suitable habitats, affecting survival, growth, and fitness. Adults: Disconnection of sloughs and similar slow-water rearing habitats may limit the availability of suitable foraging and spawning habitat for dace. In moderate gradient habitats, disconnection of floodplain habitats may limit the availability and suitability of spawning habitat for mountain sucker, and foraging and spawning habitat for margined sculpins. These stressors may thereby result in decreased foraging opportunities, and increased competition for suitable habitats, affecting survival, growth, fitness, and by extension, spawning productivity.	Require assessment of the hydraulic effects of the project before permitting and avoid permitting designs that lead to disconnection of floodplain habitat.	May affect egg survival. May affect juvenile and adult survival, growth, and fitness. May affect adult spawning productivity.
	Lacustrine								

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Eggs (dace); Juveniles (dace and mountain suckers); Adults (dace and mountain suckers)	Eggs: Adult dace spawning habitat availability may be limited by the structural footprint of outfalls, and by limitations on movement in the nearshore zone. Increased egg density may in turn increase potential egg losses from predation, localized water quality impacts, or other mechanisms, limiting egg survival and/or incubation success. Juveniles and adults: Outfalls can fragment nearshore habitats, forcing juvenile fish moving along the shoreline to migrate into deeper water. Dace, which prefer shallow water habitats, would experience increased predation exposure and increased stress and exertion as a result. Concentration in nearshore habitats due to restricted movement may limit foraging opportunities. Exposure to these stressors may limit survival, growth, and fitness. Reduced adult fitness may affect spawning productivity. Juvenile and adult suckers will experience similar stressor exposure but are less prone to the resulting effects due to their benthic orientation. Margined sculpins are found predominantly in small rivers and streams in the Tucannon and Walla Walla River drainages. The likelihood of occurrence in lakes is limited, which in turn limits the potential for stressor exposure in lacustrine environments.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect juvenile and adult survival, growth, and fitness. May affect egg survival and/or incubation success.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs ; Juveniles; Adults	The degree to which outfalls affect riparian vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine environments.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs ; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs ; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The degree to which outfalls affect riparian vegetation conditions in lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in lacustrine environments.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which outfalls affect aquatic vegetation conditions in riverine and lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine and lacustrine environments.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Water Quality Modification								
		Altered dissolved oxygen and temperature levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs; Juveniles; Adults	All exposed life-history stages: Alteration of water temperatures leading to increases or decreases beyond optimal ranges may affect growth and fitness of dace and sucker. Optimal temperatures range from 59–64°F for dace and 55–70°F for mountain sucker. Exposure to higher temperatures may lead to direct mortality or sufficient stress to affect survival. Acute low dissolved oxygen events may cause direct mortality of eggs, juveniles, and adults by asphyxiation. Juveniles and adults may exhibit temporary avoidance behavior, increased stress, increased predation exposure, and decreased foraging opportunities.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs. May affect juvenile and adult survival, growth, and fitness.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Juveniles; Adults	Eggs: Turbidity sufficient to cause fine sediment embeddedness may lead to egg burial, causing decreased survival. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses), leading to increased territoriality, reduced foraging opportunity, increased predation exposure.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs. May affect juvenile and adult survival, growth, and fitness.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Juveniles; Adults	All exposed life-history stages: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. Mobile juveniles and adults may exhibit temporary avoidance behavior, increased stress, increased predation exposure, and decreased foraging opportunities.	Avoid curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality or physiological injury in acute events. May affect survival of eggs and immobile juveniles. May affect juvenile and adult growth and fitness.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered nutrient cycling (due to effects of effluent discharge)	During and following discharge events	Long-term to permanent	Continuous	Eggs ; Juveniles; Adults	All exposed life history stages: Nutrient increases may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate effluent potential to adversely affect eutrophication. Require or encourage use of upstream treatment measures prior to discharge.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Eggs ; Juveniles; Adults	All exposed life history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs ; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow Bypass, Fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Juveniles; Adults	Eggs: Mortality due to dewatering. Adults and juveniles: Mortality, injury, or stress from capture, handling, and relocation. Small juvenile dace may be difficult to capture and relocate, leading to higher incidence of mortality. Increased competition once relocated, and reduced growth and fitness; increased predation exposure.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct mortality and injury. May affect survival, growth, and fitness at juvenile and adult life-history stages.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles	Eggs and juveniles: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Juveniles; Adults	Eggs: Potential substrate scour/or sedimentation, resulting in decreased incubation success. Juveniles and adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.	Limit alteration of flow conditions to minimal area.	May affect survival, growth, and fitness during egg and juvenile life-history stages. May affect adult spawning growth and fitness.
		Altered current and circulation conditions (lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juvenile and adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.	To greatest extent practicable, limit alteration of current and circulation patterns to minimal area.	May affect juvenile and adult survival, growth, and productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	Eggs: Potential decreased survival due to turbidity exposure and substrate disturbance. Juveniles and adults: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, reduced foraging opportunities, and increased predation risk, leading to decreased survival, growth, and fitness. See responses to related stressors under Water Quality Modification.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect egg survival. May affect juvenile and adult survival, growth, and fitness. See effects of related stressor exposure under Water Quality Modification.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect juvenile and adult growth and fitness.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs ; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs ; Juveniles; Adults	Eggs : Mortality or injury from entrainment. Juveniles: Altered migratory behavior. Decreased foraging opportunity due to short-term reduction in prey abundance. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	May cause direct mortality or injury. May affect survival during egg life-history stage. May affect juvenile growth and fitness. See effects for related stressors on all life-history stages under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs; Juveniles; Adults	Eggs: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased egg incubation success and survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. Dace are associated with low to moderate flows, which may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations, egg burial, etc.) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Eggs (dace); Juveniles; Adults	All exposed life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for juveniles and adults. This may occur through a number of specific stressors,	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at all exposed life-history stages. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition and stability		Year-round	Permanent	Continuous				

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous		including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduced cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness, or mortality.		
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs (dace); Juveniles; Adults	Eggs: Adult dace spawning habitat availability may be limited by the structural footprint of intakes and diversions, and by limitations on movement in the nearshore zone. Increased egg density may in turn increase potential egg losses from predation, localized water quality impacts, or other mechanisms, limiting egg survival and/or incubation success. Juveniles: Disconnection of floodplain habitats can lead to decreased availability and suitability of rearing habitat, and changes in food web complexity. Moderate gradient stream systems preferred by sculpins may limit the extent of suitable habitat area. Disconnection of sloughs and similar slow-flowing floodplain habitats in lower gradient systems may limit habitat area preferred by dace and juvenile suckers. These stressors may thereby result in decreased foraging opportunities and increased competition for suitable habitats, affecting survival, growth, and fitness. Adults: Disconnection of sloughs and similar slow-water rearing habitats may limit the availability of suitable foraging and spawning habitat for dace. In moderate gradient habitats, disconnection of floodplain habitats may limit the availability and suitability of spawning habitat for mountain sucker, and foraging and spawning habitat for margined sculpins. These stressors may thereby result in decreased foraging opportunities, and increased competition for suitable habitats, affecting survival, growth, fitness, and by extension, spawning productivity.	Require assessment of the hydraulic effects of the project before permitting and avoid permitting designs that lead to disconnection of floodplain habitat.	May affect egg survival. May affect juvenile and adult survival, growth, and fitness. May affect adult spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater-surface water exchange	Accumulation of fines will reduce hyporheic exchange, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs ; Juveniles; Adults	Eggs : Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage intakes and diversions placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Eggs (dace); Juveniles (dace and mountain suckers); Adults (dace and mountain suckers)	Eggs: Adult dace spawning habitat availability may be limited by the structural footprint of intakes and diversions, and by limitations on movement in the nearshore zone. Increased egg density may in turn increase potential egg losses from predation, localized water quality impacts, or other mechanisms, limiting egg survival and/or incubation success. Juveniles and adults: Intakes and diversions can fragment nearshore habitats, forcing juvenile fish moving along the shoreline to migrate into deeper water. Dace, which prefer shallow water habitats, would experience increased predation exposure and increased stress and exertion as a result. Concentration in nearshore habitats due to restricted movement may limit foraging opportunities. Exposure to these stressors may limit survival, growth, and fitness. Reduced adult fitness may affect spawning productivity. Juvenile and adult suckers will experience similar stressor exposure but are less prone to the resulting effects due to their benthic orientation. Margined sculpins are found predominantly in small rivers and streams in the Tucannon and Walla Walla River drainages. The likelihood of occurrence in lakes is limited, which in turn limits the potential for stressor exposure in lacustrine environments.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect juvenile and adult survival, growth, and fitness. May affect egg survival and/or incubation success.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Loss of LWD recruitment	Reduced availability of LWD from drift. Reduced availability of LWD from drift. Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs; Juveniles; Adults	Eggs: High water temperatures may decrease egg survival. Juveniles: Reduced growth and fitness caused by temperatures outside optimal growth range, and alteration of food web patterns. Adults and juveniles: May reduce the availability of suitable refuge and foraging habitat, leading to reduced survival, growth, and fitness. Adults: Spawning is temperature dependent; alteration of nearshore temperature may affect spawning success and productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness at all life-history stages. Mountain sucker prefer deeper water environments and are likely to be less sensitive to these effects.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs; Juveniles; Adults	Eggs: Decreased incubation success due to turbidity effects as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness at all life-history stages

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Dace feed on terrestrial insects. While less dependent, suckers are opportunistic feeders dependent on overall food web productivity. Reduced allochthonous inputs may affect food web productivity, leading to decreased foraging opportunities and decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect growth and fitness at juvenile and adult life-history stages.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased availability of suitable foraging and refuge habitat, leading to decreased foraging opportunities, increased competition, increased predation exposure, collectively affecting survival, growth, and fitness. Reduction in suitable spawning habitat area may affect spawning productivity.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile and adult survival, growth, and fitness. May affect adult spawning productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs; Juveniles; Adults	All exposed life-history stages: Dace and sucker dependency on groundwater is currently a data gap. However, decreased availability of thermal refuge may affect survival during temperature extremes.	Avoid disturbance of vegetation along stream.	Effects resulting from this impact mechanism are uncertain, as dace and sucker sensitivity to stressor exposure is currently a data gap. However, lack of suitable thermal refuge habitat may affect dace survival.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a relatively minor effect on deep lacustrine water temperatures relative to the dominant influence of currents, wind conditions, and other factors. However, protected nearshore habitats favored by dace may be sensitive to temperature extremes. Lack of suitable thermal refuge habitat may lead to decreased survival.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness at all life-history stages. Mountain sucker prefer deeper water environments and are likely to be less sensitive to these effects.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival growth and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Eggs (dace); Juveniles; Adults	Eggs: Dace may experience decreased egg survival in lacustrine spawning environments due to turbidity effects. Juveniles and adults: Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect dace egg survival. See effects for related stressors under Water Quality Modification.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Dace and suckers prey upon terrestrial insects recruited from riparian zone. Alteration of vegetation will result in decreased foraging opportunities, decreased growth and fitness, and decreased productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect growth, fitness, and productivity.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Alteration of habitat complexity may affect the suitability of spawning, rearing, and refuge habitat for dace and suckers, leading to reduced survival, growth, and fitness. Reduced habitat complexity may affect the availability of suitable spawning habitats for dace. Likelihood of effects on sucker spawning habitat is more limited due to preference for shallow riffle habitats unsuitable for intakes and diversions.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect survival, growth, and fitness during juvenile and adult life-history stages. Reduced habitat complexity may affect spawning productivity.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Reduced foraging opportunities due to decreased food web productivity, leading to decreased growth and fitness. Primary forage for suckers includes algae and aquatic invertebrates, which may be affected by decreased autochthonous production.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect survival, growth, and productivity of juvenile and adult life-history stages.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, increased predation exposure, and resulting effects on survival, growth, and fitness.		May affect survival, growth, and productivity of juvenile and adult life-history stages.
	Water Quality Modification								
		Altered dissolved oxygen and temperature levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs; Juveniles; Adults	All exposed life-history stages: Alteration of water temperatures leading to increases or decreases beyond optimal ranges may affect growth and fitness of dace and sucker. Optimal temperatures range from 59–64°F for dace and 55–70°F for mountain sucker. Exposure to higher temperatures may lead to direct mortality or sufficient stress to affect survival. Acute low dissolved oxygen events may cause direct mortality of eggs, juveniles, and adults by asphyxiation. Juveniles and adults may exhibit temporary avoidance behavior, increased stress, increased predation exposure, and decreased foraging opportunities.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs. May affect juvenile and adult survival, growth, and fitness.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Juveniles; Adults	Eggs: Turbidity sufficient to cause fine sediment embeddedness may lead to egg burial, causing decreased survival. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses), leading to increased territoriality, reduced foraging opportunity, increased predation exposure.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs. May affect juvenile and adult survival, growth, and fitness.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Juveniles; Adults	All exposed life-history stages: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. Mobile juveniles and adults may exhibit temporary avoidance behavior, increased stress, increased predation exposure, and decreased foraging opportunities.	Avoid curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality or physiological injury in acute events. May affect survival of eggs and immobile juveniles. May affect juvenile and adult growth and fitness.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs ; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs ; Juveniles; Adults	All expose life history stages: Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Tide Gates									
	Construction and Maintenance Activities								

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs ; Juveniles; Adults	<u>All exposed life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Rupture of egg membrane ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may affect survival and productivity at all life-history stages, depending on project-specific noise intensity and receptor exposure. Should exposure occur, direct mortality or injury is probable.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Juveniles; Adults	<u>Eggs:</u> Mortality due to dewatering. <u>Adults and juveniles</u>: Mortality, injury, or stress from capture, handling, and relocation. Small juvenile dace may be difficult to capture and relocate, leading to higher incidence of mortality. Increased competition once relocated, and reduced growth and fitness; increased predation exposure.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct mortality and injury. May affect survival, growth, and fitness at juvenile and adult life-history stages.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles	<u>Eggs and juveniles</u>: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when juveniles are present.	May cause direct mortality or injury at juvenile life-history stage. Stress may affect survival, growth, and fitness and adult spawning productivity.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Juveniles; Adults	<u>Eggs</u>: Potential substrate scour/or sedimentation, resulting in decreased incubation success. <u>Juveniles and adults</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.	Limit alteration of flow conditions to minimal area.	May affect survival, growth, and fitness during egg and juvenile life-history stages. May affect adult spawning growth and fitness.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered current and circulation conditions (lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juvenile and adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness.	To greatest extent practicable, limit alteration of current and circulation patterns to minimal area.	May affect juvenile and adult survival, growth, and productivity.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs; Juveniles; Adults	Eggs: Potential decreased survival due to turbidity exposure and substrate disturbance. Juveniles and adults: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, reduced foraging opportunities, and increased predation risk, leading to decreased survival, growth, and fitness. See responses to related stressors under Water Quality Modification.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect egg survival. May affect juvenile and adult survival, growth, and fitness. See effects of related stressor exposure under Water Quality Modification.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect juvenile and adult growth and fitness.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat, stranding from dewatering (during construction, maintenance, and removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs ; Juveniles; Adults	Eggs : Potential decreased egg incubation success and survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs ; Juveniles; Adults	All exposed life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	May cause direct mortality or injury. See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs; Juveniles; Adults;	Eggs and juveniles: Eggs and immobile juveniles entrained during dredging may experience direct mortality or injury. Juveniles and adults: Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid dredging in shallow water margin areas preferred by these species.	May affect juvenile productivity and fitness. See effects for related stressors under Water Quality Modification.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs; Juveniles; Adults	Eggs: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased egg incubation success and survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. Dace are associated with low to moderate flows, which may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations, egg burial, etc.) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and juvenile life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lateral and longitudinal fragmentation of habitat	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs (dace); Juveniles; Adults	Eggs: Adult dace spawning habitat availability may be limited by the structural footprint of tide gates, and by limitations on movement in the nearshore zone. Increased egg density may in turn increase potential egg losses from predation, localized water quality impacts, or other mechanisms, limiting egg survival and/or incubation success. Juveniles: Disconnection of floodplain habitats can lead to decreased availability and suitability of rearing habitat, and changes in food web complexity. Moderate gradient stream systems preferred by sculpins may limit the extent of suitable habitat area. Disconnection of sloughs and similar slow-flowing floodplain habitats in lower gradient systems may limit habitat area preferred by dace and juvenile suckers. These stressors may thereby result in decreased foraging opportunities and increased competition for suitable habitats, affecting survival, growth, and fitness. Adults: Disconnection of sloughs and similar slow-water rearing habitats may limit the availability of suitable foraging and spawning habitat for dace. In moderate gradient habitats, disconnection of floodplain habitats may limit the availability and suitability of spawning habitat for mountain sucker, and foraging and spawning habitat for margined sculpins. These stressors may thereby result in decreased foraging opportunities, and increased competition for suitable habitats, affecting survival, growth, fitness, and by extension, spawning productivity.	Require assessment of the hydraulic effects of the project before permitting and avoid permitting designs that lead to disconnection of floodplain habitat.	May affect egg survival. May affect juvenile and adult survival, growth, and fitness. May affect adult spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit the length of time that tide gates are closed as much as possible. No additional specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs ; Juveniles; Adults	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tide gates is considered to be a component of the effects of dikes and levees. The incremental effects of the tide gate are negligible in comparison.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs ; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs ; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	
	Lacustrine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tidegates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid disturbance of vegetation along shoreline.	
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Reduced foraging opportunities due to decreased food web productivity, leading to decreased growth and fitness. Primary forage for suckers includes algae and aquatic invertebrates, which may be affected by decreased autochthonous production.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect survival, growth, and productivity of juvenile and adult life-history stages.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition, increased predation exposure, and resulting effects on survival, growth, and fitness.		May affect survival, growth, and productivity of juvenile and adult life-history stages.
	Water Quality Modification								
		Altered dissolved oxygen and temperature levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns) depending on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs; Juveniles; Adults	All exposed life-history stages: Alteration of water temperatures leading to increases or decreases beyond optimal ranges may affect growth and fitness of dace and sucker. Optimal temperatures range from 59–64°F for dace and 55–70°F for mountain sucker. Exposure to higher temperatures may lead to direct mortality or sufficient stress to affect survival. Acute low dissolved oxygen events may cause direct mortality of eggs, juveniles, and adults by asphyxiation. Juveniles and adults may exhibit temporary avoidance behavior, increased stress, increased predation exposure, and decreased foraging opportunities.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs. May affect juvenile and adult survival, growth, and fitness.

Table A-12 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Umatilla Dace, Leopard Dace, Lake Chub, Margined Sculpin, and Mountain Sucker.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Juveniles; Adults	Eggs: Turbidity sufficient to cause fine sediment embeddedness may lead to egg burial, causing decreased survival. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses), leading to increased territoriality, reduced foraging opportunity, increased predation exposure.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs. May affect juvenile and adult survival, growth, and fitness.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Juveniles; Adults	All exposed life-history stages: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. Mobile juveniles and adults may exhibit temporary avoidance behavior, increased stress, increased predation exposure, and decreased foraging opportunities.	Avoid curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality or physiological injury in acute events. May affect survival of eggs and immobile juveniles. May affect juvenile and adult growth and fitness.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect juvenile and adult survival, growth, and fitness.
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Juveniles	Tide gate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent. Exposure to toxic substances may lead to behavioral avoidance in adults. For juveniles, limitations in the availability of suitable juvenile rearing habitat, or potential physiological injury may affect survival, growth, and fitness.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect adult behavior. May affect juvenile survival, growth, and fitness.

Table A-13. HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and ammocoetes; Transforming adults; Adults	All life-history stages: Very little is known of the effects of pile-driving sounds on lamprey at any life-history stage.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Little is known about the effects of anthropogenic sounds on lamprey.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Transforming adults, Adults	Adults and transforming adults: Very little is known of the effects of anthropogenic sounds on lamprey at any life-history stage.	Although little is known about the effects of anthropogenic sounds on lamprey, it is prudent to avoid/ minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	Little is known about the effects of anthropogenic sounds on lamprey.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and ammocoetes; Transforming adults; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and ammocoetes; Transforming adults; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Ammocoetes; Transforming adults; Adults	Ammocoetes: Mortality, injury, and stress, during dewatering (when buried in riverine sediments). Adults and transforming adults: Mortality, injury, or stress from capture, handling, and relocation. Transforming adults: Increased competition once relocated, and reduced growth and fitness; increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May affect survival, growth, and fitness at ammocoete, transforming adult, and adult life-history stages.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Transforming adults	Transforming adults: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when transforming adults are present.	May affect survival and fitness at transforming adult life-history stage.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	<u>Eggs and ammocoetes</u>: Potential nest scour and/or sedimentation, resulting in decreased incubation success. <u>Transforming adults</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. <u>Adults</u>: Delayed migration, increased stress, and decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and ammocoete life-history stages; may affect transforming adult growth and fitness; may affect adult spawning success.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	<u>Eggs and ammocoetes</u>: Potential decreased egg incubation success and ammocoete survival due to turbidity exposure and substrate disturbance. <u>Transforming adults and adults</u>: For Pacific and river lamprey, decreased populations of host fish such as salmon could decrease available habitat.	Adhere to system-specific in-water work windows. Avoid work during egg incubation and ammocoete stages.	May affect survival of eggs and ammocoetes. May affect growth and fitness at transforming adult and adult life-history stages.
		Localized alteration in host fish abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Transforming adults	<u>Transforming adults and adults</u>: For Pacific and river lamprey, short-term reductions in host fish due to increased competition, decreased growth, and fitness are expected to affect growth and survival for these life-stages.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at transforming adult life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	<u>All life-history-stages</u>: See responses to related stressors under Water Quality Modification. Water quality effects to ammocoetes are a data gap. However, as Pacific and river lamprey feed on host fish, effects of suspended solids on host fish could affect them. As western brook lamprey are filter feeders, this may not be a stressor for transforming adults and adults.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	<u>Eggs and ammocoetes</u>: Potential decreased egg incubation success and ammocoete survival due to water loss and stranding. <u>Transforming adults</u>: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. <u>Adults</u>: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect growth and fitness at transforming adult life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and ammocoetes; Transforming adults; Adults	<u>All life-history stages</u>: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Transforming adults; Adults	<u>Transforming adults and adults</u>: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and ammocoetes; Transforming adults; Adults	Ammocoetes: Ammocoetes of Pacific and river lamprey mature buried in fine substrates in the lower reaches and estuaries of larger rivers for extended periods and are therefore vulnerable to direct injury and mortality from dredging entrainment. Transforming adults: Decreased foraging opportunity due to short-term reduction in prey availability. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury to ammocoetes. May affect transforming adult growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and ammocoete survival. Pacific and river lamprey ammocoetes are particularly vulnerable to impact mechanisms that cause scour, deposition, or other forms of substrate modification when buried in fine substrates during rearing periods, which can last for several years. Transforming adults: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, as well as changes in food web complexity. These may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation ~~of redds~~) if potential spawning habitat is affected	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and ammocoete stages and egg and transforming adult life-history stages for host fish of Pacific and river lamprey. May also affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and ammocoete develoment)	Permanent	Continuous				
	Marine								
	Altered sediment transport	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability as a result of beach	Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous	Transforming adults; Adults (river	Transforming adults and adults: Sediment supply and substrate composition are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project	May affect growth and fitness at transforming adult life-history stages through effects on host fish. River lamprey are also known to use

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered substrate composition	erosion from altered sediment supply.	Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous	lamprey)	in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for lamprey host fish, leading to decreased foraging opportunities for transforming adult Pacific and river lamprey, and adult river lamprey.	designs that minimize effects on sediment supply to marine environments.	nearshore habitats during the adult life-history stage and will be subject to these effects during this period. Direct dependence on nearshore habitat characteristics for both species is a data gap. Decreased growth and fitness may affect survival and productivity during ocean migration life-history phase for both species. Western brook lamprey are non-anadromous and will not be exposed to these stressors.
	Ecosystem Fragmentation								
	Riverine								
	Lateral and Longitudinal habitat Fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of longitudinal (i.e., upstream-downstream) habitat connectivity; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	<u>All exposed life-history stages</u>: Dams can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and larval rearing habitat for lamprey species. Depending on configuration, these structures may also affect the transport of lamprey ammocoetes to suitable rearing habitats, potentially affecting ammocoete survival. Decreased habitat availability may lead to density-dependent effects on adult spawning success. Adult brook lamprey may also be affected by decreased availability of suitable foraging habitat.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Minimize severing upstream-downstream connectivity by installing fish passage.	May affect survival at egg, ammocoetes, and transforming adult life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Transforming adults; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect transforming adult growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and ammocoete development)	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	<u>Eggs and ammocoetes</u>: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. <u>Adults and transforming adults</u>: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. <u>Adults</u>: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dam placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible. Encourage spillway design to promote moderation of stream temperatures in downstream reaches.	May affect egg and ammocoetes survival, may affect transforming adult survival, growth, and fitness. May affect adult survival and spawning productivity.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered Community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species.	Year-round	Permanent	Continuous	Transforming adults;	Transforming adults: Dams create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect transforming adult survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Direct mortality when exposed to temperatures over 68°F for continuous periods. Transforming adults: Altered growth and fitness when exposed to temperatures outside optimal growth range, and alteration of food web patterns, including food web supporting Pacific and river lamprey host fish. Adults and transforming adults: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during incubation, rearing, and spawning. Likelihood of stressor exposure is limited, however, as most settings suitable for dam development are in larger river environments where riparian vegetation has less effect on temperature conditions.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and ammocoetes; Transforming adults; Adults	Eggs/ammocoetes: Decreased incubation success due to burial or scour of eggs and rearing ammocoetes. Decreased availability of host fish for Pacific and river lamprey. Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness for Pacific and river lamprey host fish. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Potential effects on migration and spawning productivity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during incubation and transforming adult and adult fitness of host fish for Pacific and river lamprey.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Ammocoetes; Transforming adults	Transforming adults and ammocoetes: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect growth and fitness of ammocoetes and transforming adults.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Transforming adults; Adults	Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness of host fish for Pacific and river lamprey. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat for host fish of Pacific and river lamprey. Decreased suitable lamprey spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect growth and fitness of transforming adults. May affect adult spawning success.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and ammocoetes; Adults	Lamprey responses to groundwater exchange are a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Lamprey dependence on groundwater exchange is currently a data gap. Therefore, the effects of stressor exposure are unknown.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Ammocoetes; Transforming adults	Ammocoetes and transforming adults: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness of Pacific and river lamprey host fish, and decreased prey resources for filter-feeding Western brook lamprey and ammocoete stages of Pacific and river lamprey. Altered prey resource effects to lamprey ammocoete life-history stages are a data gap. Although effects of altered autochthonous inputs for western brook lamprey are a data gap, alterations could be expected to affect prey resource availability.	Design: Limit project structural footprint to minimize alteration and shading of native aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect ammocoete and transforming adult growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Transforming adults; Adults	Transforming adults and adults: See related stressor responses under Water Quality Alteration. Effects are related to host fish effects for both Pacific and river lamprey.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Ammocoetes; Transforming adults; Adults	All exposed life-history stages: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness of Pacific and river lamprey host fish, and decreased prey resources for filter feeding Western brook lamprey and ammocoete stages of Pacific and river lamprey. Altered prey resource effects to lamprey ammocoete life-history stages are a data gap. Although effects of altered autochthonous inputs on Western brook lamprey are a data gap, alterations could be expected to affect prey resource availability.		Lamprey dependence on habitat complexity provided by freshwater aquatic vegetation is a data gap.
	Water Quality Modification								

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Direct mortality due to winter ice formation and scour. Transforming adults: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and transforming adults: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Provide sufficient streamflows to avoid temperature effects in reaches downstream of the impoundment. Promote dam designs that limit impoundment effects on downstream temperatures (e.g., draw streamflows from impoundment below the stratification layer in summer).	May affect survival, growth, and fitness during transforming adult development. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and ammocoetes; Transforming adults; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Effects on host fish are stressors to Pacific and river lamprey. Transforming adults and adults: A physiological response to exposure at toxic levels causing mortality or injury leading to reduced fitness is a data gap. However, effects on host fish are known and would affect Pacific and river lamprey. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. This is a data gap.	Avoid sediment pulses. Limit nutrient inputs and no direct waste discharge.	May affect survival of incubating eggs and ammocoetes. May affect transforming adult survival, growth, and fitness, as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Turbidity sufficient to cause fine sediment embeddedness or increased burial depth may lead to direct mortality and decreased survival of eggs and ammocoetes. Transforming adults and adults: Not a direct stressor to the lamprey. For Pacific and river lamprey, responses depend on stressor magnitude to host fish, which may include the following: unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and ammocoetes. May affect transforming adult growth and fitness, as well as adult fitness and spawning success.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and ammocoetes; Transforming adults; Adults	All exposed life history stages: Dam removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to dam removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Transforming adults; Adults	Transforming adults and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness of host fish for Pacific and river lamprey.	Limit nutrient inputs and no direct waste discharge. Avoid curing of concrete or discharge of concrete leachate to surface waters.	May affect survival, growth, and fitness of transforming adults and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and ammocoetes; Transforming adults; Adults	All exposed life history stages: Dam construction and operation may lead to introductions of toxic substances through accidental spills or other pathways. Impoundments may attract increased recreational vessel activity, creating a pathway for chronic exposure to hydrocarbons and other contaminants. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Require a spill control and containment plan for dam operations if appropriate. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources	May affect survival, growth and fitness at all exposed life history stages.
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and ammocoetes; Transforming adults; Adults	All life-history stages: Very little is known of the effects of pile-driving sounds on lamprey at any life-history stage.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Little is known about the effects of anthropogenic sounds on lamprey.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Transforming adults, Adults	Adults and transforming adults: Very little is known of the effects of anthropogenic sounds on lamprey at any life-history stage.	Although little is known about the effects of anthropogenic sounds on lamprey, it is prudent to avoid/ minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	Little is known about the effects of anthropogenic sounds on lamprey.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Ammocoetes; Transforming adults; Adults	<u>Ammocoetes:</u> Mortality, injury, and stress, during dewatering (when buried in riverine sediments). <u>Adults and transforming adults</u>: Mortality, injury, or stress from capture, handling, and relocation. <u>Transforming adults</u>: Increased competition once relocated, and reduced growth and fitness; increased predation exposure. <u>Adults</u>: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May affect survival, growth, and fitness at ammocoete, transforming adult, and adult life-history stages.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Transforming adults	<u>Transforming adults</u>: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when transforming adults are present.	May affect survival and fitness at transforming adult life-history stage.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	<u>Eggs and ammocoetes</u>: Potential nest scour and/or sedimentation, resulting in decreased incubation success. <u>Transforming adults</u>: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. <u>Adults</u>: Delayed migration, increased stress, and decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and ammocoete life-history stages; may affect transforming adult growth and fitness; may affect adult spawning success.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	<u>Eggs and ammocoetes</u>: Potential decreased egg incubation success and ammocoete survival due to turbidity exposure and substrate disturbance. <u>Transforming adults and adults</u>: For Pacific and river lamprey, decreased populations of host fish such as salmon could decrease available habitat.	Adhere to system-specific in-water work windows. Avoid work during egg incubation and ammocoete stages.	May affect survival of eggs and ammocoetes. May affect growth and fitness at transforming adult and adult life-history stages.
		Localized alteration in host fish abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Transforming adults	<u>Transforming adults and adults</u>: For Pacific and river lamprey, short-term reductions in host fish due to increased competition, decreased growth, and fitness are expected to affect growth and survival for these life-stages.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at transforming adult life-history stage.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	All life-history-stages: See responses to related stressors under Water Quality Modification. Water quality effects to ammocoetes are a data gap. However, as Pacific and river lamprey feed on host fish, effects of suspended solids on host fish could affect them. As western brook lamprey are filter feeders, this may not be a stressor for transforming adults and adults.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access and stranding (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Potential decreased egg incubation success and ammocoete survival due to water loss and stranding. Transforming adults: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at transforming adult life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and ammocoetes; Transforming adults; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Transforming adults; Adults	Transforming adults and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and ammocoetes; Transforming adults; Adults	Ammocoetes: Ammocoetes of Pacific and river lamprey mature buried in fine substrates in the lower reaches and estuaries of larger rivers for extended periods and are therefore vulnerable to direct injury and mortality from dredging entrainment. Transforming adults: Decreased foraging opportunity due to short-term reduction in prey availability. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury to ammocoetes. May affect transforming adult growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and ammocoete survival. Pacific and river lamprey ammocoetes are particularly vulnerable to impact mechanisms that cause	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and	May affect survival, growth, and fitness at egg and ammocoete stages and egg and transforming adult life-history stages for host fish of Pacific and river lamprey. May also affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered substrate composition and stability		Year round	Permanent	Continuous		scour, deposition, or other forms of substrate modification when buried in fine substrates during rearing periods, which can last for several years. Transforming adults: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, as well as changes in food web complexity. These may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation ~~of redds~~) if potential spawning habitat is affected	groundwater exchange to the greatest extent practicable.	
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation ammocoete development)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	All exposed life-history stages: Weirs can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. . This stressor may limit the availability of adult spawning and larval rearing habitat for lamprey species. Depending on configuration, these structures may also affect the transport of lamprey ammocoetes to suitable rearing habitats, potentially affecting ammocoete survival. Decreased habitat availability may lead to density-dependent effects on adult spawning success. Adult brook lamprey may also be affected by decreased availability of suitable foraging habitat.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, ammocoete, and transforming adult life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Transforming adults; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect transforming adult growth and survival, as well as spawning success and overall population productivity.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation)	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and transforming adults: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage weir placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and ammocoete survival, may affect transforming adult survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species	Year-round	Permanent	Continuous	Transforming Adults	Transforming adults: Weirs may create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred host fish, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect transforming adult survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Direct mortality when exposed to temperatures over 68°F for continuous periods. Transforming adults: Altered growth and fitness when exposed to temperatures outside optimal growth range, and alteration of food web patterns, including food web supporting Pacific and river lamprey host fish. Adults and transforming adults: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during incubation, rearing, and spawning.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and ammocoetes; Transforming adults; Adults	Eggs/ammocoetes: Decreased incubation success due to burial or scour of eggs and rearing ammocoetes. Decreased availability of host fish for Pacific and river lamprey. Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness for Pacific and river lamprey host fish. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Potential effects on migration and spawning productivity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during incubation and transforming adult and adult fitness of host fish for Pacific and river lamprey.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Ammocoetes; Transforming adults	Transforming adults and ammocoetes: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect growth and fitness of ammocoetes and transforming adults.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Transforming adults; Adults	Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness of host fish for Pacific and river lamprey. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat for host fish of Pacific and river lamprey. Decreased suitable lamprey spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect growth and fitness of transforming adults. May affect adult spawning success.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and ammocoetes; Adults	Lamprey responses to groundwater exchange are a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Lamprey dependence on groundwater exchange is currently a data gap. Therefore, the effects of stressor exposure are unknown.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Transforming adults; Adults	Transforming adults and adults: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness of Pacific and river lamprey host fish. Effects on host fish in nearshore habitats would also affect adult river lamprey forage opportunities.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect river lamprey transforming adult and adult growth and fitness, as well as productivity of Pacific and river lamprey host fish.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Transforming adults; Adults	Transforming adults and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Transforming adults; Adults	Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness of Pacific and river lamprey host fish. Adults: Decreased foraging opportunity due to decreased food web productivity, with resulting decreased growth and reproductive fitness of Pacific and river lamprey. River lamprey use nearshore habitats during this life-history phase, but dependence on habitat complexity remains a data gap.		May affect transforming adult survival and productivity. May affect adult growth and spawning productivity of Pacific and river lamprey host fish. Other effects on adult river lamprey are a data gap.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Direct mortality due to winter ice formation and scour. Transforming adults: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and transforming adults: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness of transforming adults. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and ammocoetes; Transforming adults; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Effects on host fish are stressors to Pacific and river lamprey. Transforming adults and adults: A physiological response to exposure at toxic levels causing mortality or injury leading to reduced fitness is a data gap. However, effects on host fish are known and would affect Pacific and river lamprey. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. This is a data gap.	Avoid sediment pulses. Limit nutrient inputs with direct waste discharge.	May affect survival of incubating eggs and ammocoetes. May affect transforming adult survival, growth, and fitness, as well as adult survival, productivity, and spawning success.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Turbidity sufficient to cause fine sediment embeddedness or increased burial depth may lead to direct mortality and decreased survival of eggs and ammocoetes. Transforming adults and adults: Not a direct stressor to the lamprey. For Pacific and river lamprey, responses depend on stressor magnitude to host fish, which may include the following: unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and ammocoetes. May affect transforming adult growth and fitness, as well as adult fitness and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and ammocoetes; Transforming adults; Adults	All expose life history stages: Weir removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to weir removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Transforming adults; Adults	Transforming adults and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness of host fish for Pacific and river lamprey.	Limit nutrient inputs and no direct waste discharge. Avoid curing of concrete or discharge of concrete leachate to surface waters.	May affect survival, growth, and fitness of transforming adults and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and ammocoetes; Transforming adults; Adults	All expose life history stages: Weir construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Dikes/Levees									

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and ammocoetes; Transforming adults; Adults	All life-history stages: Very little is known of the effects of pile-driving sounds on lamprey at any life-history stage.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Little is known about the effects of anthropogenic sounds on lamprey.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Transforming adults, Adults	Adults and transforming adults: Very little is known of the effects of anthropogenic sounds on lamprey at any life-history stage.	Although little is known about the effects of anthropogenic sounds on lamprey, it is prudent to avoid/ minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	Little is known about the effects of anthropogenic sounds on lamprey.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling, and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Ammocoetes; Transforming adults; Adults	Ammocoetes: Mortality, injury, and stress, during dewatering (when buried in riverine sediments). Adults and transforming adults: Mortality, injury, or stress from capture, handling, and relocation. Transforming adults: Increased competition once relocated, and reduced growth and fitness; increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May affect survival, growth, and fitness at ammocoete, transforming adult, and adult life-history stages.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Transforming adults	Transforming adults: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when transforming adults are present.	May affect survival and fitness at transforming adult life-history stage.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Potential nest scour and/or sedimentation, resulting in decreased incubation success. Transforming adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, and decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and ammocoete life-history stages; may affect transforming adult growth and fitness; may affect adult spawning success.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Transforming adults; Adults	Transforming adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, and decreased spawning fitness.	To greatest extent practicable, limit alteration of current and circulation patterns to minimal area.	May affect transforming adult survival, growth, and fitness. May affect adult spawning fitness.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Potential decreased egg incubation success and ammocoete survival due to turbidity exposure and substrate disturbance. Transforming adults and adults: For Pacific and river lamprey, decreased populations of host fish such as salmon could decrease available habitat.	Adhere to system-specific in-water work windows. Avoid work during egg incubation and ammocoete stages.	May affect survival of eggs and ammocoetes. May affect growth and fitness at transforming adult and adult life-history stages.
		Localized alteration in host fish abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Transforming adults	Transforming adults and adults: For Pacific and river lamprey, short-term reductions in host fish due to increased competition, decreased growth, and fitness are expected to affect growth and survival for these life-stages.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at transforming adult life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	All life-history-stages: See responses to related stressors under Water Quality Modification. Water quality effects to ammocoetes are a data gap. However, as Pacific and river lamprey feed on host fish, effects of suspended solids on host fish could affect them. As western brook lamprey are filter feeders, this may not be a stressor for transforming adults and adults.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Transforming adults; Adults	Transforming adults: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at transforming adult life-history stage. May affect adult survival and spawning productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and ammocoetes; Transforming adults; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Transforming adults; Adults	Transforming adults and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and ammocoetes; Transforming adults; Adults	Ammocoetes: Ammocoetes of Pacific and river lamprey mature buried in fine substrates in the lower reaches and estuaries of larger rivers for extended periods and are therefore vulnerable to direct injury and mortality from dredging entrainment. Transforming adults: Decreased foraging opportunity due to short-term reduction in prey availability. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury to ammocoetes. May affect transforming adult growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and ammocoete survival. Pacific and river lamprey ammocoetes are particularly vulnerable to impact mechanisms that cause scour, deposition, or other forms of substrate modification when buried in fine substrates during rearing periods, which can last for several years. Transforming adults: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, as well as changes in food web complexity. These may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation ~~of redds~~) if potential spawning habitat is affected	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and ammocoete stages and egg and transforming adult life-history stages for host fish of Pacific and river lamprey. May also affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and ammocoete development)	Permanent	Continuous				
	Marine								

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when transforming adults occupy nearshore habitats for rearing)	Permanent	Continuous	Transforming adults; Adults (river lamprey)	Transforming adults and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for lamprey host fish, leading to decreased foraging opportunities for transforming adult Pacific and river lamprey, and adult river lamprey.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and current patterns.	May affect growth and fitness at transforming adult life-history stages through effects on host fish. River lamprey are also known to use nearshore habitats during the adult life-history stage and will be subject to these effects during this period. Direct dependence on nearshore habitat characteristics for both species is a data gap. Decreased growth and fitness may affect survival and productivity during ocean migration life-history phase for both species. Western brook lamprey are non-anadromous and will not be exposed to these stressors.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Ammocoetes; Transforming adults; Adults	Ammocoetes: Rearing lamprey ammocoetes are found buried in nearshore lacustrine sediments. Modification of hydraulic and geomorphic conditions may alter habitat suitability, leading to limitations on the amount of available habitat and affecting survival, growth, and fitness at this life-history stage. Transforming adults and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for host fish, leading to decreased foraging opportunities for adults and transforming adults. Decreased foraging opportunities may cause decreased growth and fitness, affecting survival during marine migration and spawning productivity.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at ammocoete life-history stage. Effects on host fish may decrease survival, growth, and fitness of transforming adult and adult lamprey, and spawning productivity of adult lamprey.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lateral and longitudinal fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat, change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	<u>All exposed life-history stages</u>: Dikes and levees can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and larval rearing habitat for lamprey species. Depending on configuration, these structures may also affect the transport of lamprey ammocoetes to suitable rearing habitats, potentially affecting ammocoete survival. Decreased habitat availability may lead to density-dependent effects on adult spawning success. Adult brook lamprey may also be affected by decreased availability of suitable foraging habitat.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, ammocoete, and transforming adult life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Transforming adults; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect transforming adult growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Reduced availability of thermal refuge and decreased intragravel DO, nutrient cycling effects	Year-round	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	<u>Eggs and ammocoetes</u>: Decreased hyporheic exchange may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. <u>Adults and transforming adults</u>: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. <u>Adults</u>: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dike/levee placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and ammocoete survival, may affect transforming adult survival, growth, and fitness. May affect adult survival and spawning productivity.
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Transforming adults	<u>All exposed life-history stages</u>: Dikes and levees in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging river lamprey to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. Pacific lamprey exposure to these stressors is minimal, as they primarily reside in offshore habitats during the transforming adult and adult life-history stages. Brook lamprey do not occur in the marine environment.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at transforming adult life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Lacustrine								

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability	Year-round	Permanent	Continuous	Transforming adults; Adults	All exposed life-history stages: Dikes and levees in lacustrine environments can fragment nearshore rearing habitat, potentially affecting transport to and the suitability of nearshore rearing habitats for Pacific and river lamprey ammocoetes. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. Western brook lamprey do not typically occur in lacustrine environments; therefore, the likelihood of stressor exposure is limited.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival at transforming adult life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Direct mortality when exposed to temperatures over 68°F for continuous periods. Transforming adults: Altered growth and fitness when exposed to temperatures outside optimal growth range, and alteration of food web patterns, including food web supporting Pacific and river lamprey host fish. Adults and transforming adults: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during incubation, rearing, and spawning.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and ammocoetes; Transforming adults; Adults	Eggs/ammocoetes: Decreased incubation success due to burial or scour of eggs and rearing ammocoetes. Decreased availability of host fish for Pacific and river lamprey. Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness for Pacific and river lamprey host fish. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Potential effects on migration and spawning productivity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during incubation and transforming adult and adult fitness of host fish for Pacific and river lamprey.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Ammocoetes; Transforming adults	Transforming adults and ammocoetes: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect growth and fitness of ammocoetes and transforming adults.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Transforming adults; Adults	<u>Transforming adults:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness of host fish for Pacific and river lamprey. <u>Adults:</u> Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat for host fish of Pacific and river lamprey. Decreased suitable lamprey spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect growth and fitness of transforming adults. May affect adult spawning success.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and ammocoetes; Adults	Lamprey responses to groundwater exchange are a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Lamprey dependence on groundwater exchange is currently a data gap. Therefore, the effects of stressor exposure are unknown.
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Transforming adults; Adults	<u>Transforming adults</u>: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, transforming adult Pacific and river lamprey trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress. Similar effects on Pacific and river lamprey host fish may affect foraging success. <u>Adults</u>: River lamprey adults are found in nearshore environments and may experience similar effects as described above. Similar effects on river lamprey host fish may affect foraging success, leading to decreased growth and spawning fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness of transforming adult Pacific and river lamprey, as well as adult river lamprey.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Transforming adults; Adults	<u>Transforming adults:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness of Pacific and river lamprey host fish. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. <u>Adults</u>: River lamprey adults are found in nearshore environments and may experience similar effects as described above. Similar effects on river lamprey host fish may affect foraging success, leading to decreased growth and spawning fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect transforming adult survival and fitness.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	**When**	**Duration**	**Frequency**	**Life-history Form**			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Transforming adults; Adults	<u>Transforming adults:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness of Pacific and river lamprey host fish. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. <u>Adults</u>: River lamprey adults are found in nearshore environments and may experience similar effects as described above. Similar effects on river lamprey host fish may affect foraging success, leading to decreased growth and spawning fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness of transforming adult Pacific and river lamprey, as well as adult river lamprey.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Transforming adults; Adults	<u>Transforming adults</u>: Pacific and river lamprey host fish depend on allochthonous inputs from marine riparian vegetation. Effects on host fish survival growth and fitness may in turn affect lamprey growth and fitness. Those host fish that feed on benthic organisms (such as mollusks and amphipods) are likely linked to allochthonous material inputs. <u>Adults</u>: Adult river lamprey experience same effects as above.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	For Pacific and river lampreys, effects would be related only to host fish dependence on allochthonous inputs. Western brook lamprey have no marine life-history stage.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Transforming adults; Adults	<u>Transforming adults and adults (river lamprey)</u>: Lamprey dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Ammocoetes; Transforming adults; Adults	<u>Ammocoetes</u>: Larval western brook, river, and potentially Pacific lamprey are found in sheltered nearshore lacustrine habitats, buried in substrates. Altered water temperatures due to riparian modification could limit habitat suitability, affecting survival, growth, and fitness. <u>Adults and transforming adults</u>: Adult lamprey dependence on nearshore lacustrine habitats is currently a data gap. However, transforming adult host fish of Pacific and river lamprey may become trapped in isolated habitats, which may increase temperatures and potentially lead to mortality or increased thermal stress and decreased fitness of host fish, affecting foraging opportunities for adults and transforming adults.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect ammocoete survival, growth, and fitness. May affect growth and fitness of adults and transforming adults.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Transforming adults	Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect transforming adult survival growth and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Ammocoetes; Transforming adults; Adults	Ammocoetes: Larval western brook, river, and potentially Pacific lamprey are found in sheltered nearshore lacustrine habitats, buried in substrates. Alteration of shoreline stability could lead to increased sedimentation and burial, affecting larval survival. Adults and transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness for Pacific and river lamprey host fish. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect ammocoete survival. May affect growth and fitness of adults and transforming adults.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Ammocoetes; Transforming adults; Adults	Ammocoetes: Decrease in availability of suitable rearing habitat, leading to decreased survival, growth, and fitness. Transforming adults and adults: Decreased refuge habitat availability and foraging opportunities for host fish, potentially leading to decreased foraging opportunities for Pacific and river lamprey with resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect ammocoete survival, growth, and fitness. May affect adult growth, fitness, and spawning productivity due to effects on host fish.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Ammocoetes; Transforming adults; Adults	All life-history stages: Lamprey dependence on groundwater inflow in lacustrine habitats is currently a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible.	Effects of the action resulting from this impact mechanism are unknown.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Ammocoetes; Transforming adults	Ammocoetes and transforming adults: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness of Pacific and river lamprey host fish, and decreased prey resources for filter-feeding Western brook lamprey and ammocoete stages of Pacific and river lamprey. Altered prey resource effects to lamprey ammocoete life-history stages are a data gap. Although effects of altered autochthonous inputs for western brook lamprey are a data gap, alterations could be expected to affect prey resource availability.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect ammocoete and transforming adult growth and fitness.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Transforming adults; Adults	Transforming adults and adults: See related stressor responses under Water Quality Alteration. Effects are related to host fish effects for both Pacific and river lamprey.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Ammocoetes; Transforming adults; Adults	All exposed life-history stages: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness of Pacific and river lamprey host fish, and decreased prey resources for filter feeding Western brook lamprey and ammocoete stages of Pacific and river lamprey. Altered prey resource effects to lamprey ammocoete life-history stages are a data gap. Although effects of altered autochthonous inputs on Western brook lamprey are a data gap, alterations could be expected to affect prey resource availability.		Lamprey dependence on habitat complexity provided by freshwater aquatic vegetation is a data gap.
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Transforming adults; Adults	Transforming adults and adults: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness of Pacific and river lamprey host fish. Effects on host fish in nearshore habitats would also affect adult river lamprey forage opportunities.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect river lamprey transforming adult and adult growth and fitness, as well as productivity of Pacific and river lamprey host fish.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Transforming adults;	Transforming adults: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Transforming adults; Adults	Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness of Pacific and river lamprey host fish. Adults: Decreased foraging opportunity due to decreased food web productivity, with resulting decreased growth and reproductive fitness of Pacific and river lamprey. River lamprey use nearshore habitats during this life-history phase, but dependence on habitat complexity remains a data gap.		May affect transforming adult survival and productivity. May affect adult growth and spawning productivity of Pacific and river lamprey host fish. Other effects on adult river lamprey are a data gap.
	Water Quality Modification								

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Direct mortality due to winter ice formation and scour. Transforming adults: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and transforming adults: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during transforming adult development. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and ammocoetes; Transforming adults; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Effects on host fish are stressors to Pacific and river lamprey. Transforming adults and adults: A physiological response to exposure at toxic levels causing mortality or injury leading to reduced fitness is a data gap. However, effects on host fish are known and would affect Pacific and river lamprey. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. This is a data gap.	Avoid sediment pulses. Limit nutrient inputs and no direct waste discharge.	May affect survival of incubating eggs and ammocoetes. May affect transforming adult survival, growth, and fitness, as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Turbidity sufficient to cause fine sediment embeddedness or increased burial depth may lead to direct mortality and decreased survival of eggs and ammocoetes. Transforming adults and adults: Not a direct stressor to the lamprey. For Pacific and river lamprey, responses depend on stressor magnitude to host fish, which may include the following: unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and ammocoetes. May affect transforming adult growth and fitness, as well as adult fitness and spawning success.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and ammocoetes; Transforming adults; Adults	<u>All expose life history stages:</u> Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Outfalls									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and ammocoetes; Transforming adults; Adults	<u>All life-history stages</u>: Very little is known of the effects of pile-driving sounds on lamprey at any life-history stage.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Little is known about the effects of anthropogenic sounds on lamprey.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Transforming adults, Adults	<u>Adults and transforming adults</u>: Very little is known of the effects of anthropogenic sounds on lamprey at any life-history stage.	Although little is known about the effects of anthropogenic sounds on lamprey, it is prudent to avoid/ minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	Little is known about the effects of anthropogenic sounds on lamprey.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow Bypass, Fish handling, and Channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Ammocoetes; Transforming adults; Adults	Ammocoetes: Mortality, injury, and stress, during dewatering (when buried in riverine sediments). Adults and transforming adults: Mortality, injury, or stress from capture, handling, and relocation. Transforming adults: Increased competition once relocated, and reduced growth and fitness; increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May affect survival, growth, and fitness at ammocoete, transforming adult, and adult life-history stages.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Transforming adults	Transforming adults: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when transforming adults are present.	May affect survival and fitness at transforming adult life-history stage.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Potential nest scour and/or sedimentation, resulting in decreased incubation success. Transforming adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, and decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and ammocoete life-history stages; may affect transforming adult growth and fitness; may affect adult spawning success.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Transforming adults; Adults	Transforming adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, and decreased spawning fitness.	To greatest extent practicable, limit alteration of current and circulation patterns to minimal area.	May affect transforming adult survival, growth, and fitness. May affect adult spawning fitness.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Potential decreased egg incubation success and ammocoete survival due to turbidity exposure and substrate disturbance. Transforming adults and adults: For Pacific and river lamprey, decreased populations of host fish such as salmon could decrease available habitat.	Adhere to system-specific in-water work windows. Avoid work during egg incubation and ammocoete stages.	May affect survival of eggs and ammocoetes. May affect growth and fitness at transforming adult and adult life-history stages.
		Localized alteration in host fish abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Transforming adults	Transforming adults and adults: For Pacific and river lamprey, short-term reductions in host fish due to increased competition, decreased growth, and fitness are expected to affect growth and survival for these life-stages.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at transforming adult life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	All life-history-stages: See responses to related stressors under Water Quality Modification. Water quality effects to ammocoetes are a data gap. However, as Pacific and river lamprey feed on host fish, effects of suspended solids on host fish could affect them. As western brook lamprey are filter feeders, this may not be a stressor for transforming adults and adults.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and ammocoetes; Transforming adults; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Transforming adults; Adults	Transforming adults and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and ammocoetes; Transforming adults; Adults	Ammocoetes: Ammocoetes of Pacific and river lamprey mature buried in fine substrates in the lower reaches and estuaries of larger rivers for extended periods and are therefore vulnerable to direct injury and mortality from dredging entrainment. Transforming adults: Decreased foraging opportunity due to short-term reduction in prey availability. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury to ammocoetes. May affect transforming adult growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and ammocoete survival. Pacific and river lamprey ammocoetes are particularly vulnerable to impact mechanisms that cause scour, deposition, or other forms of substrate modification when buried in fine substrates during rearing periods, which can last for	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and ammocoete stages and egg and transforming adult life-history stages for host fish of Pacific and river lamprey. May also affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and ammocoete development)	Permanent	Continuous		several years. Transforming adults: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, as well as changes in food web complexity. These may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation ~~of redds~~) if potential spawning habitat is affected		
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when transforming adults occupy nearshore habitats for rearing)	Permanent	Continuous	Transforming adults; Adults (river lamprey)	Transforming adults and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for lamprey host fish, leading to decreased foraging opportunities for transforming adult Pacific and river lamprey, and adult river lamprey.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, a nd current patterns.	May affect growth and fitness at transforming adult life-history stages through effects on host fish. River lamprey are also known to use nearshore habitats during the adult life-history stage and will be subject to these effects during this period. Direct dependence on nearshore habitat characteristics for both species is a data gap. Decreased growth and fitness may affect survival and productivity during ocean migration life-history phase for both species. Western brook lamprey are non-anadromous and will not be exposed to these stressors.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Ammocoetes; Transforming adults; Adults	Ammocoetes: Rearing lamprey ammocoetes are found buried in nearshore lacustrine sediments. Modification of hydraulic and geomorphic conditions may alter habitat suitability, leading to limitations on the amount of available habitat and affecting survival, growth, and fitness at this life-history stage. Transforming adults and adults: Wave energy,	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at ammocoete life-history stage. Effects on host fish may decrease survival, growth, and fitness of transforming adult and adult lamprey, and spawning productivity of adult lamprey.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous		current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for host fish, leading to decreased foraging opportunities for adults and transforming adults. Decreased foraging opportunities may cause decreased growth and fitness, affecting survival during marine migration and spawning productivity.		
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of longitudinal connectivity may result from water quality barrier when high effluent discharge causes chemical barrier to migration. If constructed parallel to the channel, side channel and floodplain habitat may become fragmented. These actions will result in changes in habitat structure, availability, and suitability; reduced food web complexity.	Year-round	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	<u>All exposed life-history stages</u>: High flow outfalls can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and larval rearing habitat for lamprey species. Depending on configuration, these structures may also affect the transport of lamprey ammocoetes to suitable rearing habitats, potentially affecting ammocoete survival. Decreased habitat availability may lead to density-dependent effects on adult spawning success. Adult brook lamprey may also be affected by decreased availability of suitable foraging habitat.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, ammocoete, and transforming adult life-history stages. May affect spawning productivity.
	Marine and Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Transforming adults	<u>All exposed life-history stages</u>: Outfalls in the marine environment can fragment nearshore habitat, forcing river lamprey to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. Pacific lamprey exposure to these stressors is minimal, as they primarily reside in offshore habitats during the transforming adult and adult life-history stages. Brook lamprey do not occur in the marine environment.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at transforming adult life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Riparian Vegetation Modification								
	Riverine								

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and ammocoetes; Transforming adults; Adults	The degree to which outfalls affect riparian vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine environments.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and ammocoetes; Transforming adults; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Transforming adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Transforming adults; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	
	Marine								

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Transforming adults; Adults	Transforming adults: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, transforming adult Pacific and river lamprey trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress. Similar effects on Pacific and river lamprey host fish may affect foraging success. Adults: River lamprey adults are found in nearshore environments and may experience similar effects as described above. Similar effects on river lamprey host fish may affect foraging success, leading to decreased growth and spawning fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness of transforming adult Pacific and river lamprey, as well as adult river lamprey.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Transforming adults; Adults	Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness of Pacific and river lamprey host fish. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: River lamprey adults are found in nearshore environments and may experience similar effects as described above. Similar effects on river lamprey host fish may affect foraging success, leading to decreased growth and spawning fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness of transforming adult Pacific and river lamprey, as well as adult river lamprey.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Transforming adults; Adults	Transforming adults: Pacific and river lamprey host fish depend on allochthonous inputs from marine riparian vegetation. Effects on host fish survival growth and fitness may in turn affect lamprey growth and fitness. Those host fish that feed on benthic organisms (such as mollusks and amphipods) are likely linked to allochthonous material inputs. Adults: Adult river lamprey experience same effects as above.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	For Pacific and river lamprey, effects would be related only to host fish dependence on allochthonous inputs. Western brook lamprey have no marine life-history stage.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Transforming adults; Adults	Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness of host fish for Pacific and river lamprey. Adults: Adult river lamprey experience same effects as above.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect transforming adult survival, growth, and fitness; adult spawning success; and overall population productivity.
	Lacustrine								

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Transforming adults	The degree to which outfalls affect riparian vegetation conditions in lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in lacustrine environments.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Transforming adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Transforming adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Transforming adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Transforming adults; Adults	Transforming adults and adults: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness of Pacific and river lamprey host fish. Effects on host fish in nearshore habitats would also affect adult river lamprey forage opportunities.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect river lamprey transforming adult and adult growth and fitness, as well as productivity of Pacific and river lamprey host fish.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Transforming adults	Transforming adults: See related stressor responses for altered dissolved oxygen levels under Water Quality Alteration.		See effects for related stressors for altered dissolved oxygen levels under Water Quality Modification.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Transforming adults; Adults	Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness of Pacific and river lamprey host fish. Adults: Decreased foraging opportunity due to decreased food web productivity, with resulting decreased growth and reproductive fitness of Pacific and river lamprey. River lamprey use nearshore habitats during this life-history phase, but dependence on habitat complexity remains a data gap.		May affect transforming adult survival and productivity. May affect adult growth and spawning productivity of Pacific and river lamprey host fish. Other effects on adult river lamprey are a data gap.
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Transforming adults	The degree to which outfalls affect aquatic vegetation conditions in riverine and lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine and lacustrine environments.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Transforming adults; Adults			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Transforming adults			
	Water Quality Modification								
		Altered thermal regime (i.e., increased summer temperatures due to elevated effluent temperatures relative to receiving body)	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Transforming adults; Adults	Transforming adults: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and transforming adults: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during transforming adult develoment. May affect adult survival and spawning productivity.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and ammocoetes; Transforming adults; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Effects on host fish are stressors to Pacific and river lamprey. Transforming adults and adults: A physiological response to exposure at toxic levels causing mortality or injury leading to reduced fitness is a data gap. However, effects on host fish are known and would affect Pacific and river lamprey. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. This is a data gap.	Avoid sediment pulses. Limit nutrient inputs.	May affect survival of incubating eggs and ammocoetes. May affect transforming adult survival, growth, and fitness, as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Turbidity sufficient to cause fine sediment embeddedness or increased burial depth may lead to direct mortality and decreased survival of eggs and ammocoetes. Transforming adults and adults: Not a direct stressor to the lamprey. For Pacific and river lamprey, responses depend on stressor magnitude to host fish, which may include the following: unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and ammocoetes. May affect transforming adult growth and fitness, as well as adult fitness and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Transforming adults; Adults	Transforming adults and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness of host fish for Pacific and river lamprey.	Limit nutrient inputs and no direct waste discharge. Avoid curing of concrete or discharge of concrete leachate to surface waters.	May affect survival, growth, and fitness of transforming adults and adults.
		Altered nutrient cycling (due to effects of effluent discharge)	During and following discharge events	Long-term to permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	All exposed life history stages: Nutrient increases may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate effluent potential to adversely affect eutrophication. Require or encourage use of upstream treatment measures prior to discharge.	May affect survival, growth and fitness at all exposed life history stages.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Eggs and ammocoetes; Transforming adults; Adults	All exposed life history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and ammocoetes; Transforming adults; Adults	All life-history stages: Very little is known of the effects of pile-driving sounds on lamprey at any life-history stage.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Little is known about the effects of anthropogenic sounds on lamprey.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Transforming adults, Adults	Adults and transforming adults: Very little is known of the effects of anthropogenic sounds on lamprey at any life-history stage.	Although little is known about the effects of anthropogenic sounds on lamprey, it is prudent to avoid/ minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	Little is known about the effects of anthropogenic sounds on lamprey.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Ammocoetes; Transforming adults; Adults	Ammocoetes: Mortality, injury, and stress, during dewatering (when buried in riverine sediments). Adults and transforming adults: Mortality, injury, or stress from capture, handling, and relocation. Transforming adults: Increased competition once relocated, and reduced growth and fitness; increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May affect survival, growth, and fitness at ammocoete, transforming adult, and adult life-history stages.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Transforming adults	Transforming adults: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when transforming adults are present.	May affect survival and fitness at transforming adult life-history stage.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Potential nest scour and/or sedimentation, resulting in decreased incubation success. Transforming adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, and decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and ammocoete life-history stages; may affect transforming adult growth and fitness; may affect adult spawning success.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Transforming adults; Adults	Transforming adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, and decreased spawning fitness.	To greatest extent practicable, limit alteration of current and circulation patterns to minimal area.	May affect transforming adult survival, growth, and fitness. May affect adult spawning fitness.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Potential decreased egg incubation success and ammocoete survival due to turbidity exposure and substrate disturbance. Transforming adults and adults: For Pacific and river lamprey, decreased populations of host fish such as salmon could decrease available habitat.	Adhere to system-specific in-water work windows. Avoid work during egg incubation and ammocoete stages.	May affect survival of eggs and ammocoetes. May affect growth and fitness at transforming adult and adult life-history stages.
		Localized alteration in host fish abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Transforming adults	Transforming adults and adults: For Pacific and river lamprey, short-term reductions in host fish due to increased competition, decreased growth, and fitness are expected to affect growth and survival for these life-stages.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at transforming adult life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	All life-history-stages: See responses to related stressors under Water Quality Modification. Water quality effects to ammocoetes are a data gap. However, as Pacific and river lamprey feed on host fish, effects of suspended solids on host fish could affect them. As western brook lamprey are filter feeders, this may not be a stressor for transforming adults and adults.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and ammocoetes; Transforming adults; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Transforming adults; Adults	Transforming adults and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and ammocoetes; Transforming adults; Adults	<u>Ammocoetes:</u> Ammocoetes of Pacific and river lamprey mature buried in fine substrates in the lower reaches and estuaries of larger rivers for extended periods and are therefore vulnerable to direct injury and mortality from dredging entrainment. <u>Transforming adults</u>: Decreased foraging opportunity due to short-term reduction in prey availability. <u>All life-history stages</u>: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury to ammocoetes. May affect transforming adult growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	<u>Eggs and ammocoetes</u>: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and ammocoete survival. Pacific and river lamprey ammocoetes are particularly vulnerable to impact mechanisms that cause scour, deposition, or other forms of substrate modification when buried in fine substrates during rearing periods, which can last for several years. <u>Transforming adults</u>: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, as well as changes in food web complexity. These may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. <u>Adults</u>: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation ~~of redds~~) if potential spawning habitat is affected	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and ammocoete stages and egg and transforming adult life-history stages for host fish of Pacific and river lamprey. May also affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and ammocoete development)	Permanent	Continuous				
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when transforming adults occupy nearshore habitats for rearing)	Permanent	Continuous	Transforming adults; Adults (river lamprey)	<u>Transforming adults and adults</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on	May affect growth and fitness at transforming adult life-history stages through effects on host fish. River lamprey are also known to use nearshore habitats during the adult life-

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent		in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for lamprey host fish, leading to decreased foraging opportunities for transforming adult Pacific and river lamprey, and adult river lamprey.	sediment supply, longshore drift patterns, a nd current patterns.	history stage and will be subject to these effects during this period. Direct dependence on nearshore habitat characteristics for both species is a data gap. Decreased growth and fitness may affect survival and productivity during ocean migration life-history phase for both species. Western brook lamprey are non-anadromous and will not be exposed to these stressors.
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Ammocoetes; Transforming adults; Adults	<u>Ammocoetes</u>: Rearing lamprey ammocoetes are found buried in nearshore lacustrine sediments. Modification of hydraulic and geomorphic conditions may alter habitat suitability, leading to limitations on the amount of available habitat and affecting survival, growth, and fitness at this life-history stage. <u>Transforming adults and adults</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of rearing habitat for host fish, leading to decreased foraging opportunities for adults and transforming adults. Decreased foraging opportunities may cause decreased growth and fitness, affecting survival during marine migration and spawning productivity.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at ammocoete life-history stage. Effects on host fish may decrease survival, growth, and fitness of transforming adult and adult lamprey, and spawning productivity of adult lamprey.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition and stability		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	<u>All exposed life-history stages</u>: Intakes and diversions can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and larval rearing habitat for lamprey species. Depending on configuration, these structures may also affect the transport of lamprey ammocoetes to suitable rearing habitats, potentially affecting ammocoete survival. Decreased habitat availability may lead to density-dependent effects on adult spawning success. Adult brook lamprey may also be affected by decreased availability of suitable foraging habitat.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, ammocoete, and transforming adult life-history stages. May affect spawning productivity.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Transforming adults; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect transforming adult growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fines will reduce hyporheic exchange, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and ammocoete development)	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and transforming adults: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage intakes and diversions placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and ammocoete survival, may affect transforming adult survival, growth, and fitness. May affect adult survival and spawning productivity.
	Marine and Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Transforming adults	All exposed life-history stages: Intakes and diversions in the marine environment can fragment nearshore habitat, forcing river lamprey to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. Pacific lamprey exposure to these stressors is minimal, as they primarily reside in offshore habitats during the transforming adult and adult life-history stages. Brook lamprey do not occur in the marine environment. Western brook lamprey do not typically occur in lacustrine environments; therefore, the likelihood of stressor exposure is limited.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at transforming adult life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Loss of LWD recruitment	Reduced availability of LWD from drift. Reduced availability of LWD from drift. Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Transforming adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect transforming adult survival.
	Riparian Vegetation Modification								
	Riverine								

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Direct mortality when exposed to temperatures over 68°F for continuous periods. Transforming adults: Altered growth and fitness when exposed to temperatures outside optimal growth range, and alteration of food web patterns, including food web supporting Pacific and river lamprey host fish. Adults and transforming adults: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during incubation, rearing, and spawning.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and ammocoetes; Transforming adults; Adults	Eggs/ammocoetes: Decreased incubation success due to burial or scour of eggs and rearing ammocoetes. Decreased availability of host fish for Pacific and river lamprey. Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness for Pacific and river lamprey host fish. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. Adults: Potential effects on migration and spawning productivity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during incubation and transforming adult and adult fitness of host fish for Pacific and river lamprey.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Ammocoetes; Transforming adults	Transforming adults and ammocoetes: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect growth and fitness of ammocoetes and transforming adults.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Transforming adults; Adults	Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness of host fish for Pacific and river lamprey. Adults: Increased mortality; decreased fitness and spawning success due to decreased availability of suitable migratory and spawning habitat for host fish of Pacific and river lamprey. Decreased suitable lamprey spawning habitat.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect growth and fitness of transforming adults. May affect adult spawning success.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and ammocoetes; Adults	Lamprey responses to groundwater exchange are a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Lamprey dependence on groundwater exchange is currently a data gap. Therefore, the effects of stressor exposure are unknown.
	Marine								

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Transforming adults; Adults	<u>Transforming adults</u>: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, transforming adult Pacific and river lamprey trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress. Similar effects on Pacific and river lamprey host fish may affect foraging success. <u>Adults</u>: River lamprey adults are found in nearshore environments and may experience similar effects as described above. Similar effects on river lamprey host fish may affect foraging success, leading to decreased growth and spawning fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness of transforming adult Pacific and river lamprey, as well as adult river lamprey.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Transforming adults; Adults	<u>Transforming adults:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness of Pacific and river lamprey host fish. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. <u>Adults</u>: River lamprey adults are found in nearshore environments and may experience similar effects as described above. Similar effects on river lamprey host fish may affect foraging success, leading to decreased growth and spawning fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect transforming adult survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Transforming adults; Adults	<u>Transforming adults:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness of Pacific and river lamprey host fish. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification. <u>Adults</u>: River lamprey adults are found in nearshore environments and may experience similar effects as described above. Similar effects on river lamprey host fish may affect foraging success, leading to decreased growth and spawning fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness of transforming adult Pacific and river lamprey, as well as adult river lamprey.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Transforming adults; Adults	Transforming adults: Pacific and river lamprey host fish depend on allochthonous inputs from marine riparian vegetation. Effects on host fish survival growth and fitness may in turn affect lamprey growth and fitness. Those host fish that feed on benthic organisms (such as mollusks and amphipods) are likely linked to allochthonous material inputs. Adults: Adult river lamprey experience same effects as above.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	For Pacific and river lamprey, effects would be related only to host fish dependence on allochthonous inputs. Western brook lamprey have no marine life-history stage.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Transforming adults; Adults	Transforming adults and adults (river lamprey): Lamprey dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid disturbance of vegetation along shoreline.	Effects of the action resulting from this impact mechanism are unknown.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Ammocoetes; Transforming adults; Adults	Ammocoetes: Larval western brook, river, and potentially Pacific lamprey are found in sheltered nearshore lacustrine habitats, buried in substrates. Altered water temperatures due to riparian modification could limit habitat suitability, affecting survival, growth, and fitness. Adults and transforming adults: Adult lamprey dependence on nearshore lacustrine habitats is currently a data gap. However, transforming adult host fish of Pacific and river lamprey may become trapped in isolated habitats, which may increase temperatures and potentially lead to mortality or increased thermal stress and decreased fitness of host fish, affecting foraging opportunities for adults and transforming adults.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect ammocoete survival, growth, and fitness. May affect growth and fitness of adults and transforming adults.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Transforming adults	Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect transforming adult survival growth and fitness.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Ammocoetes; Transforming adults; Adults	<u>Ammocoetes</u>: Larval western brook, river, and potentially Pacific lamprey are found in sheltered nearshore lacustrine habitats, buried in substrates. Alteration of shoreline stability could lead to increased sedimentation and burial, affecting larval survival. <u>Adults and transforming adults:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness for Pacific and river lamprey host fish. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect ammocoete survival. May affect growth and fitness of adults and transforming adults.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Ammocoetes; Transforming adults; Adults	<u>Ammocoetes</u>: Decrease in availability of suitable rearing habitat, leading to decreased survival, growth, and fitness. <u>Transforming adults and adults:</u> Decreased refuge habitat availability and foraging opportunities for host fish, potentially leading to decreased foraging opportunities for Pacific and river lamprey with resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect ammocoete survival, growth, and fitness. May affect adult growth, fitness, and spawning productivity due to effects on host fish.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Ammocoetes; Transforming adults; Adults	<u>All life-history stages</u>: Lamprey dependence on groundwater inflow in lacustrine habitats is currently a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible.	Effects of the action resulting from this impact mechanism are unknown.
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Transforming adults; Adults	<u>Transforming adults and adults</u>: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness of Pacific and river lamprey host fish. Effects on host fish in nearshore habitats would also affect adult river lamprey forage opportunities.	<u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect river lamprey transforming adult and adult growth and fitness, as well as productivity of Pacific and river lamprey host fish.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Transforming adults;	<u>Transforming adults</u>: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Transforming adults; Adults	Transforming adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness of Pacific and river lamprey host fish. Adults: Decreased foraging opportunity due to decreased food web productivity, with resulting decreased growth and reproductive fitness of Pacific and river lamprey. River lamprey use nearshore habitats during this life-history phase, but dependence on habitat complexity remains a data gap.		May affect transforming adult survival and productivity. May affect adult growth and spawning productivity of Pacific and river lamprey host fish. Other effects on adult river lamprey are a data gap.
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Ammocoetes; Transforming adults	Ammocoetes and transforming adults: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness of Pacific and river lamprey host fish, and decreased prey resources for filter-feeding Western brook lamprey and ammocoete stages of Pacific and river lamprey. Altered prey resource effects to lamprey ammocoete life-history stages are a data gap. Although effects of altered autochthonous inputs for western brook lamprey are a data gap, alterations could be expected to affect prey resource availability.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect ammocoete and transforming adult growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Transforming adults; Adults	Transforming adults and adults: See related stressor responses under Water Quality Alteration. Effects are related to host fish effects for both Pacific and river lamprey.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Ammocoetes; Transforming adults; Adults	All exposed life-history stages: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness of Pacific and river lamprey host fish, and decreased prey resources for filter feeding Western brook lamprey and ammocoete stages of Pacific and river lamprey. Altered prey resource effects to lamprey ammocoete life-history stages are a data gap. Although effects of altered autochthonous inputs on Western brook lamprey are a data gap, alterations could be expected to affect prey resource availability.		Lamprey dependence on habitat complexity provided by freshwater aquatic vegetation is a data gap.
	Water Quality Modification								

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Direct mortality due to winter ice formation and scour. Transforming adults: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and transforming adults: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Ensure that appropriate instream flows necessary to regulate temperature and other habitat parameters are maintained.	May affect survival, growth, and fitness during transforming adult development. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and ammocoetes; Transforming adults; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Effects on host fish are stressors to Pacific and river lamprey. Transforming adults and adults: A physiological response to exposure at toxic levels causing mortality or injury leading to reduced fitness is a data gap. However, effects on host fish are known and would affect Pacific and river lamprey. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. This is a data gap.	Avoid sediment pulses. Limit nutrient inputs and no direct waste discharge.	May affect survival of incubating eggs and ammocoetes. May affect transforming adult survival, growth, and fitness, as well as adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Turbidity sufficient to cause fine sediment embeddedness or increased burial depth may lead to direct mortality and decreased survival of eggs and ammocoetes. Transforming adults and adults: Not a direct stressor to the lamprey. For Pacific and river lamprey, responses depend on stressor magnitude to host fish, which may include the following: unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and ammocoetes. May affect transforming adult growth and fitness, as well as adult fitness and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Transforming adults; Adults	Transforming adults and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness of host fish for Pacific and river lamprey.	Limit nutrient inputs and no direct waste discharge. Avoid curing of concrete or discharge of concrete leachate to surface waters.	May affect survival, growth, and fitness of transforming adults and adults.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and ammocoetes; Transforming adults; Adults	<u>All expose life history stages:</u> Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Tide Gates									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs and ammocoetes; Transforming adults; Adults	<u>All life-history stages</u>: Very little is known of the effects of pile-driving sounds on lamprey at any life-history stage.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Little is known about the effects of anthropogenic sounds on lamprey.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Transforming adults, Adults	<u>Adults and transforming adults</u>: Very little is known of the effects of anthropogenic sounds on lamprey at any life-history stage.	Although little is known about the effects of anthropogenic sounds on lamprey, it is prudent to avoid/ minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	Little is known about the effects of anthropogenic sounds on lamprey.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow Bypass, fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Ammocoetes; Transforming adults; Adults	Ammocoetes: Mortality, injury, and stress, during dewatering (when buried in riverine sediments). Adults and transforming adults: Mortality, injury, or stress from capture, handling, and relocation. Transforming adults: Increased competition once relocated, and reduced growth and fitness; increased predation exposure. Adults: Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May affect survival, growth, and fitness at ammocoete, transforming adult, and adult life-history stages.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Transforming adults	Transforming adults: Injury or mortality from entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows, avoid use when transforming adults are present.	May affect survival and fitness at transforming adult life-history stage.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Potential nest scour and/or sedimentation, resulting in decreased incubation success. Transforming adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, and decreased spawning fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during egg and ammocoete life-history stages; may affect transforming adult growth and fitness; may affect adult spawning success.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Transforming adults; Adults	Transforming adults: Altered habitat suitability, increased stress, increased competition, decreased growth and fitness. Adults: Delayed migration, increased stress, and decreased spawning fitness.	To greatest extent practicable, limit alteration of current and circulation patterns to minimal area.	May affect transforming adult survival, growth, and fitness. May affect adult spawning fitness.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Potential decreased egg incubation success and ammocoete survival due to turbidity exposure and substrate disturbance. Transforming adults and adults: For Pacific and river lamprey, decreased populations of host fish such as salmon could decrease available habitat.	Adhere to system-specific in-water work windows. Avoid work during egg incubation and ammocoete stages.	May affect survival of eggs and ammocoetes. May affect growth and fitness at transforming adult and adult life-history stages.
		Localized alteration in host fish abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Transforming adults	Transforming adults and adults: For Pacific and river lamprey, short-term reductions in host fish due to increased competition, decreased growth, and fitness are expected to affect growth and survival for these life-stages.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at transforming adult life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	All life-history-stages: See responses to related stressors under Water Quality Modification. Water quality effects to ammocoetes are a data gap. However, as Pacific and river lamprey feed on host fish, effects of suspended solids on host fish could affect them. As western brook lamprey are filter feeders, this may not be a stressor for transforming adults and adults.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Loss of habitat, stranding from dewatering (during construction, maintenance, and removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Potential decreased egg incubation success and ammocoete survival due to water loss and stranding. Transforming adults: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at transforming adult life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs and ammocoetes; Transforming adults; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Transforming adults; Adults	Transforming adults and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and ammocoetes; Transforming adults; Adults	Ammocoetes: Ammocoetes of Pacific and river lamprey mature buried in fine substrates in the lower reaches and estuaries of larger rivers for extended periods and are therefore vulnerable to direct injury and mortality from dredging entrainment. Transforming adults: Decreased foraging opportunity due to short-term reduction in prey availability. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury to ammocoetes. May affect transforming adult growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	Eggs and ammocoetes: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and ammocoete survival. Pacific and river lamprey ammocoetes are particularly vulnerable to impact mechanisms that cause scour, deposition, or other forms of substrate modification when buried in fine substrates during rearing periods, which can last for	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival, growth, and fitness at egg and ammocoete stages and egg and transforming adult life-history stages for host fish of Pacific and river lamprey. May also affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and ammocoete development)	Permanent	Continuous		several years. Transforming adults: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability, as well as changes in food web complexity. These may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation ~~of redds~~) if potential spawning habitat is affected		
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when transforming adults occupy nearshore habitats for rearing)	Permanent	Continuous	Transforming adults; Adults (river lamprey)	Transforming adults and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of rearing habitat for lamprey host fish, leading to decreased foraging opportunities for transforming adult Pacific and river lamprey, and adult river lamprey.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, a nd current patterns.	May affect growth and fitness at transforming adult life-history stages through effects on host fish. River lamprey are also known to use nearshore habitats during the adult life-history stage and will be subject to these effects during this period. Direct dependence on nearshore habitat characteristics for both species is a data gap. Decreased growth and fitness may affect survival and productivity during ocean migration life-history phase for both species. Western brook lamprey are non-anadromous and will not be exposed to these stressors.
	Altered current velocities and tidal exchange		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered channel geometry		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lateral and longitudinal fragmentation of habitat	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults	<u>All exposed life-history stages</u>: Tide gates can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of adult spawning and larval rearing habitat for lamprey species. Depending on configuration, these structures may also affect the transport of lamprey ammocoetes to suitable rearing habitats, potentially affecting ammocoete survival. Decreased habitat availability may lead to density-dependent effects on adult spawning success. Adult brook lamprey may also be affected by decreased availability of suitable foraging habitat. Upstream and downstream migrations are limited causing reduced and delayed migration and increased predation. Decreased habitat availability may lead to density-dependent effects on adult spawning success	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Limit the length of time that tide gates are closed as much as possible.	May affect survival at egg, ammocoete, and transforming adult life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Transforming adults; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit the length of time that tide gates are closed as much as possible. No additional specific recommendations.	May affect transforming adult growth and survival, as well as spawning success and overall population productivity.
	Marine								
	Lateral and longitudinal fragmentation of habitat	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Transforming adults;	<u>All exposed life-history stages</u>: Tide gates in the marine environment can fragment nearshore rearing habitat, forcing migrating and foraging river lamprey to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness. Pacific lamprey exposure to these stressors is minimal, as they primarily reside in offshore habitats during the transforming adult and adult life-history stages. Brook lamprey do not occur in the marine environment.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at transforming adult life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Loss of LWD recruitment	Reduced availability of LWD from drift Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Transforming adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit the length of time that tide gates are closed as much as possible. Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect transforming adult survival, growth and fitness.
	Riparian Vegetation Modification								

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and ammocoetes; Transforming adults; Adults	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tide gates is considered to be a component of the effects of dikes and levees. The incremental effects of the tide gate are negligible in comparison.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and ammocoetes; Transforming adults; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Transforming adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Transforming adults; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and ammocoetes; Transforming adults; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	
	Marine and Lacustrine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Transforming adults	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tidegates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Transforming adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Transforming adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Transforming adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Transforming adults		Avoid disturbance of vegetation along shoreline.	
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Ammocoetes; Transforming adults	<u>Ammocoetes and transforming adults</u>: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness of Pacific and river lamprey host fish, and decreased prey resources for filter-feeding Western brook lamprey and ammocoete stages of Pacific and river lamprey. Altered prey resource effects to lamprey ammocoete life-history stages are a data gap. Although effects of altered autochthonous inputs for western brook lamprey are a data gap, alterations could be expected to affect prey resource availability.	<u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect ammocoete and transforming adult growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Transforming adults; Adults	<u>Transforming adults and adults</u>: See related stressor responses under Water Quality Alteration. Effects are related to host fish effects for both Pacific and river lamprey.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Ammocoetes; Transforming adults; Adults	<u>All exposed life-history stages</u>: Reduced foraging opportunities due to decreased food web productivity, decreased growth and fitness of Pacific and river lamprey host fish, and decreased prey resources for filter feeding Western brook lamprey and ammocoete stages of Pacific and river lamprey. Altered prey resource effects to lamprey ammocoete life-history stages are a data gap. Although effects of altered autochthonous inputs on Western brook lamprey are a data gap, alterations could be expected to affect prey resource availability.		Lamprey dependence on habitat complexity provided by freshwater aquatic vegetation is a data gap.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Transforming adults; Adults	<u>Transforming adults and adults</u>: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness of Pacific and river lamprey host fish. Effects on host fish in nearshore habitats would also affect adult river lamprey forage opportunities.	<u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect river lamprey transforming adult and adult growth and fitness, as well as productivity of Pacific and river lamprey host fish.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Transforming adults;	Transforming adults: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Transforming adults; Adults	<u>Transforming adults:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness of Pacific and river lamprey host fish. <u>Adults</u>: Decreased foraging opportunity due to decreased food web productivity, with resulting decreased growth and reproductive fitness of Pacific and river lamprey. River lamprey use nearshore habitats during this life-history phase, but dependence on habitat complexity remains a data gap.		May affect transforming adult survival and productivity. May affect adult growth and spawning productivity of Pacific and river lamprey host fish. Other effects on adult river lamprey are a data gap.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Transforming adults; Adults	<u>Transforming adults</u>: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. <u>Adults and transforming adults</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. <u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during transforming adult development. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and ammocoetes; Transforming adults; Adults	<u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation. Effects on host fish are stressors to Pacific and river lamprey. <u>Transforming adults and adults</u>: A physiological response to exposure at toxic levels causing mortality or injury leading to reduced fitness is a data gap. However, effects on host fish are known and would affect Pacific and river lamprey. Bioaccumulation of contaminants at subacute levels resulting in chronic physiological effects leading to reduced fitness and/or mortality. This is a data gap.	Avoid sediment pulses. Limit nutrient inputs and no direct waste discharge.	May affect survival of incubating eggs and ammocoetes. May affect transforming adult survival, growth, and fitness, as well as adult survival, productivity, and spawning success.

Table A-13 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Western Brook, River, and Pacific Lamprey.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and ammocoetes; Transforming adults; Adults	<u>Eggs and ammocoetes:</u> Turbidity sufficient to cause fine sediment embeddedness or increased burial depth may lead to direct mortality and decreased survival of eggs and ammocoetes. <u>Transforming adults and adults</u>: Not a direct stressor to the lamprey. For Pacific and river lamprey, responses depend on stressor magnitude to host fish, which may include the following: unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered migration behavior. <u>Adults</u>: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs and ammocoetes. May affect transforming adult growth and fitness, as well as adult fitness and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Transforming adults; Adults	<u>Transforming adults and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness of host fish for Pacific and river lamprey.	Limit nutrient inputs and no direct waste discharge. Avoid curing of concrete or discharge of concrete leachate to surface waters.	May affect survival, growth, and fitness of transforming adults and adults.
		Altered salinity	Year-round	Long-term to permanent	Intermittent (daily)	Transforming adults	Transforming adults: Altered salinity patterns may limit habitat suitability for transforming adults in nearshore marine environments. This in turn may increase competition for available habitats, limiting survival, growth, and fitness.	Limit closure time of tide gate to maximize natural tidal exchange.	May affect transforming adult survival, growth, and fitness.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Transforming adults; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect transforming adult and adult survival, growth, and fitness.
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Transforming adults	Tide gate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent. Exposure to toxic substances may lead to behavioral avoidance in adults. For transforming adults, limitations in the availability of suitable habitat, or potential physiological injury may affect survival, growth, and fitness.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect adult behavior. May affect transforming adult survival, growth, and fitness.

Table A-14. HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs; Larvae; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Egg mortality due to membrane rupture. ▪ Fatal injury or permanent auditory tissue damage caused by barotraumas limiting to larval, juvenile, and adult survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness Note that actual sound sensitivity of primitive fish species such as sturgeon is currently a data gap, so actual harm thresholds are unknown.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May cause direct mortality or injury at all life-history stages. May affect survival, growth, and fitness at larval and juvenile life-history stages. Actual effects are uncertain as the sensitivity of these species to noise related stressors is currently a data gap.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Juveniles: Auditory masking may affect ability to avoid predators, leading to effects on survival. Behavioral responses may lead to habitat avoidance, affecting growth and fitness. Adults: May cause avoidance behavior. Note: While these responses are possible, very little is known of the effects of anthropogenic sounds on sturgeon at any life-history stage, so the actual effects of stressor exposure are uncertain.	Although, little is known about the effects of anthropogenic sounds on sturgeon, it is prudent to avoid/ minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect juvenile survival due to avoidance behavior, decreased foraging success, and increased predation risk. May cause adult avoidance behavior. Actual effects are unknown as stressor sensitivity is currently a data gap.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles	Juveniles and larvae: Mortality, injury, or stress from capture, handling, and relocation. Sturgeon larvae may be too small to capture effectively, leading to mortality or injury from asphyxiation.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct mortality or injury to larvae and juveniles. Stress from relocation may affect survival, growth, and fitness.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles	<u>Larvae and juveniles</u>: Injury or mortality from pump entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality of larvae and juveniles.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	<u>Larvae</u>: May affect settlement, leading to decreased larval survival. <u>Juveniles and adults</u>: Sturgeon feed opportunistically on benthic organisms, such as aquatic insect larvae and fish. Substrate effects on these prey organisms could affect prey availability, resulting in decreased growth and fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during larval life-history stage. May affect juvenile and adult growth and fitness.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae</u>: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Green sturgeon eggs lack thick jelly coat of other sturgeon species and develop more rapidly, indicating greater sensitivity to acute turbidity. <u>Juveniles</u>: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. <u>Adults</u>: May cause avoidance behavior, potentially delaying migration.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect survival during egg and larval life-history stages. May affect juvenile survival, growth, and productivity. May cause adult avoidance behavior, potentially delaying migration and limiting spawning productivity; however, actual sensitivity to these stressors is a data gap.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	<u>Juveniles</u>: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae</u>: Potential decreased egg incubation success and larvae survival due to water loss and stranding. <u>Juveniles</u>: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. <u>Adults</u>: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses above under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Non-mobile eggs and larvae may experience injury or mortality from dredge entrainment. Juveniles and adults: Decreased growth and fitness due to stress and exertion caused by avoidance behavior and decreased foraging opportunity caused by short-term reduction in prey availability. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct injury or mortality of eggs and larvae. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles Adults	Eggs and larvae: Sturgeon are believed to spawn in swift current environments in part because the high velocities protect eggs from predation. Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success, and potentially increased predation exposure. Changes in flow regime may cause larvae to be transported to environments unfavorable for survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Juvenile dependence on groundwater exchange is a data gap; however, loss of thermal refuge may decrease the availability of suitable rearing habitat, leading to decreased growth and fitness. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations) if potential spawning habitat is affected	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg and larval life-history stages. May affect juvenile growth and fitness. May affect adult spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Marine								
	Altered sediment	Change in habitat structure and	Year-round (beginning with	Permanent	Continuous	Adults	Adults: Sediment supply and substrate	Carefully evaluate project siting and	May affect adult growth and fitness.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	transport	habitat suitability, reduced food web complexity, habitat availability and suitability as a result of beach erosion from altered sediment supply.	project installation and becoming more pronounced over time)				composition are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing marine food web productivity and availability of prey species. This could lead to decreased adult growth and fitness, however incremental effects may not be significant considering the wide ranging marine habitats of adult sturgeon.	design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply.	
	Altered substrate composition		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and Longitudinal habitat Fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of longitudinal (i.e., upstream-downstream) habitat connectivity; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Dams can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of larval sturgeon rearing habitat. Decreased habitat availability may lead to density-dependent effects on larval and juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Minimize severing upstream-downstream connectivity by installing fish passage.	May affect survival at egg, larvae, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dam placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible. Encourage spillway design to promote moderation of stream temperatures in downstream reaches.	May affect egg and larvae survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered Community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species.	Year-round	Permanent	Continuous	Juveniles	Juveniles: Dams create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Direct mortality of embryos at temperatures in excess of 68°F (20°C). Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Decreased growth when exposed to temperatures in excess of 75°F (24°C). Adults: Exposure to thermal barriers is unlikely as spawning migrations occur in mid- to late-winter and spawning occurs in turbulent river mainstems.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during incubation, rearing, and spawning.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles;	Eggs and larvae: Decreased incubation success and larval survival due to effects of turbidity exposure as described above under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival during incubation larval dispersal, as well as survival, growth, and fitness during juvenile rearing.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Juvenile sturgeon are opportunistic feeders and may utilize allochthonous inputs in the form of terrestrially insect-fall. Reduced foraging opportunities due to decreased food web productivity may lead to decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of habitat features.	May affect juvenile survival, growth, and fitness.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Juveniles	Juveniles: Sturgeon dependence on groundwater exchange is currently a data gap. However, juveniles are dependent on water temperatures less than 75°F (24°C) for optimal growth. Reduction in thermal refuge habitat may lead to avoidance behavior, decreased growth, and decreased fitness.	Avoid disturbance of vegetation along stream.	Effects of action resulting from this impact mechanism are unknown, as sturgeon dependence on groundwater-surface water exchange is a data gap. However, loss of thermal refuge habitat may affect juvenile growth and fitness.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Juvenile sturgeon are known to feed opportunistically upon benthic prey organisms and fish dependent upon autochthonous material; reducing autochthonous production may decrease foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Design: Limit project structural footprint to minimize alteration and shading of native aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile productivity.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Reduced aquatic habitat complexity may limit the availability of suitable refuge and foraging habitat, leading to increased predation exposure and decreased foraging opportunities, affecting survival, growth, and fitness.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Provide sufficient streamflows to avoid temperature effects in reaches downstream of the impoundment. Promote dam designs that limit impoundment effects on downstream temperatures (e.g., draw streamflows from impoundment below the stratification layer in summer).	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Physiological responses to exposure at levels exceeding tolerance thresholds, causing mortality or injury leading to reduced fitness. Avoidance behavior during subacute events.	Avoid sediment pulses. Limit nutrient inputs associated. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs and larvae. May affect juvenile and adult survival, growth, and fitness.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity may lead to direct mortality and decreased survival of eggs and larvae. Green sturgeon eggs lack thick jelly coat of other sturgeon species and develop more rapidly, indicating greater sensitivity to acute turbidity. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to reduced foraging opportunity, increased predation exposure, and altered migration behavior.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of eggs and larvae. May affect juvenile productivity and adult productivity and spawning success. May cause direct mortality or injury in acute events.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Dam removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to dam removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs and no direct waste discharge. Prevent in-water curing of concrete and discharge of concrete leachate to surface waters.	May affect survival and productivity of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect survival, growth and fitness at all exposed life history stages.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Dam construction and operation may lead to introductions of toxic substances through accidental spills or other pathways. Impoundments may attract increased recreational vessel activity, creating a pathway for chronic exposure to hydrocarbons and other contaminants. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Require a spill control and containment plan for dam operations if appropriate. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources	May affect survival, growth and fitness at all exposed life history stages.
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs; Larvae; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Egg mortality due to membrane rupture. ▪ Fatal injury or permanent auditory tissue damage caused by barotraumas limiting to larval, juvenile, and adult survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness Note that actual sound sensitivity of primitive fish species such as sturgeon is currently a data gap, so actual harm thresholds are unknown.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May cause direct mortality or injury at all life-history stages. May affect survival, growth, and fitness at larval and juvenile life-history stages. Actual effects are uncertain as the sensitivity of these species to noise related stressors is currently a data gap.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Juveniles: Auditory masking may affect ability to avoid predators, leading to effects on survival. Behavioral responses may lead to habitat avoidance, affecting growth and fitness. Adults: May cause avoidance behavior. Note: While these responses are possible, very little is known of the effects of anthropogenic sounds on sturgeon at any life-history stage, so the actual effects of stressor exposure are uncertain.	Although, little is known about the effects of anthropogenic sounds on sturgeon, it is prudent to avoid/ minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect juvenile survival due to avoidance behavior, decreased foraging success, and increased predation risk. May cause adult avoidance behavior. Actual effects are unknown as stressor sensitivity is currently a data gap.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles	Juveniles and larvae: Mortality, injury, or stress from capture, handling, and relocation. Sturgeon larvae may be too small to capture effectively, leading to mortality or injury from asphyxiation.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct mortality or injury to larvae and juveniles. Stress from relocation may affect survival, growth, and fitness.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles	Larvae and juveniles: Injury or mortality from pump entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality of larvae and juveniles.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae: May affect settlement, leading to decreased larval survival. Juveniles and adults: Sturgeon feed opportunistically on benthic organisms, such as aquatic insect larvae and fish. Substrate effects on these prey organisms could affect prey availability, resulting in decreased growth and fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during larval life-history stage. May affect juvenile and adult growth and fitness.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Green sturgeon eggs lack thick jelly coat of other sturgeon species and develop more rapidly, indicating greater sensitivity to acute turbidity. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: May cause avoidance behavior, potentially delaying migration.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect survival during egg and larval life-history stages. May affect juvenile survival, growth, and productivity. May cause adult avoidance behavior, potentially delaying migration and limiting spawning productivity; however, actual sensitivity to these stressors is a data gap.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Loss of habitat access and stranding (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larvae survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses above under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Non-mobile eggs and larvae may experience injury or mortality from dredge entrainment. Juveniles and adults: Decreased growth and fitness due to stress and exertion caused by avoidance behavior and decreased foraging opportunity caused by short-term reduction in prey availability. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct injury or mortality of eggs and larvae. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles Adults	Eggs and larvae: Sturgeon are believed to spawn in swift current environments in part because the high velocities protect eggs from predation. Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success, and potentially increased predation exposure. Changes in flow regime may cause larvae to be transported to environments unfavorable for survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg and larval life-history stages. May affect juvenile growth and fitness. May affect adult spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
							changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Juvenile dependence on groundwater exchange is a data gap; however, loss of thermal refuge may decrease the availability of suitable rearing habitat, leading to decreased growth and fitness. <u>Adults</u>: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations) if potential spawning habitat is affected		
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	<u>All exposed life-history stages</u>: Weirs can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of larval sturgeon rearing habitat. Decreased habitat availability may lead to density-dependent effects on larval and juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting, and avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, larvae, and juvenile life-history stages. May affect spawning productivity. .
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae</u>: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. <u>Adults and juveniles</u>: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. <u>Adults</u>: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage weir placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and larvae survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species	Year-round	Permanent	Continuous	Juveniles	Juveniles: Weirs may create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Direct mortality of embryos at temperatures in excess of 68°F (20°C). Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Decreased growth when exposed to temperatures in excess of 75°F (24°C). Adults: Exposure to thermal barriers is unlikely as spawning migrations occur in mid- to late-winter and spawning occurs in turbulent river mainstems.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during incubation, rearing, and spawning.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles;	Eggs and larvae: Decreased incubation success and larval survival due to effects of turbidity exposure as described above under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival during incubation larval dispersal, as well as survival, growth, and fitness during juvenile rearing.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Juvenile sturgeon are opportunistic feeders and may utilize allochthonous inputs in the form of terrestrially insect-fall. Reduced foraging opportunities due to decreased food web productivity may lead to decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival, growth, and fitness.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Juveniles	Juveniles: Sturgeon dependence on groundwater exchange is currently a data gap. However, juveniles are dependent on water temperatures less than 75°F (24°C) for optimal growth. Reduction in thermal refuge habitat may lead to avoidance behavior, decreased growth, and decreased fitness.	Avoid disturbance of vegetation along stream.	Effects of action resulting from this impact mechanism are unknown, as sturgeon dependence on groundwater-surface water exchange is a data gap. However, loss of thermal refuge habitat may affect juvenile growth and fitness.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Adults	Adults: Adult sturgeon dependence on nearshore aquatic vegetation is a data gap. However, this species feeds on mollusks, fish, and invertebrate species dependent on nearshore food web productivity. Therefore, this stressor could indirectly affect adult growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect adult growth and fitness. However, localized effects are likely to be insignificant.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Adults	Adults: Adult sturgeon dependence on nearshore habitat complexity is limited. However, effects on habitat complexity may limit the availability and productivity of prey species; therefore, this stressor could indirectly affect adult growth and fitness. Given the extended marine foraging habitats used by sturgeon, localized effects are likely to be insignificant.		May affect adult growth and fitness. However, localized effects are likely to be insignificant.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Physiological responses to exposure at levels exceeding tolerance thresholds, causing mortality or injury leading to reduced fitness. Avoidance behavior during subacute events.	Avoid sediment pulses. Limit nutrient inputs associated. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs and larvae. May affect juvenile and adult survival, growth, and fitness.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity may lead to direct mortality and decreased survival of eggs and larvae. Green sturgeon eggs lack thick jelly coat of other sturgeon species and develop more rapidly, indicating greater sensitivity to acute turbidity. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to reduced foraging opportunity, increased predation exposure, and altered migration behavior.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of eggs and larvae. May affect juvenile productivity and adult productivity and spawning success. May cause direct mortality or injury in acute events.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All expose life history stages: Weir removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to weir removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs from direct waste discharge. Prevent in-water curing of concrete and discharge of concrete leachate to surface waters.	May affect survival and productivity of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All expose life history stages: Weir construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Dikes/Levees									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs; Larvae; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Egg mortality due to membrane rupture. ▪ Fatal injury or permanent auditory tissue damage caused by barotraumas limiting to larval, juvenile, and adult survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness Note that actual sound sensitivity of primitive fish species such as sturgeon is currently a data gap, so actual harm thresholds are unknown.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May cause direct mortality or injury at all life-history stages. May affect survival, growth, and fitness at larval and juvenile life-history stages. Actual effects are uncertain as the sensitivity of these species to noise related stressors is currently a data gap.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Juveniles: Auditory masking may affect ability to avoid predators, leading to effects on survival. Behavioral responses may lead to habitat avoidance, affecting growth and fitness. Adults: May cause avoidance behavior. Note: While these responses are possible, very little is known of the effects of anthropogenic sounds on sturgeon at any life-history stage, so the actual effects of stressor exposure are uncertain.	Although, little is known about the effects of anthropogenic sounds on sturgeon, it is prudent to avoid/ minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect juvenile survival due to avoidance behavior, decreased foraging success, and increased predation risk. May cause adult avoidance behavior. Actual effects are unknown as stressor sensitivity is currently a data gap.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling, and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles	Juveniles and larvae: Mortality, injury, or stress from capture, handling, and relocation. Sturgeon larvae may be too small to capture effectively, leading to mortality or injury from asphyxiation.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct mortality or injury to larvae and juveniles. Stress from relocation may affect survival, growth, and fitness.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles	Larvae and juveniles: Injury or mortality from pump entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality of larvae and juveniles.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae: May affect settlement, leading to decreased larval survival. Juveniles and adults: Sturgeon feed opportunistically on benthic organisms, such as aquatic insect larvae and fish. Substrate effects on these prey organisms could affect prey availability, resulting in decreased growth and fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during larval life-history stage. May affect juvenile and adult growth and fitness.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juvenile (over 1 ft length-[marine]) and adults: Because of the limited temporal and spatial extent of alteration to sturgeon marine habitat, project effects on marine circulation are a relatively inconsequential component. Therefore, the magnitude of project hydrologic modification is expected to be negligible. As such, this stressor is not expected to significantly affect the marine environment, and there will be no response to the stressor.	To greatest extent practicable, limit alteration of current and circulation patterns to minimal area.	Effects from exposure to this stressor are expected to be insignificant and discountable.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Green sturgeon eggs lack thick jelly coat of other sturgeon species and develop more rapidly, indicating greater sensitivity to acute turbidity. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: May cause avoidance behavior, potentially delaying migration.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect survival during egg and larval life-history stages. May affect juvenile survival, growth, and productivity. May cause adult avoidance behavior, potentially delaying migration and limiting spawning productivity; however, actual sensitivity to these stressors is a data gap.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses above under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Non-mobile eggs and larvae may experience injury or mortality from dredge entrainment. Juveniles and adults: Decreased growth and fitness due to stress and exertion caused by avoidance behavior and decreased foraging opportunity caused by short-term reduction in prey availability. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct injury or mortality of eggs and larvae. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles Adults	Eggs and larvae: Sturgeon are believed to spawn in swift current environments in part because the high velocities protect eggs from predation. Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success, and potentially increased predation exposure. Changes in flow regime may cause larvae to be transported to environments unfavorable	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg and larval life-history stages. May affect juvenile growth and fitness. May affect adult spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous		for survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Juvenile dependence on groundwater exchange is a data gap; however, loss of thermal refuge may decrease the availability of suitable rearing habitat, leading to decreased growth and fitness. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations) if potential spawning habitat is affected		
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Adults	Adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing marine food web productivity and availability of prey species. This could lead to decreased adult growth and fitness, however incremental effects may not be significant considering the wide ranging marine habitats of adult sturgeon.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect adult growth and fitness.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of juvenile rearing habitat. This may occur through increased predation exposure, food	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival at larval life-history stage. May affect growth and fitness at juvenile life-history stage. May affect adult growth and fitness, and adult spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous		web alterations, and decreased foraging opportunity. Alteration of current and circulation patterns may prevent larvae transport to suitable rearing environments. The combined effect of these stressors can result in decreased survival, growth, and fitness at larval and juvenile life-history stages. <u>Adults</u>: Adult sturgeon are generally less sensitive to these stressors. However, food web productivity in large reservoir environments may be affected by these impact mechanisms. This could lead to reduced adult foraging opportunities in residualized populations, and decreased growth, fitness, and spawning productivity.		
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat, change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	<u>All exposed life-history stages</u>: Dikes and levees can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of larval sturgeon rearing habitat. Decreased habitat availability may lead to density-dependent effects on larval and juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, larvae, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Reduced availability of thermal refuge and decreased intragravel DO, nutrient cycling effects	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae</u>: Decreased hyporheic exchange may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. <u>Adults and juveniles</u>: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. <u>Adults</u>: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dike/levee placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and larvae survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	<u>All exposed life-history stages</u>: Dikes and levees in the marine environment can fragment nearshore habitat. Sturgeon dependence on these habitat types is currently a data gap; therefore, the effects of this stressor are unknown	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Lacustrine								

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Dikes and levees in lacustrine environments can fragment nearshore habitat, forcing foraging larval and juvenile sturgeon to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion, affecting survival, growth, and fitness..	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Direct mortality of embryos at temperatures in excess of 68°F (20°C). Juveniles: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Decreased growth when exposed to temperatures in excess of 75°F (24°C). Adults: Exposure to thermal barriers is unlikely as spawning migrations occur in mid- to late-winter and spawning occurs in turbulent river mainstems.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during incubation, rearing, and spawning.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults	Eggs/larvae: Decreased incubation success due to decreased ~~redd~~ dissolved oxygen as described for related stressor responses under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles;	Eggs and larvae: Decreased incubation success and larval survival due to effects of turbidity exposure as described above under Water Quality Modification. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival during incubation larval dispersal, as well as survival, growth, and fitness during juvenile rearing.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Juvenile sturgeon are opportunistic feeders and may utilize allochthonous inputs in the form of terrestrially insect-fall. Reduced foraging opportunities due to decreased food web productivity may lead to decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival, growth, and fitness.
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Adults	Adults: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. Adult use of nearshore marine habitats is limited; therefore, stressor exposure is unlikely to occur.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Effects of stressor exposure on adult sturgeon are expected to be insignificant and discountable.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. This effect may be limited in magnitude, however, as juvenile use of littoral habitats is relatively limited. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Adults	Adults: Adult use of nearshore marine habitats is limited; therefore, stressor exposure is unlikely to occur.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Effects of stressor exposure on adult sturgeon are expected to be insignificant and discountable.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Adults	Adults: Sturgeon dependence on autochthonous inputs from marine riparian vegetation is a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap; therefore, the effects of the action from this impact mechanism are unknown.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Adults	Adults: Adult use of nearshore marine habitats is limited; therefore, stressor exposure is unlikely to occur.	Encourage project designs that limit permanent alteration of high-quality habitat features.	Effects of stressor exposure on adult sturgeon are expected to be insignificant and discountable.
	Lacustrine								

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of turnover time, stratification patterns, wind conditions, and other factors. However, the suitability of some protected habitats such as isolated embayments may be affected, leading to decreased rearing habitat availability and increased competition, leading to decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival growth and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Sturgeon dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. However, juvenile sturgeon are opportunistic feeders. Loss of terrestrial insect-fall could lead to decreased foraging opportunities, affecting growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and fitness.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Juvenile sturgeon are known to feed opportunistically upon benthic prey organisms and fish dependent upon autochthonous material; reducing autochthonous production may decrease foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile productivity.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Reduced aquatic habitat complexity may limit the availability of suitable refuge and foraging habitat, leading to increased predation exposure and decreased foraging opportunities, affecting survival, growth, and fitness.		May affect juvenile survival, growth, and fitness.
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Adults	Adults: Adult sturgeon dependence on nearshore aquatic vegetation is a data gap. However, this species feeds on mollusks, fish, and invertebrate species dependent on nearshore food web productivity. Therefore, this stressor could indirectly affect adult growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect adult growth and fitness. However, localized effects are likely to be insignificant.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Adults	Adults: Adult sturgeon dependence on nearshore habitat complexity is limited. However, effects on habitat complexity may limit the availability and productivity of prey species; therefore, this stressor could indirectly affect adult growth and fitness. Given the extended marine foraging habitats used by sturgeon, localized effects are likely to be insignificant.		May affect adult growth and fitness. However, localized effects are likely to be insignificant.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Physiological responses to exposure at levels exceeding tolerance thresholds, causing mortality or injury leading to reduced fitness. Avoidance behavior during subacute events.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs and larvae. May affect juvenile and adult survival, growth, and fitness.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Turbidity may lead to direct mortality and decreased survival of eggs and larvae. Green sturgeon eggs lack thick jelly coat of other sturgeon species and develop more rapidly, indicating greater sensitivity to acute turbidity. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to reduced foraging opportunity, increased predation exposure, and altered migration behavior.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of eggs and larvae. May affect juvenile productivity and adult productivity and spawning success. May cause direct mortality or injury in acute events.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All expose life history stages: Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Outfalls									
	Construction and Maintenance Activities								

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs; Larvae; Juveniles; Adults	<u>All exposed life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Egg mortality due to membrane rupture. ▪ Fatal injury or permanent auditory tissue damage caused by barotraumas limiting to larval, juvenile, and adult survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness Note that actual sound sensitivity of primitive fish species such as sturgeon is currently a data gap, so actual harm thresholds are unknown.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May cause direct mortality or injury at all life-history stages. May affect survival, growth, and fitness at larval and juvenile life-history stages. Actual effects are uncertain as the sensitivity of these species to noise related stressors is currently a data gap.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Juveniles</u>: Auditory masking may affect ability to avoid predators, leading to effects on survival. Behavioral responses may lead to habitat avoidance, affecting growth and fitness. <u>Adults</u>: May cause avoidance behavior. Note: While these responses are possible, very little is known of the effects of anthropogenic sounds on sturgeon at any life-history stage, so the actual effects of stressor exposure are uncertain.	Although, little is known about the effects of anthropogenic sounds on sturgeon, it is prudent to avoid/ minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect juvenile survival due to avoidance behavior, decreased foraging success, and increased predation risk. May cause adult avoidance behavior. Actual effects are unknown as stressor sensitivity is currently a data gap.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling, and Channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles	<u>Juveniles and larvae</u>: Mortality, injury, or stress from capture, handling, and relocation. Sturgeon larvae may be too small to capture effectively, leading to mortality or injury from asphyxiation.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct mortality or injury to larvae and juveniles. Stress from relocation may affect survival, growth, and fitness.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles	<u>Larvae and juveniles</u>: Injury or mortality from pump entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality of larvae and juveniles.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae: May affect settlement, leading to decreased larval survival. Juveniles and adults: Sturgeon feed opportunistically on benthic organisms, such as aquatic insect larvae and fish. Substrate effects on these prey organisms could affect prey availability, resulting in decreased growth and fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during larval life-history stage. May affect juvenile and adult growth and fitness.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juvenile (over 1 ft length-[marine]) and adults: Because of the limited temporal and spatial extent of alteration to sturgeon marine habitat, project effects on marine circulation are a relatively inconsequential component. Therefore, the magnitude of project hydrologic modification is expected to be negligible. As such, this stressor is not expected to significantly affect the marine environment, and there will be no response to the stressor.	To greatest extent practicable, limit alteration of current and circulation patterns to minimal area.	Effects from exposure to this stressor are expected to be insignificant and discountable.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Green sturgeon eggs lack thick jelly coat of other sturgeon species and develop more rapidly, indicating greater sensitivity to acute turbidity. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: May cause avoidance behavior, potentially delaying migration.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect survival during egg and larval life-history stages. May affect juvenile survival, growth, and productivity. May cause adult avoidance behavior, potentially delaying migration and limiting spawning productivity; however, actual sensitivity to these stressors is a data gap.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses above under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Non-mobile eggs and larvae may experience injury or mortality from dredge entrainment. Juveniles and adults: Decreased growth and fitness due to stress and exertion caused by avoidance behavior and decreased foraging opportunity caused by short-term reduction in prey availability. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct injury or mortality of eggs and larvae. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles Adults	Eggs and larvae: Sturgeon are believed to spawn in swift current environments in part because the high velocities protect eggs from predation. Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success, and potentially increased predation exposure. Changes in flow regime may cause larvae to be transported to environments unfavorable for survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Juvenile dependence on groundwater exchange is a data gap; however, loss of thermal refuge may decrease the availability of suitable rearing habitat, leading to decreased growth and fitness. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations) if potential spawning habitat is affected	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg and larval life-history stages. May affect juvenile growth and fitness. May affect adult spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Adults	Adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects	May affect adult growth and fitness.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent		more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing marine food web productivity and availability of prey species. This could lead to decreased adult growth and fitness, however incremental effects may not be significant considering the wide ranging marine habitats of adult sturgeon.	on sediment supply, longshore drift patterns, and wave energy and current patterns.	
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of juvenile rearing habitat. This may occur through increased predation exposure, food web alterations, and decreased foraging opportunity. Alteration of current and circulation patterns may prevent larvae transport to suitable rearing environments. The combined effect of these stressors can result in decreased survival, growth, and fitness at larval and juvenile life-history stages. Adults: Adult sturgeon are generally less sensitive to these stressors. However, food web productivity in large reservoir environments may be affected by these impact mechanisms. This could lead to reduced adult foraging opportunities in residualized populations, and decreased growth, fitness, and spawning productivity.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival at larval life-history stage. May affect growth and fitness at juvenile life-history stage. May affect adult growth and fitness, and adult spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of longitudinal connectivity may result from water quality barrier when high effluent discharge causes chemical barrier to migration. If constructed parallel to the channel, side channel and floodplain habitat may become fragmented. These actions will result in changes in habitat structure, availability, and suitability; reduced food web complexity.	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: High flow outfalls can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of larval sturgeon rearing habitat. Decreased habitat availability may lead to density-dependent effects on larval and juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, larvae, and juvenile life-history stages. May affect spawning productivity.
	Marine and Lacustrine								

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	<u>All exposed life-history stages</u>: Outfalls in the marine environment can fragment nearshore habitat. Sturgeon dependence on these habitat types is currently a data gap; therefore, the effects of this stressor are unknown.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and larvae; Juveniles; Adults	The degree to which outfalls affect riparian vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine environments.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~<u>benthic</u> dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	
	Marine								

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Adults	Adults: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. Adult use of nearshore marine habitats is limited; therefore, stressor exposure is unlikely to occur.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Effects of stressor exposure on adult sturgeon are expected to be insignificant and discountable.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Adults	Adults: Adult use of nearshore marine habitats is limited; therefore, stressor exposure is unlikely to occur.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Effects of stressor exposure on adult sturgeon are expected to be insignificant and discountable.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Adults	Adults: Sturgeon dependence on autochthonous inputs from marine riparian vegetation is a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap; therefore, the effects of the action from this impact mechanism are unknown.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Adults	Adults: Adult use of nearshore marine habitats is limited; therefore, stressor exposure is unlikely to occur.	Encourage project designs that limit permanent alteration of high-quality habitat features.	Effects of stressor exposure on adult sturgeon are expected to be insignificant and discountable.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The degree to which outfalls affect riparian vegetation conditions in lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in lacustrine environments.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Adults	Adults: Adult sturgeon dependence on nearshore aquatic vegetation is a data gap. However, this species feeds on mollusks, fish, and invertebrate species dependent on nearshore food web productivity. Therefore, this stressor could indirectly affect adult growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect adult growth and fitness. However, localized effects are likely to be insignificant.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Adults	Juveniles: See related stressor responses for altered dissolved oxygen levels under Water Quality Alteration.		See effects for related stressors for altered dissolved oxygen levels under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Adults	Adults: Adult sturgeon dependence on nearshore habitat complexity is limited. However, effects on habitat complexity may limit the availability and productivity of prey species; therefore, this stressor could indirectly affect adult growth and fitness. Given the extended marine foraging habitats used by sturgeon, localized effects are likely to be insignificant.		May affect adult growth and fitness. However, localized effects are likely to be insignificant.
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which outfalls affect aquatic vegetation conditions in riverine and lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine and lacustrine environments.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Water Quality Modification								

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered thermal regime (i.e., increased summer temperatures due to elevated effluent temperatures relative to receiving body)	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	<u>Juveniles</u>: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. <u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. <u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	<u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation. <u>Juveniles and adults</u>: Physiological responses to exposure at levels exceeding tolerance thresholds, causing mortality or injury leading to reduced fitness. Avoidance behavior during subacute events.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs and larvae. May affect juvenile and adult survival, growth, and fitness.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae:</u> Turbidity may lead to direct mortality and decreased survival of eggs and larvae. Green sturgeon eggs lack thick jelly coat of other sturgeon species and develop more rapidly, indicating greater sensitivity to acute turbidity. <u>Juveniles and adults</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to reduced foraging opportunity, increased predation exposure, and altered migration behavior.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of eggs and larvae. May affect juvenile productivity and adult productivity and spawning success. May cause direct mortality or injury in acute events.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs and no direct waste discharge. Prevent in-water curing of concrete and discharge of concrete leachate to surface waters.	May affect survival and productivity of juveniles and adults.
		Altered nutrient cycling (due to effects of effluent discharge)	During and following discharge events	Long-term to permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Nutrient increases may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate effluent potential to adversely affect eutrophication. Require or encourage use of upstream treatment measures prior to discharge.	May affect survival, growth and fitness at all exposed life history stages.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs; Larvae; Juveniles; Adults	All exposed life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Egg mortality due to membrane rupture. ▪ Fatal injury or permanent auditory tissue damage caused by barotraumas limiting to larval, juvenile, and adult survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness Note that actual sound sensitivity of primitive fish species such as sturgeon is currently a data gap, so actual harm thresholds are unknown.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May cause direct mortality or injury at all life-history stages. May affect survival, growth, and fitness at larval and juvenile life-history stages. Actual effects are uncertain as the sensitivity of these species to noise related stressors is currently a data gap.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Juveniles: Auditory masking may affect ability to avoid predators, leading to effects on survival. Behavioral responses may lead to habitat avoidance, affecting growth and fitness. Adults: May cause avoidance behavior. Note: While these responses are possible, very little is known of the effects of anthropogenic sounds on sturgeon at any life-history stage, so the actual effects of stressor exposure are uncertain.	Although, little is known about the effects of anthropogenic sounds on sturgeon, it is prudent to avoid/ minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect juvenile survival due to avoidance behavior, decreased foraging success, and increased predation risk. May cause adult avoidance behavior. Actual effects are unknown as stressor sensitivity is currently a data gap.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles	Juveniles and larvae: Mortality, injury, or stress from capture, handling, and relocation. Sturgeon larvae may be too small to capture effectively, leading to mortality or injury from asphyxiation.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct mortality or injury to larvae and juveniles. Stress from relocation may affect survival, growth, and fitness.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles	Larvae and juveniles: Injury or mortality from pump entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality of larvae and juveniles.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae: May affect settlement, leading to decreased larval survival. Juveniles and adults: Sturgeon feed opportunistically on benthic organisms, such as aquatic insect larvae and fish. Substrate effects on these prey organisms could affect prey availability, resulting in decreased growth and fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during larval life-history stage. May affect juvenile and adult growth and fitness.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juvenile (over 1 ft length-[marine]) and adults: Because of the limited temporal and spatial extent of alteration to sturgeon marine habitat, project effects on marine circulation are a relatively inconsequential component. Therefore, the magnitude of project hydrologic modification is expected to be negligible. As such, this stressor is not expected to significantly affect the marine environment, and there will be no response to the stressor.	To greatest extent practicable, limit alteration of current and circulation patterns to minimal area.	Effects from exposure to this stressor are expected to be insignificant and discountable.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Green sturgeon eggs lack thick jelly coat of other sturgeon species and develop more rapidly, indicating greater sensitivity to acute turbidity. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: May cause avoidance behavior, potentially delaying migration.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect survival during egg and larval life-history stages. May affect juvenile survival, growth, and productivity. May cause adult avoidance behavior, potentially delaying migration and limiting spawning productivity; however, actual sensitivity to these stressors is a data gap.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses above under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Non-mobile eggs and larvae may experience injury or mortality from dredge entrainment. Juveniles and adults: Decreased growth and fitness due to stress and exertion caused by avoidance behavior and decreased foraging opportunity caused by short-term reduction in prey availability. All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct injury or mortality of eggs and larvae. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles Adults	Eggs and larvae: Sturgeon are believed to spawn in swift current environments in part because the high velocities protect eggs from predation. Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success, and potentially increased predation exposure. Changes in flow regime may cause larvae to be transported to environments unfavorable	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg and larval life-history stages. May affect juvenile growth and fitness. May affect adult spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous		for survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Juvenile dependence on groundwater exchange is a data gap; however, loss of thermal refuge may decrease the availability of suitable rearing habitat, leading to decreased growth and fitness. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations) if potential spawning habitat is affected		
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Adults	Adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing marine food web productivity and availability of prey species. This could lead to decreased adult growth and fitness, however incremental effects may not be significant considering the wide ranging marine habitats of adult sturgeon.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect adult growth and fitness.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, potentially decreasing the suitability of juvenile rearing habitat. This may occur through increased predation exposure, food	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival at larval life-history stage. May affect growth and fitness at juvenile life-history stage. May affect adult growth and fitness, and adult spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition and stability		Year-round	Permanent	Continuous				

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous		web alterations, and decreased foraging opportunity. Alteration of current and circulation patterns may prevent larvae transport to suitable rearing environments. The combined effect of these stressors can result in decreased survival, growth, and fitness at larval and juvenile life-history stages. Adults: Adult sturgeon are generally less sensitive to these stressors. However, food web productivity in large reservoir environments may be affected by these impact mechanisms. This could lead to reduced adult foraging opportunities in residualized populations, and decreased growth, fitness, and spawning productivity.		
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Intakes and diversions can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of larval sturgeon rearing habitat. Decreased habitat availability may lead to density-dependent effects on larval and juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, larvae, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fines will reduce hyporheic exchange, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage intakes and diversions placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg and larvae survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Marine and Lacustrine								

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	<u>All exposed life-history stages</u>: Intakes and diversions in the marine environment can fragment nearshore marine habitat. Sturgeon dependence on these habitat types is currently a data gap; therefore, the effects of this stressor are unknown.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Loss of LWD recruitment	Reduced availability of LWD from drift. Reduced availability of LWD from drift. Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae:</u> Direct mortality of embryos at temperatures in excess of 68°F (20°C). <u>Juveniles</u>: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns. Decreased growth when exposed to temperatures in excess of 75°F (24°C). <u>Adults</u>: Exposure to thermal barriers is unlikely as spawning migrations occur in mid- to late-winter and spawning occurs in turbulent river mainstems.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during incubation, rearing, and spawning.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles;	<u>Eggs and larvae:</u> Decreased incubation success and larval survival due to effects of turbidity exposure as described above under Water Quality Modification. <u>Juveniles:</u> Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival during incubation larval dispersal, as well as survival, growth, and fitness during juvenile rearing.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Juvenile sturgeon are opportunistic feeders and may utilize allochthonous inputs in the form of terrestrially insect-fall. Reduced foraging opportunities due to decreased food web productivity may lead to decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival, growth, and fitness.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Juveniles	Juveniles: Sturgeon dependence on groundwater exchange is currently a data gap. However, juveniles are dependent on water temperatures less than 75°F (24°C) for optimal growth. Reduction in thermal refuge habitat may lead to avoidance behavior, decreased growth, and decreased fitness.	Avoid disturbance of vegetation along stream.	Effects of action resulting from this impact mechanism are unknown, as sturgeon dependence on groundwater-surface water exchange is a data gap. However, loss of thermal refuge habitat may affect juvenile growth and fitness.
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Adults	Adults: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. Adult use of nearshore marine habitats is limited; therefore, stressor exposure is unlikely to occur.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Effects of stressor exposure on adult sturgeon are expected to be insignificant and discountable.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Adults	Adults: Adult use of nearshore marine habitats is limited; therefore, stressor exposure is unlikely to occur.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Effects of stressor exposure on adult sturgeon are expected to be insignificant and discountable.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Adults	Adults: Sturgeon dependence on autochthonous inputs from marine riparian vegetation is a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap; therefore, the effects of the action from this impact mechanism are unknown.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Adults	Adults: Adult use of nearshore marine habitats is limited; therefore, stressor exposure is unlikely to occur.	Encourage project designs that limit permanent alteration of high-quality habitat features.	Effects of stressor exposure on adult sturgeon are expected to be insignificant and discountable.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Adults	Adult: Sturgeon dependence on groundwater inflow to nearshore marine habitats is currently a data gap. However, adult use of nearshore marine habitats is limited; therefore, stressor exposure is unlikely to occur.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap; therefore, the effects of the action from this impact mechanism are unknown.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of turnover time, stratification patterns, wind conditions, and other factors. However, the suitability of some protected habitats such as isolated embayments may be affected, leading to decreased rearing habitat availability and increased competition, leading to decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Sturgeon dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. However, juvenile sturgeon are opportunistic feeders. Loss of terrestrial insect-fall could lead to decreased foraging opportunities, affecting growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile growth and fitness.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Sturgeon dependence on groundwater inflow to nearshore lacustrine habitats is currently a data gap. However, juveniles are dependent on water temperatures less than 75°F (24°C) for optimal growth. Reduction in thermal refuge habitat may lead to avoidance behavior, decreased growth, and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible.	Effects of action resulting from this impact mechanism are unknown, as sturgeon dependence on lacustrine groundwater inflow is a data gap. However, loss of thermal refuge habitat may affect juvenile growth and fitness.
	Aquatic Vegetation Modification								
	Marine								

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Adults	Adults: Adult sturgeon dependence on nearshore aquatic vegetation is a data gap. However, this species feeds on mollusks, fish, and invertebrate species dependent on nearshore food web productivity. Therefore, this stressor could indirectly affect adult growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect adult growth and fitness. However, localized effects are likely to be insignificant.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Adults	Adults: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Adults	Adults: Adult sturgeon dependence on nearshore habitat complexity is limited. However, effects on habitat complexity may limit the availability and productivity of prey species; therefore, this stressor could indirectly affect adult growth and fitness. Given the extended marine foraging habitats used by sturgeon, localized effects are likely to be insignificant.		May affect adult growth and fitness. However, localized effects are likely to be insignificant.
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Juvenile sturgeon are known to feed opportunistically upon benthic prey organisms and fish dependent upon autochthonous material; reducing autochthonous production may decrease foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile productivity.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Reduced aquatic habitat complexity may limit the availability of suitable refuge and foraging habitat, leading to increased predation exposure and decreased foraging opportunities, affecting survival, growth, and fitness.		May affect juvenile survival, growth, and fitness.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Ensure that appropriate instream flows necessary to regulate temperature and other habitat parameters are maintained.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	<u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation. <u>Juveniles and adults</u>: Physiological responses to exposure at levels exceeding tolerance thresholds, causing mortality or injury leading to reduced fitness. Avoidance behavior during subacute events.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs and larvae. May affect juvenile and adult survival, growth, and fitness.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae:</u> Turbidity may lead to direct mortality and decreased survival of eggs and larvae. Green sturgeon eggs lack thick jelly coat of other sturgeon species and develop more rapidly, indicating greater sensitivity to acute turbidity. <u>Juveniles and adults</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to reduced foraging opportunity, increased predation exposure, and altered migration behavior.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of eggs and larvae. May affect juvenile productivity and adult productivity and spawning success. May cause direct mortality or injury in acute events.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs and no direct waste discharge. Prevent in-water curing of concrete and discharge of concrete leachate to surface waters.	May affect survival and productivity of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	<u>All expose life history stages:</u> Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Tide Gates									
	Construction and Maintenance Activities								

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs; Larvae; Juveniles; Adults	<u>All exposed life-history stages</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Egg mortality due to membrane rupture. ▪ Fatal injury or permanent auditory tissue damage caused by barotraumas limiting to larval, juvenile, and adult survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness Note that actual sound sensitivity of primitive fish species such as sturgeon is currently a data gap, so actual harm thresholds are unknown.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work-areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May cause direct mortality or injury at all life-history stages. May affect survival, growth, and fitness at larval and juvenile life-history stages. Actual effects are uncertain as the sensitivity of these species to noise related stressors is currently a data gap.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Juveniles</u>: Auditory masking may affect ability to avoid predators, leading to effects on survival. Behavioral responses may lead to habitat avoidance, affecting growth and fitness. <u>Adults</u>: May cause avoidance behavior. Note: While these responses are possible, very little is known of the effects of anthropogenic sounds on sturgeon at any life-history stage, so the actual effects of stressor exposure are uncertain.	Although, little is known about the effects of anthropogenic sounds on sturgeon, it is prudent to avoid/ minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	May affect juvenile survival due to avoidance behavior, decreased foraging success, and increased predation risk. May cause adult avoidance behavior. Actual effects are unknown as stressor sensitivity is currently a data gap.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles	<u>Juveniles and larvae</u>: Mortality, injury, or stress from capture, handling, and relocation. Sturgeon larvae may be too small to capture effectively, leading to mortality or injury from asphyxiation.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May cause direct mortality or injury to larvae and juveniles. Stress from relocation may affect survival, growth, and fitness.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles	Larvae and juveniles: Injury or mortality from pump entrainment or impingement.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when juveniles are present.	May cause direct mortality of larvae and juveniles.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae: May affect settlement, leading to decreased larval survival. Juveniles and adults: Sturgeon feed opportunistically on benthic organisms, such as aquatic insect larvae and fish. Substrate effects on these prey organisms could affect prey availability, resulting in decreased growth and fitness.	Limit alteration of flow conditions to minimal area.	May affect survival during larval life-history stage. May affect juvenile and adult growth and fitness.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juvenile (over 1 ft length-[marine]) and adults: Because of the limited temporal and spatial extent of alteration to sturgeon marine habitat, project effects on marine circulation are a relatively inconsequential component. Therefore, the magnitude of project hydrologic modification is expected to be negligible. As such, this stressor is not expected to significantly affect the marine environment, and there will be no response to the stressor.	To greatest extent practicable, limit alteration of current and circulation patterns to minimal area.	Effects from exposure to this stressor are expected to be insignificant and discountable.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Green sturgeon eggs lack thick jelly coat of other sturgeon species and develop more rapidly, indicating greater sensitivity to acute turbidity. Juveniles: Stress and behavioral modifications by rearing juveniles exposed to sediment pulses, migration delay, reduced foraging opportunities, and increased predation risk. Adults: May cause avoidance behavior, potentially delaying migration.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	May affect survival during egg and larval life-history stages. May affect juvenile survival, growth, and productivity. May cause adult avoidance behavior, potentially delaying migration and limiting spawning productivity; however, actual sensitivity to these stressors is a data gap.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Short-term reduction in foraging opportunity, increased competition, decreased growth and fitness.	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Loss of habitat, stranding from dewatering (during construction, maintenance, and removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae</u>: Potential decreased egg incubation success and larvae survival due to water loss and stranding. <u>Juveniles</u>: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. <u>Adults</u>: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses above under Hydraulic and Geomorphic Modifications.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	<u>Juveniles and adults</u>: See responses under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae:</u> Non-mobile eggs and larvae may experience injury or mortality from dredge entrainment. <u>Juveniles and adults</u>: Decreased growth and fitness due to stress and exertion caused by avoidance behavior and decreased foraging opportunity caused by short-term reduction in prey availability. <u>All life-history stages</u>: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct injury or mortality of eggs and larvae. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles Adults	<u>Eggs and larvae</u>: Sturgeon are believed to spawn in swift current environments in part because the high velocities protect eggs from predation. Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success, and potentially increased predation exposure. Changes in flow regime may cause larvae to be transported to environments unfavorable	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg and larval life-history stages. May affect juvenile growth and fitness. May affect adult spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous		for survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Juvenile dependence on groundwater exchange is a data gap; however, loss of thermal refuge may decrease the availability of suitable rearing habitat, leading to decreased growth and fitness. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations) if potential spawning habitat is affected		
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Adults	Adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing marine food web productivity and availability of prey species. This could lead to decreased adult growth and fitness, however incremental effects may not be significant considering the wide ranging marine habitats of adult sturgeon.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect adult growth and fitness.
	Altered current velocities and tidal exchange		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered channel geometry		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation of habitat	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults	All exposed life-history stages: Tide gates can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of larval sturgeon rearing habitat. Decreased habitat availability may lead to density-dependent effects on larval and juvenile survival, growth, and fitness.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat. Limit the length of time that tide gates are closed as much as possible.	May affect survival at egg, larvae, and juvenile life-history stages. May affect spawning productivity.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit the length of time that tide gates are closed as much as possible. No additional specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Marine								
	Lateral and longitudinal fragmentation of habitat	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles	All exposed life-history stages: Tide gates in the marine environment can fragment nearshore habitat. Sturgeon dependence on these habitat types is currently a data gap; therefore, the effects of this stressor are unknown.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Loss of LWD recruitment	Reduced availability of LWD from drift Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Limit the length of time that tide gates are closed as much as possible. Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs and larvae; Juveniles; Adults	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tide gates is considered to be a component of the effects of dikes and levees. The incremental effects of the tide gate are negligible in comparison.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs and larvae; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs and larvae; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	
	Marine and Lacustrine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tidegates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid disturbance of vegetation along shoreline.	
	Aquatic Vegetation Modification								
	Riverine								

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Juvenile sturgeon are known to feed opportunistically upon benthic prey organisms and fish dependent upon autochthonous material; reducing autochthonous production may decrease foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Modification.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Reduced aquatic habitat complexity may limit the availability of suitable refuge and foraging habitat, leading to increased predation exposure and decreased foraging opportunities, affecting survival, growth, and fitness.		May affect juvenile survival, growth, and fitness.
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Adults	Adults: Adult sturgeon dependence on nearshore aquatic vegetation is a data gap. However, this species feeds on mollusks, fish, and invertebrate species dependent on nearshore food web productivity. Therefore, this stressor could indirectly affect adult growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect adult growth and fitness. However, localized effects are likely to be insignificant.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Adults	Juveniles: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Adults	Adults: Adult sturgeon dependence on nearshore habitat complexity is limited. However, effects on habitat complexity may limit the availability and productivity of prey species; therefore, this stressor could indirectly affect adult growth and fitness. Given the extended marine foraging habitats used by sturgeon, localized effects are likely to be insignificant.		May affect adult growth and fitness. However, localized effects are likely to be insignificant.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.

Table A-14 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Green and White Sturgeon.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	<u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation. <u>Juveniles and adults</u>: Physiological responses to exposure at levels exceeding tolerance thresholds, causing mortality or injury leading to reduced fitness. Avoidance behavior during subacute events.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs and larvae. May affect juvenile and adult survival, growth, and fitness.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae:</u> Turbidity may lead to direct mortality and decreased survival of eggs and larvae. Green sturgeon eggs lack thick jelly coat of other sturgeon species and develop more rapidly, indicating greater sensitivity to acute turbidity. <u>Juveniles and adults</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to reduced foraging opportunity, increased predation exposure, and altered migration behavior.	Ensure that project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of eggs and larvae. May affect juvenile productivity and adult productivity and spawning success. May cause direct mortality or injury in acute events.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs and no direct waste discharge. Prevent in-water curing of concrete and discharge of concrete leachate to surface waters.	May affect survival and productivity of juveniles and adults.
		Altered salinity	Year-round	Long-term to permanent	Intermittent (daily)	Juveniles	Juveniles: Altered salinity patterns may limit habitat suitability for juvenile rearing in nearshore marine environments. This in turn may increase competition for available habitats, limiting survival, growth, and fitness.	Limit closure time of tide gate to maximize natural tidal exchange.	May affect juvenile survival, growth, and fitness.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect juvenile and adult survival, growth, and fitness.
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Juveniles	Tide gate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent. Exposure to toxic substances may lead to behavioral avoidance in adults. For juveniles, limitations in the availability of suitable juvenile rearing habitat, or potential physiological injury may affect survival, growth, and fitness.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect adult behavior. May affect juvenile survival, growth, and fitness.

Table A-15. HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	**When**	**Duration**	**Frequency**	**Life-history Form**			
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs; Larvae; Juveniles; Adults	Eggs and larvae: Noise of sufficient magnitude may cause direct mortality of eggs and larval smelt or permanent injury leading to decreased survival and fitness. Adults and juveniles: Stressor response, depending on noise magnitude and project-specific environmental conditions, may range from: • Fatal injury or permanent auditory tissue damage limiting to survival. • Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to system-specific in-water work windows to avoid stressor exposure during spawning, incubation, and larval dispersal (November to April, depending on system). If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Unlikely to affect smelt populations when activities are conducted in prescribed in-water work windows, avoiding spawning, incubation, and larval dispersal. The potential for juvenile exposure is less well known. Except for the landlocked Lake Washington population of longfin smelt, juvenile habitat use by these species is poorly understood. Subadults are known to migrate to offshore areas on the continental shelf.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults.	Unlikely to affect smelt populations when activities are conducted in prescribed in-water work windows, avoiding spawning disruptions. Exposure to stressor may affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Eggs; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles (Lake Washington longfin smelt); Adults	Eggs and larvae: Channel dewatering will cause egg mortality. Juveniles: Juvenile smelt are generally believed to migrate offshore and will therefore not likely be exposed to dewatering. Lake Washington longfin smelt are an exception; potential nearshore habitat use by this population is currently a data gap. Adults: Capture, handling, and relocation are likely to cause mortality or injury and stress leading to mortality or decreased spawning fitness. Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults.	Unlikely to affect eggs, larvae, and adults if activities are conducted during in-water work windows. Capture and removal of eggs, larvae, and juveniles is impractical, meaning that activities occurring during incubation and emigration periods may affect survival during these life-history stages. Capture and removal of adults are likely to affect survival and spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Eggs, larvae, and juveniles: Pump entrainment is highly likely to cause mortality of larvae and drifting eggs. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles. Adults: Impingement is likely to cause adult mortality.	Adhere to system-specific in-water work windows; avoid use of dewatering pumps during spawning, incubation, and larval dispersal.	Unlikely to affect survival and productivity during egg and larvae and adult life-history stages if activities are conducted outside in-water work windows. If activities are permitted during in-water work windows, activity may affect adult and egg and larval survival. The potential for effects on juvenile smelt survival in marine habitats and Lake Washington are unknown because habitat use by this life-history stage is a data gap.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Adults	Eggs and larvae: Potential scour of spawning substrate and/or sedimentation, resulting in decreased incubation success. Potential larval dispersal to unfavorable habitats, decreasing larval survival and productivity. Adults: Decreased availability of suitable spawning sites; decreased spawning success.	Adhere to system-specific in-water work windows, avoid use during spawning, incubation, and larval dispersal. Limit alteration of flow conditions to minimal area.	Unlikely to affect survival and productivity during egg and larvae and adult life-history stages if activities are conducted during in-water work windows. If activities are permitted during in-water work windows, activity may affect adult spawning productivity and egg and larval survival.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Adults: Stress and behavioral modifications by adult spawners exposed to sediment pulses, migration delay, increased predation exposure, decreased spawning habitat suitability.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	Unlikely to affect egg survival and adult spawning productivity when activities are conducted during in-water work windows. May affect these parameters if activities occur during spawning and incubation.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: With the exception of the Lake Washington longfin population, smelt do not feed on benthic organisms in freshwater systems and will be unaffected by this stressor. In Lake Washington and in marine systems, smelt are planktonic feeders that are not likely to be affected by temporary decreases in benthic invertebrate abundance.	Limit area of dewatering to the greatest extent practicable.	Not likely to affect smelt at any life-history stage.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Juveniles; Adults	Eggs: Potential decreased egg incubation success and survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect growth and fitness at juvenile life-history stage, survival at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs; Larvae; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	Eggs and larvae: Incubating eggs entrained during dredging will suffer high mortality. Juveniles: The potential for juvenile exposure to these stressors is unknown because habitat use is currently a data gap. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	Unlikely to affect survival of eggs and larvae if activities are conducted during in-water work windows. Likely to affect egg survival and larval survival and productivity if exposure occurs. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	Eggs: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and larval survival. Larvae and juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg and larval life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous		opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation ~~of redds~~) if potential spawning habitat is affected.		
	Marine								
	Altered sediment transport	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability as a result of beach erosion from altered sediment supply.	Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Sediment supply and substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Longfin smelt and eulachon dependence on these habitats is currently a data gap. However, alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment. Adults: Alteration of nearshore habitat parameters may affect survival and foraging opportunities at larval and juvenile life-history stages, leading to decreased adult fitness, decreased survival, and decreased spawning productivity.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at the larval and juvenile life-history stages. Decreased fitness may affect survival and productivity during ocean migration life-history phase, and may affect spawning productivity.
	Altered substrate composition		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and Longitudinal habitat Fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of longitudinal (i.e., upstream-downstream) habitat connectivity; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Larvae; Adults	Adults: Dams can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor is unlikely to significantly affect mainstem spawning eulachon and longfin smelt. Planktonic larvae are carried downstream to estuarine habitats, and are not dependent on floodplain habitats.	Require assessment of the hydraulic effects of the project before permitting, and avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs; Juveniles; Adults	<u>Eggs</u>: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. <u>Adults and juveniles</u>: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. <u>Adults</u>: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage dam placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible. Encourage spillway design to promote moderation of stream temperatures in downstream reaches.	May affect egg survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered Community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species.	Year-round	Permanent	Continuous	Juveniles	<u>Juveniles</u>: Dams create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Adults	<u>Adults</u>: Decreased spawning productivity and fitness due to migration delays caused by low water temperatures.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~<u>benthic</u> dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs; Larvae; Adults	<u>Eggs and larvae:</u> Decreased incubation success due to smothering of eggs as described for related stressor responses under Water Quality Modification. <u>Adults:</u> Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival during egg incubation; may affect spawning fitness and productivity.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Larvae	Larvae: Larval longfin smelt and eulachon feed on forage on riverine plankton following emergence and transport to estuarine and marine habitats. Reduced allochthonous inputs may affect food web productivity, leading to decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect larval growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Adults	Adults: Reduced habitat complexity may affect the availability of suitable spawning habitat leading to decreased spawning productivity.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect adult spawning productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Unknown	Longfin smelt and eulachon dependence on groundwater exchange is currently a data gap.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Eggs; Larvae; Adults	All exposed life-history stages: Smelt dependence on freshwater submerged aquatic vegetation is currently a data gap. Therefore, the potential for exposure to these stressors is unknown.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Eggs ; Juveniles; Adults	Eggs : Direct mortality due to winter ice formation and scour. Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Provide sufficient streamflows to avoid temperature effects in reaches downstream of the impoundment. Promote dam designs that limit impoundment effects on downstream temperatures (e.g., draw streamflows from impoundment below the stratification layer in summer).	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved events due to asphyxiation. Juveniles and adults: Avoidance behavior and increased stress, leading to reduced growth and fitness.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs. May affect juvenile survival and productivity and adult survival, productivity, and spawning success.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause burial or coating of eggs may lead to direct mortality. Increased turbidity may decrease larval foraging success, resulting in decreased growth and fitness. Juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs. May affect juvenile productivity, adult productivity, and spawning success.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Juveniles; Adults	All exposed life history stages: Dam removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to dam removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient no direct waste discharge. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs ; Juveniles; Adults	All exposed life history stages: Dam construction and operation may lead to introductions of toxic substances through accidental spills or other pathways. Impoundments may attract increased recreational vessel activity, creating a pathway for chronic exposure to hydrocarbons and other contaminants. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Require a spill control and containment plan for dam operations if appropriate. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources	May affect survival, growth and fitness at all exposed life history stages.
Weirs									

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs; Larvae; Juveniles; Adults	<u>Eggs and larvae</u>: Noise of sufficient magnitude may cause direct mortality of eggs and larval smelt or permanent injury leading to decreased survival and fitness. <u>Adults and juveniles</u>: Stressor response, depending on noise magnitude and project-specific environmental conditions, may range from: • Fatal injury or permanent auditory tissue damage limiting to survival. • Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to system-specific in-water work windows to avoid stressor exposure during spawning, incubation, and larval dispersal (November to April, depending on system). If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Unlikely to affect smelt populations when activities are conducted in prescribed in-water work windows, avoiding spawning, incubation, and larval dispersal. The potential for juvenile exposure is less well known. Except for the landlocked Lake Washington population of longfin smelt, juvenile habitat use by these species is poorly understood. Subadults are known to migrate to offshore areas on the continental shelf.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults.	Unlikely to affect smelt populations when activities are conducted in prescribed in-water work windows, avoiding spawning disruptions. Exposure to stressor may affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles (Lake Washington longfin smelt); Adults	Eggs and larvae: Channel dewatering will cause egg mortality. Juveniles: Juvenile smelt are generally believed to migrate offshore and will therefore not likely be exposed to dewatering. Lake Washington longfin smelt are an exception; potential nearshore habitat use by this population is currently a data gap. Adults: Capture, handling, and relocation are likely to cause mortality or injury and stress leading to mortality or decreased spawning fitness. Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults.	Unlikely to affect eggs, larvae, and adults if activities are conducted during in-water work windows. Capture and removal of eggs, larvae, and juveniles is impractical, meaning that activities occurring during incubation and emigration periods may affect survival during these life-history stages. Capture and removal of adults are likely to affect survival and spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Eggs, larvae, and juveniles: Pump entrainment is highly likely to cause mortality of larvae and drifting eggs. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles. Adults: Impingement is likely to cause adult mortality.	Adhere to system-specific in-water work windows; avoid use of dewatering pumps during spawning, incubation, and larval dispersal.	Unlikely to affect survival and productivity during egg and larvae and adult life-history stages if activities are conducted outside in-water work windows. If activities are permitted during in-water work windows, activity may affect adult and egg and larval survival. The potential for effects on juvenile smelt survival in marine habitats and Lake Washington are unknown because habitat use by this life-history stage is a data gap.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Adults	Eggs and larvae: Potential scour of spawning substrate and/or sedimentation, resulting in decreased incubation success. Potential larval dispersal to unfavorable habitats, decreasing larval survival and productivity. Adults: Decreased availability of suitable spawning sites; decreased spawning success.	Adhere to system-specific in-water work windows, avoid use during spawning, incubation, and larval dispersal. Limit alteration of flow conditions to minimal area.	Unlikely to affect survival and productivity during egg and larvae and adult life-history stages if activities are conducted during in-water work windows. If activities are permitted during in-water work windows, activity may affect adult spawning productivity and egg and larval survival.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Adults: Stress and behavioral modifications by adult spawners exposed to sediment pulses, migration delay, increased predation exposure, decreased spawning habitat suitability.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	Unlikely to affect egg survival and adult spawning productivity when activities are conducted during in-water work windows. May affect these parameters if activities occur during spawning and incubation.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: With the exception of the Lake Washington longfin population, smelt do not feed on benthic organisms in freshwater systems and will be unaffected by this stressor. In Lake Washington and in marine systems, smelt are planktonic feeders that are not likely to be affected by temporary decreases in benthic invertebrate abundance.	Limit area of dewatering to the greatest extent practicable.	Not likely to affect smelt at any life-history stage.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access and stranding (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Juveniles; Adults	Eggs: Potential decreased egg incubation success and survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs; Larvae; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	Eggs and larvae: Incubating eggs entrained during dredging will suffer high mortality. Juveniles: The potential for juvenile exposure to these stressors is unknown because habitat use is currently a data gap. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	Unlikely to affect survival of eggs and larvae if activities are conducted during in-water work windows. Likely to affect egg survival and larval survival and productivity if exposure occurs. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	Eggs: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and larval survival. Larvae and juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg and larval life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
							corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation ~~of redds~~) if potential spawning habitat is affected.		
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Larvae; Adults	Adults: Weirs can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor is unlikely to significantly affect mainstem spawning eulachon and longfin smelt. Planktonic larvae are carried downstream to estuarine habitats, and are not dependent on floodplain habitats.	Require assessment of the hydraulic effects of the project before permitting, and avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs; Juveniles; Adults	Eggs: Decreased hyporheic exchange in downstream reaches may lead to decreased incubation success (i.e., decreased survival) due to decreased intragravel DO levels. Adults and juveniles: Decreased availability of thermal refuge habitat provided by groundwater upwelling may lead to decreased survival, growth, and fitness. Adults: Decreased availability of desirable spawning sites (due to lack of groundwater induced upwelling) may lead to decreased spawning productivity.	Encourage weir placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species	Year-round	Permanent	Continuous	Juveniles	Juveniles: Weirs may create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Adults	Adults: Decreased spawning productivity and fitness due to migration delays caused by low water temperatures.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs; Larvae; Adults	Eggs and larvae: Decreased incubation success due to smothering of eggs as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival during egg incubation; may affect spawning fitness and productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Larvae	Larvae: Larval longfin smelt and eulachon feed on forage on riverine plankton following emergence and transport to estuarine and marine habitats. Reduced allochthonous inputs may affect food web productivity, leading to decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect larval growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Adults	Adults: Reduced habitat complexity may affect the availability of suitable spawning habitat leading to decreased spawning productivity.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect adult spawning productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Unknown	Longfin smelt and eulachon dependence on groundwater exchange is currently a data gap.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Eggs; Larvae; Adults	All exposed life-history stages: Smelt dependence on freshwater submerged aquatic vegetation is currently a data gap. Therefore, the potential for exposure to these stressors is unknown.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal			of aquatic vegetation during project construction.	
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs; Juveniles; Adults	<u>Juveniles</u>: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. <u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. <u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	<u>All life-history stages</u>: Mortality in acute low dissolved events due to asphyxiation. <u>Juveniles and adults</u>: Avoidance behavior and increased stress, leading to reduced growth and fitness.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs. May affect juvenile survival and productivity and adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	<u>Eggs and larvae:</u> Turbidity sufficient to cause burial or coating of eggs may lead to direct mortality. Increased turbidity may decrease larval foraging success, resulting in decreased growth and fitness. <u>Juveniles</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness. <u>Adults</u>: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs. May affect juvenile productivity, adult productivity, and spawning success.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Juveniles; Adults	All expose life history stages: Weir removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to weir removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs and no direct waste discharge. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Juveniles; Adults	All expose life history stages: Weir construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Dikes/Levees									
	Construction and Maintenance Activities								

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs; Larvae; Juveniles; Adults	Eggs and larvae: Noise of sufficient magnitude may cause direct mortality of eggs and larval smelt or permanent injury leading to decreased survival and fitness. Adults and juveniles: Stressor response, depending on noise magnitude and project-specific environmental conditions, may range from: • Fatal injury or permanent auditory tissue damage limiting to survival. • Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to system-specific in-water work windows to avoid stressor exposure during spawning, incubation, and larval dispersal (November to April, depending on system). If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Unlikely to affect smelt populations when activities are conducted in prescribed in-water work windows, avoiding spawning, incubation, and larval dispersal. The potential for juvenile exposure is less well known. Except for the landlocked Lake Washington population of longfin smelt, juvenile habitat use by these species is poorly understood. Subadults are known to migrate to offshore areas on the continental shelf.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults.	Unlikely to affect smelt populations when activities are conducted in prescribed in-water work windows, avoiding spawning disruptions. Exposure to stressor may affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling, and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles (Lake Washington longfin smelt); Adults	Eggs and larvae: Channel dewatering will cause egg mortality. Juveniles: Juvenile smelt are generally believed to migrate offshore and will therefore not likely be exposed to dewatering. Lake Washington longfin smelt are an exception; potential nearshore habitat use by this population is currently a data gap. Adults: Capture, handling, and relocation are likely to cause mortality or injury and stress leading to mortality or decreased spawning fitness. Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults.	Unlikely to affect eggs, larvae, and adults if activities are conducted during in-water work windows. Capture and removal of eggs, larvae, and juveniles is impractical, meaning that activities occurring during incubation and emigration periods may affect survival during these life-history stages. Capture and removal of adults are likely to affect survival and spawning productivity.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Eggs, larvae, and juveniles: Pump entrainment is highly likely to cause mortality of larvae and drifting eggs. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles. Adults: Impingement is likely to cause adult mortality.	Adhere to system-specific in-water work windows; avoid use of dewatering pumps during spawning, incubation, and larval dispersal.	Unlikely to affect survival and productivity during egg and larvae and adult life-history stages if activities are conducted outside in-water work windows. If activities are permitted during in-water work windows, activity may affect adult and egg and larval survival. The potential for effects on juvenile smelt survival in marine habitats and Lake Washington are unknown because habitat use by this life-history stage is a data gap.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Adults	Eggs and larvae: Potential scour of spawning substrate and/or sedimentation, resulting in decreased incubation success. Potential larval dispersal to unfavorable habitats, decreasing larval survival and productivity. Adults: Decreased availability of suitable spawning sites; decreased spawning success.	Adhere to system-specific in-water work windows, avoid use during spawning, incubation, and larval dispersal. Limit alteration of flow conditions to minimal area.	Unlikely to affect survival and productivity during egg and larvae and adult life-history stages if activities are conducted during in-water work windows. If activities are permitted during in-water work windows, activity may affect adult spawning productivity and egg and larval survival.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Nearshore habitat use by smelt is currently a data gap, so the potential for exposure to this stressor is unknown.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	The potential for this mechanism to affect juvenile smelt is currently unknown because dependence on nearshore circulation patterns is currently a data gap.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Adults: Stress and behavioral modifications by adult spawners exposed to sediment pulses, migration delay, increased predation exposure, decreased spawning habitat suitability.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	Unlikely to affect egg survival and adult spawning productivity when activities are conducted during in-water work windows. May affect these parameters if activities occur during spawning and incubation.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: With the exception of the Lake Washington longfin population, smelt do not feed on benthic organisms in freshwater systems and will be unaffected by this stressor. In Lake Washington and in marine systems, smelt are planktonic feeders that are not likely to be affected by temporary decreases in benthic invertebrate abundance.	Limit area of dewatering to the greatest extent practicable.	Not likely to affect smelt at any life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival and spawning productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs; Larvae; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	Eggs and larvae: Incubating eggs entrained during dredging will suffer high mortality. Juveniles: The potential for juvenile exposure to these stressors is unknown because habitat use is currently a data gap. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	Unlikely to affect survival of eggs and larvae if activities are conducted during in-water work windows. Likely to affect egg survival and larval survival and productivity if exposure occurs. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	Eggs: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and larval survival. Larvae and juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation ~~of redds~~) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg and larval life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Marine								

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Longfin smelt and eulachon dependence on these habitats is currently a data gap. However, alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment. Adults: Alteration of nearshore habitat parameters may affect survival and foraging opportunities at larval and juvenile life-history stages, leading to decreased adult fitness, decreased survival, and decreased spawning productivity.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at the larval and juvenile life-history stages. Decreased fitness may affect survival and productivity during ocean migration life-history phase, and may affect spawning productivity.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Lake Washington longfin smelt. Larvae; Juveniles; Adults	Larvae, juveniles, and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, with concomitant food web effects throughout the lacustrine ecosystem. Therefore, alteration of these parameters may affect foraging opportunities for longfin smelt at larval and juvenile life-history stages, leading to decreased adult fitness and decreased spawning success.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect productivity at larval and juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat, change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Larvae; Adults	Adults Dikes and levees can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor is unlikely to significantly affect mainstem spawning eulachon and longfin smelt. Planktonic larvae are carried downstream to estuarine habitats, and are not dependent on floodplain habitats.	Require assessment of the hydraulic effects of the project before permitting, and avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater-surface water exchange	Reduced availability of thermal refuge and decreased intragravel DO, nutrient cycling effects	Year-round	Permanent	Continuous	Eggs ; Juveniles; Adults	Longfin smelt and eulachon dependence on groundwater exchange is currently a data gap.	Encourage dike/levee placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect egg survival, may affect juvenile survival, growth, and fitness. May affect adult survival and spawning productivity.
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juvenile; Adult	<u>All exposed life-history stages</u>: Dikes and levees in the marine environment can fragment nearshore habitat. Eulachon and longfin smelt are known to use these habitat types during juvenile and adult life-history stages, and are likely to occur as larvae as well. May alter migration of adults toward spawning habitats, larval dispersal, and juvenile foraging, affecting survival, growth, and fitness at all life-history stages.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Lacustrine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability	Year-round	Permanent	Continuous	Lake Washington longfin smelt. Larvae; Juveniles; Adults	<u>All exposed life-history stages</u>: Longfin smelt dependence on nearshore habitats in Lake Washington is currently a data gap. Therefore the effects of this stressor are unknown.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival at juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Adults	<u>Adults</u>: Decreased spawning productivity and fitness due to migration delays caused by low water temperatures.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~<u>benthic</u> dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs; Larvae; Adults	<u>Eggs and larvae:</u> Decreased incubation success due to smothering of eggs as described for related stressor responses under Water Quality Modification. <u>Adults:</u> Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival during egg incubation; may affect spawning fitness and productivity.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Larvae	Larvae: Larval longfin smelt and eulachon feed on forage on riverine plankton following emergence and transport to estuarine and marine habitats. Reduced allochthonous inputs may affect food web productivity, leading to decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect larval growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Adults	Adults: Reduced habitat complexity may affect the availability of suitable spawning habitat leading to decreased spawning productivity.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect adult spawning productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Unknown	Longfin smelt and eulachon dependence on groundwater exchange is currently a data gap.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Larvae; Juveniles	Larvae and juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. Dependence of larval and juvenile longfin smelt and eulachon on these habitats is currently a data gap. Therefore, the potential for exposure to these stressors is unknown.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Larvae; Juveniles	Larvae and juveniles: Dependence of larval and juvenile longfin smelt and eulachon on these habitats is currently a data gap. Therefore, the potential for exposure to these stressors is unknown.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Longfin smelt and eulachon dependence on allochthonous inputs from marine riparian vegetation is a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Larvae; Juveniles	Larvae and juveniles: Dependence of larval and juvenile smelt on these habitats is currently a data gap. Therefore, the potential for exposure to these stressors is unknown.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Dependence of larval and juvenile smelt on surface water and groundwater exchange in nearshore habitats is currently a data gap. Therefore, the potential for exposure to these stressors is unknown.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Lake Washington longfin smelt. Larvae; Juveniles; Adults	Larvae, juveniles, and adults: Riparian shade and ambient temperature has a relatively minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade. Dependence of juvenile longfin smelt on these habitats is currently a data gap Therefore the potential for exposure to these stressors is unknown.	Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible.	Potential effects resulting from this impact mechanism are unknown.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Lake Washington longfin smelt. Larvae; Juveniles; Adults	Larvae, juveniles, and adults: Potential habitat avoidance and/or injury/mortality caused by excessive turbidity, potential for decreased foraging success leading to decreased growth and fitness as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult survival and productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Lake Washington longfin smelt. Larvae; Juveniles; Adults	Larvae, juveniles, and adults: Longfin smelt dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. Therefore the potential for exposure to these stressors is unknown.	Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible.	Potential effects resulting from this impact mechanism are unknown.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Lake Washington longfin smelt. Larvae; Juveniles; Adults	Larvae, juveniles, and adults: Dependence of larval, juvenile, and adult longfin smelt on these habitats is currently a data gap, Therefore the potential for exposure to these stressors is unknown.	Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible.	Potential effects resulting from this impact mechanism are unknown.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Lake Washington longfin smelt. Larvae; Juveniles; Adults	Larvae, juveniles, and adults: Longfin smelt dependence on groundwater inflow to nearshore lacustrine habitats is currently a data gap. Therefore the potential for exposure to these stressors is unknown.	Avoid disturbance of vegetation along stream	Effects of the action resulting from this impact mechanism are unknown.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Eggs; Larvae; Adults	All exposed life-history stages: Smelt dependence on freshwater submerged aquatic vegetation is currently a data gap. Therefore, the potential for exposure to these stressors is unknown.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal			of aquatic vegetation during project construction.	
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Larvae; Juveniles; Adults	<u>All exposed life-history stages</u>: Longfin smelt and eulachon dependence on marine littoral vegetation and the nearshore marine environment is currently a data gap. Therefore, the potential for exposure to these stressors is unknown.	<u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal				
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs ; Juveniles; Adults	<u>Eggs</u> : Direct mortality due to winter ice formation and scour. <u>Juveniles</u>: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. <u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. <u>Adults</u>: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	<u>All life-history stages</u>: Mortality in acute low dissolved events due to asphyxiation. <u>Juveniles and adults</u>: Avoidance behavior and increased stress, leading to reduced growth and fitness.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs. May affect juvenile survival and productivity and adult survival, productivity, and spawning success.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	<u>Eggs and larvae:</u> Turbidity sufficient to cause burial or coating of eggs may lead to direct mortality. Increased turbidity may decrease larval foraging success, resulting in decreased growth and fitness. <u>Juveniles</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness. <u>Adults</u>: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs. May affect juvenile productivity, adult productivity, and spawning success.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Juveniles; Adults	<u>All expose life history stages:</u> Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Outfalls									
	Construction and Maintenance Activities								

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs; Larvae; Juveniles; Adults	Eggs and larvae: Noise of sufficient magnitude may cause direct mortality of eggs and larval smelt or permanent injury leading to decreased survival and fitness. Adults and juveniles: Stressor response, depending on noise magnitude and project-specific environmental conditions, may range from: • Fatal injury or permanent auditory tissue damage limiting to survival. • Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to system-specific in-water work windows to avoid stressor exposure during spawning, incubation, and larval dispersal (November to April, depending on system). If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Unlikely to affect smelt populations when activities are conducted in prescribed in-water work windows, avoiding spawning, incubation, and larval dispersal. The potential for juvenile exposure is less well known. Except for the landlocked Lake Washington population of longfin smelt, juvenile habitat use by these species is poorly understood. Subadults are known to migrate to offshore areas on the continental shelf.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults.	Unlikely to affect smelt populations when activities are conducted in prescribed in-water work windows, avoiding spawning disruptions. Exposure to stressor may affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling, and Channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles (Lake Washington longfin smelt); Adults	Eggs and larvae: Channel dewatering will cause egg mortality. Juveniles: Juvenile smelt are generally believed to migrate offshore and will therefore not likely be exposed to dewatering. Lake Washington longfin smelt are an exception; potential nearshore habitat use by this population is currently a data gap. Adults: Capture, handling, and relocation are likely to cause mortality or injury and stress leading to mortality or decreased spawning fitness. Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults.	Unlikely to affect eggs, larvae, and adults if activities are conducted during in-water work windows. Capture and removal of eggs, larvae, and juveniles is impractical, meaning that activities occurring during incubation and emigration periods may affect survival during these life-history stages. Capture and removal of adults are likely to affect survival and spawning productivity.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Eggs, larvae, and juveniles: Pump entrainment is highly likely to cause mortality of larvae and drifting eggs. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles. Adults: Impingement is likely to cause adult mortality.	Adhere to system-specific in-water work windows; avoid use of dewatering pumps during spawning, incubation, and larval dispersal.	Unlikely to affect survival and productivity during egg and larvae and adult life-history stages if activities are conducted outside in-water work windows. If activities are permitted during in-water work windows, activity may affect adult and egg and larval survival. The potential for effects on juvenile smelt survival in marine habitats and Lake Washington are unknown because habitat use by this life-history stage is a data gap.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Adults	Eggs and larvae: Potential scour of spawning substrate and/or sedimentation, resulting in decreased incubation success. Potential larval dispersal to unfavorable habitats, decreasing larval survival and productivity. Adults: Decreased availability of suitable spawning sites; decreased spawning success.	Adhere to system-specific in-water work windows, avoid use during spawning, incubation, and larval dispersal. Limit alteration of flow conditions to minimal area.	Unlikely to affect survival and productivity during egg and larvae and adult life-history stages if activities are conducted during in-water work windows. If activities are permitted during in-water work windows, activity may affect adult spawning productivity and egg and larval survival.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Nearshore habitat use by smelt is currently a data gap, so the potential for exposure to this stressor is unknown.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	The potential for this mechanism to affect juvenile smelt is currently unknown because dependence on nearshore circulation patterns is currently a data gap.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Adults: Stress and behavioral modifications by adult spawners exposed to sediment pulses, migration delay, increased predation exposure, decreased spawning habitat suitability.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	Unlikely to affect egg survival and adult spawning productivity when activities are conducted during in-water work windows. May affect these parameters if activities occur during spawning and incubation.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: With the exception of the Lake Washington longfin population, smelt do not feed on benthic organisms in freshwater systems and will be unaffected by this stressor. In Lake Washington and in marine systems, smelt are planktonic feeders that are not likely to be affected by temporary decreases in benthic invertebrate abundance.	Limit area of dewatering to the greatest extent practicable.	Not likely to affect smelt at any life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs; Larvae; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	<u>Eggs and larvae</u>: Incubating eggs entrained during dredging will suffer high mortality. <u>Juveniles</u>: The potential for juvenile exposure to these stressors is unknown because habitat use is currently a data gap. <u>All life-history stages</u>: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	Unlikely to affect survival of eggs and larvae if activities are conducted during in-water work windows. Likely to affect egg survival and larval survival and productivity if exposure occurs. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	<u>Eggs</u>: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and larval survival. <u>Larvae and juveniles</u>: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. <u>Adults</u>: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation ~~of redds~~) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg and larval life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Larvae; Juveniles; Adults	<u>Larvae and juveniles</u>: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Longfin smelt and eulachon dependence on these habitats is currently a data gap. However, alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at the larval and juvenile life-history stages. Decreased fitness may affect survival and productivity during ocean migration life-history phase, and may affect spawning productivity.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous		for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment. Adults: Alteration of nearshore habitat parameters may affect survival and foraging opportunities at larval and juvenile life-history stages, leading to decreased adult fitness, decreased survival, and decreased spawning productivity.		
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Lake Washington longfin smelt. Larvae; Juveniles; Adults	Larvae, juveniles, and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, with concomitant food web effects throughout the lacustrine ecosystem. Therefore, alteration of these parameters may affect foraging opportunities for longfin smelt at larval and juvenile life-history stages, leading to decreased adult fitness and decreased spawning success.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect productivity at larval and juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of longitudinal connectivity may result from water quality barrier when high effluent discharge causes chemical barrier to migration. If constructed parallel to the channel, side channel and floodplain habitat may become fragmented. These actions will result in changes in habitat structure, availability, and suitability; reduced food web complexity.	Year-round	Permanent	Continuous	Larvae; Adults	Adults: High flow outfalls can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor is unlikely to significantly affect mainstem spawning eulachon and longfin smelt. Planktonic larvae are carried downstream to estuarine habitats, and are not dependent on floodplain habitats.	Require assessment of the hydraulic effects of the project before permitting, and avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg and juvenile life-history stages. May affect spawning productivity.
	Marine and Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juvenile; Adult	All exposed life-history stages: Outfalls in the marine environment can fragment nearshore habitat. Eulachon and longfin smelt are known to use these habitat types during juvenile and adult life-history stages, and are likely to occur as larvae as well. Outfalls may alter migration of adults toward spawning habitats, larval dispersal, and juvenile foraging, affecting survival, growth, and fitness at all life-history stages.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Riparian Vegetation Modification								
	Riverine								

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs ; Juveniles; Adults	The degree to which outfalls affect riparian vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine environments.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs ; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs ; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Larvae; Juveniles	<u>Larvae and juveniles</u>: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. Dependence of larval and juvenile longfin smelt and eulachon on these habitats is currently a data gap. Therefore, the potential for exposure to these stressors is unknown.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Larvae; Juveniles	<u>Larvae and juveniles</u>: Dependence of larval and juvenile longfin smelt and eulachon on these habitats is currently a data gap. Therefore, the potential for exposure to these stressors is unknown.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Longfin smelt and eulachon dependence on allochthonous inputs from marine riparian vegetation is a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Larvae; Juveniles	Larvae and juveniles: Dependence of larval and juvenile smelt on these habitats is currently a data gap. Therefore, the potential for exposure to these stressors is unknown.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The degree to which outfalls affect riparian vegetation conditions in lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in lacustrine environments.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Aquatic Vegetation Modification								
	Marine Littoral								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Larvae; Juveniles; Adults	All exposed life-history stages: Longfin smelt and eulachon dependence on marine littoral vegetation and the nearshore marine environment is currently a data gap. Therefore, the potential for exposure to these stressors is unknown.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal				

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which outfalls affect aquatic vegetation conditions in riverine and lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine and lacustrine environments.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Water Quality Modification								
		Altered thermal regime (i.e., increased summer temperatures due to elevated effluent temperatures relative to receiving body)	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved events due to asphyxiation. Juveniles and adults: Avoidance behavior and increased stress, leading to reduced growth and fitness.	Avoid sediment pulses. Limit nutrient inputs. . Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs. May affect juvenile survival and productivity and adult survival, productivity, and spawning success.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause burial or coating of eggs may lead to direct mortality. Increased turbidity may decrease larval foraging success, resulting in decreased growth and fitness. Juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs. May affect juvenile productivity, adult productivity, and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling (due to effects of effluent discharge)	During and following discharge events	Long-term to permanent	Continuous	Eggs; Juveniles; Adults	All exposed life history stages: Nutrient increases may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate effluent potential to adversely affect eutrophication. Require or encourage use of upstream treatment measures prior to discharge.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Eggs; Juveniles; Adults	All exposed life history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs; Larvae; Juveniles; Adults	Eggs and larvae: Noise of sufficient magnitude may cause direct mortality of eggs and larval smelt or permanent injury leading to decreased survival and fitness. Adults and juveniles: Stressor response, depending on noise magnitude and project-specific environmental conditions, may range from: • Fatal injury or permanent auditory tissue damage limiting to survival. • Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. ▪ Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to system-specific in-water work windows to avoid stressor exposure during spawning, incubation, and larval dispersal (November to April, depending on system). If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Unlikely to affect smelt populations when activities are conducted in prescribed in-water work windows, avoiding spawning, incubation, and larval dispersal. The potential for juvenile exposure is less well known. Except for the landlocked Lake Washington population of longfin smelt, juvenile habitat use by these species is poorly understood. Subadults are known to migrate to offshore areas on the continental shelf.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults.	Unlikely to affect smelt populations when activities are conducted in prescribed in-water work windows, avoiding spawning disruptions. Exposure to stressor may affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles (Lake Washington longfin smelt); Adults	Eggs and larvae: Channel dewatering will cause egg mortality. Juveniles: Juvenile smelt are generally believed to migrate offshore and will therefore not likely be exposed to dewatering. Lake Washington longfin smelt are an exception; potential nearshore habitat use by this population is currently a data gap. Adults: Capture, handling, and relocation are likely to cause mortality or injury and stress leading to mortality or decreased spawning fitness. Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults.	Unlikely to affect eggs, larvae, and adults if activities are conducted during in-water work windows. Capture and removal of eggs, larvae, and juveniles is impractical, meaning that activities occurring during incubation and emigration periods may affect survival during these life-history stages. Capture and removal of adults are likely to affect survival and spawning productivity.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Eggs, larvae, and juveniles: Pump entrainment is highly likely to cause mortality of larvae and drifting eggs. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles. Adults: Impingement is likely to cause adult mortality.	Adhere to system-specific in-water work windows; avoid use of dewatering pumps during spawning, incubation, and larval dispersal.	Unlikely to affect survival and productivity during egg and larvae and adult life-history stages if activities are conducted outside in-water work windows. If activities are permitted during in-water work windows, activity may affect adult and egg and larval survival. The potential for effects on juvenile smelt survival in marine habitats and Lake Washington are unknown because habitat use by this life-history stage is a data gap.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Adults	Eggs and larvae: Potential scour of spawning substrate and/or sedimentation, resulting in decreased incubation success. Potential larval dispersal to unfavorable habitats, decreasing larval survival and productivity. Adults: Decreased availability of suitable spawning sites; decreased spawning success.	Adhere to system-specific in-water work windows, avoid use during spawning, incubation, and larval dispersal. Limit alteration of flow conditions to minimal area.	Unlikely to affect survival and productivity during egg and larvae and adult life-history stages if activities are conducted during in-water work windows. If activities are permitted during in-water work windows, activity may affect adult spawning productivity and egg and larval survival.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Nearshore habitat use by smelt is currently a data gap, so the potential for exposure to this stressor is unknown.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	The potential for this mechanism to affect juvenile smelt is currently unknown because dependence on nearshore circulation patterns is currently a data gap.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Adults: Stress and behavioral modifications by adult spawners exposed to sediment pulses, migration delay, increased predation exposure, decreased spawning habitat suitability.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	Unlikely to affect egg survival and adult spawning productivity when activities are conducted during in-water work windows. May affect these parameters if activities occur during spawning and incubation.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: With the exception of the Lake Washington longfin population, smelt do not feed on benthic organisms in freshwater systems and will be unaffected by this stressor. In Lake Washington and in marine systems, smelt are planktonic feeders that are not likely to be affected by temporary decreases in benthic invertebrate abundance.	Limit area of dewatering to the greatest extent practicable.	Not likely to affect smelt at any life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs; Larvae; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	Eggs and larvae: Incubating eggs entrained during dredging will suffer high mortality. Juveniles: The potential for juvenile exposure to these stressors is unknown because habitat use is currently a data gap. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	Unlikely to affect survival of eggs and larvae if activities are conducted during in-water work windows. Likely to affect egg survival and larval survival and productivity if exposure occurs. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	Eggs: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and larval survival. Larvae and juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation ~~of redds)~~) if potential spawning habitat is affected.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg and larval life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous				
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Longfin smelt and eulachon dependence on these habitats is currently a data gap. However, alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at the larval and juvenile life-history stages. Decreased fitness may affect survival and productivity during ocean migration life-history phase, and may affect spawning productivity.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous		for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment. Adults: Alteration of nearshore habitat parameters may affect survival and foraging opportunities at larval and juvenile life-history stages, leading to decreased adult fitness, decreased survival, and decreased spawning productivity.		
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Lacustrine								
	Altered wave energy (short-period waves)	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability.	Year-round (with predominant effects from fall through spring when wind-driven waves are most pronounced)	Permanent	Continuous	Lake Washington longfin smelt. Larvae; Juveniles; Adults	Larvae, juveniles, and adults: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter lacustrine littoral habitats, with concomitant food web effects throughout the lacustrine ecosystem. Therefore, alteration of these parameters may affect foraging opportunities for longfin smelt at larval and juvenile life-history stages, leading to decreased adult fitness and decreased spawning success.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect productivity at larval and juvenile life-history stage. Decreased fitness may lead to reduced spawning productivity.
	Altered current velocities		Year-round (with effects more predominant in reservoirs versus natural lakes)	Permanent	Common				
	Altered substrate composition and stability		Year-round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Larvae; Adults	Adults: Intakes and diversions can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor is unlikely to significantly affect mainstem spawning eulachon and longfin smelt. Planktonic larvae are carried downstream to estuarine habitats, and are not dependent on floodplain habitats.	Require assessment of the hydraulic effects of the project before permitting, and avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fines will reduce hyporheic exchange, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous	Eggs; Juveniles; Adults	Longfin smelt and eulachon dependence on groundwater exchange is currently a data gap.	Encourage intakes and diversions placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	Effects of the action resulting from this impact mechanism are unknown.
	Marine and Lacustrine								

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juvenile; Adult	All exposed life-history stages: Intakes and diversions in the marine environment can fragment nearshore habitat. Eulachon and longfin smelt are known to use these habitat types during juvenile and adult life-history stages, and are likely to occur as larvae as well. Intakes and diversions may alter migration of adults toward spawning habitats, larval dispersal, and juvenile foraging, affecting survival, growth, and fitness at all life-history stages.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Loss of LWD recruitment	Reduced availability of LWD from drift. Reduced availability of LWD from drift. Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles.	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Adults	Adults: Decreased spawning productivity and fitness due to migration delays caused by low water temperatures.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect spawning productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs; Larvae; Adults	Eggs and larvae: Decreased incubation success due to smothering of eggs as described for related stressor responses under Water Quality Modification. Adults: Decreased spawning success due to decreased availability of suitable spawning habitat. Potential, migration delay, habitat avoidance, and/or injury and mortality caused by excessive turbidity as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival during egg incubation; may affect spawning fitness and productivity.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Larvae	Larvae: Larval longfin smelt and eulachon feed on forage on riverine plankton following emergence and transport to estuarine and marine habitats. Reduced allochthonous inputs may affect food web productivity, leading to decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect larval growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Adults	Adults: Reduced habitat complexity may affect the availability of suitable spawning habitat leading to decreased spawning productivity.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect adult spawning productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Unknown	Longfin smelt and eulachon dependence on groundwater exchange is currently a data gap.	Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Larvae; Juveniles	Larvae and juveniles: Riparian shade and ambient temperature have a relatively minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. Dependence of larval and juvenile longfin smelt and eulachon on these habitats is currently a data gap. Therefore, the potential for exposure to these stressors is unknown.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Larvae; Juveniles	Larvae and juveniles: Dependence of larval and juvenile longfin smelt and eulachon on these habitats is currently a data gap. Therefore, the potential for exposure to these stressors is unknown.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Longfin smelt and eulachon dependence on allochthonous inputs from marine riparian vegetation is a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Larvae; Juveniles	Larvae and juveniles: Dependence of larval and juvenile smelt on these habitats is currently a data gap. Therefore, the potential for exposure to these stressors is unknown.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Dependence of larval and juvenile smelt on surface water and groundwater exchange in nearshore habitats is currently a data gap. Therefore, the potential for exposure to these stressors is unknown.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Lake Washington longfin smelt. Larvae; Juveniles; Adults	Larvae, juveniles, and adults: Riparian shade and ambient temperature has a relatively minor effect on nearshore water temperatures relative to the dominant influence of lake stratification, reservoir current patterns, wind conditions and other factors. However, shallow littoral habitats may experience increased temperatures due to lack of shade. Dependence of juvenile longfin smelt on these habitats is currently a data gap Therefore the potential for exposure to these stressors is unknown.	Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible.	Potential effects resulting from this impact mechanism are unknown.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Lake Washington longfin smelt. Larvae; Juveniles; Adults	Larvae, juveniles, and adults: Potential habitat avoidance and/or injury/mortality caused by excessive turbidity, potential for decreased foraging success leading to decreased growth and fitness as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult survival and productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Lake Washington longfin smelt. Larvae; Juveniles; Adults	Larvae, juveniles, and adults: Longfin smelt dependence on allochthonous inputs from lacustrine riparian vegetation is a data gap. Therefore the potential for exposure to these stressors is unknown.	Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible.	Potential effects resulting from this impact mechanism are unknown.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Lake Washington longfin smelt. Larvae; Juveniles; Adults	Larvae, juveniles, and adults: Dependence of larval, juvenile, and adult longfin smelt on these habitats is currently a data gap, Therefore the potential for exposure to these stressors is unknown.	Avoid/minimize disturbance of riparian vegetation. Maintain system appropriate riparian buffer widths to the greatest extent possible.	Potential effects resulting from this impact mechanism are unknown.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Lake Washington longfin smelt. Larvae; Juveniles; Adults	Larvae, juveniles, and adults: Longfin smelt dependence on groundwater inflow to nearshore lacustrine habitats is currently a data gap. Therefore the potential for exposure to these stressors is unknown.	Avoid disturbance of vegetation along stream	Effects of the action resulting from this impact mechanism are unknown.
	Aquatic Vegetation Modification								
	Marine Littoral								

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Larvae; Juveniles; Adults	All exposed life-history stages: Longfin smelt and eulachon dependence on marine littoral vegetation and the nearshore marine environment is currently a data gap. Therefore, the potential for exposure to these stressors is unknown.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal				
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Eggs; Larvae; Adults	All exposed life-history stages: Smelt dependence on freshwater submerged aquatic vegetation is currently a data gap. Therefore, the potential for exposure to these stressors is unknown.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal				
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Eggs; Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Ensure that appropriate instream flows necessary to regulate temperature and other habitat parameters are maintained.	May affect survival, growth, and fitness. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved events due to asphyxiation. Juveniles and adults: Avoidance behavior and increased stress, leading to reduced growth and fitness.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs. May affect juvenile survival and productivity and adult survival, productivity, and spawning success.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause burial or coating of eggs may lead to direct mortality. Increased turbidity may decrease larval foraging success, resulting in decreased growth and fitness. Juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs. May affect juvenile productivity, adult productivity, and spawning success.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Eggs; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Juveniles; Adults	All expose life history stages: Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Tide Gates									
	Construction and Maintenance Activities								

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs; Larvae; Juveniles; Adults	Eggs and larvae: Noise of sufficient magnitude may cause direct mortality of eggs and larval smelt or permanent injury leading to decreased survival and fitness. Adults and juveniles: Stressor response, depending on noise magnitude and project-specific environmental conditions, may range from: • Fatal injury or permanent auditory tissue damage limiting to survival. • Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to system-specific in-water work windows to avoid stressor exposure during spawning, incubation, and larval dispersal (November to April, depending on system). If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Unlikely to affect smelt populations when activities are conducted in prescribed in-water work windows, avoiding spawning, incubation, and larval dispersal. The potential for juvenile exposure is less well known. Except for the landlocked Lake Washington population of longfin smelt, juvenile habitat use by these species is poorly understood. Subadults are known to migrate to offshore areas on the continental shelf.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults.	Unlikely to affect smelt populations when activities are conducted in prescribed in-water work windows, avoiding spawning disruptions. Exposure to stressor may affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles (Lake Washington longfin smelt); Adults	Eggs and larvae: Channel dewatering will cause egg mortality. Juveniles: Juvenile smelt are generally believed to migrate offshore and will therefore not likely be exposed to dewatering. Lake Washington longfin smelt are an exception; potential nearshore habitat use by this population is currently a data gap. Adults: Capture, handling, and relocation are likely to cause mortality or injury and stress leading to mortality or decreased spawning fitness. Delayed migration resulting in decreased fitness and spawning success.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults.	Unlikely to affect eggs, larvae, and adults if activities are conducted during in-water work windows. Capture and removal of eggs, larvae, and juveniles is impractical, meaning that activities occurring during incubation and emigration periods may affect survival during these life-history stages. Capture and removal of adults are likely to affect survival and spawning productivity.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Eggs, larvae, and juveniles: Pump entrainment is highly likely to cause mortality of larvae and drifting eggs. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles. Adults: Impingement is likely to cause adult mortality.	Adhere to system-specific in-water work windows; avoid use of dewatering pumps during spawning, incubation, and larval dispersal.	Unlikely to affect survival and productivity during egg and larvae and adult life-history stages if activities are conducted outside in-water work windows. If activities are permitted during in-water work windows, activity may affect adult and egg and larval survival. The potential for effects on juvenile smelt survival in marine habitats and Lake Washington are unknown because habitat use by this life-history stage is a data gap.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Adults	Eggs and larvae: Potential scour of spawning substrate and/or sedimentation, resulting in decreased incubation success. Potential larval dispersal to unfavorable habitats, decreasing larval survival and productivity. Adults: Decreased availability of suitable spawning sites; decreased spawning success.	Adhere to system-specific in-water work windows, avoid use during spawning, incubation, and larval dispersal. Limit alteration of flow conditions to minimal area.	Unlikely to affect survival and productivity during egg and larvae and adult life-history stages if activities are conducted during in-water work windows. If activities are permitted during in-water work windows, activity may affect adult spawning productivity and egg and larval survival.
		Altered current and circulation conditions (marine and lacustrine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: Nearshore habitat use by smelt is currently a data gap, so the potential for exposure to this stressor is unknown.	Limit alteration of current and circulation patterns to greatest extent practicable to minimal area.	The potential for this mechanism to affect juvenile smelt is currently unknown because dependence on nearshore circulation patterns is currently a data gap.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to turbidity exposure and substrate disturbance. Adults: Stress and behavioral modifications by adult spawners exposed to sediment pulses, migration delay, increased predation exposure, decreased spawning habitat suitability.	Adhere to system-specific in-water work windows. Avoid work during egg incubation periods.	Unlikely to affect egg survival and adult spawning productivity when activities are conducted during in-water work windows. May affect these parameters if activities occur during spawning and incubation.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles	Juveniles: With the exception of the Lake Washington longfin population, smelt do not feed on benthic organisms in freshwater systems and will be unaffected by this stressor. In Lake Washington and in marine systems, smelt are planktonic feeders that are not likely to be affected by temporary decreases in benthic invertebrate abundance.	Limit area of dewatering to the greatest extent practicable.	Not likely to affect smelt at any life-history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Loss of habitat, stranding from dewatering (during construction, maintenance, and removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Juveniles; Adults	Eggs: Potential decreased egg incubation success and survival due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, migration delay, reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay, leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs; Larvae; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modifications.	Avoid fill or if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	Eggs and larvae: Incubating eggs entrained during dredging will suffer high mortality. Juveniles: The potential for juvenile exposure to these stressors is unknown because habitat use is currently a data gap. All life-history stages: See responses described for related stressors under Water Quality Modification.	Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	Unlikely to affect survival of eggs and larvae if activities are conducted during in-water work windows. Likely to affect egg survival and larval survival and productivity if exposure occurs. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	Eggs: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased incubation success and larval survival. Larvae and juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit foraging	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at egg and larval life-history stages. May affect spawning productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange		Year-round (with stressor exposure occurring during egg incubation and juvenile rearing)	Permanent	Continuous		opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to alteration of the migratory corridor and a reduction in suitable resting habitat, leading to increased stress and decreased spawning success. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity may lead to decreased spawning success (e.g., through reduction in suitable spawning locations and/or increased scour and/or sedimentation ~~of redds~~) if potential spawning habitat is affected.		
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Longfin smelt and eulachon dependence on these habitats is currently a data gap. However, alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment. Adults: Alteration of nearshore habitat parameters may affect survival and foraging opportunities at larval and juvenile life-history stages, leading to decreased adult fitness, decreased survival, and decreased spawning productivity.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at the larval and juvenile life-history stages. Decreased fitness may affect survival and productivity during ocean migration life-history phase, and may affect spawning productivity.
	Altered current velocities and tidal exchange		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered channel geometry		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation of habitat	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Larvae; Adults	Adults: Tide gates can force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor is unlikely to significantly affect mainstem spawning eulachon and longfin smelt. Planktonic larvae are carried downstream to estuarine habitats, and are not dependent on floodplain habitats.	Require assessment of the hydraulic effects of the project before permitting, and avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at egg, and juvenile life-history stages. May affect spawning productivity.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as spawning success and overall population productivity.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Lateral and longitudinal fragmentation of habitat	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juvenile; Adult	<u>All exposed life-history stages</u>: Tide gates in the marine environment can fragment nearshore habitat. Eulachon and longfin smelt are known to use these habitat types during juvenile and adult life-history stages, and are likely to occur as larvae as well. Tide gates may alter migration of adults toward spawning habitats, larval dispersal, and juvenile foraging, affecting survival, growth, and fitness at all life-history stages.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and productivity at juvenile life-history stage. Decreased fitness may affect survival and productivity during ocean migration life-history phase.
	Loss of LWD recruitment	Reduced availability of LWD from drift Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles.	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs ; Juveniles; Adults	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tide gates is considered to be a component of the effects of dikes and levees. The incremental effects of the tide gate are negligible in comparison.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~<u>benthic</u> dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs ; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Eggs ; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	
	Marine and Lacustrine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tidegates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid disturbance of vegetation along shoreline.	
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Eggs; Larvae; Adults	<u>All exposed life-history stages</u>: Smelt dependence on freshwater submerged aquatic vegetation is currently a data gap. Therefore, the potential for exposure to these stressors is unknown.	<u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	.		
	Marine								

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Larvae; Juveniles; Adults	All exposed life-history stages: Longfin smelt and eulachon dependence on marine littoral vegetation and the nearshore marine environment is currently a data gap. Therefore, the potential for exposure to these stressors is unknown.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Sensitivity to stressor exposure is currently a data gap for these species; therefore, the potential effects resulting from this impact mechanism are unknown.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds. Adults: Decreased spawning fitness due to migration delays caused by thermal barriers.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile rearing. May affect adult survival and spawning productivity.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved events due to asphyxiation. Juveniles and adults: Avoidance behavior and increased stress, leading to reduced growth and fitness.	Avoid sediment pulses. Limit nutrient inputs.	May affect survival of incubating eggs. May affect juvenile survival and productivity and adult survival, productivity, and spawning success.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	Eggs and larvae: Turbidity sufficient to cause burial or coating of eggs may lead to direct mortality. Increased turbidity may decrease larval foraging success, resulting in decreased growth and fitness. Juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating eggs. May affect juvenile productivity, adult productivity, and spawning success.

Table A-15 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Longfin Smelt and Eulachon (Smelt).

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered salinity	Year-round	Long-term to permanent	Intermittent (daily)	Juveniles	Juveniles: Altered salinity patterns may limit habitat suitability for juvenile rearing in nearshore marine environments. This in turn may increase competition for available habitats, limiting survival, growth, and fitness.	Limit closure time of tide gate to maximize natural tidal exchange.	May affect juvenile survival, growth, and fitness.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect juvenile and adult survival, growth, and fitness.
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Juveniles	Tide gate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent. Exposure to toxic substances may lead to behavioral avoidance in adults. For juveniles, limitations in the availability of suitable juvenile rearing habitat, or potential physiological injury may affect survival, growth, and fitness.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect adult behavior. May affect juvenile survival, growth, and fitness.

Table A-16. HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered ambient noise levels	NA	NA	NA	NA	NA	NA	
		Bank/shoreline/channel disturbance, resulting in increased sediments	NA	NA	NA	NA	NA	NA	
		Exposure to toxic chemicals from accidental spills	NA	NA	NA	NA	NA	NA	
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	NA	NA	NA	NA	NA	NA	
		Entrainment in pumps or impingement on pump screens	NA	NA	NA	NA	NA	NA	
		Bottom disturbance, increased turbidity (associated with site rewatering)	NA	NA	NA	NA	NA	NA	
		Localized alteration in invertebrate abundance	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	NA	NA	NA	NA	NA	NA	
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	NA	NA	NA	NA	NA	NA	
		Aquatic vegetation removal and delayed recovery	NA	NA	NA	NA	NA	NA	
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	NA	NA	NA	NA	NA	NA	
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered sediment transport	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability as a result of beach erosion from altered sediment supply.	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered substrate composition		NA	NA	NA				
	Ecosystem Fragmentation								

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lateral and Longitudinal habitat Fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of longitudinal (i.e., upstream-downstream) habitat connectivity; change in habitat structure, availability, and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	NA	NA	NA	NA	NA	NA	
	Riparian Vegetation Modification								
	Marine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	NA	NA	NA	NA	NA	NA	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA	NA	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Aquatic Vegetation Modification								
	Marine								

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA		
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Increased sediment contamination	NA	NA	NA	NA	NA	NA	
		Altered pH levels	NA	NA	NA	NA	NA	NA	
		Altered nutrient cycling	NA	NA	NA	NA	NA	NA	
		Introduction of toxic substances	NA	NA	NA	NA	NA	NA	
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	NA	NA	NA	NA	▪ NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered ambient noise levels	NA	NA	NA	NA	NA	NA	
		Bank/shoreline/channel disturbance, resulting in increased sediments	NA	NA	NA	NA	NA	NA	
		Exposure to toxic chemicals from accidental spills	NA	NA	NA	NA	NA	NA	
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	NA	NA	NA	NA	NA	NA	
		Entrainment in pumps or impingement on pump screens	NA	NA	NA	NA	NA	NA	

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Bottom disturbance, increased turbidity (associated with site rewatering)	NA	NA	NA	NA	NA	NA	
		Localized alteration in invertebrate abundance	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Loss of habitat access and stranding (during construction and maintenance)	NA	NA	NA	NA	NA	NA	
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	NA	NA	NA	NA	NA	NA	
		Aquatic vegetation removal and delayed recovery	NA	NA	NA	NA	NA	NA	
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	NA	NA	NA	NA	NA	NA	
	Hydraulic and Geomorphic Modification								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered flow regime		NA	NA	NA				
	Altered substrate composition and stability		NA	NA	NA				
	Altered groundwater–surface water exchange		NA	NA	NA				
	Ecosystem Fragmentation								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	NA	NA	NA	NA	NA	NA	
	Riparian Vegetation Modification								
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	NA	NA	NA	NA	NA	NA	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA	NA	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Aquatic Vegetation Modification								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA		
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Increased sediment contamination	NA	NA	NA	NA	NA	NA	
		Altered pH levels	NA	NA	NA	NA	NA	NA	
		Altered nutrient cycling	NA	NA	NA	NA	NA	NA	
		Introduction of toxic substances	NA	NA	NA	NA	NA	NA	
Dikes/Levees									
	Construction and Maintenance Activities								

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Larvae; Juveniles; Adults	Larvae: Noise of sufficient magnitude may cause direct mortality of larvae, or permanent injury leading to decreased survival and fitness. Eggs are unlikely to be exposed to pile driving noise due to position in intertidal environment. Adults and juveniles: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Where possible, avoid stressor exposure during site-specific spawn timing, incubation, and larval dispersal. Require review of available data and/or site surveys to avoid exposure of spawners to stressor. If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity during larval, juvenile, and adult life-history stages.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: May cause avoidance behavior leading to increased stress and decreased foraging opportunity. Auditory masking or temporary hearing threshold effects may increase risk of predation due to decreased ability to sense predators.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults.	May affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling, and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae and juveniles: These life-history stages will be difficult to capture and relocate effectively. Adults: Capture, handling, and relocation is likely to cause mortality, or injury and stress leading to mortality or decreased spawning fitness.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Require review of available data and/or site surveys to reduce likelihood of stressor exposure.	Capture/removal of larvae and juveniles is impractical, meaning that these activities are likely to affect larval and juvenile survival. Capture and removal of adults is likely to affect survival and spawning productivity.

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae and juveniles: Pump entrainment is likely to cause mortality of drifting larvae. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles. Adults: Impingement is likely to cause adult mortality.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Require review of available data and/or site surveys to reduce likelihood of stressor exposure.	May cause injury and mortality of larvae, juveniles, and adults. Effects are less likely to occur if activities are conducted outside of spawning season.
		Altered current and circulation conditions (marine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles;	Juveniles: Nearshore habitat use by smelt is currently a data gap, so the potential for exposure to this stressor is unknown.	To greatest extent practicable, limit alteration of current and circulation patterns to minimal area.	The potential for this mechanism to affect juvenile smelt is currently unknown because dependence on nearshore circulation patterns is a data gap.
		Bottom disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae: Potential decreased larval foraging success due to turbidity exposure and substrate disturbance, leading to decreased growth and fitness. Adults and juveniles: Stress caused by avoidance behavior; decreased foraging success due to increased turbidity levels.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May affect larval productivity. May affect juvenile and adult survival and productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	All life-history stages: Surf smelt and sand lance dependence on benthic invertebrates for forage is likely limited but is currently a data gap. Therefore, the potential effects of stressor exposure are unknown.	Limit area of dewatering to the greatest extent practicable.	Potential effects resulting from this impact mechanism are unknown.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Larvae; Juveniles; Adults	All life-history stages: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Larvae; Juveniles; Adults	All life-history stages: Entrainment of smelt and sand lance during dredging is likely to cause mortality or injury, leading to decreased survival. See responses described for related stressors under Water Quality Modification.	Require review of available data and/or site surveys to reduce likelihood of larval and adult stressor exposure. Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	Unlikely to affect survival of larvae and adults if activities are conducted during in-water work windows. Likely to affect survival at any life-history stage if exposure occurs. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Egg incubation success may be affected by alteration in wave energy patterns and groundwater inputs. Alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment. Therefore, alteration of these parameters may affect foraging opportunities for at larval and juvenile life-history stages, leading to decreased adult fitness, decreased survival, and decreased spawning productivity.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival at the larval and juvenile life-history stages. May affect juvenile and adult growth and fitness. Decreased fitness may affect spawning productivity.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Dikes and levees in the marine environment can fragment nearshore rearing habitat, forcing larval and juvenile surf-smelt and sandlance to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion. These stressors may affect survival, growth, and fitness. Adults: The physical footprint of dikes and levees and their geomorphic effects on the upper intertidal zone may eliminate or decrease the suitability of spawning habitat, potentially limiting the spawning productivity of affected populations.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval and juvenile survival, growth, and fitness. May affect adult survival, fitness, and spawning productivity.
	Riparian Vegetation Modification								
	Marine								

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs	Eggs: Surf smelt and sand lance incubation success is demonstrably affected by microclimate conditions in the nearshore environment that are influenced by riparian vegetation. Alteration of riparian vegetation has been demonstrated to reduce egg survival and incubation success.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect egg survival, decreasing population productivity.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs; Larvae; Juveniles; Adults	Eggs: Smothering of incubating eggs or alteration of substrate composition may decrease egg survival. Larvae and juveniles: See responses to increased turbidity exposure described under Water Quality Modification. Adults: Potential reduction of suitable spawning habitat, leading to decreased spawning productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect egg survival. May affect growth and fitness at larval and juvenile life-history stages. May affect adult spawning fitness and productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	Eggs: Leaf litter and other detritus may influence microclimate conditions in spawning substrates. Reduction in leaf litter may cause reduced incubation success. Larvae, juveniles, and adults: Dependence on allochthonous inputs from marine riparian vegetation is a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs. Potential effects resulting from this impact mechanism on remaining life-history stages are unknown.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Larvae; Juveniles; Adults	All life-history stages: Altered habitat complexity is likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap for these species; the potential effects resulting from this impact mechanism are unknown.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	Eggs: Groundwater inflow demonstrably affects substrate temperatures, creating favorable conditions for egg incubation. Larvae and juveniles: Dependence of larval and juvenile forage fish on surface water and groundwater exchange in nearshore habitats is currently a data gap; the potential for exposure to these stressors is unknown. Adults: Altered groundwater inflow may affect spawning habitat suitability, leading to decreased spawning success.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect egg survival and adult spawning productivity. Potential effects resulting from this impact mechanism on larvae and juveniles are unknown.

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	Eggs: Alteration or reduction of submerged aquatic vegetation component of beach wrack may affect microclimate conditions in spawning substrates, decreasing egg survival (particularly during spring and summer spawning). All life-history stages: Altered autochthonous production and habitat complexity are likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect growth and fitness at egg, larval, juvenile, and adult life-history stages.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Avoidance behavior and increased stress, leading to reduced growth and fitness.	Avoid sediment pulses. Limit nutrient. Other mechanism-specific measures as appropriate.	May affect larval, juvenile, and adult survival and productivity. Reduced adult fitness may affect spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Larvae; Juveniles; Adults	Larvae: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness. Adults and juveniles: Same effects as above, as well as increased stress and decreased foraging opportunity due to avoidance behavior.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival and productivity at larval, juvenile, and adult life-history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All expose life history stages: Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Outfalls									
	Construction and Maintenance Activities								

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Larvae; Juveniles; Adults	Larvae: Noise of sufficient magnitude may cause direct mortality of larvae, or permanent injury leading to decreased survival and fitness. Eggs are unlikely to be exposed to pile driving noise due to position in intertidal environment. Adults and juveniles: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Where possible, avoid stressor exposure during site-specific spawn timing, incubation, and larval dispersal. Require review of available data and/or site surveys to avoid exposure of spawners to stressor. If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity during larval, juvenile, and adult life-history stages.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: May cause avoidance behavior leading to increased stress and decreased foraging opportunity. Auditory masking or temporary hearing threshold effects may increase risk of predation due to decreased ability to sense predators.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults.	May affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling, and Channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae and juveniles: These life-history stages will be difficult to capture and relocate effectively. Adults: Capture, handling, and relocation is likely to cause mortality, or injury and stress leading to mortality or decreased spawning fitness.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Require review of available data and/or site surveys to reduce likelihood of stressor exposure.	Capture/removal of larvae and juveniles is impractical, meaning that these activities are likely to affect larval and juvenile survival. Capture and removal of adults is likely to affect survival and spawning productivity.

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

		Exposure							
Sub-activity Type	Mechanism of Impact	Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae and juveniles: Pump entrainment is likely to cause mortality of drifting larvae. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles. Adults: Impingement is likely to cause adult mortality.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Require review of available data and/or site surveys to reduce likelihood of stressor exposure.	May cause injury and mortality of larvae, juveniles, and adults. Effects are less likely to occur if activities are conducted outside of spawning season.
		Altered current and circulation conditions (marine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles;	Juveniles: Nearshore habitat use by smelt is currently a data gap, so the potential for exposure to this stressor is unknown.	To greatest extent practicable, limit alteration of current and circulation patterns to minimal area.	The potential for this mechanism to affect juvenile smelt is currently unknown because dependence on nearshore circulation patterns is a data gap.
		Bottom disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae: Potential decreased larval foraging success due to turbidity exposure and substrate disturbance, leading to decreased growth and fitness. Adults and juveniles: Stress caused by avoidance behavior; decreased foraging success due to increased turbidity levels.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May affect larval productivity. May affect juvenile and adult survival and productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	All life-history stages: Surf smelt and sand lance dependence on benthic invertebrates for forage is likely limited but is currently a data gap. Therefore, the potential effects of stressor exposure are unknown.	Limit area of dewatering to the greatest extent practicable.	Potential effects resulting from this impact mechanism are unknown.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Larvae; Juveniles; Adults	All life-history stages: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Larvae; Juveniles; Adults	All life-history stages: Entrainment of smelt and sand lance during dredging is likely to cause mortality or injury, leading to decreased survival. See responses described for related stressors under Water Quality Modification.	Require review of available data and/or site surveys to reduce likelihood of larval and adult stressor exposure. Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	Unlikely to affect survival of larvae and adults if activities are conducted during in-water work windows. Likely to affect survival at any life-history stage if exposure occurs. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Egg incubation success may be affected by alteration in wave energy patterns and groundwater inputs. Alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment. Therefore, alteration of these parameters may affect foraging opportunities for at larval and juvenile life-history stages, leading to decreased adult fitness, decreased survival, and decreased spawning productivity.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival at the larval and juvenile life-history stages. May affect juvenile and adult growth and fitness. Decreased fitness may affect spawning productivity.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Outfalls in the marine environment can fragment nearshore rearing habitat, forcing larval and juvenile surf-smelt and sandlance to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion. These stressors may affect survival, growth, and fitness. Adults: The physical footprint of outfalls and their geomorphic effects on the upper intertidal zone may eliminate or decrease the suitability of spawning habitat, potentially limiting the spawning productivity of affected populations.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval and juvenile survival, growth, and fitness. May affect adult survival, fitness, and spawning productivity.
	Riparian Vegetation Modification								
	Marine								

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs	Eggs: Surf smelt and sand lance incubation success is demonstrably affected by microclimate conditions in the nearshore environment that are influenced by riparian vegetation. Alteration of riparian vegetation has been demonstrated to reduce egg survival and incubation success.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect egg survival, decreasing population productivity.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs; Larvae; Juveniles; Adults	Eggs: Smothering of incubating eggs or alteration of substrate composition may decrease egg survival. Larvae and juveniles: See responses to increased turbidity exposure described under Water Quality Modification. Adults: Potential reduction of suitable spawning habitat, leading to decreased spawning productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect egg survival. May affect growth and fitness at larval and juvenile life-history stages. May affect adult spawning fitness and productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	Eggs: Leaf litter and other detritus may influence microclimate conditions in spawning substrates. Reduction in leaf litter may cause reduced incubation success. Larvae, juveniles, and adults: Dependence on allochthonous inputs from marine riparian vegetation is a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs. Potential effects resulting from this impact mechanism on remaining life-history stages are unknown.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Larvae; Juveniles; Adults	All life-history stages: Altered habitat complexity is likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap for these species; the potential effects resulting from this impact mechanism are unknown.
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	Eggs: Alteration or reduction of submerged aquatic vegetation component of beach wrack may affect microclimate conditions in spawning substrates, decreasing egg survival (particularly during spring and summer	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize	May affect growth and fitness at egg, larval, juvenile, and adult life-history stages.

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous		spawning). All life-history stages: Altered autochthonous production and habitat complexity are likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness.	disturbance of aquatic vegetation during project construction.	
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Avoidance behavior and increased stress, leading to reduced growth and fitness.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect larval, juvenile, and adult survival and productivity. Reduced adult fitness may affect spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Larvae; Juveniles; Adults	Larvae: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness. Adults and juveniles: Same effects as above, as well as increased stress and decreased foraging opportunity due to avoidance behavior.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival and productivity at larval, juvenile, and adult life-history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect survival and fitness of juveniles and adults.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Larvae; Juveniles; Adults	<u>Larvae</u>: Noise of sufficient magnitude may cause direct mortality of larvae, or permanent injury leading to decreased survival and fitness. Eggs are unlikely to be exposed to pile driving noise due to position in intertidal environment. <u>Adults and juveniles</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Where possible, avoid stressor exposure during site-specific spawn timing, incubation, and larval dispersal. Require review of available data and/or site surveys to avoid exposure of spawners to stressor. If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity during larval, juvenile, and adult life-history stages.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: May cause avoidance behavior leading to increased stress and decreased foraging opportunity. Auditory masking or temporary hearing threshold effects may increase risk of predation due to decreased ability to sense predators.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults.	May affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	<u>Larvae and juveniles</u>: These life-history stages will be difficult to capture and relocate effectively. <u>Adults</u>: Capture, handling, and relocation is likely to cause mortality, or injury and stress leading to mortality or decreased spawning fitness.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Require review of available data and/or site surveys to reduce likelihood of stressor exposure.	Capture/removal of larvae and juveniles is impractical, meaning that these activities are likely to affect larval and juvenile survival. Capture and removal of adults is likely to affect survival and spawning productivity.

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae and juveniles: Pump entrainment is likely to cause mortality of drifting larvae. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles. Adults: Impingement is likely to cause adult mortality.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Require review of available data and/or site surveys to reduce likelihood of stressor exposure.	May cause injury and mortality of larvae, juveniles, and adults. Effects are less likely to occur if activities are conducted outside of spawning season.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles;	Juveniles: Nearshore habitat use by smelt is currently a data gap, so the potential for exposure to this stressor is unknown.	To greatest extent practicable, limit alteration of current and circulation patterns to minimal area.	The potential for this mechanism to affect juvenile smelt is currently unknown because dependence on nearshore circulation patterns is a data gap.
		Bottom disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae: Potential decreased larval foraging success due to turbidity exposure and substrate disturbance, leading to decreased growth and fitness. Adults and juveniles: Stress caused by avoidance behavior; decreased foraging success due to increased turbidity levels.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May affect larval productivity. May affect juvenile and adult survival and productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	All life-history stages: Surf smelt and sand lance dependence on benthic invertebrates for forage is likely limited but is currently a data gap. Therefore, the potential effects of stressor exposure are unknown.	Limit area of dewatering to the greatest extent practicable.	Potential effects resulting from this impact mechanism are unknown.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Larvae; Juveniles; Adults	All life-history stages: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Larvae; Juveniles; Adults	All life-history stages: Entrainment of smelt and sand lance during dredging is likely to cause mortality or injury, leading to decreased survival. See responses described for related stressors under Water Quality Modification.	Require review of available data and/or site surveys to reduce likelihood of larval and adult stressor exposure. Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	Unlikely to affect survival of larvae and adults if activities are conducted during in-water work windows. Likely to affect survival at any life-history stage if exposure occurs. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Egg incubation success may be affected by alteration in wave energy patterns and groundwater inputs. Alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment. Therefore, alteration of these parameters may affect foraging opportunities for at larval and juvenile life-history stages, leading to decreased adult fitness, decreased survival, and decreased spawning productivity.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival at the larval and juvenile life-history stages. May affect juvenile and adult growth and fitness. Decreased fitness may affect spawning productivity.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Intakes and diversions in the marine environment can fragment nearshore rearing habitat, forcing larval and juvenile surf-smelt and sandlance to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion. These stressors may affect survival, growth, and fitness. Adults: The physical footprint of intakes and diversions and their geomorphic effects on the upper intertidal zone may eliminate or decrease the suitability of spawning habitat, potentially limiting the spawning productivity of affected populations.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval and juvenile survival, growth, and fitness. May affect adult survival, fitness, and spawning productivity.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Marine								

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs	Eggs: Surf smelt and sand lance incubation success is demonstrably affected by microclimate conditions in the nearshore environment that are influenced by riparian vegetation. Alteration of riparian vegetation has been demonstrated to reduce egg survival and incubation success.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect egg survival, decreasing population productivity.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs; Larvae; Juveniles; Adults	Eggs: Smothering of incubating eggs or alteration of substrate composition may decrease egg survival. Larvae and juveniles: See responses to increased turbidity exposure described under Water Quality Modification. Adults: Potential reduction of suitable spawning habitat, leading to decreased spawning productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect egg survival. May affect growth and fitness at larval and juvenile life-history stages. May affect adult spawning fitness and productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	Eggs: Leaf litter and other detritus may influence microclimate conditions in spawning substrates. Reduction in leaf litter may cause reduced incubation success. Larvae, juveniles, and adults: Dependence on allochthonous inputs from marine riparian vegetation is a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of incubating eggs. Potential effects resulting from this impact mechanism on remaining life-history stages are unknown.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Larvae; Juveniles; Adults	All life-history stages: Altered habitat complexity is likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Sensitivity to stressor exposure is currently a data gap for these species; the potential effects resulting from this impact mechanism are unknown.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	Eggs: Groundwater inflow demonstrably affects substrate temperatures, creating favorable conditions for egg incubation. Larvae and juveniles: Dependence of larval and juvenile forage fish on surface water and groundwater exchange in nearshore habitats is currently a data gap; the potential for exposure to these stressors is unknown. Adults: Altered groundwater inflow may affect spawning habitat suitability, leading to decreased spawning success.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect egg survival and adult spawning productivity. Potential effects resulting from this impact mechanism on larvae and juveniles are unknown.

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	Eggs: Alteration or reduction of submerged aquatic vegetation component of beach wrack may affect microclimate conditions in spawning substrates, decreasing egg survival (particularly during spring and summer spawning). All life-history stages: Altered autochthonous production and habitat complexity are likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect growth and fitness at egg, larval, juvenile, and adult life-history stages.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Avoidance behavior and increased stress, leading to reduced growth and fitness.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect larval, juvenile, and adult survival and productivity. Reduced adult fitness may affect spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Larvae; Juveniles; Adults	Larvae: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness. Adults and juveniles: Same effects as above, as well as increased stress and decreased foraging opportunity due to avoidance behavior.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival and productivity at larval, juvenile, and adult life-history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All expose life history stages: Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Tide Gates									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Larvae; Juveniles; Adults	Larvae: Noise of sufficient magnitude may cause direct mortality of larvae, or permanent injury leading to decreased survival and fitness. Eggs are unlikely to be exposed to pile driving noise due to position in intertidal environment. Adults and juveniles: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Where possible, avoid stressor exposure during site-specific spawn timing, incubation, and larval dispersal. Require review of available data and/or site surveys to avoid exposure of spawners to stressor. If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival and productivity during larval, juvenile, and adult life-history stages.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: May cause avoidance behavior leading to increased stress and decreased foraging opportunity. Auditory masking or temporary hearing threshold effects may increase risk of predation due to decreased ability to sense predators.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable. Limit activities to system-specific in-water work windows where practicable to avoid effects on spawning adults.	May affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae and juveniles: These life-history stages will be difficult to capture and relocate effectively. Adults: Capture, handling, and relocation is likely to cause mortality, or injury and stress leading to mortality or decreased spawning fitness.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Require review of available data and/or site surveys to reduce likelihood of stressor exposure.	Capture/removal of larvae and juveniles is impractical, meaning that these activities are likely to affect larval and juvenile survival. Capture and removal of adults is likely to affect survival and spawning productivity.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae and juveniles: Pump entrainment is likely to cause mortality of drifting larvae. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles. Adults: Impingement is likely to cause adult mortality.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts. Require review of available data and/or site surveys to reduce likelihood of stressor exposure.	May cause injury and mortality of larvae, juveniles, and adults. Effects are less likely to occur if activities are conducted outside of spawning season.
		Altered current and circulation conditions (marine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles;	Juveniles: Nearshore habitat use by smelt is currently a data gap, so the potential for exposure to this stressor is unknown.	To greatest extent practicable, limit alteration of current and circulation patterns to minimal area.	The potential for this mechanism to affect juvenile smelt is currently unknown because dependence on nearshore circulation patterns is a data gap.
		Bottom disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae: Potential decreased larval foraging success due to turbidity exposure and substrate disturbance, leading to decreased growth and fitness. Adults and juveniles: Stress caused by avoidance behavior; decreased foraging success due to increased turbidity levels.	Use protocols established by NOAA Fisheries and WDFW/WSDOT to avoid and minimize impacts.	May affect larval productivity. May affect juvenile and adult survival and productivity.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	All life-history stages: Surf smelt and sand lance dependence on benthic invertebrates for forage is likely limited but is currently a data gap. Therefore, the potential effects of stressor exposure are unknown.	Limit area of dewatering to the greatest extent practicable.	Potential effects resulting from this impact mechanism are unknown.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to system-specific in-water work windows.	See effects for related stressors under Water Quality Modification.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Loss of habitat, stranding from dewatering (during construction, maintenance, and removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success and larval survival due to water loss and stranding. Juveniles: loss of habitat accessibility, stranding, reduced foraging opportunities, mortality and increased predation risk. Adults: reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Larvae; Juveniles; Adults	All life-history stages: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Larvae; Juveniles; Adults	All life-history stages: Entrainment of smelt and sand lance during dredging is likely to cause mortality or injury, leading to decreased survival. See responses described for related stressors under Water Quality Modification.	Require review of available data and/or site surveys to reduce likelihood of larval and adult stressor exposure. Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	Unlikely to affect survival of larvae and adults if activities are conducted during in-water work windows. Likely to affect survival at any life-history stage if exposure occurs. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Egg incubation success may be affected by alteration in wave energy patterns and groundwater inputs. Alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment. Therefore, alteration of these parameters may affect foraging	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival at the larval and juvenile life-history stages. May affect juvenile and adult growth and fitness. Decreased fitness may affect spawning productivity.
	Altered current velocities and tidal exchange		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered channel geometry		Year-round	Permanent	Continuous		opportunities for at larval and juvenile life-history stages, leading to decreased adult fitness, decreased survival, and decreased spawning productivity.		
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Tide gates in the marine environment can fragment nearshore rearing habitat, forcing larval and juvenile surf-smelt and sandlance to navigate away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion. These stressors may affect survival, growth, and fitness. Adults: The physical footprint of tide gates and their geomorphic effects on the upper intertidal zone may eliminate or decrease the suitability of spawning habitat, potentially limiting the spawning productivity of affected populations.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval and juvenile survival, growth, and fitness. May affect adult survival, fitness, and spawning productivity.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tidegates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid disturbance of vegetation along shoreline.	
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	Eggs: Alteration or reduction of submerged aquatic vegetation component of beach wrack may affect microclimate conditions in spawning substrates, decreasing egg survival (particularly during spring and summer spawning). All life-history stages: Altered autochthonous production and habitat complexity are likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect growth and fitness at egg, larval, juvenile, and adult life-history stages.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Avoidance behavior and increased stress, leading to reduced growth and fitness.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect larval, juvenile, and adult survival and productivity. Reduced adult fitness may affect spawning productivity.

Table A-16 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Surf Smelt and Sand Lance.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Larvae; Juveniles; Adults	Larvae: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness. Adults and juveniles: Same effects as above, as well as increased stress and decreased foraging opportunity due to avoidance behavior.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival and productivity at larval, juvenile, and adult life-history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered salinity	Year-round	Long-term to permanent	Intermittent (daily)	Juveniles	Juveniles: Altered salinity patterns may limit habitat suitability for juvenile rearing in nearshore marine environments. This in turn may increase competition for available habitats, limiting survival, growth, and fitness.	Limit closure time of tide gate to maximize natural tidal exchange.	May affect juvenile survival, growth, and fitness.
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Juveniles	Tide gate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent. Exposure to toxic substances may lead to behavioral avoidance in adults. For juveniles, limitations in the availability of suitable juvenile rearing habitat, or potential physiological injury may affect survival, growth, and fitness.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect adult behavior. May affect juvenile survival, growth, and fitness.

Table A-17. HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered ambient noise levels	NA	NA	NA	NA	NA	NA	
		Bank/shoreline/channel disturbance, resulting in increased sediments	NA	NA	NA	NA	NA	NA	
		Exposure to toxic chemicals from accidental spills	NA	NA	NA	NA	NA	NA	
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	NA	NA	NA	NA	NA	NA	
		Entrainment in pumps or impingement on pump screens	NA	NA	NA	NA	NA	NA	
		Bottom disturbance, increased turbidity (associated with site rewatering)	NA	NA	NA	NA	NA	NA	
		Localized alteration in invertebrate abundance	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	NA	NA	NA	NA	NA	NA	
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	NA	NA	NA	NA	NA	NA	
		Aquatic vegetation removal and delayed recovery	NA	NA	NA	NA	NA	NA	
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	NA	NA	NA	NA	NA	NA	
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered sediment transport	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability as a result of beach erosion from altered sediment supply.	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered substrate composition		NA	NA	NA				
	Ecosystem Fragmentation								

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lateral and Longitudinal habitat Fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of longitudinal (i.e., upstream-downstream) habitat connectivity; change in habitat structure, availability, and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	NA	NA	NA	NA	NA	NA	
	Riparian Vegetation Modification								
	Marine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	NA	NA	NA	NA	NA	NA	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA	NA	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Aquatic Vegetation Modification								
	Marine								

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA		
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Increased sediment contamination	NA	NA	NA	NA	NA	NA	
		Altered pH levels	NA	NA	NA	NA	NA	NA	
		Altered nutrient cycling	NA	NA	NA	NA	NA	NA	
		Introduction of toxic substances	NA	NA	NA	NA	NA	NA	
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	NA	NA	NA	NA	▪ NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered ambient noise levels	NA	NA	NA	NA	NA	NA	
		Bank/shoreline/channel disturbance, resulting in increased sediments	NA	NA	NA	NA	NA	NA	
		Exposure to toxic chemicals from accidental spills	NA	NA	NA	NA	NA	NA	
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	NA	NA	NA	NA	NA	NA	
		Entrainment in pumps or impingement on pump screens	NA	NA	NA	NA	NA	NA	
		Bottom disturbance, increased turbidity (associated with site rewatering)	NA	NA	NA	NA	NA	NA	
		Localized alteration in invertebrate abundance	NA	NA	NA	NA	NA	NA	

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Loss of habitat access and stranding (during construction and maintenance)	NA	NA	NA	NA	NA	NA	
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	NA	NA	NA	NA	NA	NA	
		Aquatic vegetation removal and delayed recovery	NA	NA	NA	NA	NA	NA	
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	NA	NA	NA	NA	NA	NA	
	Hydraulic and Geomorphic Modification								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered flow regime		NA	NA	NA				
	Altered substrate composition and stability		NA	NA	NA				
	Altered groundwater–surface water exchange		NA	NA	NA				
	Ecosystem Fragmentation								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	NA	NA	NA	NA	NA	NA	
	Riparian Vegetation Modification								
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	NA	NA	NA	NA	NA	NA	

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA	NA	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Aquatic Vegetation Modification								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA		
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Increased sediment contamination	NA	NA	NA	NA	NA	NA	
		Altered pH levels	NA	NA	NA	NA	NA	NA	
		Altered nutrient cycling	NA	NA	NA	NA	NA	NA	
		Introduction of toxic substances	NA	NA	NA	NA	NA	NA	
Dikes/Levees									
	Construction and Maintenance Activities								

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs; Larvae; Juveniles; Adults	Eggs and larvae: Noise of sufficient magnitude may cause direct mortality of eggs and larvae, or permanent injury leading to decreased survival and fitness. Adults and juveniles: Stressor response, dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Where possible, avoid stressor exposure during site-specific spawn timing, incubation, and larval dispersal. Require review of available data and/or site surveys to determine if spawning adults or rearing larvae are likely to be present, and time activities to avoid stressor exposure. If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival during egg, larval, juvenile, and adult life-history stages.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: May cause avoidance behavior leading to increased stress and decreased foraging opportunity. Auditory masking or temporary hearing threshold effects may increase risk of predation due to decreased ability to sense predators.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable. Limit activities to in-water work windows where practicable.	May affect growth, fitness, and survival due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling, and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles; Adults	Eggs: Extended dewatering may lead to egg desiccation or thermal exposure, causing mortality, or larval abnormalities limiting to survival. Larvae and juveniles: Dewatering is likely to lead to mortality, as larval and juvenile herring will be difficult to capture and relocate effectively. Adults: Capture, handling, and relocation are likely to cause mortality, or injury and stress, leading to mortality or decreased spawning fitness.	Limit activities to in-water work windows where practicable.	Dewatering and fish removal in marine habitats is an unlikely requirement for dike and levee development. However, in the event that such activities are required, adverse effects on exposed life-history stages should be expected. Capture and removal of larvae and juveniles is impractical, meaning that these activities are likely to affect larval and juvenile survival. Capture and removal of adults is likely to affect survival and spawning productivity.

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae and juveniles: Pump entrainment is likely to cause mortality of drifting larvae. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles. Adults: Impingement is likely to cause adult mortality.	Adhere to in-water work windows; avoid use during spawning, incubation, and larval dispersal.	May cause injury and mortality of larvae, juveniles, and adults. Effects are less likely to occur if activities are conducted outside of spawning season.
		Altered current and circulation conditions (marine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae	Larvae: Alteration of nearshore current and circulation patterns may cause larvae to be transported offshore or into habitats with increased predation risk and reduced foraging opportunity, limiting survival, growth, and fitness.	To the greatest extent practicable, limit alteration of current and circulation patterns to minimal area.	May affect larval survival, growth, and fitness.
		Bottom disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles; Adults	Larvae: Potential decreased larval foraging success due to turbidity exposure and substrate disturbance, leading to decreased growth and fitness. Adults and juveniles: Stress caused by avoidance behavior; decreased foraging success due to increased turbidity levels. Adults: Decreased availability of spawning substrate due to sedimentation effects on submerged aquatic vegetation. All life-history stages: See responses to related stressors under Water Quality Modification.	Adhere to in-water work windows; avoid activity during spawning, incubation, and larval dispersal.	The likely stressor is increased suspended solids. May affect larval growth and survival. May affect juvenile and adult survival. May affect adult spawning productivity.
		Localized alteration in invertebrate abundance	NA	NA	NA	NA	NA	NA	NA
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Larvae; Juveniles; Adults	All life-history stages: Entrainment of larval herring during dredging is likely to cause mortality or injury, leading to decreased survival. See responses described for related stressors under Water Quality Modification.	Require review of available data and/or site surveys to determine if spawning adults or rearing larvae are likely to be present, and time activities to avoid stressor exposure. Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	Increased suspended solids and resuspension of contaminated sediments would be the likely stressors. Unlikely to affect survival of larvae and adults if activities are conducted during in-water work windows. Likely to affect survival at any life-history stage if exposure occurs. See effects for related stressors under Water Quality Modification.

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	All exposed life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Alteration in the aerial extent and composition of the submerged aquatic vegetation community resulting from these mechanisms may reduce available spawning habitat, leading to reduced spawning productivity. Egg incubation success may be affected by alteration in wave energy patterns. Alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment. Therefore, alteration of these parameters may affect foraging opportunities at the juvenile life-history stage, over time leading to decreased adult fitness, decreased survival, and decreased spawning productivity.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect egg and larval survival and larval fitness. Decreased larval fitness may affect survival and productivity during juvenile and adult life-history phases in offshore and open ocean environments, and may affect spawning productivity. Loss or alteration of suitable spawning habitat may affect spawning productivity.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Dikes and levees in the marine environment can fragment nearshore rearing habitat, potentially forcing planktonic herring away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion. Adults: The physical footprint of dikes and levees and their geomorphic effects on the middle and lower intertidal zone may eliminate or decrease the suitability of spawning habitat, potentially limiting the spawning productivity of affected populations.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval and juvenile survival, growth, and fitness. May affect adult survival, fitness, and spawning productivity.
	Marine								

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs	Eggs: The influence of marine riparian shading on herring incubation is likely limited due to the typical elevation of herring spawn in the upper subtidal zone. However, the effects of this stressor are currently a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Potential effects resulting from this impact mechanism are unknown.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs; Larvae; Juveniles; Adults	Eggs, larvae, and juveniles: See responses to increased turbidity exposure described under Water Quality Modification. Adults: Potential reduction of suitable spawning habitat, leading to decreased spawning productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect egg survival. May affect productivity at larval and juvenile life-history stages. May affect adult spawning productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Dependence on autochthonous inputs from marine riparian vegetation is a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Potential effects resulting from this impact mechanism on remaining life-history stages are unknown.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Larvae; Juveniles; Adults	All life-history stages: Altered habitat complexity is likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect larval, juvenile, and adult productivity. May affect adult spawning productivity.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Eggs; Larvae; Adults	Eggs and larvae: Herring egg and larval development is demonstrably affected by surface water salinities beyond tolerance thresholds. Alteration of salinity characteristics may limit egg survival or cause larval abnormalities limiting to survival, growth, and fitness. Adults: The influence of surface water and groundwater exchange on spawning habitat suitability is currently a data gap. However, alteration of this habitat parameter that affect submerged aquatic vegetation may decrease availability and/or suitability of spawning habitat.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect egg and larval survival and productivity. May affect adult spawning productivity.
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring	Permanent	Continuous	Eggs;	All life-history stages: Altered habitat complexity is likely to affect food web	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the	May affect productivity at larval, juvenile, and adult life-history stages.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
			and summer when vegetation growth is most extensive)			Larvae; Juveniles; Adults	dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness. Adults: Reductions in available submerged aquatic vegetation or alteration of submerged aquatic vegetation community composition may limit spawning productivity.	greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Avoidance behavior and increased stress, leading to reduced growth and fitness.	Limit nutrient inputs. Other mechanism-specific measures as appropriate.	Decreased spawning habitat area. May affect larval, juvenile, and adult survival and productivity. Reduced adult fitness may affect spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	Eggs: Effects of suspended sediments on incubating herring eggs is currently a data gap. Larvae: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness. Adults and juveniles: Same effects as above, as well as increased stress and decreased foraging opportunity due to avoidance behavior.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bluff/bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival and productivity at egg, larval, juvenile, and adult life-history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All expose life history stages: Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Outfalls									
	Construction and Maintenance Activities								

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs; Larvae; Juveniles; Adults	<u>Eggs and larvae</u>: Noise of sufficient magnitude may cause direct mortality of eggs and larvae, or permanent injury leading to decreased survival and fitness. <u>Adults and juveniles</u>: Stressor response, dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Where possible, avoid stressor exposure during site-specific spawn timing, incubation, and larval dispersal. Require review of available data and/or site surveys to determine if spawning adults or rearing larvae are likely to be present, and time activities to avoid stressor exposure. If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival during egg, larval, juvenile, and adult life-history stages.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: May cause avoidance behavior leading to increased stress and decreased foraging opportunity. Auditory masking or temporary hearing threshold effects may increase risk of predation due to decreased ability to sense predators.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable. Limit activities to in-water work windows where practicable.	May affect growth, fitness, and survival due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling, and Channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles; Adults	<u>Eggs</u>: Extended dewatering may lead to egg desiccation or thermal exposure, causing mortality, or larval abnormalities limiting to survival. <u>Larvae and juveniles</u>: Dewatering is likely to lead to mortality, as larval and juvenile herring will be difficult to capture and relocate effectively. <u>Adults</u>: Capture, handling, and relocation are likely to cause mortality, or injury and stress, leading to mortality or decreased spawning fitness.	Limit activities to in-water work windows where practicable.	Dewatering and fish removal in marine habitats is an unlikely requirement for outfall development. However, in the event that such activities are required, adverse effects on exposed life-history stages should be expected. Capture and removal of larvae and juveniles is impractical, meaning that these activities are likely to affect larval and juvenile survival. Capture and removal of adults is likely to affect survival and spawning productivity.

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae and juveniles: Pump entrainment is likely to cause mortality of drifting larvae. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles. Adults: Impingement is likely to cause adult mortality.	Adhere to in-water work windows; avoid use during spawning, incubation, and larval dispersal.	May cause injury and mortality of larvae, juveniles, and adults. Effects are less likely to occur if activities are conducted outside of spawning season.
		Altered current and circulation conditions (marine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae	Larvae: Alteration of nearshore current and circulation patterns may cause larvae to be transported offshore or into habitats with increased predation risk and reduced foraging opportunity, limiting survival, growth, and fitness.	To the greatest extent practicable, limit alteration of current and circulation patterns to minimal area.	May affect larval survival, growth, and fitness.
		Bottom disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles; Adults	Larvae: Potential decreased larval foraging success due to turbidity exposure and substrate disturbance, leading to decreased growth and fitness. Adults and juveniles: Stress caused by avoidance behavior; decreased foraging success due to increased turbidity levels. Adults: Decreased availability of spawning substrate due to sedimentation effects on submerged aquatic vegetation. All life-history stages: See responses to related stressors under Water Quality Modification.	Adhere to in-water work windows; avoid activity during spawning, incubation, and larval dispersal.	The likely stressor is increased suspended solids. May affect larval growth and survival. May affect juvenile and adult survival. May affect adult spawning productivity.
		Localized alteration in invertebrate abundance	NA	NA	NA	NA	NA	NA	NA
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Larvae; Juveniles; Adults	All life-history stages: Entrainment of larval herring during dredging is likely to cause mortality or injury, leading to decreased survival. See responses described for related stressors under Water Quality Modification.	Require review of available data and/or site surveys to determine if spawning adults or rearing larvae are likely to be present, and time activities to avoid stressor exposure. Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	Increased suspended solids and resuspension of contaminated sediments would be the likely stressors. Unlikely to affect survival of larvae and adults if activities are conducted during in-water work windows. Likely to affect survival at any life-history stage if exposure occurs. See effects for related stressors under Water Quality Modification.

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	All exposed life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Alteration in the aerial extent and composition of the submerged aquatic vegetation community resulting from these mechanisms may reduce available spawning habitat, leading to reduced spawning productivity. Egg incubation success may be affected by alteration in wave energy patterns. Alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment. Therefore, alteration of these parameters may affect foraging opportunities at the juvenile life-history stage, over time leading to decreased adult fitness, decreased survival, and decreased spawning productivity.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect egg and larval survival and larval fitness. Decreased larval fitness may affect survival and productivity during juvenile and adult life-history phases in offshore and open ocean environments, and may affect spawning productivity. Loss or alteration of suitable spawning habitat may affect spawning productivity.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Outfalls in the marine environment can fragment nearshore rearing habitat, potentially forcing planktonic herring away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion. Adults: The physical footprint of outfalls and their geomorphic effects on the middle and lower intertidal zone may eliminate or decrease the suitability of spawning habitat, potentially limiting the spawning productivity of affected populations.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval and juvenile survival, growth, and fitness. May affect adult survival, fitness, and spawning productivity.
	Riparian Vegetation Modification								
	Marine								

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs	Eggs: The influence of marine riparian shading on herring incubation is likely limited due to the typical elevation of herring spawn in the upper subtidal zone. However, the effects of this stressor are currently a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Potential effects resulting from this impact mechanism are unknown.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs; Larvae; Juveniles; Adults	Eggs: Smothering of incubating eggs or alteration of substrate composition may decrease egg survival. Larvae and juveniles: See responses to increased turbidity exposure described under Water Quality Modification. Adults: Potential reduction of suitable spawning habitat, leading to decreased spawning productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect egg survival. May affect growth and fitness at larval and juvenile life-history stages. May affect adult spawning fitness and productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	Eggs, larvae, and juveniles: See responses to increased turbidity exposure described under Water Quality Modification. Adults: Potential reduction of suitable spawning habitat, leading to decreased spawning productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect egg survival. May affect productivity at larval and juvenile life-history stages. May affect adult spawning productivity.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Dependence on autochthonous inputs from marine riparian vegetation is a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Potential effects resulting from this impact mechanism on remaining life-history stages are unknown.
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	All life-history stages: Altered habitat complexity is likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness. Adults: Reductions in available submerged aquatic vegetation or alteration of submerged aquatic vegetation community composition may limit spawning productivity.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect productivity at larval, juvenile, and adult life-history stages.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	<u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation. <u>Juveniles and adults</u>: Avoidance behavior and increased stress, leading to reduced growth and fitness.	Limit nutrient inputs. Other mechanism-specific measures as appropriate.	Decreased spawning habitat area. May affect larval, juvenile, and adult survival and productivity. Reduced adult fitness may affect spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	<u>Eggs</u>: Effects of suspended sediments on incubating herring eggs is currently a data gap. <u>Larvae</u>: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness. <u>Adults and juveniles</u>: Same effects as above, as well as increased stress and decreased foraging opportunity due to avoidance behavior.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bluff/bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival and productivity at egg, larval, juvenile, and adult life-history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	<u>All life-history stages</u>: Physiological responses to pH levels outside of optimal thresholds, causing direct mortality or injury leading to reduced fitness. <u>Juveniles and adults</u>: Avoidance behavior and increased stress, leading to reduced growth and fitness.	Limit nutrient inputs. Avoid curing of concrete or discharge of concrete leachate to surface waters.	May affect survival of eggs and larvae, juveniles, and adults.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Eggs and larvae; Juveniles; Adults	<u>All exposed life history stages</u>: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs; Larvae; Juveniles; Adults	Eggs and larvae: Noise of sufficient magnitude may cause direct mortality of eggs and larvae, or permanent injury leading to decreased survival and fitness. Adults and juveniles: Stressor response, dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Where possible, avoid stressor exposure during site-specific spawn timing, incubation, and larval dispersal. Require review of available data and/or site surveys to determine if spawning adults or rearing larvae are likely to be present, and time activities to avoid stressor exposure. If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival during egg, larval, juvenile, and adult life-history stages.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: May cause avoidance behavior leading to increased stress and decreased foraging opportunity. Auditory masking or temporary hearing threshold effects may increase risk of predation due to decreased ability to sense predators.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable. Limit activities to in-water work windows where practicable.	May affect growth, fitness, and survival due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles; Adults	Eggs: Extended dewatering may lead to egg desiccation or thermal exposure, causing mortality, or larval abnormalities limiting to survival. Larvae and juveniles: Dewatering is likely to lead to mortality, as larval and juvenile herring will be difficult to capture and relocate effectively. Adults: Capture, handling, and relocation are likely to cause mortality, or injury and stress, leading to mortality or decreased spawning fitness.	Limit activities to in-water work windows where practicable.	Dewatering and fish removal in marine habitats is an unlikely requirement for intakes and diversion development. However, in the event that such activities are required, adverse effects on exposed life-history stages should be expected. Capture and removal of larvae and juveniles is impractical, meaning that these activities are likely to affect larval and juvenile survival. Capture and removal of adults is likely to affect survival and spawning productivity.

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae and juveniles: Pump entrainment is likely to cause mortality of drifting larvae. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles. Adults: Impingement is likely to cause adult mortality.	Adhere to in-water work windows; avoid use during spawning, incubation, and larval dispersal.	May cause injury and mortality of larvae, juveniles, and adults. Effects are less likely to occur if activities are conducted outside of spawning season.
		Altered current and circulation conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae	Larvae: Alteration of nearshore current and circulation patterns may cause larvae to be transported offshore or into habitats with increased predation risk and reduced foraging opportunity, limiting survival, growth, and fitness.	To the greatest extent practicable, limit alteration of current and circulation patterns to minimal area.	May affect larval survival, growth, and fitness.
		Bottom disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles; Adults	Larvae: Potential decreased larval foraging success due to turbidity exposure and substrate disturbance, leading to decreased growth and fitness. Adults and juveniles: Stress caused by avoidance behavior; decreased foraging success due to increased turbidity levels. Adults: Decreased availability of spawning substrate due to sedimentation effects on submerged aquatic vegetation. All life-history stages: See responses to related stressors under Water Quality Modification.	Adhere to in-water work windows; avoid activity during spawning, incubation, and larval dispersal.	The likely stressor is increased suspended solids. May affect larval growth and survival. May affect juvenile and adult survival. May affect adult spawning productivity.
		Localized alteration in invertebrate abundance	NA	NA	NA	NA	NA	NA	NA
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to in-water work windows.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Larvae; Juveniles; Adults	All life-history stages: Entrainment of larval herring during dredging is likely to cause mortality or injury, leading to decreased survival. See responses described for related stressors under Water Quality Modification.	Require review of available data and/or site surveys to determine if spawning adults or rearing larvae are likely to be present, and time activities to avoid stressor exposure. Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	Increased suspended solids and resuspension of contaminated sediments would be the likely stressors. Unlikely to affect survival of larvae and adults if activities are conducted during in-water work windows. Likely to affect survival at any life-history stage if exposure occurs. See effects for related stressors under Water Quality Modification.

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	All exposed life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Alteration in the aerial extent and composition of the submerged aquatic vegetation community resulting from these mechanisms may reduce available spawning habitat, leading to reduced spawning productivity. Egg incubation success may be affected by alteration in wave energy patterns. Alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment. Therefore, alteration of these parameters may affect foraging opportunities at the juvenile life-history stage, over time leading to decreased adult fitness, decreased survival, and decreased spawning productivity.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect egg and larval survival and larval fitness. Decreased larval fitness may affect survival and productivity during juvenile and adult life-history phases in offshore and open ocean environments, and may affect spawning productivity. Loss or alteration of suitable spawning habitat may affect spawning productivity.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Intakes and diversions in the marine environment can fragment nearshore rearing habitat, potentially forcing planktonic herring away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion. Adults: The physical footprint of intakes and diversions and their geomorphic effects on the middle and lower intertidal zone may eliminate or decrease the suitability of spawning habitat, potentially limiting the spawning productivity of affected populations.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval and juvenile survival, growth, and fitness. May affect adult survival, fitness, and spawning productivity.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Marine								

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Eggs	Eggs: The influence of marine riparian shading on herring incubation is likely limited due to the typical elevation of herring spawn in the upper subtidal zone. However, the effects of this stressor are currently a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Potential effects resulting from this impact mechanism are unknown.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Eggs; Larvae; Juveniles; Adults	Eggs: Smothering of incubating eggs or alteration of substrate composition may decrease egg survival. Larvae and juveniles: See responses to increased turbidity exposure described under Water Quality Modification. Adults: Potential reduction of suitable spawning habitat, leading to decreased spawning productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect egg survival. May affect growth and fitness at larval and juvenile life-history stages. May affect adult spawning fitness and productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	Eggs, larvae, and juveniles: See responses to increased turbidity exposure described under Water Quality Modification. Adults: Potential reduction of suitable spawning habitat, leading to decreased spawning productivity.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect egg survival. May affect productivity at larval and juvenile life-history stages. May affect adult spawning productivity.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Dependence on autochthonous inputs from marine riparian vegetation is a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Potential effects resulting from this impact mechanism on remaining life-history stages are unknown.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Larvae; Juveniles; Adults	All life-history stages: Altered habitat complexity is likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect larval, juvenile, and adult productivity. May affect adult spawning productivity.
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Eggs; Larvae; Juveniles;	All life-history stages: Altered habitat complexity is likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of	May affect productivity at larval, juvenile, and adult life-history stages.

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Adults	Adults: Reductions in available submerged aquatic vegetation or alteration of submerged aquatic vegetation community composition may limit spawning productivity.	aquatic vegetation during project construction.	
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Avoidance behavior and increased stress, leading to reduced growth and fitness.	Limit nutrient inputs. Other mechanism-specific measures as appropriate.	Decreased spawning habitat area. May affect larval, juvenile, and adult survival and productivity. Reduced adult fitness may affect spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	Eggs: Effects of suspended sediments on incubating herring eggs is currently a data gap. Larvae: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness. Adults and juveniles: Same effects as above, as well as increased stress and decreased foraging opportunity due to avoidance behavior.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bluff/bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival and productivity at egg, larval, juvenile, and adult life-history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	All life-history stages: Physiological responses to pH levels outside of optimal thresholds, causing direct mortality or injury leading to reduced fitness. Juveniles and adults: Avoidance behavior and increased stress, leading to reduced growth and fitness.	Limit nutrient inputs. Avoid curing of concrete or discharge of concrete leachate to surface waters.	May affect survival of eggs and larvae, juveniles, and adults.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All expose life history stages: Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Tide Gates									
	Construction and Maintenance Activities								

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Eggs; Larvae; Juveniles; Adults	Eggs and larvae: Noise of sufficient magnitude may cause direct mortality of eggs and larvae, or permanent injury leading to decreased survival and fitness. Adults and juveniles: Stressor response, dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Where possible, avoid stressor exposure during site-specific spawn timing, incubation, and larval dispersal. Require review of available data and/or site surveys to determine if spawning adults or rearing larvae are likely to be present, and time activities to avoid stressor exposure. If pile driving is necessary during spawning period, use double-confined bubble curtain to attenuate sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	May affect survival during egg, larval, juvenile, and adult life-history stages.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: May cause avoidance behavior leading to increased stress and decreased foraging opportunity. Auditory masking or temporary hearing threshold effects may increase risk of predation due to decreased ability to sense predators.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable. Limit activities to in-water work windows where practicable.	May affect growth, fitness, and survival due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles; Adults	Eggs: Extended dewatering may lead to egg desiccation or thermal exposure, causing mortality, or larval abnormalities limiting to survival. Larvae and juveniles: Dewatering is likely to lead to mortality, as larval and juvenile herring will be difficult to capture and relocate effectively. Adults: Capture, handling, and relocation are likely to cause mortality, or injury and stress, leading to mortality or decreased spawning fitness.	Limit activities to in-water work windows where practicable.	Dewatering and fish removal in marine habitats is an unlikely requirement for tide gates development. However, in the event that such activities are required, adverse effects on exposed life-history stages should be expected. Capture and removal of larvae and juveniles is impractical, meaning that these activities are likely to affect larval and juvenile survival. Capture and removal of adults is likely to affect survival and spawning productivity.

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	Larvae and juveniles: Pump entrainment is likely to cause mortality of drifting larvae. This effect cannot be avoided by pump screening. Entrainment and impingement are likely to cause mortality of juveniles. Adults: Impingement is likely to cause adult mortality.	Adhere to in-water work windows; avoid use during spawning, incubation, and larval dispersal.	May cause injury and mortality of larvae, juveniles, and adults. Effects are less likely to occur if activities are conducted outside of spawning season.
		Altered current and circulation conditions (marine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae	Larvae: Alteration of nearshore current and circulation patterns may cause larvae to be transported offshore or into habitats with increased predation risk and reduced foraging opportunity, limiting survival, growth, and fitness.	To the greatest extent practicable, limit alteration of current and circulation patterns to minimal area.	May affect larval survival, growth, and fitness.
		Bottom disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles; Adults	Larvae: Potential decreased larval foraging success due to turbidity exposure and substrate disturbance, leading to decreased growth and fitness. Adults and juveniles: Stress caused by avoidance behavior; decreased foraging success due to increased turbidity levels. Adults: Decreased availability of spawning substrate due to sedimentation effects on submerged aquatic vegetation. All life-history stages: See responses to related stressors under Water Quality Modification.	Adhere to in-water work windows; avoid activity during spawning, incubation, and larval dispersal.	The likely stressor is increased suspended solids. May affect larval growth and survival. May affect juvenile and adult survival. May affect adult spawning productivity.
		Localized alteration in invertebrate abundance	NA	NA	NA	NA	NA	NA	NA
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering. Adhere to in-water work windows.	See effects for related stressors under Water Quality Modification.
		Loss of habitat, stranding from dewatering (during construction, maintenance, and removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success due to water loss and stranding. Juveniles: Barrier to migration, loss of habitat accessibility, stranding, reduced foraging opportunities, mortality and increased predation risk. Adults: reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Eggs; Larvae; Juveniles; Adults	All life-history stages: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Larvae; Juveniles; Adults	All life-history stages: Entrainment of larval herring during dredging is likely to cause mortality or injury, leading to decreased survival. See responses described for related stressors under Water Quality Modification.	Require review of available data and/or site surveys to determine if spawning adults or rearing larvae are likely to be present, and time activities to avoid stressor exposure. Limit dredging-related turbidity to the greatest extent practicable. Adhere to system-specific in-water work windows.	Increased suspended solids and resuspension of contaminated sediments would be the likely stressors. Unlikely to affect survival of larvae and adults if activities are conducted during in-water work windows. Likely to affect survival at any life-history stage if exposure occurs. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	All exposed life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats. Alteration in the aerial extent and composition of the submerged aquatic vegetation community resulting from these mechanisms may reduce available spawning habitat, leading to reduced spawning productivity. Egg incubation success may be affected by alteration in wave energy patterns. Alteration of current velocities and circulation patterns may cause transportation of planktonic larvae to unfavorable habitats for growth and development. Alteration of nearshore habitat productivity may also have concomitant effects on food web relationships in the offshore environment. Therefore, alteration of these parameters may affect foraging opportunities at the juvenile life-history stage, over time leading to decreased adult fitness, decreased survival, and decreased spawning productivity.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect egg and larval survival and larval fitness. Decreased larval fitness may affect survival and productivity during juvenile and adult life-history phases in offshore and open ocean environments, and may affect spawning productivity. Loss or alteration of suitable spawning habitat may affect spawning productivity.
	Altered current velocities and tidal exchange		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered channel geometry		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles; Adults	<u>Larvae and juveniles</u>: Tide gates in the marine environment can fragment nearshore rearing habitat, potentially forcing planktonic herring away from nearshore habitats. This stressor may increase exposure to predation, as well as stress and exertion. <u>Adults</u>: The physical footprint of tide gates and their geomorphic effects on the middle and lower intertidal zone may eliminate or decrease the suitability of spawning habitat, potentially limiting the spawning productivity of affected populations.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval and juvenile survival, growth, and fitness. May affect adult survival, fitness, and spawning productivity.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tidegates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid disturbance of vegetation along shoreline.	
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Eggs; Larvae; Juveniles; Adults	All life-history stages: Altered habitat complexity is likely to affect food web dynamics and available foraging opportunities, potentially resulting in decreased growth and fitness. Adults: Reductions in available submerged aquatic vegetation or alteration of submerged aquatic vegetation community composition may limit spawning productivity.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect productivity at larval, juvenile, and adult life-history stages.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Avoidance behavior and increased stress, leading to reduced growth and fitness.	Limit nutrient inputs. Other mechanism-specific measures as appropriate.	Decreased spawning habitat area. May affect larval, juvenile, and adult survival and productivity. Reduced adult fitness may affect spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	Eggs: Effects of suspended sediments on incubating herring eggs is currently a data gap. Larvae: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may decrease foraging success, resulting in decreased growth and fitness. Adults and juveniles: Same effects as above, as well as increased stress and decreased foraging opportunity due to avoidance behavior.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bluff/bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival and productivity at egg, larval, juvenile, and adult life-history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	All life-history stages: Physiological responses to pH levels outside of optimal thresholds, causing direct mortality or injury leading to reduced fitness. Juveniles and adults: Avoidance behavior and increased stress, leading to reduced growth and fitness.	Limit nutrient inputs. Avoid curing of concrete or discharge of concrete leachate to surface waters.	May affect survival of eggs and larvae, juveniles, and adults.

Table A-17 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Herring.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered salinity	Year-round	Long-term to permanent	Intermittent (daily)	Juveniles	Juveniles: Altered salinity patterns may limit habitat suitability for juvenile rearing in nearshore marine environments. This in turn may increase competition for available habitats, limiting survival, growth, and fitness.	Limit closure time of tide gate to maximize natural tidal exchange.	May affect juvenile survival, growth, and fitness.
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Juveniles	Tide gate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent. Exposure to toxic substances may lead to behavioral avoidance in adults. For juveniles, limitations in the availability of suitable juvenile rearing habitat or potential physiological injury may affect survival, growth, and fitness.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect adult behavior. May affect juvenile survival, growth, and fitness.

Table A-18. HPA HCP Flow Control Structures Exposure and Response Matrix for Lingcod.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered ambient noise levels	NA	NA	NA	NA	NA	NA	
		Bank/shoreline/channel disturbance, resulting in increased sediments	NA	NA	NA	NA	NA	NA	
		Exposure to toxic chemicals from accidental spills	NA	NA	NA	NA	NA	NA	
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	NA	NA	NA	NA	NA	NA	
		Aquatic vegetation removal and delayed recovery	NA	NA	NA	NA	NA	NA	
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	NA	NA	NA	NA	NA	NA	
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered sediment transport	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability as a result of beach erosion from altered sediment supply.	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered substrate composition		NA	NA	NA				
	Ecosystem Fragmentation								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	NA	NA	NA	NA	NA	NA	
	Riparian Vegetation Modification								
	Marine								

Table A-18 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Lingcod.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	NA	NA	NA	NA	NA	NA	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA	NA	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA		
	Water Quality Modification								

Table A-18 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Lingcod.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Increased sediment contamination	NA	NA	NA	NA	NA	NA	
		Altered pH levels	NA	NA	NA	NA	NA	NA	
		Altered nutrient cycling	NA	NA	NA	NA	NA	NA	
		Introduction of toxic substances	NA	NA	NA	NA	NA	NA	
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	NA	NA	NA	NA	▪ NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered ambient noise levels	NA	NA	NA	NA	NA	NA	
		Bank/shoreline/channel disturbance, resulting in increased sediments	NA	NA	NA	NA	NA	NA	
		Exposure to toxic chemicals from accidental spills	NA	NA	NA	NA	NA	NA	
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	NA	NA	NA	NA	NA	NA	
		Aquatic vegetation removal and delayed recovery	NA	NA	NA	NA	NA	NA	
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	NA	NA	NA	NA	NA	NA	
	Hydraulic and Geomorphic Modification								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is

Table A-18 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Lingcod.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered flow regime	rearing habitat availability and suitability	NA	NA	NA				no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered substrate composition and stability		NA	NA	NA				
	Altered groundwater–surface water exchange		NA	NA	NA				
	Ecosystem Fragmentation								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	NA	NA	NA	NA	NA	NA	
	Riparian Vegetation Modification								
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	NA	NA	NA	NA	NA	NA	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA	NA	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Aquatic Vegetation Modification								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.

Table A-18 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Lingcod.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA		
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Increased sediment contamination	NA	NA	NA	NA	NA	NA	
		Altered pH levels	NA	NA	NA	NA	NA	NA	
		Altered nutrient cycling	NA	NA	NA	NA	NA	NA	
		Introduction of toxic substances	NA	NA	NA	NA	NA	NA	
Dikes/Levees									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Juveniles and adults: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may cause direct mortality or otherwise affect survival, growth, and fitness at all life-history stages, depending on project-specific noise intensity and receptor exposure.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk. Actual effects are unknown as stressor sensitivity is currently a data gap.

Table A-18 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Lingcod.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	Adults and juveniles: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described above under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Juveniles; Adults	Juveniles: Post-settlement, juveniles may suffer injury or mortality as they are insufficiently mobile to avoid entrainment. Juveniles may experience temporary decrease in foraging opportunity due to short-term reduction in prey availability leading to decreased growth and fitness. All exposed life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury to juveniles. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval lingcod settlement in nearshore areas favorable for rearing, as well as the overall suitability of rearing habitat for juveniles. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at larval and juvenile life-history stages.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								

Table A-18 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Lingcod.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Dikes and levees in the marine environment can fragment nearshore rearing habitat, potentially affecting settlement of larval lingcod. May increase nearshore habitat suitability for juvenile lingcod by providing interstitial cover; however, the resulting potential effects on lingcod populations are a data gap. Adults: Dikes and levees in the marine environment may create three-dimensional habitat suitable for adult lingcod in the nearshore environment, encouraging occupation. The resulting potential effects on lingcod populations are a data gap.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval survival. Potential effects on juvenile and adult lingcod are a data gap.
	Riparian Vegetation Modification								
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and productivity. Currently a data gap.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival. Currently a data gap.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Lingcod dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, juveniles are known to use shallow vegetated habitats and pocket estuaries which contain food sources that depend on marine riparian allochthonous input. Decreased food web productivity may result in reduced foraging opportunities.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival, growth, and fitness.

Table A-18 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Lingcod.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Juvenile lingcod are known to selectively settle and rear in areas with reduced salinities; therefore, groundwater inflow may provide increased habitat suitability. Reduction in suitable habitat area may affect survival, growth, and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness of juveniles.
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival. May affect adult growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events. (Egg exposure may occur in rare circumstances if nests are located close to shore.) Juveniles and adults: Avoidance behavior or asphyxiation during acute events.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs and larvae. May affect juvenile and adult survival. May cause temporary avoidance behavior, potentially leading to decreased growth and fitness.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Increased suspended solids in microlayer habitat may lead to direct mortality and decreased survival of eggs and larvae. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival, growth, and fitness at larval, juvenile, and adult life-history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All expose life history stages: Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.

Table A-18 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Lingcod.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Outfalls									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Juveniles and adults: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may cause direct mortality or otherwise affect survival, growth, and fitness at all life-history stages, depending on project-specific noise intensity and receptor exposure.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk. Actual effects are unknown as stressor sensitivity is currently a data gap.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	Adults and juveniles: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described above under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.

Table A-18 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Lingcod.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Juveniles; Adults	Juveniles: Post-settlement, juveniles may suffer injury or mortality as they are insufficiently mobile to avoid entrainment. Juveniles may experience temporary decrease in foraging opportunity due to short-term reduction in prey availability leading to decreased growth and fitness. All exposed life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury to juveniles. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval lingcod settlement in nearshore areas favorable for rearing, as well as the overall suitability of rearing habitat for juveniles. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at larval and juvenile life-history stages.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Outfalls in the marine environment can fragment nearshore rearing habitat, potentially affecting settlement of larval lingcod. May increase nearshore habitat suitability for juvenile lingcod by providing interstitial cover; however, the resulting potential effects on lingcod populations are a data gap. Adults: Outfalls in the marine environment may create three-dimensional habitat suitable for adult lingcod in the nearshore environment, encouraging occupation. The resulting potential effects on lingcod populations are a data gap.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval survival. Potential effects on juvenile and adult lingcod are a data gap.
	Riparian Vegetation Modification								
	Marine								

Table A-18 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Lingcod.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and productivity. Currently a data gap.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival. Currently a data gap.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Lingcod dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, juveniles are known to use shallow vegetated habitats and pocket estuaries which contain food sources that depend on marine riparian allochthonous input. Decreased food web productivity may result in reduced foraging opportunities.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival, growth, and fitness.
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival. May affect adult growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								

Table A-18 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Lingcod.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events. (Egg exposure may occur in rare circumstances if nests are located close to shore.) Juveniles and adults: Avoidance behavior or asphyxiation during acute events.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs and larvae. May affect juvenile and adult survival. May cause temporary avoidance behavior, potentially leading to decreased growth and fitness.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Increased suspended solids in microlayer habitat may lead to direct mortality and decreased survival of eggs and larvae. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival, growth, and fitness at larval, juvenile, and adult life-history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	All life-history stages: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. Adult and juvenile avoidance behavior at subacute exposure levels.	Limit nutrient inputs. Prevent in-water curing of concrete and discharge of concrete leachate to surface waters.	Acute exposure may cause mortality at all exposed life-history stages. Juveniles and adults avoidance behavior at subacute exposure levels.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								

Table A-18 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Lingcod.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Juveniles and adults: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may cause direct mortality or otherwise affect survival, growth, and fitness at all life-history stages, depending on project-specific noise intensity and receptor exposure.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk. Actual effects are unknown as stressor sensitivity is currently a data gap.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	Adults and juveniles: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described above under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Juveniles; Adults	Juveniles: Post-settlement, juveniles may suffer injury or mortality as they are insufficiently mobile to avoid entrainment. Juveniles may experience temporary decrease in foraging opportunity due to short-term reduction in prey availability leading to decreased growth and fitness. All exposed life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury to juveniles. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Marine								

Table A-18 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Lingcod.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval lingcod settlement in nearshore areas favorable for rearing, as well as the overall suitability of rearing habitat for juveniles. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at larval and juvenile life-history stages.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Intakes and diversions in the marine environment can fragment nearshore rearing habitat, potentially affecting settlement of larval lingcod. May increase nearshore habitat suitability for juvenile lingcod by providing interstitial cover; however, the resulting potential effects on lingcod populations are a data gap. Adults: Intakes and diversions in the marine environment may create three-dimensional habitat suitable for adult lingcod in the nearshore environment, encouraging occupation. The resulting potential effects on lingcod populations are a data gap.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval survival. Potential effects on juvenile and adult lingcod are a data gap.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Marine								

Table A-18 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Lingcod.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and productivity. Currently a data gap.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival. Currently a data gap.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Lingcod dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, juveniles are known to use shallow vegetated habitats and pocket estuaries which contain food sources that depend on marine riparian allochthonous input. Decreased food web productivity may result in reduced foraging opportunities.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival, growth, and fitness.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Juvenile lingcod are known to selectively settle and rear in areas with reduced salinities; therefore, groundwater inflow may provide increased habitat suitability. Reduction in suitable habitat area may affect survival, growth, and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness of juveniles.
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. Juveniles: Decreased refuge habitat availability	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of	May affect juvenile survival. May affect adult growth and fitness.

Table A-18 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Lingcod.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous		and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.	aquatic vegetation during project construction.	
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events. (Egg exposure may occur in rare circumstances if nests are located close to shore.) Juveniles and adults: Avoidance behavior or asphyxiation during acute events.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs and larvae. May affect juvenile and adult survival. May cause temporary avoidance behavior, potentially leading to decreased growth and fitness.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Increased suspended solids in microlayer habitat may lead to direct mortality and decreased survival of eggs and larvae. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival, growth, and fitness at larval, juvenile, and adult life-history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	All life-history stages: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. Adult and juvenile avoidance behavior at subacute exposure levels.	Limit nutrient inputs Prevent in-water curing of concrete and discharge of concrete leachate to surface waters.	Acute exposure may cause mortality at all exposed life-history stages. Juveniles and adults avoidance behavior at subacute exposure levels.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All expose life history stages: Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Tide Gates									
	Construction and Maintenance Activities								

Table A-18 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Lingcod.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Juveniles and adults</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may cause direct mortality or otherwise affect survival, growth, and fitness at all life-history stages, depending on project-specific noise intensity and receptor exposure.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Adults and juveniles</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival and productivity due to avoidance behavior, decreased foraging success, and increased predation risk. Actual effects are unknown as stressor sensitivity is currently a data gap.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
		Loss of habitat, stranding from dewatering (during construction, maintenance, and removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	<u>Eggs and larvae</u>: Potential decreased egg incubation success due to water loss and stranding. <u>Juveniles</u>: loss of habitat accessibility, stranding, , reduced foraging opportunities, mortality and increased predation risk. <u>Adults</u>: reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	<u>Adults and juveniles</u>: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	<u>Juveniles and adults</u>: See responses described above under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.

Table A-18 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Lingcod.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Juveniles; Adults	Juveniles: Post-settlement, juveniles may suffer injury or mortality as they are insufficiently mobile to avoid entrainment. Juveniles may experience temporary decrease in foraging opportunity due to short-term reduction in prey availability leading to decreased growth and fitness. All exposed life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality or injury to juveniles. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval lingcod settlement in nearshore areas favorable for rearing, as well as the overall suitability of rearing habitat for juveniles. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at larval and juvenile life-history stages.
	Altered current velocities and tidal exchange		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered channel geometry		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Tide gates in the marine environment can fragment nearshore rearing habitat, potentially affecting settlement of larval lingcod. May increase nearshore habitat suitability for juvenile lingcod by providing interstitial cover; however, the resulting potential effects on lingcod populations are a data gap. Adults: Tide gates in the marine environment may create three-dimensional habitat suitable for adult lingcod in the nearshore environment, encouraging occupation. The resulting potential effects on lingcod populations are a data gap.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval survival. Potential effects on juvenile and adult lingcod are a data gap.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.

Table A-18 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Lingcod.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The effects of tide gates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tide gates is considered to be a component of the effects of dikes and levees. The incremental effects of the tide gate are negligible in comparison.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid disturbance of vegetation along shoreline.	
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. Adults: Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival. May affect adult growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				

Table A-18 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Lingcod.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events. (Egg exposure may occur in rare circumstances if nests are located close to shore.) Juveniles and adults: Avoidance behavior or asphyxiation during acute events.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating eggs and larvae. May affect juvenile and adult survival. May cause temporary avoidance behavior, potentially leading to decreased growth and fitness.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Increased suspended solids in microlayer habitat may lead to direct mortality and decreased survival of eggs and larvae. Juveniles and adults: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior. Adults: Reduction in suitable spawning habitat (due to substrate embeddedness) and reduced spawning success.	Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival, growth, and fitness at larval, juvenile, and adult life-history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs; Larvae; Juveniles; Adults	All life-history stages: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness. Adult and juvenile avoidance behavior at subacute exposure levels.	Limit nutrient inputs. Prevent in-water curing of concrete and discharge of concrete leachate to surface waters.	Acute exposure may cause mortality at all exposed life-history stages. Juveniles and adults avoidance behavior at subacute exposure levels.
		Altered salinity	Year-round	Long-term to permanent	Intermittent (daily)	Juveniles	Juveniles: Altered salinity patterns may limit habitat suitability for juvenile rearing in nearshore marine environments. This in turn may increase competition for available habitats, limiting survival, growth, and fitness.	Limit closure time of tide gate to maximize natural tidal exchange.	May affect juvenile survival, growth, and fitness.
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Juveniles	Tide gate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent. Exposure to toxic substances may lead to behavioral avoidance in adults. For juveniles, limitations in the availability of suitable juvenile rearing habitat, or potential physiological injury may affect survival, growth, and fitness.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect adult behavior. May affect juvenile survival, growth, and fitness.

Table A-19. HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Cod, Hake, and Walleye Pollock.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered ambient noise levels	NA	NA	NA	NA	NA	NA	
		Bank/shoreline/channel disturbance, resulting in increased sediments	NA	NA	NA	NA	NA	NA	
		Exposure to toxic chemicals from accidental spills	NA	NA	NA	NA	NA	NA	
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	NA	NA	NA	NA	NA	NA	
		Aquatic vegetation removal and delayed recovery	NA	NA	NA	NA	NA	NA	
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	NA	NA	NA	NA	NA	NA	
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered sediment transport Altered substrate composition	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability as a result of beach erosion from altered sediment supply.	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Ecosystem Fragmentation								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	NA	NA	NA	NA	NA	NA	
	Riparian Vegetation Modification								
	Marine								

Table A-19 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Cod, Hake, and Walleye Pollock.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	NA	NA	NA	NA	NA	NA	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA	NA	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA		
	Water Quality Modification								

Table A-19 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Cod, Hake, and Walleye Pollock.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Increased sediment contamination	NA	NA	NA	NA	NA	NA	
		Altered pH levels	NA	NA	NA	NA	NA	NA	
		Altered nutrient cycling	NA	NA	NA	NA	NA	NA	
		Introduction of toxic substances	NA	NA	NA	NA	NA	NA	
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	NA	NA	NA	NA	▪ NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered ambient noise levels	NA	NA	NA	NA	NA	NA	
		Bank/shoreline/channel disturbance, resulting in increased sediments	NA	NA	NA	NA	NA	NA	
		Exposure to toxic chemicals from accidental spills	NA	NA	NA	NA	NA	NA	
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	NA	NA	NA	NA	NA	NA	
		Aquatic vegetation removal and delayed recovery	NA	NA	NA	NA	NA	NA	
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	NA	NA	NA	NA	NA	NA	
	Hydraulic and Geomorphic Modification								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is

Table A-19 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Cod, Hake, and Walleye Pollock.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered flow regime	rearing habitat availability and suitability	NA	NA	NA				no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered substrate composition and stability		NA	NA	NA				
	Altered groundwater–surface water exchange		NA	NA	NA				
	Ecosystem Fragmentation								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	NA	NA	NA	NA	NA	NA	
	Riparian Vegetation Modification								
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	NA	NA	NA	NA	NA	NA	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA	NA	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Aquatic Vegetation Modification								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.

Table A-19 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Cod, Hake, and Walleye Pollock.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA		
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Increased sediment contamination	NA	NA	NA	NA	NA	NA	
		Altered pH levels	NA	NA	NA	NA	NA	NA	
		Altered nutrient cycling	NA	NA	NA	NA	NA	NA	
		Introduction of toxic substances	NA	NA	NA	NA	NA	NA	
Dikes/Levees									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Larvae; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Barotraumas causing fatal injury or permanent auditory tissue damage in larvae, juveniles, and adults limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by these species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may cause direct mortality or otherwise affect survival, growth, and fitness and at all life-history stages, depending on project-specific noise intensity and receptor exposure.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.

Table A-19 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Cod, Hake, and Walleye Pollock.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Larvae; Juveniles	Juveniles: Post-settlement juveniles may suffer injury or mortality as they are insufficiently mobile to avoid entrainment. Juveniles may experience temporary decrease in foraging opportunity due to short-term reduction in prey availability leading to decreased growth and fitness. All exposed life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality of juveniles. May affect juvenile survival, growth, and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval settlement in nearshore areas favorable for rearing, as well as the overall suitability of juvenile rearing habitat. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at larval and juvenile life-history stages.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Dikes and levees in the marine environment can fragment nearshore rearing habitat, potentially affecting settlement of larval cod, pollock, and hake. Physical footprint of structures may eliminate suitable rearing habitat or decrease habitat suitability, potentially affecting larval survival, growth, and fitness	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval survival, growth, and fitness.
	Riparian Vegetation Modification								
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and productivity. Currently a data gap.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Pacific cod, hake and walleye pollock dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, juvenile Pacific cod, hake, and walleye pollock are known to use shallow vegetated habitats that could have marine riparian allochthonous input. Decreased food web productivity may result in reduced foraging opportunities.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival, growth, and fitness.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Pacific cod, hake, and walleye pollock dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Effects of action are unknown as receptor sensitivity to this stressor is currently a data gap.
	Aquatic Vegetation Modification								

Table A-19 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Cod, Hake, and Walleye Pollock.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Larvae; Juveniles	Larvae: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events. Juveniles: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Avoidance behavior leading to increased competition, predation exposure, and decreased foraging opportunity.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May cause direct mortality of larvae and juveniles. May affect juvenile survival, growth, and fitness.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Larvae; Juveniles	Larvae: Increased suspended solids in microlayer habitat may lead to direct mortality and decreased larval survival. Juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior.	Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival, growth, and fitness at larval and juvenile life-history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All expose life history stages: Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Outfalls									
	Construction and Maintenance Activities								

Table A-19 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Cod, Hake, and Walleye Pollock.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Larvae; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Barotraumas causing fatal injury or permanent auditory tissue damage in larvae, juveniles, and adults limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by these species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may cause direct mortality or otherwise affect survival, growth, and fitness and at all life-history stages, depending on project-specific noise intensity and receptor exposure.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Larvae; Juveniles	Juveniles: Post-settlement juveniles may suffer injury or mortality as they are insufficiently mobile to avoid entrainment. Juveniles may experience temporary decrease in foraging opportunity due to short-term reduction in prey availability leading to decreased growth and fitness. All exposed life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality of juveniles. May affect juvenile survival, growth, and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Marine								

Table A-19 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Cod, Hake, and Walleye Pollock.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval settlement in nearshore areas favorable for rearing, as well as the overall suitability of juvenile rearing habitat. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at larval and juvenile life-history stages.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Outfalls in the marine environment can fragment nearshore rearing habitat, potentially affecting settlement of larval cod, pollock, and hake. Physical footprint of structures may eliminate suitable rearing habitat or decrease habitat suitability, potentially affecting larval survival, growth, and fitness	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval survival, growth, and fitness.
	Riparian Vegetation Modification								
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and productivity. Currently a data gap.

Table A-19 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Cod, Hake, and Walleye Pollock.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Pacific cod, hake and walleye pollock dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, juvenile Pacific cod, hake, and walleye pollock are known to use shallow vegetated habitats that could have marine riparian allochthonous input. Decreased food web productivity may result in reduced foraging opportunities.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival, growth, and fitness.
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Larvae; Juveniles	Larvae: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events. Juveniles: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Avoidance behavior leading to increased competition, predation exposure, and decreased foraging opportunity.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May cause direct mortality of larvae and juveniles. May affect juvenile survival, growth, and fitness.

Table A-19 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Cod, Hake, and Walleye Pollock.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Larvae; Juveniles	Larvae: Increased suspended solids in microlayer habitat may lead to direct mortality and decreased larval survival. Juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior.	Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival, growth, and fitness at larval and juvenile life-history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Larvae; Juveniles	Larvae and juveniles: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Prevent in-water curing of concrete and discharge of concrete leachate to surface waters.	Acute exposure may cause mortality at all exposed life-history stages. Juvenile and adult avoidance behavior at subacute exposure levels.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Eggs and larvae; Juveniles; Adults	All exposed life history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Larvae; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Barotraumas causing fatal injury or permanent auditory tissue damage in larvae, juveniles, and adults limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by these species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may cause direct mortality or otherwise affect survival, growth, and fitness and at all life-history stages, depending on project-specific noise intensity and receptor exposure.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.

Table A-19 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Cod, Hake, and Walleye Pollock.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Larvae; Juveniles	Juveniles: Post-settlement juveniles may suffer injury or mortality as they are insufficiently mobile to avoid entrainment. Juveniles may experience temporary decrease in foraging opportunity due to short-term reduction in prey availability leading to decreased growth and fitness. All exposed life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality of juveniles. May affect juvenile survival, growth, and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval settlement in nearshore areas favorable for rearing, as well as the overall suitability of juvenile rearing habitat. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at larval and juvenile life-history stages.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								

Table A-19 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Cod, Hake, and Walleye Pollock.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Intakes and diversions in the marine environment can fragment nearshore rearing habitat, potentially affecting settlement of larval cod, pollock, and hake. Physical footprint of structures may eliminate suitable rearing habitat or decrease habitat suitability, potentially affecting larval survival, growth, and fitness	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval survival, growth, and fitness.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles.	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and productivity. Currently a data gap.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival and productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Pacific cod, hake and walleye pollock dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, juvenile Pacific cod, hake, and walleye pollock are known to use shallow vegetated habitats that could have marine riparian allochthonous input. Decreased food web productivity may result in reduced foraging opportunities.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile, growth, and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival, growth, and fitness.

Table A-19 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Cod, Hake, and Walleye Pollock.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Pacific cod, hake, and walleye pollock dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Effects of action are unknown as receptor sensitivity to this stressor is currently a data gap.
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous		Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness.		
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Larvae; Juveniles	Larvae: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events. Juveniles: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Avoidance behavior leading to increased competition, predation exposure, and decreased foraging opportunity.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May cause direct mortality of larvae and juveniles. May affect juvenile survival, growth, and fitness.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Larvae; Juveniles	Larvae: Increased suspended solids in microlayer habitat may lead to direct mortality and decreased larval survival. Juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior.	Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival, growth, and fitness at larval and juvenile life-history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Larvae; Juveniles	Larvae and juveniles: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Prevent in-water curing of concrete and discharge of concrete leachate to surface waters.	Acute exposure may cause mortality at all exposed life-history stages. Juvenile and adult avoidance behavior at subacute exposure levels.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Eggs and larvae; Juveniles; Adults	All expose life history stages: Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.

Table A-19 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Cod, Hake, and Walleye Pollock.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Tide Gates									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Larvae; Juveniles; Adults	All life-history stages: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Barotraumas causing fatal injury or permanent auditory tissue damage in larvae, juveniles, and adults limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by these species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may cause direct mortality or otherwise affect survival, growth, and fitness and at all life-history stages, depending on project-specific noise intensity and receptor exposure.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Adults and juveniles: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect survival, growth, and fitness due to avoidance behavior, decreased foraging success, and increased predation risk.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
		Loss of habitat, stranding from dewatering (during construction, maintenance, and removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Eggs and larvae; Juveniles; Adults	Eggs and larvae: Potential decreased egg incubation success survival due to water loss and stranding. Juveniles: Barrier to migration (hake), loss of habitat accessibility, stranding, migration delay (hake), reduced foraging opportunities, mortality and increased predation risk. Adults: Potential migration barrier and delay (hake), leading to reduced spawning productivity, foraging success, mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages, adult spawning fitness and productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.

Table A-19 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Cod, Hake, and Walleye Pollock.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Larvae; Juveniles	Juveniles: Post-settlement juveniles may suffer injury or mortality as they are insufficiently mobile to avoid entrainment. Juveniles may experience temporary decrease in foraging opportunity due to short-term reduction in prey availability leading to decreased growth and fitness. All exposed life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May cause direct mortality of juveniles. May affect juvenile survival, growth, and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval settlement in nearshore areas favorable for rearing, as well as the overall suitability of juvenile rearing habitat. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at larval and juvenile life-history stages.
	Altered current velocities and tidal exchange		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered channel geometry		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Tide gates in the marine environment can fragment nearshore rearing habitat, potentially affecting settlement of larval cod, pollock, and hake. Physical footprint of structures may eliminate suitable rearing habitat or decrease habitat suitability, potentially affecting larval survival, growth, and fitness	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval survival, growth, and fitness.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles.	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Marine								

Table A-19 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Cod, Hake, and Walleye Pollock.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tidegates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid disturbance of vegetation along shoreline.	
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								

Table A-19 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Pacific Cod, Hake, and Walleye Pollock.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Larvae; Juveniles	Larvae: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events. Juveniles: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Avoidance behavior leading to increased competition, predation exposure, and decreased foraging opportunity.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May cause direct mortality of larvae and juveniles. May affect juvenile survival, growth, and fitness.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Larvae; Juveniles	Larvae: Increased suspended solids in microlayer habitat may lead to direct mortality and decreased larval survival. Juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior.	Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival, growth, and fitness at larval and juvenile life-history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Larvae; Juveniles	Larvae and juveniles: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Prevent in-water curing of concrete and discharge of concrete leachate to surface waters.	Acute exposure may cause mortality at all exposed life-history stages. Juvenile and adult avoidance behavior at subacute exposure levels.
		Altered salinity	Year-round	Long-term to permanent	Intermittent (daily)	Juveniles	Juveniles: Altered salinity patterns may limit habitat suitability for juvenile rearing in nearshore marine environments. This in turn may increase competition for available habitats, limiting survival, growth, and fitness.	Limit closure time of tide gate to maximize natural tidal exchange.	May affect juvenile survival, growth, and fitness.
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Juveniles	Tide gate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent. Exposure to toxic substances may lead to behavioral avoidance in adults. For juveniles, limitations in the availability of suitable juvenile rearing habitat, or potential physiological injury may affect survival, growth, and fitness.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect adult behavior. May affect juvenile survival, growth, and fitness.

Table A-20. HPA HCP Flow Control Structures Exposure and Response Matrix for Group 20—Rockfish Species.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered ambient noise levels	NA	NA	NA	NA	NA	NA	
		Bank/shoreline/channel disturbance, resulting in increased sediments	NA	NA	NA	NA	NA	NA	
		Exposure to toxic chemicals from accidental spills	NA	NA	NA	NA	NA	NA	
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	NA	NA	NA	NA	NA	NA	
		Aquatic vegetation removal and delayed recovery	NA	NA	NA	NA	NA	NA	
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	NA	NA	NA	NA	NA	NA	
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered sediment transport	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability as a result of beach erosion from altered sediment supply.	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered substrate composition		NA	NA	NA				
	Ecosystem Fragmentation								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification				NA	NA	NA	
	Riparian Vegetation Modification								

Table A-20 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Group 20—Rockfish Species.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	NA	NA	NA	NA	NA	NA	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA	NA	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA		
	Water Quality Modification								

Table A-20 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Group 20—Rockfish Species.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Increased sediment contamination	NA	NA	NA	NA	NA	NA	
		Altered pH levels	NA	NA	NA	NA	NA	NA	
		Altered nutrient cycling	NA	NA	NA	NA	NA	NA	
		Introduction of toxic substances	NA	NA	NA	NA	NA	NA	
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered ambient noise levels	NA	NA	NA	NA	NA	NA	
		Bank/shoreline/channel disturbance, resulting in increased sediments	NA	NA	NA	NA	NA	NA	
		Exposure to toxic chemicals from accidental spills	NA	NA	NA	NA	NA	NA	
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	NA	NA	NA	NA	NA	NA	
		Aquatic vegetation removal and delayed recovery	NA	NA	NA	NA	NA	NA	
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	NA	NA	NA	NA	NA	NA	
	Hydraulic and Geomorphic Modification								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related
	Altered flow regime		NA	NA	NA				

Table A-20 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Group 20—Rockfish Species.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered substrate composition and stability	suitability	NA	NA	NA				impact mechanisms and related stressors.
	Altered groundwater–surface water exchange		NA	NA	NA				
	Ecosystem Fragmentation								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	NA	NA	NA	NA	NA	NA	
	Riparian Vegetation Modification								
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	NA	NA	NA	NA	NA	NA	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA	NA	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Aquatic Vegetation Modification								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA		

Table A-20 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Group 20—Rockfish Species.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Increased sediment contamination	NA	NA	NA	NA	NA	NA	
		Altered pH levels	NA	NA	NA	NA	NA	NA	
		Altered nutrient cycling	NA	NA	NA	NA	NA	NA	
		Introduction of toxic substances	NA	NA	NA	NA	NA	NA	
Dikes/Levees									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Juveniles and adults</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by these species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may cause direct mortality or injury affecting juvenile and adult survival, depending on project-specific noise intensity and receptor exposure.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Juveniles and adults</u>: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. However, rockfish sensitivity to this stressor is currently a data gap.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect juvenile and adult survival due to avoidance behavior, decreased foraging success, and increased predation risk. Actual effects are unknown as stressor sensitivity is a data gap.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.

Table A-20 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Group 20—Rockfish Species.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Juveniles; Adults	Juveniles: Direct mortality or injury from entrainment. Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness. Adults : See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects background levels.	May cause direct mortality or injury to juveniles. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval rockfish settlement in nearshore areas favorable for rearing, as well as the overall suitability of rearing habitat. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at larval and juvenile life-history stages.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								

Table A-20 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Group 20—Rockfish Species.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Dikes and levees in the marine environment can fragment nearshore rearing habitat, potentially affecting settlement of larval rockfish. May increase nearshore habitat suitability for juvenile rockfish, however the resulting potential effects on rockfish populations are a data gap. Adults: Dikes and levees in the marine environment may create three dimensional habitat suitable for adult rockfish in the nearshore environment, encouraging occupation. The resulting potential effects on rockfish populations are a data gap.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval survival. Potential effects on juvenile and adult rockfish are a data gap.
	Riparian Vegetation Modification								
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival. Currently a data gap.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival. Currently a data gap.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Rockfish dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, juvenile rockfish are known to use shallow vegetated habitats and pocket estuaries which contain food sources that depend on marine riparian allochthonous input. Decreased food web productivity may result in reduced foraging opportunities.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival, growth, and fitness.

Table A-20 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Group 20—Rockfish Species.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Rockfish dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Effects of the action resulting from this impact mechanism are unknown.
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect growth and fitness at larval, juvenile, and adult life-history stages.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased refuge habitat availability. Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.		
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Larvae; Juveniles	Larvae and juveniles: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events. Juveniles: Avoidance behavior or asphyxiation during acute events.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect larval survival. May affect juvenile survival. May cause temporary avoidance behavior.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Larvae; Juveniles	Larvae: Increased suspended solids in microlayer habitat may lead to direct mortality and decreased survival of larvae. Juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior.	Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival, growth, and fitness at larval and juvenile life-history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Larvae; Juveniles; Adults	All expose life history stages: Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.

Table A-20 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Group 20—Rockfish Species.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Outfalls									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Juveniles and adults: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by these species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may cause direct mortality or injury affecting juvenile and adult survival, depending on project-specific noise intensity and receptor exposure.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Juveniles and adults: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. However, rockfish sensitivity to this stressor is currently a data gap.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect juvenile and adult survival due to avoidance behavior, decreased foraging success, and increased predation risk. Actual effects are unknown as stressor sensitivity is a data gap.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Juveniles; Adults	Juveniles: Direct mortality or injury from entrainment. Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness. Adults : See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects background levels.	May cause direct mortality or injury to juveniles. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Marine								

Table A-20 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Group 20—Rockfish Species.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval rockfish settlement in nearshore areas favorable for rearing, as well as the overall suitability of rearing habitat. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at larval and juvenile life-history stages.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Outfalls in the marine environment can fragment nearshore rearing habitat, potentially affecting settlement of larval rockfish. May increase nearshore habitat suitability for juvenile rockfish, however the resulting potential effects on rockfish populations are a data gap. Adults: Outfalls in the marine environment may create three dimensional habitat suitable for adult rockfish in the nearshore environment, encouraging occupation. The resulting potential effects on rockfish populations are a data gap.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval survival. Potential effects on juvenile and adult rockfish are a data gap.
	Riparian Vegetation Modification								
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival. Currently a data gap.

Table A-20 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Group 20—Rockfish Species.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival. Currently a data gap.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Rockfish dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, juvenile rockfish are known to use shallow vegetated habitats and pocket estuaries which contain food sources that depend on marine riparian allochthonous input. Decreased food web productivity may result in reduced foraging opportunities.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival, growth, and fitness.
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased refuge habitat availability. Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival. May affect adult growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Larvae; Juveniles	Larvae and juveniles: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events. Juveniles: Avoidance behavior or asphyxiation during acute events.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect larval survival. May affect juvenile survival. May cause temporary avoidance behavior.

Table A-20 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Group 20—Rockfish Species.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Larvae; Juveniles	<u>Larvae:</u> Increased suspended solids in microlayer habitat may lead to direct mortality and decreased survival of larvae. <u>Juveniles:</u> Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior.	Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival, growth, and fitness at larval and juvenile life-history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect survival and fitness of juveniles and adults.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Larvae; Juveniles; Adults	<u>All exposed life history stages</u>: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Juveniles and adults</u>: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by these species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may cause direct mortality or injury affecting juvenile and adult survival, depending on project-specific noise intensity and receptor exposure.

Table A-20 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Group 20—Rockfish Species.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Juveniles and adults: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. However, rockfish sensitivity to this stressor is currently a data gap.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect juvenile and adult survival due to avoidance behavior, decreased foraging success, and increased predation risk. Actual effects are unknown as stressor sensitivity is a data gap.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Juveniles; Adults	Juveniles: Direct mortality or injury from entrainment. Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness. Adults : See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects background levels.	May cause direct mortality or injury to juveniles. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval rockfish settlement in nearshore areas favorable for rearing, as well as the overall suitability of rearing habitat. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at larval and juvenile life-history stages.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								

Table A-20 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Group 20—Rockfish Species.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Intakes and diversions in the marine environment can fragment nearshore rearing habitat, potentially affecting settlement of larval rockfish. May increase nearshore habitat suitability for juvenile rockfish, however the resulting potential effects on rockfish populations are a data gap. Adults: Intakes and diversions in the marine environment may create three dimensional habitat suitable for adult rockfish in the nearshore environment, encouraging occupation. The resulting potential effects on rockfish populations are a data gap.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval survival. Potential effects on juvenile and adult rockfish are a data gap.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	Juveniles: Riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors. However, juveniles trapped in habitats isolated by tidal exchange (e.g., pocket estuaries) may experience increased temperatures where shade and buffer influence has been altered, potentially leading to mortality or increased thermal stress and decreased fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival. Currently a data gap.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness. Potential habitat avoidance and/or injury and mortality caused by excessive turbidity, as described for related stressor responses under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile survival. Currently a data gap.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Rockfish dependence on allochthonous inputs from marine riparian vegetation is a data gap. However, juvenile rockfish are known to use shallow vegetated habitats and pocket estuaries which contain food sources that depend on marine riparian allochthonous input. Decreased food web productivity may result in reduced foraging opportunities.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile growth and fitness.

Table A-20 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Group 20—Rockfish Species.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles	Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival, growth, and fitness.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles	Juveniles: Rockfish dependence on groundwater inflow to nearshore marine habitats is currently a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Effects of the action resulting from this impact mechanism are unknown.
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness. Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased refuge habitat availability. Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival. May affect adult growth and fitness.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Larvae; Juveniles	Larvae and juveniles: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events. Juveniles: Avoidance behavior or asphyxiation during acute events.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect larval survival. May affect juvenile survival. May cause temporary avoidance behavior.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Larvae; Juveniles	Larvae: Increased suspended solids in microlayer habitat may lead to direct mortality and decreased survival of larvae. Juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior.	Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival, growth, and fitness at larval and juvenile life-history stages.

Table A-20 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Group 20—Rockfish Species.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Larvae; Juveniles; Adults	All expose life history stages: Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Tide Gates									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Juveniles and adults: Stressor response dependent on noise magnitude and project-specific environmental conditions; may range from: ▪ Fatal injury or permanent auditory tissue damage limiting to survival. ▪ Increased predation risk and decreased foraging success due to auditory masking and/or temporary hearing threshold effects that increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and prey. Increased exertion due to behavioral responses (e.g., startle and flight) and habitat avoidance, leading to decreased growth and fitness.	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by these species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	Activity may cause direct mortality or injury affecting juvenile and adult survival, depending on project-specific noise intensity and receptor exposure.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Juveniles and adults: Auditory masking or temporary hearing threshold effects may increase risk of predation and/or decrease foraging efficiency due to decreased ability to sense predators and/or prey. However, rockfish sensitivity to this stressor is currently a data gap.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	May affect juvenile and adult survival due to avoidance behavior, decreased foraging success, and increased predation risk. Actual effects are unknown as stressor sensitivity is a data gap.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.

Table A-20 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Group 20—Rockfish Species.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Juveniles; Adults	Juveniles: Direct mortality or injury from entrainment. Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness. Adults : See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects background levels.	May cause direct mortality or injury to juveniles. May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Larvae; Juveniles	Larvae and juveniles: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the likelihood of larval rockfish settlement in nearshore areas favorable for rearing, as well as the overall suitability of rearing habitat. This may occur through a number of specific stressors, including increased exertion and stress due to change in current and wave energy patterns, increased predation exposure due to reduction in available cover or exposure to deep water habitat, food web alterations and decreased foraging opportunity, and increased competition for suitable habitats. The combined effect of these stressors can result in decreased growth, decreased fitness, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at larval and juvenile life-history stages.
	Altered current velocities and tidal exchange		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered channel geometry		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles; Adults	Larvae and juveniles: Tide gates in the marine environment can fragment nearshore rearing habitat, potentially affecting settlement of larval rockfish. May increase nearshore habitat suitability for juvenile rockfish, however the resulting potential effects on rockfish populations are a data gap. Adults: Tide gates in the marine environment may create three dimensional habitat suitable for adult rockfish in the nearshore environment, encouraging occupation. The resulting potential effects on rockfish populations are a data gap.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval survival. Potential effects on juvenile and adult rockfish are a data gap.

Table A-20 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Group 20—Rockfish Species.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tidegates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid disturbance of vegetation along shoreline.	
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Juveniles: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable.	May affect juvenile survival. May affect adult growth and fitness.

Table A-20 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Group 20—Rockfish Species.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	**When**	**Duration**	**Frequency**	**Life-history Form**			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous		Juveniles: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and predation exposure resulting in decreased survival, growth, and fitness. Adults: Decreased refuge habitat availability. Decreased foraging opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.	Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Larvae; Juveniles	Larvae and juveniles: Mortality due to asphyxiation in acute low microlayer dissolved oxygen events. Juveniles: Avoidance behavior or asphyxiation during acute events.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect larval survival. May affect juvenile survival. May cause temporary avoidance behavior.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Larvae; Juveniles	Larvae: Increased suspended solids in microlayer habitat may lead to direct mortality and decreased survival of larvae. Juveniles: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause physical injury and/or physiological effects (e.g., gill trauma, altered osmoregulation, blood chemistry changes). Moderate to high turbidity may cause behavioral alteration (e.g., avoidance responses) leading to increased territoriality, reduced foraging opportunity, increased predation exposure, and altered movement behavior.	Ensure project design avoids and/or minimizes habitat alterations leading to increased suspended solids. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival, growth, and fitness at larval and juvenile life-history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Larvae; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered salinity	Year-round	Long-term to permanent	Intermittent (daily)	Juveniles	Juveniles: Altered salinity patterns may limit habitat suitability for juvenile rearing in nearshore marine environments. This in turn may increase competition for available habitats, limiting survival, growth, and fitness.	Limit closure time of tide gate to maximize natural tidal exchange.	May affect juvenile survival, growth, and fitness.

Table A-20 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Group 20—Rockfish Species.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Juveniles	Tide gate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent. Exposure to toxic substances may lead to behavioral avoidance in adults. For juveniles, limitations in the availability of suitable juvenile rearing habitat or potential physiological injury may affect survival, growth, and fitness.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect adult behavior. May affect juvenile survival, growth, and fitness.

Table A-21. HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered ambient noise levels	NA	NA	NA	NA	NA	NA	
		Bank/shoreline/channel disturbance, resulting in increased sediments	NA	NA	NA	NA	NA	NA	
		Exposure to toxic chemicals from accidental spills	NA	NA	NA	NA	NA	NA	
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	NA	NA	NA	NA	NA	NA	
		Aquatic vegetation removal and delayed recovery	NA	NA	NA	NA	NA	NA	
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	NA	NA	NA	NA	NA	NA	
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered sediment transport	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability as a result of beach erosion from altered sediment supply.	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered substrate composition		NA	NA	NA				
	Ecosystem Fragmentation								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification				NA	NA	NA	
	Riparian Vegetation Modification								
	Marine								

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	NA	NA	NA	NA	NA	NA	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA	NA	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA		
	Water Quality Modification								

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Increased sediment contamination	NA	NA	NA	NA	NA	NA	
		Altered pH levels	NA	NA	NA	NA	NA	NA	
		Altered nutrient cycling	NA	NA	NA	NA	NA	NA	
		Introduction of toxic substances	NA	NA	NA	NA	NA	NA	
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	NA	NA	NA	NA	▪ NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered ambient noise levels	NA	NA	NA	NA	NA	NA	
		Bank/shoreline/channel disturbance, resulting in increased sediments	NA	NA	NA	NA	NA	NA	
		Exposure to toxic chemicals from accidental spills	NA	NA	NA	NA	NA	NA	
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	NA	NA	NA	NA	NA	NA	
		Aquatic vegetation removal and delayed recovery	NA	NA	NA	NA	NA	NA	
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	NA	NA	NA	NA	NA	NA	
	Hydraulic and Geomorphic Modification								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore,

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered flow regime	availability and suitability	NA	NA	NA				there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered substrate composition and stability		NA	NA	NA				
	Altered groundwater–surface water exchange		NA	NA	NA				
	Ecosystem Fragmentation								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	NA	NA	NA	NA	NA	NA	
	Riparian Vegetation Modification								
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	NA	NA	NA	NA	NA	NA	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA	NA	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Aquatic Vegetation Modification								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA		
	Water Quality Modification								

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Increased sediment contamination	NA	NA	NA	NA	NA	NA	
		Altered pH levels	NA	NA	NA	NA	NA	NA	
		Altered nutrient cycling	NA	NA	NA	NA	NA	NA	
		Introduction of toxic substances	NA	NA	NA	NA	NA	NA	
Dikes/Levees									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Veliger larvae; Juveniles; Adults	All life-history stages: Effect of piling driving sound is a data gap.	Effect of increased underwater noise level on Olympic oyster is a data gap.	Effect of increased underwater noise level on Olympic oyster is a data gap.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Veliger larvae; Juveniles, Adults	All life-history stages: Effect of anthropogenic sound is a data gap.	Effect of increased ambient noise level on Olympic oyster is a data gap.	Effect of increased ambient noise level on Olympic oyster is a data gap.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Veliger larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Veliger larvae Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Veliger larvae; Juveniles; Adults	All life-history stages: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Veliger larvae; Juveniles; Adults;	All life-history stages: Mortality from entrainment. Decreased growth and fitness. See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May affect veliger larvae productivity and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Veliger larvae; Juveniles; Adults	All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at all life-history stages.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous		habitats, potentially decreasing the suitability of settling and rearing habitat for Olympia oyster. This may occur through a number of specific stressors, including food web alterations and decreased prey resources, introduced non-native species, and increased competition for suitable habitats. Alteration of circulation patterns may also affect spawn timing and the transport and settlement of veliger larvae. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine movement, and direct mortality.		
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Veliger larvae; Juveniles; Adults	<u>All exposed life-history stages</u>: The structural footprint of dikes and levees may limit the area suitable for larval settlement, decreasing overall juvenile and adult abundance.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval survival, in turn affecting juvenile and adult population abundance.
	Riparian Vegetation Modification								
	Marine								

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles; Adults	Juveniles and adults: Although, riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors, Olympia oysters along the intertidal zone can gain benefits from extreme cold or heat that are known to cause mortality in other species.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness of juvenile and adult oysters (effects may be beneficial).
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults	Juveniles and adults: Burial can smother Olympia oysters. Siltation is a known limiting factor causing injury or mortality. See turbidity effects described in Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult survival.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Olympia oyster dependence on allochthonous and allochthonous inputs from marine riparian vegetation is a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Effects of this impact mechanism and related stressors are currently a data gap.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased food resources, leading to adverse effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival, adult spawning success, and overall population productivity.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Veliger larvae; Juveniles: Adults	All life history stages: Olympia oyster are known to prefer areas where freshwater seepage into the intertidal zone likely limits extremes in temperature.	Avoid disturbance of riparian vegetation.	Effects from this impact mechanism may also include protection from predators unable to tolerate low salinity habitats.
	Aquatic Vegetation Modification								

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Reduced feeding opportunities due to decreased food web productivity; decreased growth and fitness. Juveniles: Decreased habitat availability and feeding opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. Adults: Decreased feeding opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival. May affect adult growth and spawning productivity.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Veliger larvae; Juveniles; Adults	All life-history stages: Olympia oyster dissolved oxygen effect thresholds are currently a data gap. Sensitivity to dissolved oxygen levels appears to be low, however.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating larvae, juveniles, and adults. May affect juvenile and adult survival, growth, and fitness, including adult spawning success. Actual effects are unknown, as sensitivity to this stressor and effects thresholds are currently data gaps.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Veliger larvae; Juveniles; Adults	All life-history stages: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause mortality.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating larvae and juveniles. May affect juvenile productivity and adult productivity.

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Veliger larvae; Juveniles; Adults	All expose life history stages: Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Outfalls									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Veliger larvae; Juveniles; Adults	All life-history stages: Effect of piling driving sound is a data gap.	Effect of increased underwater noise level on Olympic oyster is a data gap.	Effect of increased underwater noise level on Olympic oyster is a data gap.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Veliger larvae; Juveniles, Adults	All life-history stages: Effect of anthropogenic sound is a data gap.	Effect of increased ambient noise level on Olympic oyster is a data gap.	Effect of increased ambient noise level on Olympic oyster is a data gap.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Veliger larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Veliger larvae Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Veliger larvae; Juveniles; Adults	All life-history stages: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Veliger larvae; Juveniles; Adults;	All life-history stages: Mortality from entrainment. Decreased growth and fitness. See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May affect veliger larvae productivity and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Veliger larvae; Juveniles; Adults	All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at all life-history stages.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous		habitats, potentially decreasing the suitability of settling and rearing habitat for Olympia oyster. This may occur through a number of specific stressors, including food web alterations and decreased prey resources, introduced non-native species, and increased competition for suitable habitats. Alteration of circulation patterns may also affect spawn timing and the transport and settlement of veliger larvae. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine movement, and direct mortality.		
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Veliger larvae; Juveniles; Adults	<u>All exposed life-history stages</u>: The structural footprint of outfalls may limit the area suitable for larval settlement, decreasing overall juvenile and adult abundance.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval survival, in turn affecting juvenile and adult population abundance.
	Riparian Vegetation Modification								
	Marine								

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles; Adults	Juveniles and adults: Although, riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors, Olympia oysters along the intertidal zone can gain benefits from extreme cold or heat that are known to cause mortality in other species.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness of juvenile and adult oysters (effects may be beneficial).
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults	Juveniles and adults: Burial can smother Olympia oysters. Siltation is a known limiting factor causing injury or mortality. See turbidity effects described in Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult survival.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Olympia oyster dependence on allochthonous and allochthonous inputs from marine riparian vegetation is a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Effects of this impact mechanism and related stressors are currently a data gap.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased food resources, leading to adverse effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival, adult spawning success, and overall population productivity.
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Reduced feeding opportunities due to decreased food web productivity;	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent	May affect growth and fitness at larval, juvenile, and adult life-history stages.

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous		decreased growth and fitness. Juveniles: Decreased habitat availability and feeding opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. Adults: Decreased feeding opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.	practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Veliger larvae; Juveniles; Adults	All life-history stages: Olympia oyster dissolved oxygen effect thresholds are currently a data gap. Sensitivity to dissolved oxygen levels appears to be low, however.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating larvae, juveniles, and adults. May affect juvenile and adult survival, growth, and fitness, including adult spawning success. Actual effects are unknown, as sensitivity to this stressor and effects thresholds are currently data gaps.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Veliger larvae; Juveniles; Adults	All life-history stages: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause mortality.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating larvae and juveniles. May affect juvenile productivity and adult productivity.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect survival and fitness of juveniles and adults.

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Veliger larvae; Juveniles; Adults	All exposed life history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Veliger larvae; Juveniles; Adults	All life-history stages: Effect of piling driving sound is a data gap.	Effect of increased underwater noise level on Olympic oyster is a data gap.	Effect of increased underwater noise level on Olympic oyster is a data gap.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Veliger larvae; Juveniles, Adults	All life-history stages: Effect of anthropogenic sound is a data gap.	Effect of increased ambient noise level on Olympic oyster is a data gap.	Effect of increased ambient noise level on Olympic oyster is a data gap.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Veliger larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Veliger larvae Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Veliger larvae; Juveniles; Adults	All life-history stages: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Veliger larvae; Juveniles; Adults;	All life-history stages: Mortality from entrainment. Decreased growth and fitness. See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May affect veliger larvae productivity and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Veliger larvae; Juveniles; Adults	All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of settling and rearing habitat for Olympia oyster. This may occur through a number of specific stressors, including food web alterations and decreased prey resources, introduced non-native species, and increased competition for suitable habitats. Alteration of circulation patterns may also affect spawn timing and the transport and settlement of veliger larvae. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine movement, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at all life-history stages.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Veliger larvae; Juveniles; Adults	All exposed life-history stages: The structural footprint of intakes and diversions may limit the area suitable for larval settlement, decreasing overall juvenile and adult abundance.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval survival, in turn affecting juvenile and adult population abundance.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles; Adults	Juveniles and adults: Although, riparian shade and ambient temperature have a minor effect on nearshore water temperatures relative to the dominant influence of marine tidal and current patterns, wind conditions, and other factors, Olympia oysters along the intertidal zone can gain benefits from extreme cold or heat that are known to cause mortality in other species.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness of juvenile and adult oysters (effects may be beneficial).
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults	Juveniles and adults: Burial can smother Olympia oysters. Siltation is a known limiting factor causing injury or mortality. See turbidity effects described in Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult survival.

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Olympia oyster dependence on allochthonous and allochthonous inputs from marine riparian vegetation is a data gap.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	Effects of this impact mechanism and related stressors are currently a data gap.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased food resources, leading to adverse effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival, adult spawning success, and overall population productivity.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Veliger larvae; Juveniles: Adults	All life history stages: Olympia oyster are known to prefer areas where freshwater seepage into the intertidal zone likely limits extremes in temperature.	Avoid disturbance of riparian vegetation.	Effects from this impact mechanism may also include protection from predators unable to tolerate low salinity habitats.
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Reduced feeding opportunities due to decreased food web productivity; decreased growth and fitness. Juveniles: Decreased habitat availability and feeding opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. Adults: Decreased feeding opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival. May affect adult growth and spawning productivity.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Veliger larvae; Juveniles; Adults	All life-history stages: Olympia oyster dissolved oxygen effect thresholds are currently a data gap. Sensitivity to dissolved oxygen levels appears to be low, however.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating larvae, juveniles, and adults. May affect juvenile and adult survival, growth, and fitness, including adult spawning success. Actual effects are unknown, as sensitivity to this stressor and effects thresholds are currently data gaps.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Veliger larvae; Juveniles; Adults	All life-history stages: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause mortality.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating larvae and juveniles. May affect juvenile productivity and adult productivity.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Veliger larvae; Juveniles; Adults	All expose life history stages: Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Tide Gates									
	Construction and Maintenance Activities								

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Veliger larvae; Juveniles; Adults	All life-history stages: Effect of piling driving sound is a data gap.	Effect of increased underwater noise level on Olympic oyster is a data gap.	Effect of increased underwater noise level on Olympic oyster is a data gap.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Veliger larvae; Juveniles, Adults	All life-history stages: Effect of anthropogenic sound is a data gap.	Effect of increased ambient noise level on Olympic oyster is a data gap.	Effect of increased ambient noise level on Olympic oyster is a data gap.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Veliger larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Veliger larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Veliger larvae Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Veliger larvae; Juveniles; Adults	All life-history stages: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Veliger larvae; Juveniles; Adults;	All life-history stages: Mortality from entrainment. Decreased growth and fitness. See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May affect veliger larvae productivity and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Veliger larvae; Juveniles; Adults	All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project.	May affect survival, growth, and fitness at all life-history stages.

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered current velocities and tidal exchange		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent		groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of settling and rearing habitat for Olympia oyster. This may occur through a number of specific stressors, including food web alterations and decreased prey resources, introduced non-native species, and increased competition for suitable habitats. Alteration of circulation patterns may also affect spawn timing and the transport and settlement of veliger larvae. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine movement, and direct mortality.	Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered channel geometry		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Veliger larvae; Juveniles; Adults	All exposed life-history stages: The structural footprint of tide gates may limit the area suitable for larval settlement, decreasing overall juvenile and adult abundance.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect larval survival, in turn affecting juvenile and adult population abundance.

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The risk of take from riparian vegetation modification associated with tidegates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid disturbance of vegetation along shoreline.	
	Aquatic Vegetation Modification								
	Marine								

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Reduced feeding opportunities due to decreased food web productivity; decreased growth and fitness. Juveniles: Decreased habitat availability and feeding opportunities, leading to increased competition and predation exposure, resulting in decreased survival, growth, and fitness. Adults: Decreased feeding opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile survival. May affect adult growth and spawning productivity.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Veliger larvae; Juveniles; Adults	All life-history stages: Olympia oyster dissolved oxygen effect thresholds are currently a data gap. Sensitivity to dissolved oxygen levels appears to be low, however.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of incubating larvae, juveniles, and adults. May affect juvenile and adult survival, growth, and fitness, including adult spawning success. Actual effects are unknown, as sensitivity to this stressor and effects thresholds are currently data gaps.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Veliger larvae; Juveniles; Adults	All life-history stages: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause mortality.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival of incubating larvae and juveniles. May affect juvenile productivity and adult productivity.

Table A-21 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Olympia Oyster.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered salinity	Year-round	Long-term to permanent	Intermittent (daily)	Veliger larvae; Juveniles; Adults	All life-history stages: Permanent alterations in salinity conditions would be expected to alter habitat suitability	Limit closure time of tide gate to maximize natural tidal exchange.	May affect survival, growth, and fitness.
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Juveniles	Tide gate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect juvenile and adult survival, growth, and fitness.

Table A-22. HPA HCP Flow Control Structures Exposure and Response Matrix for Northern Abalone.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered ambient noise levels	NA	NA	NA	NA	NA	NA	
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	NA	NA	NA	NA	NA	NA	
		Aquatic vegetation removal and delayed recovery	NA	NA	NA	NA	NA	NA	
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	NA	NA	NA	NA	NA	NA	
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered sediment transport	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability as a result of beach erosion from altered sediment supply.	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered substrate composition		NA	NA	NA				
	Ecosystem Fragmentation								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	NA	NA	NA	NA	NA	NA	
	Riparian Vegetation Modification								
	Marine								

Table A-22 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Northern Abalone.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	NA	NA	NA	NA	NA	NA	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA	NA	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA		
	Water Quality Modification								

Table A-22 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Northern Abalone.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Increased sediment contamination	NA	NA	NA	NA	NA	NA	
		Altered pH levels	NA	NA	NA	NA	NA	NA	
		Altered nutrient cycling	NA	NA	NA	NA	NA	NA	
		Introduction of toxic substances	NA	NA	NA	NA	NA	NA	
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	NA	NA	NA	NA	▪ NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered ambient noise levels	NA	NA	NA	NA	NA	NA	
		Bank/shoreline/channel disturbance, resulting in increased sediments	NA	NA	NA	NA	NA	NA	
		Exposure to toxic chemicals from accidental spills	NA	NA	NA	NA	NA	NA	
	Flow Bypass, Fish Handling and Channel Rewatering	Fish removal, relocation, and exclusion	NA	NA	NA	NA	NA	NA	
		Entrainment in pumps or impingement on pump screens	NA	NA	NA	NA	NA	NA	
		Altered flow conditions	NA	NA	NA	NA	NA	NA	
		Bottom disturbance, increased turbidity (associated with site rewatering)	NA	NA	NA	NA	NA	NA	
		Localized alteration in invertebrate abundance	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Loss of habitat access and stranding (during construction and maintenance)	NA	NA	NA	NA	NA	NA	

Table A-22 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Northern Abalone.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	NA	NA	NA	NA	NA	NA	
		Aquatic vegetation removal and delayed recovery	NA	NA	NA	NA	NA	NA	
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	NA	NA	NA	NA	NA	NA	
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered flow regime		NA	NA	NA				
	Altered substrate composition and stability		NA	NA	NA				
	Altered groundwater–surface water exchange		NA	NA	NA				
	Ecosystem Fragmentation								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	NA	NA	NA	NA	NA	NA	NA
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species	NA	NA	NA	NA	NA	NA	NA
	Riparian Vegetation Modification								

Table A-22 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Northern Abalone.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	NA	NA	NA	NA	NA	NA	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA	NA	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Aquatic Vegetation Modification								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels due to reduced photosynthesis	NA	NA	NA	NA	NA		
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA		
	Water Quality Modification								

Table A-22 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Northern Abalone.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Increased sediment contamination	NA	NA	NA	NA	NA	NA	
		Altered pH levels	NA	NA	NA	NA	NA	NA	
		Altered nutrient cycling	NA	NA	NA	NA	NA	NA	
		Introduction of toxic substances	NA	NA	NA	NA	NA	NA	
Dikes/Levees									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dikes and levees development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered ambient noise levels	NA	NA	NA	NA	NA	NA	
		Bank/shoreline/channel disturbance, resulting in increased sediments	NA	NA	NA	NA	NA	NA	
		Exposure to toxic chemicals from accidental spills	NA	NA	NA	NA	NA	NA	
	Flow Bypass, Fish Handling, and Channel Rewatering	Fish removal, relocation, and exclusion	NA	NA	NA	NA	NA	NA	
		Entrainment in pumps or impingement on pump screens	NA	NA	NA	NA	NA	NA	
		Altered flow conditions (riverine)	NA	NA	NA	NA	NA	NA	
		Altered current and circulation conditions (marine)	NA	NA	NA	NA	NA	NA	
		Bottom disturbance, increased turbidity (associated with site rewatering)	NA	NA	NA	NA	NA	NA	
		Localized alteration in invertebrate abundance	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Loss of habitat access (during construction and maintenance)	NA	NA	NA	NA	NA	NA	

Table A-22 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Northern Abalone.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	NA	NA	NA	NA	NA	NA	
		Aquatic vegetation removal and delayed recovery	NA	NA	NA	NA	NA	NA	
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	NA	NA	NA	NA	NA	NA	
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dikes and levees development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered current velocities		NA	NA	NA				
	Altered substrate composition and stability		NA	NA	NA				
	Altered groundwater–surface water exchange		NA	NA	NA				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dikes and levees development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Riparian Vegetation Modification								
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dikes and levees development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.

Table A-22 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Northern Abalone.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	NA	NA	NA	NA	NA	NA	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA	NA	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dikes and levees development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels due to reduced photosynthesis	NA	NA	NA	NA	NA		
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA		
	Marine								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dikes and levees development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels due to reduced photosynthesis	NA	NA	NA				
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	NA	NA	NA				
	Water Quality Modification								

Table A-22 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Northern Abalone.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dikes and levees development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Altered nutrient cycling	NA	NA	NA	NA	NA	NA	
		Introduction of toxic substances	NA	NA	NA	NA	NA	NA	
Outfalls									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary	Interannual to decadal (during project construction and maintenance)	Larvae; Juveniles; Adults	<u>All life-history stages</u>: Effect of piling driving sound on northern abalone is a data gap.	Effect of pile driving sound pressure on northern abalone is a data gap. Therefore appropriate minimization measures are unclear.	Effect of pile driving sound pressure on northern abalone is a data gap.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	<u>Juveniles and adults</u>: Effect of anthropogenic sound on northern abalone is a data gap.	Effect of anthropogenic sound pressure on northern abalone is a data gap. Therefore appropriate minimization measures are unclear.	Effect of anthropogenic sound on northern abalone is a data gap.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	<u>Larvae</u>: Decreased survival; increased incidence of developmental abnormalities leading to decreased survival and fitness. <u>Juveniles and adults</u>: Mortality, increased stress, reduced growth and fitness, tissue bioaccumulation, increased disease incidence, and reduced additional stressor toleration.	Ensure procedures are in place to quickly contain and clean up spills of toxic substances. Encourage the use of non-toxic, biodegradable lubricants in construction vessels.	May affect survival and productivity of all life-history stages. May also affect adult spawning productivity.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Larvae; Juveniles; Adults	<u>Juveniles and adults</u>: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Larvae; Juveniles; Adults	<u>All life-history stages</u>: Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness. Mortality due to entrainment. See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May affect juvenile productivity and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Marine								

Table A-22 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Northern Abalone.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Larvae; Juveniles; Adults	All life-history stages: Wave energy, current velocity, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of settling and rearing habitat for northern abalone. This may occur through a number of specific stressors, including food web alterations and decreased prey resources, introduced non-native species, and increased competition for suitable habitats. Loss of marine macroalgae may increase the visibility of the northern abalone to predators. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine movement, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival at all life-history stages.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles; Adults	All exposed life-history stages: The structural footprint of jetties may eliminate suitable habitat for larval settlement and juvenile and adult foraging. Over time, increased hard surface area associated with structures may increase the amount of surface area available for abalone foraging, but these beneficial effects may be offset by stressors related to hydraulic and geomorphic modification.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival, growth, and fitness at all life-history stages.
	Riparian Vegetation Modification								
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	NA	NA	NA	NA	NA	NA	NA

Table A-22 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Northern Abalone.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults	Juveniles and adults: Burial can smother northern abalones if large pulses of landslide debris were to enter Puget Sound waters. Siltation is a known limiting factor causing injury or mortality. See turbidity effects described under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult survival.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	NA	NA	NA	NA	NA	NA	NA
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA	NA	NA
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Northern abalone dependence on allochthonous and autochthonous inputs from marine aquatic vegetation is a data gap. Northern abalone are known to use intertidal and subtidal vegetation and phytoplankton that could be a product of aquatic vegetation autochthonous input. Juveniles: Decreased refuge and rearing habitat availability and food resource availability, leading to increased competition and predation exposure and resulting in decreased survival, growth, and fitness. Adults: Decreased feeding opportunity due to decreased food web productivity. Decreased growth and reproductive fitness.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Effect from autochthonous production is currently a data gap. May affect juvenile growth, fitness, and survival. May affect adult growth and spawning productivity.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of all life-history stages.

Table A-22 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Northern Abalone.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Larvae; Juveniles; Adults	All life-history stages: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause mortality or hinder feeding.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival and productivity of all life-history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling (due to effects of effluent discharge)	During and following discharge events	Long-term to permanent	Continuous	Larvae; Juveniles; Adults	All exposed life history stages: Nutrient increases may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate effluent potential to adversely affect eutrophication. Require or encourage use of upstream treatment measures prior to discharge.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	larvae; Juveniles; Adults	All exposed life history stages: Physiological responses to exposure at toxic levels, causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for intakes and diversions development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered ambient noise levels	NA	NA	NA	NA	NA	NA	
		Exposure to toxic chemicals from accidental spills	NA	NA	NA	NA	NA		
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	NA	NA	NA	NA	NA	NA	NA
		Aquatic vegetation removal and delayed recovery	NA	NA	NA	NA	NA	NA	NA
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	NA	NA	NA	NA	NA	NA	NA

Table A-22 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Northern Abalone.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for intakes and diversions development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered current velocities		NA	NA	NA				
	Altered substrate composition and stability		NA	NA	NA				
	Altered groundwater–surface water exchange		NA	NA	NA				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for intakes and diversions development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	NA	NA	NA	NA	NA	NA	
	Riparian Vegetation Modification								
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for intakes and diversions development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	NA	NA	NA	NA	NA	NA	

Table A-22 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Northern Abalone.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	NA	NA	NA	NA	NA	NA	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA	NA	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for intakes and diversions development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels due to reduced photosynthesis	NA	NA	NA				
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	NA	NA	NA				
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	
		Altered dissolved oxygen levels	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Altered pH levels	NA	NA	NA	NA	NA	NA	
		Altered nutrient cycling	NA	NA	NA	NA	NA	NA	
		Introduction of toxic substances	NA	NA	NA	NA	NA	NA	
Tide Gates									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Larvae; Juveniles; Adults	All life-history stages: Effect of piling driving sound on northern abalone is a data gap.	Effect of pile driving sound pressure on northern abalone is a data gap. Therefore appropriate minimization measures are unclear.	Effect of pile driving sound pressure on northern abalone is a data gap.

Table A-22 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Northern Abalone.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	Juveniles and adults: Effect of anthropogenic sound on northern abalone is a data gap.	Effect of anthropogenic sound pressure on northern abalone is a data gap. Therefore appropriate minimization measures are unclear.	Effect of anthropogenic sound on northern abalone is a data gap.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Larvae; Juveniles; Adults	All life-history stages: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Larvae; Juveniles; Adults	All life-history stages: Decreased foraging opportunity due to short-term reduction in prey availability. Decreased growth and fitness. Mortality due to entrainment. See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May affect juvenile productivity and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Larvae; Juveniles; Adults	All life-history stages: Wave energy, current velocity, channel geometry and substrate composition,are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially decreasing the suitability of settling and rearing habitat for northern abalone. This may occur through a number of specific stressors, including food web alterations and decreased prey resources, introduced non-native species, and increased competition for suitable habitats. Loss of marine macroalgae may increase the visibility of the northern abalone to predators. The combined effect of these stressors can result in decreased growth and productivity, decreased fitness for marine movement, and direct mortality.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival at all life-history stages.
	Altered current velocities and tidal exchange		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered channel geometry		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								

Table A-22 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Northern Abalone.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Larvae; Juveniles; Adults	All exposed life-history stages: The structural footprint of tide gates may eliminate suitable habitat for larval settlement and juvenile and adult foraging. Over time, increased hard surface area associated with structures may increase the amount of surface area available for abalone foraging, but these beneficial effects may be offset by stressors related to hydraulic and geomorphic modification.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival, growth, and fitness at all life-history stages.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	NA	NA	NA	NA	NA	NA	NA
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults	Juveniles and adults: Burial can smother northern abalones if large pulses of landslide debris were to enter Puget Sound waters. Siltation is a known limiting factor causing injury or mortality. See turbidity effects described under Water Quality Modification.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult survival.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	NA	NA	NA	NA	NA	NA	NA
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA	NA	NA
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	NA	NA	NA	NA	NA	NA	NA

Table A-22 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Northern Abalone.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Northern abalone dependence on allochthonous and autochthonous inputs from marine aquatic vegetation is a data gap. Northern abalone are known to use intertidal and subtidal vegetation and phytoplankton that could be a product of aquatic vegetation autochthonous input.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	Effect from this impact mechanism is currently a data gap.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Juveniles and adults: Physiological responses to exposure at toxic levels causing mortality or injury leading to reduced fitness. Bioaccumulation of contaminants at subacute levels, resulting in chronic physiological effects leading to reduced fitness and/or mortality.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect survival of all life-history stages.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Larvae; Juveniles; Adults	All life-history stages: Responses vary depending on stressor magnitude. Unavoidable extreme turbidity may cause mortality or hinder feeding.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect survival and productivity of all life-history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered salinity	Year-round	Long-term to permanent	Intermittent (daily)	Juveniles; Adults	Juveniles and adults: Altered salinity patterns may limit habitat suitability in nearshore marine environments. This in turn may increase competition for available habitats, limiting survival, growth, and fitness.	Limit closure time of tide gate to maximize natural tidal exchange.	May affect juvenile survival, growth, and fitness.
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintanence)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)	Juveniles; Adults	Tide gate installation and draining of wetlands are likely to expose anaerobic sediments to oxidation, releasing sequestered contaminants. These contaminants will be discharged at elevated concentrations in tidegate effluent.	Carefully evaluate the justification for proposed tidegate projects. Require applicant evaluation of potential water quality effects. Deny permitting where practicable for projects likely to lead to adverse effects.	May affect juvenile and adult survival, growth, and fitness.

Table A-23. HPA HCP Flow Control Structures Exposure and Response Matrix for Newcomb's Littorine Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered ambient noise levels	NA	NA	NA	NA	NA	NA	
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	NA	NA	NA	NA	NA	NA	
		Aquatic vegetation removal and delayed recovery	NA	NA	NA	NA	NA	NA	
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	NA	NA	NA	NA	NA	NA	
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered sediment transport	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability as a result of beach erosion from altered sediment supply.	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered substrate composition		NA	NA	NA				
	Ecosystem Fragmentation								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under *Riparian Vegetation Modification*	NA	NA	NA	NA	NA	NA	
	Riparian Vegetation Modification								
	Marine								

Table A-23 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Newcomb's Littorine Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	NA	NA	NA	NA	NA	NA	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA	NA	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA		

Table A-23 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Newcomb's Littorine Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for dam development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Increased sediment contamination	NA	NA	NA	NA	NA	NA	
		Altered pH levels	NA	NA	NA	NA	NA	NA	
		Altered nutrient cycling	NA	NA	NA	NA	NA	NA	
		Introduction of toxic substances	NA	NA	NA	NA	NA	NA	
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered ambient noise levels	NA	NA	NA	NA	NA	NA	
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	NA	NA	NA	NA	NA	NA	
		Aquatic vegetation removal and delayed recovery	NA	NA	NA	NA	NA	NA	
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	NA	NA	NA	NA	NA	NA	
	Hydraulic and Geomorphic Modification								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered flow regime		NA	NA	NA				
	Altered substrate composition and stability		NA	NA	NA				

Table A-23 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Newcomb's Littorine Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange		NA	NA	NA				
	Ecosystem Fragmentation								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under *Riparian Vegetation Modification*	NA	NA	NA	NA	NA	NA	
	Riparian Vegetation Modification								
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	NA	NA	NA	NA	NA	NA	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA	NA	
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	NA	NA	NA	NA	NA	NA	
	Aquatic Vegetation Modification								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA		

Table A-23 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Newcomb's Littorine Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for weir development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Increased sediment contamination	NA	NA	NA	NA	NA	NA	
		Altered pH levels	NA	NA	NA	NA	NA	NA	
		Altered nutrient cycling	NA	NA	NA	NA	NA	NA	
		Introduction of toxic substances	NA	NA	NA	NA	NA	NA	
Dikes/Levees									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	NA	Habitats used by this species are restricted to a narrow band of littorine and riparian terrestrial vegetation; therefore, it is not exposed to aquatic impacts from dikes and levee construction.	NA	NA
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)				
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal				
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal				
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal				
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles; Adults	Juveniles: Wave energy, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on	May affect survival, growth, and fitness at all life-history stages. However, actual effects are uncertain as life-history specific sensitivity to these impact mechanisms and related

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent		parameters can fundamentally alter marine littoral habitats, potentially altering the extent and composition of *Salicornia* habitat for Newcomb's littorine snail. In particular, alteration of littoral wave energy and sediment characteristics could lead to reductions in the amount of *Salicornia* habitat, or more frequent inundation leading to reduced habitat suitability. These alterations could lead to reduced survival, growth, and fitness; however, life-history specific sensitivity to these stressors is currently a data gap. As Newcomb's littorine snail is not a truly aquatic species and spends little time below the water surface, it is not affected by changes in current and circulation patterns.	sediment supply, longshore drift patterns, and wave energy and current patterns.	stressors is currently a data gap.
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	<u>All exposed life-history stages</u>: The onshore component of the structural footprint of dikes and levees may eliminate suitable habitat for this species, affecting survival and overall population abundance.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and overall population abundance.
	Riparian Vegetation Modification								
	Marine								
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles; Adults	Newcomb's littorine snail it is an intertidal mollusk species that lives under and on the stems of glasswort (*Salicornia Virginica*), which occurs in narrow bands on the fringes of salt marshes. Little is known of the life-history of this species, although its limited distribution and dependence on specific vegetation types increases sensitivity to specific types of riparian impacts. *Salicornia* fringe habitats are typically less influenced by riparian shade, but the actual shade requirements and life-history specific temperature requirements of this species are unknown. While tolerant of both salt and fresh water, it avoids immersion for long periods and will drown if trapped. Actual dependence on freshwater inflow is a data gap. However, salt marsh habitats in general are shaped by combined surface and ground water flows; therefore, alteration of freshwater inflow may lead to reduction in suitable habitat area.	Avoid/minimize disturbance of salt marsh vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Encourage project designs that limit permanent alteration of high-quality habitat features. Avoid disturbance of salt marsh vegetation, particularly the *Salicornia* fringe.	Riparian vegetation modification leading to the alteration of *Salicornia* habitat in salt marsh environments where this species occurs is likely to lead to reduced survival, growth, and fitness at one or more life-history stages. Effects resulting from exposure to specific impact mechanisms are unknown, however, as sensitivity to stressor exposure and life-history requirements are a data gap.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)				
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous				

Table A-23 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Newcomb's Littorine Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous				
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous				
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	NA
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	NA	NA	NA				
	Water Quality Modification								
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	NA	Habitats used by this species are restricted to a narrow band littorine and riparian terrestrial vegetation and is therefore not exposed to aquatic impacts from dikes and levees.	NA	NA
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)				
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)				
Outfalls									
	Construction and Maintenance Activities								

Table A-23 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Newcomb's Littorine Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	NA	Habitats used by this species are restricted to a narrow band of littorine and riparian terrestrial vegetation; therefore, it is not exposed to aquatic impacts from outfalls construction.	NA NA NA NA NA	NA
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	NA			NA
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	NA			NA
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	NA			NA
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	NA			NA
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	NA	Juveniles: Wave energy, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially altering the extent and composition of *Salicornia* habitat for Newcomb's littorine snail. In particular, alteration of littoral wave energy and sediment characteristics could lead to reductions in the amount of *Salicornia* habitat, or more frequent inundation leading to reduced habitat suitability. These alterations could lead to reduced survival, growth, and fitness; however, life-history specific sensitivity to these stressors is currently a data gap. As Newcomb's littorine snail is not a truly aquatic species and spends little time below the water surface, it is not affected by changes in current and circulation patterns.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at all life-history stages. However, actual effects are uncertain as life-history specific sensitivity to these impact mechanisms and related stressors is currently a data gap.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: The onshore component of the structural footprint of outfalls may eliminate suitable habitat for this species, affecting survival and overall population abundance.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and overall population abundance.
	Riparian Vegetation Modification								
	Marine								

Table A-23 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Newcomb's Littorine Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles; Adults	Newcomb's littorine snail it is an intertidal mollusk species that lives under and on the stems of glasswort (*Salicornia Virginica*), which occurs in narrow bands on the fringes of salt marshes. Little is known of the life-history of this species, although its limited distribution and dependence on specific vegetation types increases sensitivity to specific types of riparian impacts. *Salicornia* fringe habitats are typically less influenced by riparian shade, but the actual shade requirements and life-history specific temperature requirements of this species are unknown. While tolerant of both salt and fresh water, it avoids immersion for long periods and will drown if trapped. Actual dependence on freshwater inflow is a data gap. However, salt marsh habitats in general are shaped by combined surface and ground water flows; therefore, alteration of freshwater inflow may lead to reduction in suitable habitat area.	Avoid/minimize disturbance of salt marsh vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Encourage project designs that limit permanent alteration of high-quality habitat features. Avoid disturbance of salt marsh vegetation, particularly the *Salicornia* fringe.	Riparian vegetation modification leading to the alteration of *Salicornia* habitat in salt marsh environments where this species occurs is likely to lead to reduced survival, growth, and fitness at one or more life-history stages. Effects resulting from exposure to specific impact mechanisms are unknown, however, as sensitivity to stressor exposure and life-history requirements are a data gap.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)				
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous				
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous				
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	NA
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	NA	NA	NA				
	Water Quality Modification								

Table A-23 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Newcomb's Littorine Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	NA	Habitats used by this species are restricted to a narrow band littorine and riparian terrestrial vegetation and is therefore not exposed to aquatic impacts from outfalls.	NA	NA
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)				
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)				
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)				
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	NA	Habitats used by this species are restricted to a narrow band of littorine and riparian terrestrial vegetation; therefore, it is not exposed to aquatic impacts from intakes and diversions construction.	NA	NA
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	NA		NA	NA
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	NA		NA	NA
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	NA		NA	NA
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	NA		NA	NA

Table A-23 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Newcomb's Littorine Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles; Adults	<u>Juveniles</u>: Wave energy, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially altering the extent and composition of *Salicornia* habitat for Newcomb's littorine snail. In particular, alteration of littoral wave energy and sediment characteristics could lead to reductions in the amount of *Salicornia* habitat, or more frequent inundation leading to reduced habitat suitability. These alterations could lead to reduced survival, growth, and fitness; however, life-history specific sensitivity to these stressors is currently a data gap. As Newcomb's littorine snail is not a truly aquatic species and spends little time below the water surface, it is not affected by changes in current and circulation patterns.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at all life-history stages. However, actual effects are uncertain as life-history specific sensitivity to these impact mechanisms and related stressors is currently a data gap.
	Altered current velocities		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	<u>All exposed life-history stages</u>: The onshore component of the structural footprint of intakes and diversions may eliminate suitable habitat for this species, affecting survival and overall population abundance.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and overall population abundance.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under *Riparian Vegetation Modification*	Year-round	Permanent	Continuous	Juveniles; Adults	The importance of LWD recruitment to Newcomb's littorine snail is currently a data gap, therefore the effects of stressor exposure are unknown. However, except for the potential effects of this impact mechanism on the quantity and quality of available *Salicornia* habitat, the effects of this stressor are likely limited.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	The effects of exposure to this stressor are unknown, but are likely to be insignificant.
	Riparian Vegetation Modification								
	Marine								

Table A-23 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Newcomb's Littorine Snail.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles; Adults	Newcomb's littorine snail it is an intertidal mollusk species that lives under and on the stems of glasswort (*Salicornia Virginica*), which occurs in narrow bands on the fringes of salt marshes. Little is known of the life-history of this species, although its limited distribution and dependence on specific vegetation types increases sensitivity to specific types of riparian impacts. *Salicornia* fringe habitats are typically less influenced by riparian shade, but the actual shade requirements and life-history specific temperature requirements of this species are unknown. While tolerant of both salt and fresh water, it avoids immersion for long periods and will drown if trapped. Actual dependence on freshwater inflow is a data gap. However, salt marsh habitats in general are shaped by combined surface and ground water flows; therefore, alteration of freshwater inflow may lead to reduction in suitable habitat area.	Avoid/minimize disturbance of salt marsh vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Encourage project designs that limit permanent alteration of high-quality habitat features. Avoid disturbance of salt marsh vegetation, particularly the *Salicornia* fringe.	Riparian vegetation modification leading to the alteration of *Salicornia* habitat in salt marsh environments where this species occurs is likely to lead to reduced survival, growth, and fitness at one or more life-history stages. Effects resulting from exposure to specific impact mechanisms are unknown, however, as sensitivity to stressor exposure and life-history requirements are a data gap.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)				
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous				
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous				
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous				
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	NA	NA	NA	NA
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								

Table A-23 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Newcomb's Littorine Snail.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	NA	Habitats used by this species are restricted to a narrow band littorine and riparian terrestrial vegetation and is therefore not exposed to aquatic impacts from intakes and diversions.	NA	NA
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)				
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)				
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)				
Tide Gates									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	NA	Habitats used by this species are restricted to a narrow band of littorine and riparian terrestrial vegetation; therefore, it is not exposed to aquatic impacts from tide gates construction.	NA	NA
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	NA		NA	NA
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	NA		NA	NA
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	NA		NA	NA
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	NA		NA	NA

Table A-23 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Newcomb's Littorine Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic and Geomorphic Modification								
	Marine								
	Altered wave energy	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round (with stressor exposure occurring in spring and summer when juveniles occupy nearshore habitats for rearing)	Permanent	Continuous	Juveniles; Adults	Juveniles: Wave energy, sediment supply, substrate composition, and groundwater inputs are core ecosystem processes and characteristics that compose the nearshore ecosystem. Alteration in one or more of these parameters can fundamentally alter marine littoral habitats, potentially altering the extent and composition of *Salicornia* habitat for Newcomb's littorine snail. In particular, alteration of littoral wave energy and sediment characteristics could lead to reductions in the amount of *Salicornia* habitat, or more frequent inundation leading to reduced habitat suitability. These alterations could lead to reduced survival, growth, and fitness; however, life-history specific sensitivity to these stressors is currently a data gap. As Newcomb's littorine snail is not a truly aquatic species and spends little time below the water surface, it is not affected by changes in current and circulation patterns.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on sediment supply, longshore drift patterns, and wave energy and current patterns.	May affect survival, growth, and fitness at all life-history stages. However, actual effects are uncertain as life-history specific sensitivity to these impact mechanisms and related stressors is currently a data gap.
	Altered current velocities and tidal exchange		Year-round (with variable effects depending on site-specific current dynamics and project configuration)	Permanent	Intermittent				
	Altered substrate composition and stability		Year-round (beginning with project installation and becoming more pronounced over time)	Permanent	Continuous				
	Altered channel geometry		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Marine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: The onshore component of the structural footprint of tide gates may eliminate suitable habitat for this species, affecting survival and overall population abundance.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival and overall population abundance.
	Loss of LWD recruitment	Reduced availability of LWD from drift. See altered allochthonous inputs and altered habitat complexity stressors under *Riparian Vegetation Modification*	Year-round	Permanent	Continuous	Juveniles; Adults	The importance of LWD recruitment to Newcomb's littorine snail is currently a data gap, therefore the effects of stressor exposure are unknown. However, except for the potential effects of this impact mechanism on the quantity and quality of available *Salicornia* habitat, the effects of this stressor are likely limited.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	The effects of exposure to this stressor are unknown, but are likely to be insignificant.
	Riparian Vegetation Modification								
	Marine								

Table A-23 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Newcomb's Littorine Snail.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered shading, solar input, and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures)	Year-round (pronounced in summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles; Adults	The effects of tidegates on riparian vegetation are expected to be negligible relative to the effects of the dikes and levees these structures are typically integrated with. See responses to stressor exposure for Dikes and Levees.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Encourage project designs that limit permanent alteration of high-quality habitat features. Avoid disturbance of salt marsh vegetation, particularly the *Salicornia* fringe.	The risk of take from riparian vegetation modification associated with tidegates is considered to be a component of the effects of dikes and levees. The incremental effects of the tidegate are negligible in comparison.
	Altered shoreline and bluff stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)				
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous				
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous				
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous				
	Aquatic Vegetation Modification								
	Marine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	NA	NA	NA	NA
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous				
	Water Quality Modification								

Table A-23 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Newcomb's Littorine Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., discharge of high temperature nutrient rich water from land upstream of tidegate), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	NA	Habitats used by this species are restricted to a narrow band littorine and riparian terrestrial vegetation and is therefore not exposed to aquatic impacts from tide gates.	NA	NA
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)				
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)				
		Altered salinity	Year-round	Long-term to permanent	Intermittent (daily)				
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	Year-round	Intermediate-term to long-term	Intermittent (daily with tidal fluctuations)				

Table A-24. HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	All life-history stages: The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap.	Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles, Adults	All life-history stages: The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Juveniles, Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Juveniles, Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Species Handling and Channel Rewatering	Species removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Mortality from dewatering.	Perform channel work on areas where these species do not occur (these species are rarely found in sandy substrate).	Mortality and reduced survival and productivity at affected life-history stages.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	These species' potential for entrainment in pumps or impingement on pump screens is a data gap.	Perform channel work on areas where these species do not occur (these species are rarely found in sandy substrate).	These species' potential for entrainment in pumps or impingement on pump screens is a data gap.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Potential downstream sedimentation resulting in decreased downstream habitat suitability; decreased dissolved oxygen levels, reduced prey resource availability, and reduced suitable settling habitat; decreased fitness, growth, and productivity.	Limit alteration of flow conditions to minimal area.	May affect survival and productivity during all affected life-history stages.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Decreased prey resource availability, decreased dissolved oxygen, decreased suitable settling habitat; resulting in decreased fitness, growth, and survival.	Adhere to system-specific in-water work windows.	May affect growth and productivity at all life-history stages.
		Localized alteration in periphyton abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Decreased growth and fitness due to loss a food resources (scouring of periphyton caused by bed disturbance).	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile and adult life history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Reduced foraging opportunities, increased predation risk. Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect growth and fitness at juvenile life-history stage, survival at all life-history stages.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	All life-history stages: See responses described above under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: Decreased prey resource availability; decreased fitness, growth, and productivity of adults and juveniles. See responses described above under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Juveniles; Adults	All life-history stages: Mortality from entrainment and decreased prey availability resulting in decreased growth and fitness. See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May affect all life-history stages; decreased fitness, growth and survival of affected stages. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	All life-history stages: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit prey resource availability and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to habitat alteration, leading to increased stress and predation rate. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect all life-history stages; decreased growth, survival, and productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lateral and Longitudinal habitat Fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of longitudinal (i.e., upstream-downstream) habitat connectivity; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Dams can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of habitat if the dam presents a barrier to host fish passage. Decreased habitat availability may lead to density-dependent effects on populations.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival all exposed life history stages.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect survival all exposed life history stages.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Changes in thermal regime may result, see water quality modification for responses to this stressor. Also, alteration of aquatic vegetation may result, see responses under aquatic vegetation modification.	Encourage dam placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible. Encourage spillway design to promote moderation of stream temperatures in downstream reaches.	May affect survival all exposed life history stages.
	Altered Community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species.	Year-round	Permanent	Continuous	Juveniles	Juveniles: Dams create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect survival all exposed life history stages.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles; Adults	All life-history stages: Prefers cool water and temperature regulation form shading. Altered growth and productivity caused by temperatures outside optimal growth range and alteration of food web patterns. Wide tolerance range but prefers cooler waters. Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival and productivity.

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults	All life-history stages: Prefers high levels of dissolved oxygen and cool water. Altered growth and productivity caused by temperatures outside optimal growth range and alteration of food web patterns. Wide tolerance range but prefers cooler waters. Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival and productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced prey resource availability due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult life-history stages.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased prey resource availability, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality and decreased fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	NA	NA	NA	NA	NA	NA	NA.
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Juvenile and adults: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Site majority of facility offshore to limit grounding and prop wash effects. Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Design overwater structures and mooring buoys in accordance with USACE guidance to limit shading and anchor scour effects. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile and adult productivity and survival.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: See related stressor responses under Water Quality Alteration.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased prey resource availability leading to increased competition, and resulting effects on growth and fitness. Adults: Increased mortality and decreased fitness		May affect juvenile and adult survival and productivity.
	Water Quality Modification								

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Juveniles; Adults	<u>Juveniles</u>: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. <u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Provide sufficient streamflows to avoid temperature effects in reaches downstream of the impoundment. Promote dam designs that limit impoundment effects on downstream temperatures (e.g., draw streamflows from impoundment below the stratification layer in summer).	May affect survival, growth, and fitness during all exposed life-history stages.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>All life-history stages:</u> Requires high dissolved oxygen content. Mortality, decreased fitness, growth, and survival.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect productivity and survival of all life-history stages.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>All life-history stages:</u> Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and burial. Responses vary depending on stressor magnitude. Reduction in suitable settling habitat (due to substrate embeddedness) and reduced dissolved oxygen could limit growth and survival.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May decrease survival and productivity.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	All exposed life history stages: Dam removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to dam removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs and no direct waste discharge. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and productivity of all life stages.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	<u>All exposed life history stages:</u> Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect survival, growth and fitness at all exposed life history stages.

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	All exposed life history stages: Dam construction and operation may lead to introductions of toxic substances through accidental spills or other pathways. Impoundments may attract increased recreational vessel activity, creating a pathway for chronic exposure to hydrocarbons and other contaminants. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Require a spill control and containment plan for dam operations if appropriate. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources	May affect survival, growth and fitness at all exposed life history stages.
Weirs									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	▪ All life-history stages: The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap.	Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles, Adults	All life-history stages: The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Species Handling and Channel Rewatering	Species removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Mortality from dewatering.	Perform channel work on areas where these species do not occur (these species are rarely found in sandy substrate).	Mortality and reduced survival and productivity at affected life-history stages.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	These species' potential for entrainment in pumps or impingement on pump screens is a data gap.	Perform channel work on areas where these species do not occur (these species are rarely found in sandy substrate).	These species' potential for entrainment in pumps or impingement on pump screens is a data gap.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Potential downstream sedimentation resulting in decreased downstream habitat suitability; decreased dissolved oxygen levels, reduced prey resource availability, and reduced suitable settling habitat; decreased fitness, growth, and productivity.	Limit alteration of flow conditions to minimal area.	May affect survival and productivity during all affected life-history stages.

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>All life-history stages:</u> Decreased prey resource availability, decreased dissolved oxygen, decreased suitable settling habitat; resulting in decreased fitness, growth, and survival.	Adhere to system-specific in-water work windows.	May affect growth and productivity at all life-history stages.
		Localized alteration in periphyton abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>All life-history stages:</u> Decreased growth and fitness due to loss a food resources (scouring of periphyton caused by bed disturbance).	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile and adult life history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access and stranding (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>Juveniles and adults</u>: Loss of habitat accessibility, stranding, reduced foraging opportunities, mortality and increased predation risk.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness, and mortality at all life-history stages.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	<u>All life-history stages</u>: See responses described above under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	<u>Juveniles and adults</u>: Decreased prey resource availability; decreased fitness, growth, and productivity of adults and juveniles. See responses described above under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Juveniles; Adults	<u>All life-history stages:</u> Mortality from entrainment and decreased prey availability resulting in decreased growth and fitness. See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May affect all life-history stages; decreased fitness, growth and survival of affected stages. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	<u>All life-history stages</u>: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased survival. <u>Juveniles</u>: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit prey resource availability and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect all life-history stages; decreased growth, survival, and productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
							Adults: Changes in channel morphology may lead to habitat alteration, leading to increased stress and predation rate. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity.		
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Weirs can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of habitat if the dam presents a barrier to host fish passage. Decreased habitat availability may lead to density-dependent effects on populations.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival all exposed life history stages.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect survival all exposed life history stages.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Changes in thermal regime may result, see water quality modification for responses to this stressor. Also, alteration of aquatic vegetation may result, see responses under aquatic vegetation modification.	Encourage weir placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect survival all exposed life history stages.
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species	Year-round	Permanent	Continuous	Juveniles	Juveniles: Weirs create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect survival all exposed life history stages.
	Riparian Vegetation Modification								
	Riverine								

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles; Adults	All life-history stages: Prefers cool water and temperature regulation form shading. Altered growth and productivity caused by temperatures outside optimal growth range and alteration of food web patterns. Wide tolerance range but prefers cooler waters. Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival and productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults	All life-history stages: Prefers high levels of dissolved oxygen and cool water. Altered growth and productivity caused by temperatures outside optimal growth range and alteration of food web patterns. Wide tolerance range but prefers cooler waters. Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival and productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced prey resource availability due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult life-history stages.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles: Decreased prey resource availability, leading to increased competition and resulting effects on growth and fitness. Adults: Increased mortality and decreased fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	NA	NA	NA	NA	NA	NA	NA.
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	Juvenile and adults: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	Design: Site majority of facility offshore to limit grounding and prop wash effects. Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Design overwater structures and mooring buoys in accordance with USACE guidance to limit shading and anchor scour effects. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile and adult productivity and survival.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased prey resource availability leading to increased competition, and resulting effects on growth and fitness. Adults: Increased mortality and decreased fitness		May affect juvenile and adult survival and productivity.

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during juvenile stage. May affect adult survival .
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Juveniles; Adults	All life-history stages: Requires high dissolved oxygen content. Mortality, decreased fitness, growth, and survival.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect productivity and survival of all life-history stages.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	All life-history stages: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and burial. Responses vary depending on stressor magnitude. Reduction in suitable settling habitat (due to substrate embeddedness) and reduced dissolved oxygen could limit growth and survival.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May decrease survival and productivity.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	All expose life history stages: Weir removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to weir removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs and no direct waste discharge. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	All expose life history stages: Weir construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Dikes/Levees									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	▪ All life-history stages: The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap.	Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles, Adults	All life-history stages: The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Species Handling, and Channel Rewatering	Species removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Mortality from dewatering.	Perform channel work on areas where these species do not occur (these species are rarely found in sandy substrate).	Mortality and reduced survival and productivity at affected life-history stages.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	These species' potential for entrainment in pumps or impingement on pump screens is a data gap.	Perform channel work on areas where these species do not occur (these species are rarely found in sandy substrate).	These species' potential for entrainment in pumps or impingement on pump screens is a data gap.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Potential downstream sedimentation resulting in decreased downstream habitat suitability; decreased dissolved oxygen levels, reduced prey resource availability, and reduced suitable settling habitat; decreased fitness, growth, and productivity.	Limit alteration of flow conditions to minimal area.	May affect survival and productivity during all affected life-history stages.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Decreased prey resource availability, decreased dissolved oxygen, decreased suitable settling habitat; resulting in decreased fitness, growth, and survival.	Adhere to system-specific in-water work windows.	May affect growth and productivity at all life-history stages.

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Localized alteration in periphyton abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Decreased growth and fitness due to loss a food resources (scouring of periphyton caused by bed disturbance).	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile and adult life history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Loss of habitat accessibility, stranding, reduced foraging opportunities, mortality and increased predation risk.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage. May affect adult survival.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Juveniles; Adults	All life-history stages: See responses described above under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: Decreased prey resource availability; decreased fitness, growth, and productivity of adults and juveniles. See responses described above under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Juveniles; Adults	All life-history stages: Mortality from entrainment and decreased prey availability resulting in decreased growth and fitness. See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May affect all life-history stages; decreased fitness, growth and survival of affected stages. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	All life-history stages: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased survival. Juveniles: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit prey resource availability and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to habitat alteration, leading to increased stress and predation rate. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect all life-history stages; decreased growth, survival, and productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riverine								
	Lateral and longitudinal fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat, change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: Dikes and levees can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of habitat if the dam presents a barrier to host fish passage. Decreased habitat availability may lead to density-dependent effects on populations.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival all exposed life history stages.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect survival all exposed life history stages.
	Altered groundwater-surface water exchange	Reduced availability of thermal refuge and decreased intragravel DO, nutrient cycling effects	Year-round	Permanent	Continuous	Juveniles; Adults	Adults and juveniles: Changes in thermal regime may result, see water quality modification for responses to this stressor. Also, alteration of aquatic vegetation may result, see responses under aquatic vegetation modification.	Encourage dike and levee placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible. Encourage spillway design to promote moderation of stream temperatures in downstream reaches.	May affect survival all exposed life history stages.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles; Adults	All life-history stages: Prefers cool water and temperature regulation form shading. Altered growth and productivity caused by temperatures outside optimal growth range and alteration of food web patterns. Wide tolerance range but prefers cooler waters. Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival and productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults	All life-history stages: Prefers high levels of dissolved oxygen and cool water. Altered growth and productivity caused by temperatures outside optimal growth range and alteration of food web patterns. Wide tolerance range but prefers cooler waters. Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival and productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	Juveniles: Reduced prey resource availability due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult life-history stages.

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	<u>Juveniles:</u> Decreased prey resource availability, leading to increased competition and resulting effects on growth and fitness. <u>Adults:</u> Increased mortality and decreased fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	NA	NA	NA	NA	NA	NA	NA.
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	<u>Juvenile and adults</u>: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	<u>Design</u>: Site majority of facility offshore to limit grounding and prop wash effects. Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Design overwater structures and mooring buoys in accordance with USACE guidance to limit shading and anchor scour effects. <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect juvenile and adult productivity and survival.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover,	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	<u>Juveniles and adults:</u> Decreased prey resource availability leading to increased competition, and resulting effects on growth and fitness. <u>Adults:</u> Increased mortality and decreased fitness		May affect juvenile and adult survival and productivity.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	<u>Juveniles</u>: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. <u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during all exposed life-history stages.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>All life-history stages:</u> Requires high dissolved oxygen content. Mortality, decreased fitness, growth, and survival.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect productivity and survival of all life-history stages.

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	All life-history stages: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and burial. Responses vary depending on stressor magnitude. Reduction in suitable settling habitat (due to substrate embeddedness) and reduced dissolved oxygen could limit growth and survival.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May decrease survival and productivity.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	All expose life history stages: Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Outfalls									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	▪ All life-history stages: The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap.	Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles, Adults	All life-history stages: The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Species handling, and Channel rewatering	Species removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Mortality from dewatering.	Perform channel work on areas where these species do not occur (these species are rarely found in sandy substrate).	Mortality and reduced survival and productivity at affected life-history stages.

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	These species' potential for entrainment in pumps or impingement on pump screens is a data gap.	Perform channel work on areas where these species do not occur (these species are rarely found in sandy substrate).	These species' potential for entrainment in pumps or impingement on pump screens is a data gap.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>All life-history stages:</u> Potential downstream sedimentation resulting in decreased downstream habitat suitability; decreased dissolved oxygen levels, reduced prey resource availability, and reduced suitable settling habitat; decreased fitness, growth, and productivity.	Limit alteration of flow conditions to minimal area.	May affect survival and productivity during all affected life-history stages.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>All life-history stages:</u> Decreased prey resource availability, decreased dissolved oxygen, decreased suitable settling habitat; resulting in decreased fitness, growth, and survival.	Adhere to system-specific in-water work windows.	May affect growth and productivity at all life-history stages.
		Localized alteration in periphyton abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>All life-history stages:</u> Decreased growth and fitness due to loss a food resources (scouring of periphyton caused by bed disturbance).	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile and adult life history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	<u>All life-history stages</u>: See responses described above under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	<u>Juveniles and adults</u>: Decreased prey resource availability; decreased fitness, growth, and productivity of adults and juveniles. See responses described above under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Juveniles; Adults	<u>All life-history stages:</u> Mortality from entrainment and decreased prey availability resulting in decreased growth and fitness. See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May affect all life-history stages; decreased fitness, growth and survival of affected stages. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	<u>All life-history stages</u>: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased survival. <u>Juveniles</u>: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit prey resource availability and increase	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect all life-history stages; decreased growth, survival, and productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous		competition for suitable habitats, leading to decreased growth, fitness, and survival. Adults: Changes in channel morphology may lead to habitat alteration, leading to increased stress and predation rate. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity.		
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of longitudinal connectivity may result from water quality barrier when high effluent discharge causes chemical barrier to migration. If constructed parallel to the channel, side channel and floodplain habitat may become fragmented. These actions will result in changes in habitat structure, availability, and suitability; reduced food web complexity.	Year-round	Permanent	Continuous	Juveniles; Adults	All exposed life-history stages: High flow outfalls can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of habitat if the dam presents a barrier to host fish passage. Decreased habitat availability may lead to density-dependent effects on populations.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival all exposed life history stages.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles; Adults	The degree to which outfalls affect riparian vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine environments.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which outfalls affect aquatic vegetation conditions in riverine and lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	<u>Design</u>: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. <u>Construction</u>: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine and lacustrine environments.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Water Quality Modification								
		Altered thermal regime (i.e., increased summer temperatures due to elevated effluent temperatures relative to receiving body)	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	<u>Juveniles</u>: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. <u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness at all exposed life history stages.

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Juveniles; Adults	All life-history stages: Requires high dissolved oxygen content. Mortality, decreased fitness, growth, and survival.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism-specific measures as appropriate.	May affect productivity and survival of all life-history stages.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	All life-history stages: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and burial. Responses vary depending on stressor magnitude. Reduction in suitable settling habitat (due to substrate embeddedness) and reduced dissolved oxygen could limit growth and survival.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May decrease survival and productivity.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling (due to effects of effluent discharge)	During and following discharge events	Long-term to permanent	Continuous	Juveniles; Adults	All exposed life history stages: Nutrient increases may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen concentrations.	Evaluate effluent potential to adversely affect eutrophication. Require or encourage use of upstream treatment measures prior to discharge.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Juveniles; Adults	All exposed life history stages: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles; Adults	▪ All life-history stages: The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap.	Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap.

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	**When**	**Duration**	**Frequency**	**Life-history Form**			
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Juveniles, Adults	All life-history stages: The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap.	Avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/antivibration technology where practicable.	The effects of pile-driving sounds and other anthropogenic sounds to Columbia River limpet and Columbia River spire snail are a data gap.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Species handling and channel rewatering	Species removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Mortality from dewatering.	Perform channel work on areas where these species do not occur (these species are rarely found in sandy substrate).	Mortality and reduced survival and productivity at affected life-history stages.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	These species' potential for entrainment in pumps or impingement on pump screens is a data gap.	Perform channel work on areas where these species do not occur (these species are rarely found in sandy substrate).	These species' potential for entrainment in pumps or impingement on pump screens is a data gap.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Potential downstream sedimentation resulting in decreased downstream habitat suitability; decreased dissolved oxygen levels, reduced prey resource availability, and reduced suitable settling habitat; decreased fitness, growth, and productivity.	Limit alteration of flow conditions to minimal area.	May affect survival and productivity during all affected life-history stages.
		Stream bed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Decreased prey resource availability, decreased dissolved oxygen, decreased suitable settling habitat; resulting in decreased fitness, growth, and survival.	Adhere to system-specific in-water work windows.	May affect growth and productivity at all life-history stages.
		Localized alteration in periphyton abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: Decreased growth and fitness due to loss a food resources (scouring of periphyton caused by bed disturbance).	Limit area of dewatering to the greatest extent practicable.	May affect growth and fitness at juvenile and adult life history stage.
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual–decadal	Juveniles; Adults	All life-history stages: See responses described above under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats.	See effects for related stressors under Hydraulic and Geomorphic Modification
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual–decadal	Juveniles; Adults	Juveniles and adults: Decreased prey resource availability; decreased fitness, growth, and productivity of adults and juveniles. See responses described above under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual–decadal	Juveniles; Adults	<u>All life-history stages:</u> Mortality from entrainment and decreased prey availability resulting in decreased growth and fitness. See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May affect all life-history stages; decreased fitness, growth and survival of affected stages. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	Year-round	Permanent	Continuous	Juveniles; Adults	<u>All life-history stages</u>: Changes in channel morphology, flow velocity, and substrate composition can alter substrate composition and stability, leading to decreased survival. <u>Juveniles</u>: Altered channel geometry, flow velocity, and substrate composition can result in decreased rearing habitat suitability and changes in food web complexity. This may limit prey resource availability and increase competition for suitable habitats, leading to decreased growth, fitness, and survival. <u>Adults</u>: Changes in channel morphology may lead to habitat alteration, leading to increased stress and predation rate. Changes in substrate composition and stability resulting from altered channel geometry and flow velocity.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selections of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect all life-history stages; decreased growth, survival, and productivity.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Juveniles; Adults	<u>All exposed life-history stages</u>: Intakes and diversions can reduce flow and force channel incision, leading to disconnection of side channel and floodplain habitats under lower flow conditions. This stressor may limit the availability of habitat if the dam presents a barrier to host fish passage. Decreased habitat availability may lead to density-dependent effects on populations.	Require assessment of the hydraulic effects of the project before permitting; avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival all exposed life history stages.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect survival all exposed life history stages.
	Altered groundwater-surface water exchange	Accumulation of fines will reduce hyporheic exchange, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round	Permanent	Continuous	Juveniles; Adults	<u>Adults and juveniles</u>: Changes in thermal regime may result, see water quality modification for responses to this stressor. Also, alteration of aquatic vegetation maybresult, see responses under aquatic vegetation modification.	Encourage intakes and diversions placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	May affect survival all exposed life history stages.

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles; Adults	<u>All life-history stages:</u> Prefers cool water and temperature regulation form shading. Altered growth and productivity caused by temperatures outside optimal growth range and alteration of food web patterns. Wide tolerance range but prefers cooler waters. Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival and productivity.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~<u>benthic</u> dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults	<u>All life-history stages:</u> Prefers high levels of dissolved oxygen and cool water. Altered growth and productivity caused by temperatures outside optimal growth range and alteration of food web patterns. Wide tolerance range but prefers cooler waters. Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival and productivity.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles	<u>Juveniles:</u> Reduced prey resource availability due to decreased food web productivity; decreased growth and fitness.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult life-history stages.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	<u>Juveniles:</u> Decreased prey resource availability, leading to increased competition and resulting effects on growth and fitness. <u>Adults:</u> Increased mortality and decreased fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	NA	NA	NA	NA	NA	NA	NA.
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles; Adults	<u>Juvenile and adults</u>: Reduced foraging opportunities due to decreased food web productivity; decreased growth and fitness.	<u>Design</u>: Site majority of facility offshore to limit grounding and prop wash effects. Limit project structural footprint to minimize shading of	May affect juvenile and adult productivity and survival.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased prey resource availability leading to increased competition, and resulting effects on growth and fitness. Adults: Increased mortality and decreased fitness	aquatic vegetation to the greatest extent practicable. Design overwater structures and mooring buoys in accordance with USACE guidance to limit shading and anchor scour effects. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction. .	May affect juvenile and adult survival and productivity.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	Juveniles: Altered growth and survival caused by temperatures outside optimal growth range and alteration of food web patterns. Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Ensure that appropriate instream flows necessary to regulate temperature and other habitat parameters are maintained.	May affect survival, growth, and fitness during all exposed life-history stages.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation.	Avoid sediment pulses. Avoid nutrient inputs when possible.	May cause direct mortality in acute events. May affect juvenile survival and fitness as well as adult survival and spawning productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	All life-history stages: Turbidity sufficient to cause fine sediment embeddedness may lead to direct mortality and burial. Responses vary depending on stressor magnitude. Reduction in suitable settling habitat (due to substrate embeddedness) and reduced dissolved oxygen could limit growth and survival.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May decrease survival and productivity.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	All life-history stages: Requires high dissolved oxygen content. Mortality, decreased fitness, growth, and survival.	Avoid sediment pulses. Limit nutrient. Other mechanism-specific measures as appropriate.	May affect productivity and survival of all life-history stages.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>All expose life history stages:</u> Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Tide Gates									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	NA	NA	NA	NA	▪ NA	NA	This species does not occur in habitats suitable for tide gate development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered ambient noise levels	NA	NA	NA	NA	NA	NA	
		Bank/shoreline/channel disturbance, resulting in increased sediments	NA	NA	NA	NA	NA	NA	
		Exposure to toxic chemicals from accidental spills	NA	NA	NA	NA	NA	NA	
	Flow Bypass, fish handling and channel rewatering	Fish removal, relocation, and exclusion	NA	NA	NA	NA	NA	NA	
		Entrainment in pumps or impingement on pump screens	NA	NA	NA	NA	NA	NA	
		Altered flow conditions (riverine)	NA	NA	NA	NA	NA	NA	
		Streambed disturbance, increased turbidity (associated with site rewatering)	NA	NA	NA	NA	NA	NA	
		Localized alteration in invertebrate abundance	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Loss of habitat, stranding from dewatering (during construction, maintenance, and removal)	NA	NA	NA	NA	NA	NA	
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	NA	NA	NA	NA	NA	NA	
		Aquatic vegetation removal and delayed recovery	NA	NA	NA	NA	NA	NA	
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	NA	NA	NA	NA	NA	NA	

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced spawning and rearing habitat availability and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for tide gate development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered flow regime		NA	NA	NA				
	Altered substrate composition and stability		NA	NA	NA				
	Altered groundwater–surface water exchange		NA	NA	NA				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation of habitat	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for tide gate development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	NA	NA	NA	NA	NA	NA	
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for tide gate development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased ~~redd~~benthic dissolved oxygen; decreased area of suitable spawning habitat; reduced habitat complexity (e.g., filling of pools)	NA	NA	NA	NA		NA	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	NA	NA	NA	NA		NA	

Table A-24 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for Giant Columbia River Limpet and Great Columbia River Spire Snail.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available spawning habitat (freshwater)	NA	NA	NA	NA		NA	
	Altered groundwater–surface water exchange	Reduced available suitable spawning habitat; reduced gravel dissolved oxygen	NA	NA	NA	NA		NA	
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for tide gate development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA		
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for tide gate development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Altered pH levels	NA	NA	NA	NA	NA	NA	
		Altered salinity	NA	NA	NA	NA	NA	NA	
		Altered nutrient cycling	NA	NA	NA	NA	NA	NA	
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	NA	NA	NA	NA	NA	NA	

Table A-25. HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
Dams									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Glochidia larvae; Juveniles; Adults	All life-history stages: The effect of pile-driving sound pressure on California floater and western ridged mussels at any life-history stage is a data gap. Any potential impact would likely occur on the host fish species for the glochidia larvae (California floater= native minnows; western ridge = coldwater stream fish such as trout and salmon).	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	This is a data gap for these species. However, effects on host fish species for glochidia larvae will affect population productivity of this species. This indirect effect applies to all stressors.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Glochidia larvae; Juveniles, Adults	All life-history stages: The effect of pile-driving sound pressure on California floater and western ridged mussels is a data gap.	Although little is known on the effects of anthropogenic sounds on California floater and western ridged mussels, it is prudent to avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	Very little is known of the effects of pile-driving sounds on California floater and western ridged mussels at any life-history stage.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Glochidia larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (during project construction and maintenance)	Glochidia larvae; Juveniles; Adults	All exposed life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish and species removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Mortality from dewatering.	River beds containing live freshwater mussels should not be disturbed. If live mussels are encountered during excavation of the bed, operations should immediately cease and should be relocated a minimum of 200 ft away from the mussels.	May affect survival at juvenile and adult life-history stages.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae	Glochidia larvae: Any potential impact would only occur if the glochidia fish host is entrained or impinged.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when glochidia fish host are present.	Any potential impact would only occur if the glochidia fish host is entrained or impinged.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	All life-history stages: Potential downstream sedimentation, resulting in decreased downstream habitat suitability, decreased dissolved oxygen levels, reduced food resource availability, and reduced suitable habitat; decreased fitness, growth, and productivity.	Limit alteration of flow conditions to minimal area.	May affect survival in all life stages.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Mortality from increased sedimentation.	Adhere to system-specific in-water work windows.	May affect survival at juvenile and adult life-history stages.

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Localized alteration in invertebrate abundance	NA	NA	NA	NA	NA	NA	NA
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access or stranding (during construction and maintenance or dam removal)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	Glochidia larvae: Potential decreased incubation success and survival due to water loss and stranding. Juveniles: Loss of habitat accessibility, stranding, increased predation risk. Stranding may lead to direct mortality. Adults: Stranding may lead to direct mortality.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival in all life stages.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Glochidia larvae; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. River beds containing live freshwater mussels should not be disturbed. If live mussels are encountered during excavation of the bed, operations should immediately cease and should be relocated a minimum of 200 ft away from the mussels.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Glochidia larvae; Juveniles; Adults;	All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced habitat availability and suitability	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	Glochidia larvae: Changes in channel morphology, flow velocity, and substrate composition can affect host fish. Juveniles and adults: As filter feeders, constant water flow is required. Altered channel geometry, flow velocity, and substrate composition can result in decrease habitat suitability and changes in food web complexity. This may limit prey resource availability and foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at all life-history stages and affect life-history stages and productivity of host-fish.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lateral and Longitudinal habitat Fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of longitudinal (i.e., upstream-downstream) habitat connectivity; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	Glochidia larvae: Changes in habitat availability may indirectly affect survival through effects on host fish. Juveniles and adults: The structural footprint of dams may permanently modify habitat suitable for juveniles and adults, affecting survival and overall population abundance.	Require assessment of the hydraulic effects of the project before permitting and avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at all life-history stages and affect life-history stages and productivity of host-fish.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round	Permanent	Continuous	Juveniles;	Mussel responses to altered groundwater-surface water exchange are a data gap.	Encourage dam placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible. Encourage spillway design to promote moderation of stream temperatures in downstream reaches.	Effect of groundwater exchange to mussel health and fitness is a data gap.
	Altered Community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species.	Year-round	Permanent	Continuous	Juveniles	Juveniles: Dams create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Glochidia larvae; Juveniles; Adults	All life-history stages: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns (including food web supporting host fish). Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival and productivity at all life history stages.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Glochidia larvae; Juveniles; Adults	All life-history stages: Decreased food resource availability, leading to increased competition and resulting effects on growth and fitness for mussels and host fish. Decreased suitable habitat, injury, or mortality caused by excessive turbidity or resulting smothering by burial.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult fitness and survival of mussels and host fish.

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Glochidia larvae	Mussel dependence upon allochthonous input is a data gap. However, could affect host fish.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect productivity.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased habitat availability and food availability, leading to increased competition and resulting effects on growth and fitness, including health of host fish.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	Mussel responses to groundwater exchange are a data gap.	Avoid disturbance of vegetation along stream.	Effect of groundwater exchange to mussel health and fitness is a data gap.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced prey availability due to decreased food web productivity, decreased growth and fitness of host fish. Although effects specific to altered autochthonous inputs for the California floater and Western ridged mussels are a data gap, alterations could be expected to affect prey resource availability.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect all life-history stages.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: Require high levels of dissolved oxygen. See related stressor responses under Water Quality Alteration. Effects include effects to shot fish.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Reduced prey resources due to decreased food web productivity, decrease growth and fitness of the California floater and Western ridged mussel prey and host fish. Altered autochthonous could be expected to effect prey resource availability.		May affect all life stages.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent	Seasonal	Glochidia larvae; Juveniles; Adults	Glochidia larvae: Host-fish of the California floater and Western ridged mussel may be affected by increased temperatures, which may lead to mortality or increased thermal stress and decreased fitness of host fish. Juveniles and adults: Mortality due to increased temperatures.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Provide sufficient streamflows to avoid temperature effects in reaches downstream of the impoundment. Promote dam designs that limit impoundment effects on downstream temperatures (e.g., draw streamflows from impoundment below the stratification layer in summer).	May affect all life stages.

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	When	Duration	Frequency	Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to long-term (e.g., from eutrophication effects induced by the impoundment), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Glochidia larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Effects to host-fish could be stressor to these mussels. Juveniles and adults: A physiological response to exposure at toxic levels, causing mortality or injury leading to reduced fitness is a data gap.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism specific measures as appropriate.	May affect survival of larvae. May affect juvenile survival and adult survival and productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Effects depend on the magnitude of increased suspended solids. Turbidity sufficient to cause fine sediment embeddedness may bury these mussels and lead to direct mortality and decreased population survival.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect juvenile and adult survival.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Glochidia larvae; Juveniles; Adults	All exposed life history stages: Dam removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to dam removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs and no direct waste discharge. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Glochidia larvae; Juveniles; Adults	All exposed life history stages: Dam construction and operation may lead to introductions of toxic substances through accidental spills or other pathways. Impoundments may attract increased recreational vessel activity, creating a pathway for chronic exposure to hydrocarbons and other contaminants. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Require a spill control and containment plan for dam operations if appropriate. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources	May affect survival, growth and fitness at all exposed life history stages.
Weirs									

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Glochidia larvae; Juveniles; Adults	▪ All life-history stages: The effect of pile-driving sound pressure on California floater and western ridged mussels at any life-history stage is a data gap. Any potential impact would likely occur on the host fish species for the glochidia larvae (California floater= native minnows; western ridge = coldwater stream fish such as trout and salmon).	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	This is a data gap for these species. However, effects on host fish species for glochidia larvae will affect population productivity of this species. This indirect effect applies to all stressors.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Glochidia larvae; Juveniles, Adults	All life-history stages: The effect of pile-driving sound pressure on California floater and western ridged mussels is a data gap.	Although little is known on the effects of anthropogenic sounds on California floater and western ridged mussels, it is prudent to avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	Very little is known of the effects of pile-driving sounds on California floater and western ridged mussels at any life-history stage.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles, Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles, Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling and Channel Rewatering	Fish and species removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Mortality from dewatering.	River beds containing live freshwater mussels should not be disturbed. If live mussels are encountered during excavation of the bed, operations should immediately cease and should be relocated a minimum of 200 ft away from the mussels.	May affect survival at juvenile and adult life-history stages.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae	Glochidia larvae: Any potential impact would only occur if the glochidia fish host is entrained or impinged.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when glochidia fish host are present.	Any potential impact would only occur if the glochidia fish host is entrained or impinged.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	All life-history stages: Potential downstream sedimentation, resulting in decreased downstream habitat suitability, decreased dissolved oxygen levels, reduced food resource availability, and reduced suitable habitat; decreased fitness, growth, and productivity.	Limit alteration of flow conditions to minimal area.	May affect survival in all life stages.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Mortality from increased sedimentation.	Adhere to system-specific in-water work windows.	May affect survival at juvenile and adult life-history stages.
		Localized alteration in invertebrate abundance	NA	NA	NA	NA	NA	NA	NA

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access and stranding (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	<u>Juveniles</u>: Loss of habitat accessibility, stranding, and increased predation risk.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May effect growth and fitness at juvenile life-history stage, mortality at all life-history stages..
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Glochidia larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. River beds containing live freshwater mussels should not be disturbed. If live mussels are encountered during excavation of the bed, operations should immediately cease and should be relocated a minimum of 200 ft away from the mussels.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	<u>Juveniles and adults</u>: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Glochidia larvae; Juveniles; Adults;	<u>All life-history stages</u>: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity.	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	<u>Glochidia larvae</u>: Changes in channel morphology, flow velocity, and substrate composition can affect host fish. <u>Juveniles and adults</u>: As filter feeders, constant water flow is required. Altered channel geometry, flow velocity, and substrate composition can result in decrease habitat suitability and changes in food web complexity. This may limit prey resource availability and foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at all life-history stages and affect life-history stages and productivity of host-fish.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	Glochidia larvae: Changes in habitat availability may indirectly affect survival through effects on host fish. Juveniles and adults: The structural footprint of weirs may permanently modify habitat suitable for juveniles and adults, affecting survival and overall population abundance.	Require assessment of the hydraulic effects of the project before permitting and avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at all life-history stages and affect life-history stages and productivity of host-fish.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fine sediment layer in the impoundment may ultimately reduce hyporheic exchange in downstream reaches, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round	Permanent	Continuous	Juveniles;	Mussel responses to altered groundwater-surface water exchange are a data gap. .	Encourage weir placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	Effect of groundwater exchange to mussel health and fitness is a data gap.
	Altered community composition	Reduced food web complexity, altered predator-prey relationships, increases in invasive species	Year-round	Permanent	Continuous	Juveniles	Juveniles: Weirs may create impoundments and may also alter streamflow and temperature characteristics in downstream reaches. These environmental alterations may create suitable habitats for non-native predatory or competitor species, or alter food web interactions between native species. These effects may impose stressors in the form of increased competition, increased predation, and decreased availability of preferred prey resources, leading to decreased survival, growth, and fitness.	No specific recommendations	May affect juvenile survival, growth and fitness.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Glochidia larvae; Juveniles; Adults	All life-history stages: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns (including food web supporting host fish). Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival and productivity during all exposed life history stages.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased suitable habitat.	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Glochidia larvae; Juveniles; Adults	All life-history stages: Decreased food resource availability, leading to increased competition and resulting effects on growth and fitness for mussels and host fish. Decreased suitable habitat, injury, or mortality caused by excessive turbidity or resulting smothering by burial.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult fitness and survival of mussels and host fish.

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Glochidia larvae	Mussel dependence upon allochthonous input is a data gap. However, could affect host fish.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect productivity.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduction in available habitat.	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased habitat availability and food availability, leading to increased competition and resulting effects on growth and fitness, including health of host fish.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival, , and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	Mussel responses to groundwater exchange are a data gap.	Avoid disturbance of vegetation along stream.	Effect of groundwater exchange to mussel health and fitness is a data gap.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced prey availability due to decreased food web productivity, decreased growth and fitness of host fish. Although effects specific to altered autochthonous inputs for the California floater and Western ridged mussels are a data gap, alterations could be expected to affect prey resource availability.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect all life-history stages.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: Require high levels of dissolved oxygen. See related stressor responses under Water Quality Alteration. Effects include effects to shot fish.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Reduced prey resources due to decreased food web productivity, decrease growth and fitness of the California floater and Western ridged mussel prey and host fish. Altered autochthonous could be expected to effect prey resource availability.		May affect all life stages.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Glochidia larvae; Juveniles; Adults	Glochidia larvae: Host-fish of the California floater and Western ridged mussel may be affected by increased temperatures, which may lead to mortality or increased thermal stress and decreased fitness of host fish. Juveniles and adults: Mortality due to increased temperatures.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth and fitness at all exposed life history stages.

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Glochidia larvae; Juveniles; Adults	<u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation. Effects to host-fish could be stressor to these mussels. <u>Juveniles and adults</u>: A physiological response to exposure at toxic levels, causing mortality or injury leading to reduced fitness is a data gap.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism specific measures as appropriate.	May affect survival of larvae. May affect juvenile survival and adult survival and productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>Juveniles and adults:</u> Effects depend on the magnitude of increased suspended solids. Turbidity sufficient to cause fine sediment embeddedness may bury these mussels and lead to direct mortality and decreased population survival.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect juvenile and adult survival.
		Increased sediment contamination	Dependent on contributing mechanism of impact	Short-term to long-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Glochidia larvae; Juveniles; Adults	<u>All expose life history stages:</u> Weir removal may lead to rapid release of contaminated sediments accumulated upstream of dams creating an exposure pathway for organisms in downstream reaches. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate potential sediment contamination issues prior to weir removal. If necessary, reduce volume of contaminated material by dredging and disposal at an approved site.	May affect survival, growth and fitness at all exposed life history stages.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs and no direct waste discharge. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	All exposed life history stages: Nutrient increase may result from decreased nutrient cycling from loss of riparian and aquatic vegetation, altered groundwater-surface water exchange, and altered temperatures. Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Glochidia larvae; Juveniles; Adults	<u>All expose life history stages:</u> Weir construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Dikes/Levees									
	Construction and Maintenance Activities								

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Glochidia larvae; Juveniles; Adults	▪ All life-history stages: The effect of pile-driving sound pressure on California floater and western ridged mussels at any life-history stage is a data gap. Any potential impact would likely occur on the host fish species for the glochidia larvae (California floater= native minnows; western ridge = coldwater stream fish such as trout and salmon).	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	This is a data gap for these species. However, effects on host fish species for glochidia larvae will affect population productivity of this species. This indirect effect applies to all stressors.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Glochidia larvae; Juveniles, Adults	All life-history stages: The effect of pile-driving sound pressure on California floater and western ridged mussels is a data gap.	Although little is known on the effects of anthropogenic sounds on California floater and western ridged mussels, it is prudent to avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	Very little is known of the effects of pile-driving sounds on California floater and western ridged mussels at any life-history stage.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles, Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles, Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish Handling, and Channel Rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Mortality from dewatering.	River beds containing live freshwater mussels should not be disturbed. If live mussels are encountered during excavation of the bed, operations should immediately cease and should be relocated a minimum of 200 ft away from the mussels.	May affect survival at juvenile and adult life-history stages.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae	Glochidia larvae: Any potential impact would only occur if the glochidia fish host is entrained or impinged.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when glochidia fish host are present.	Any potential impact would only occur if the glochidia fish host is entrained or impinged.
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	All life-history stages: Potential downstream sedimentation, resulting in decreased downstream habitat suitability, decreased dissolved oxygen levels, reduced food resource availability, and reduced suitable habitat; decreased fitness, growth, and productivity.	Limit alteration of flow conditions to minimal area.	May affect survival in all life stages.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Mortality from increased sedimentation.	Adhere to system-specific in-water work windows.	May affect survival at juvenile and adult life-history stages.
		Localized alteration in invertebrate abundance	NA	NA	NA	NA	NA	NA	NA

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
		Loss of habitat access (during construction and maintenance)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	<u>Juveniles</u>: Loss of habitat accessibility, stranding, mortality and increased predation risk.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering. Perform slow dewatering activities to allow for movement into suitable habitats.	May affect survival, growth, and fitness at juvenile life-history stage.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Glochidia larvae; Juveniles; Adults	<u>All life-history stages</u>: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. River beds containing live freshwater mussels should not be disturbed. If live mussels are encountered during excavation of the bed, operations should immediately cease and should be relocated a minimum of 200 ft away from the mussels.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	<u>Juveniles and adults</u>: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Glochidia larvae; Juveniles; Adults;	<u>All life-history stages</u>: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	<u>Glochidia larvae</u>: Changes in channel morphology, flow velocity, and substrate composition can affect host fish. <u>Juveniles and adults</u>: As filter feeders, constant water flow is required. Altered channel geometry, flow velocity, and substrate composition can result in decrease habitat suitability and changes in food web complexity. This may limit prey resource availability and foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at all life-history stages and affect life-history stages and productivity of host-fish.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lateral and longitudinal fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat, change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	Glochidia larvae: Changes in habitat availability may indirectly affect survival through effects on host fish. Juveniles and adults: The structural footprint of dikes and levees may permanently modify habitat suitable for juveniles and adults, affecting survival and overall population abundance.	Require assessment of the hydraulic effects of the project before permitting and avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at all life-history stages and affect life-history stages and productivity of host-fish.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as overall population productivity.
	Altered groundwater-surface water exchange	Reduced availability of thermal refuge and decreased intragravel DO, nutrient cycling effects	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	Mussel responses to altered groundwater-surface water exchange are a data gap.	Encourage dike/levee placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	Effect of groundwater exchange to mussel health and fitness is a data gap.
	Lacustrine								
	Habitat loss and fragmentation	Change in habitat structure and habitat suitability, reduced food web complexity, and reduced habitat availability and suitability	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	Glochidia larvae: Changes in habitat availability may indirectly affect survival through effects on host fish. Juveniles and adults: The structural footprint of Dikes and levees may permanently modify habitat suitable for juveniles and adults, affecting survival and overall population abundance.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival at all life-history stages and affect life-history stages and productivity of host-fish.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Glochidia larvae; Juveniles; Adults	All life-history stages: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns (including food web supporting host fish). Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival and productivity at all life-history stages.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Glochidia larvae; Juveniles; Adults	All life-history stages: Decreased food resource availability, leading to increased competition and resulting effects on growth and fitness for mussels and host fish. Decreased suitable habitat, injury, or mortality caused by excessive turbidity or resulting smothering by burial.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult fitness and survival of mussels and host fish.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Glochidia larvae	Mussel dependence upon allochthonous input is a data gap. However, could affect host fish.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect productivity.

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available habitat.	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased habitat availability and food availability, leading to increased competition and resulting effects on growth and fitness, including health of host fish.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival, and overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	Mussel responses to groundwater exchange are a data gap.	Avoid disturbance of vegetation along stream.	Effect of groundwater exchange to mussel health and fitness is a data gap.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Glochidia larvae; Juveniles; Adults	Glochidia larvae: Host-fish of the California floater and Western ridged mussel may be affected by increased temperatures, which may lead to mortality or increased thermal stress and decreased fitness of host fish. Juveniles and adults: Mortality due to increased temperatures.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of all life-history stages.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults	Juveniles and adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness for mussel host-fish.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult survival.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	All life-history stages: Mussel dependence on allochthonous inputs from shoreline riparian vegetation is a data gap. This could be a stressor to host fish.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult growth, fitness, and productivity.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Glochidia larvae; Juveniles; Adult	All life-history stages: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival and productivity, as well as overall population productivity.
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Mussel dependence on groundwater inflow is currently a data gap.	Avoid disturbance of vegetation along shoreline	Effects of the action resulting from this impact mechanism are unknown.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced prey availability due to decreased food web productivity, decreased growth and fitness of host fish. Although effects specific to altered autochthonous inputs for the California floater and Western ridged mussels are a data gap, alterations could be expected to affect prey resource availability.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect all life-history stages.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: Require high levels of dissolved oxygen. See related stressor responses under Water Quality Alteration. Effects include effects to shot fish.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Reduced prey resources due to decreased food web productivity, decrease growth and fitness of the California floater and Western ridged mussel prey and host fish. Altered autochthonous could be expected to effect prey resource availability.		May affect all life stages.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Glochidia larvae; Juveniles; Adults	All life-history stages: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns (including food web supporting host fish). Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness at all exposed life-history stages.
		Altered dissolved oxygen levels	*Dependent on contributing mechanism of impact*	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Glochidia larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Effects to host-fish could be stressor to these mussels. Juveniles and adults: A physiological response to exposure at toxic levels, causing mortality or injury leading to reduced fitness is a data gap..	Avoid sediment pulses. Limit nutrient inputs. Other mechanism specific measures as appropriate.	May affect survival of larvae. May affect juvenile survival and adult surviva and productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Effects depend on the magnitude of increased suspended solids. Turbidity sufficient to cause fine sediment embeddedness may bury these mussels and lead to direct mortality and decreased population survival.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect juvenile and adult survival.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	Mussel responses to altered groundwater-surface water exchange are a data gap.	No specific recommendations.	Effect of groundwater exchange to mussel health and fitness is a data gap.

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Glochidia larvae; Juveniles; Adults	All expose life history stages: Dike and levee construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Outfalls									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Glochidia larvae; Juveniles; Adults	▪ All life-history stages: The effect of pile-driving sound pressure on California floater and western ridged mussels at any life-history stage is a data gap. Any potential impact would likely occur on the host fish species for the glochidia larvae (California floater= native minnows; western ridge = coldwater stream fish such as trout and salmon).	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	This is a data gap for these species. However, effects on host fish species for glochidia larvae will affect population productivity of this species. This indirect effect applies to all stressors.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Glochidia larvae; Juveniles, Adults	All life-history stages: The effect of pile-driving sound pressure on California floater and western ridged mussels is a data gap.	Although little is known on the effects of anthropogenic sounds on California floater and western ridged mussels, it is prudent to avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	Very little is known of the effects of pile-driving sounds on California floater and western ridged mussels at any life-history stage.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles, Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles, Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling, and Channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Mortality from dewatering.	River beds containing live freshwater mussels should not be disturbed. If live mussels are encountered during excavation of the bed, operations should immediately cease and should be relocated a minimum of 200 ft away from the mussels.	May affect survival at juvenile and adult life-history stages.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae	Glochidia larvae: Any potential impact would only occur if the glochidia fish host is entrained or impinged.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when glochidia fish host are present.	Any potential impact would only occur if the glochidia fish host is entrained or impinged.

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered flow conditions (riverine)	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	All life-history stages: Potential downstream sedimentation, resulting in decreased downstream habitat suitability, decreased dissolved oxygen levels, reduced food resource availability, and reduced suitable habitat; decreased fitness, growth, and productivity.	Limit alteration of flow conditions to minimal area.	May affect survival in all life stages.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Mortality from increased sedimentation.	Adhere to system-specific in-water work windows.	May affect survival at juvenile and adult life-history stages.
		Localized alteration in invertebrate abundance	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	NA	NA	NA	NA
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Glochidia larvae; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. River beds containing live freshwater mussels should not be disturbed. If live mussels are encountered during excavation of the bed, operations should immediately cease and should be relocated a minimum of 200 ft away from the mussels.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Glochidia larvae; Juveniles; Adults;	All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	Glochidia larvae: Changes in channel morphology, flow velocity, and substrate composition can affect host fish. Juveniles and adults: As filter feeders, constant water flow is required. Altered channel geometry, flow velocity, and substrate composition can result in decrease habitat suitability and changes in food web complexity. This may limit prey resource availability and foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at all life-history stages and affect life-history stages and productivity of host-fish.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Ecosystem Fragmentation								
	Riverine and Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of longitudinal connectivity may result from water quality barrier when high effluent discharge causes chemical barrier to host fish migration. If constructed parallel to the channel, side channel and floodplain habitat may become fragmented. These actions will result in changes in habitat structure, availability, and suitability; reduced food web complexity.	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	Glochidia larvae: Changes in habitat availability may indirectly affect survival through effects on host fish. Juveniles and adults: The structural footprint of outfalls may permanently modify habitat suitable for juveniles and adults, affecting survival and overall population abundance.	Require assessment of the hydraulic effects of the project before permitting and avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at all life-history stages and affect life-history stages and productivity of host-fish.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Glochidia larvae; Juveniles; Adults	The degree to which outfalls affect riparian vegetation conditions in riverine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine environments.
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Glochidia larvae; Juveniles; Adults		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Altered groundwater–surface water exchange	Reduced available suitable habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults		Avoid permitting of projects in areas with springs, seeps, or other sources of significant groundwater discharge. Limit alteration of riparian vegetation to greatest extent practicable.	

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Juveniles	The degree to which outfalls affect riparian vegetation conditions in lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in lacustrine environments.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles		Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles		Encourage project designs that limit permanent alteration of high-quality habitat features.	
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	The degree to which outfalls affect aquatic vegetation conditions in riverine and lacustrine environments is anticipated to be limited. The magnitude of the resulting effects from riparian vegetation modification are expected to be insignificant.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	The effects of stressor exposure resulting from this mechanism of impact are expected to be insignificant in riverine and lacustrine environments.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults			
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles			
	Water Quality Modification								

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Altered thermal regime (i.e., increased summer temperatures due to elevated effluent temperatures relative to receiving body)	Annually	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Juveniles; Adults	<u>All life-history stages:</u> Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns (including food web supporting host fish). <u>Adults and juveniles</u>: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival, growth, and fitness during all exposed life-history stages.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Glochidia larvae; Juveniles; Adults	<u>All life-history stages</u>: Mortality in acute low dissolved oxygen events due to asphyxiation. Effects to host-fish could be stressor to these mussels. <u>Juveniles and adults</u>: A physiological response to exposure at toxic levels, causing mortality or injury leading to reduced fitness is a data gap.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism specific measures as appropriate.	May affect survival of larvae. May affect juvenile survival and adult survival and productivity.
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>Juveniles and adults:</u> Effects depend on the magnitude of increased suspended solids. Turbidity sufficient to cause fine sediment embeddedness may bury these mussels and lead to direct mortality and decreased population survival.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect juvenile and adult survival.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	<u>Juveniles and adults</u>: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Avoid nutrient inputs where practicable. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May cause direct mortality in acute events. May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling (due to effects of effluent discharge)	During and following discharge events	Long-term to permanent	Continuous	Glochidia larvae; Juveniles; Adults	Mussel responses to altered groundwater-surface water exchange are a data gap.	Evaluate effluent potential to adversely affect eutrophication. Require or encourage use of upstream treatment measures prior to discharge.	Effect of groundwater exchange to mussel health and fitness is a data gap.
		Introduction of toxic substances (PAHs, metals, organic pollutants)	During discharge events	Long-term to permanent	Intermittent to continuous (concurrent with discharge events and actions of persistent pollutants)	Glochidia larvae; Juveniles; Adults	<u>All exposed life history stages</u>: Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Evaluate effluent potential to introduce toxic substances. Require or encourage use of upstream treatment measures prior to discharge. Coordinate enforcement of water quality standards with Ecology.	May affect survival, growth and fitness at all exposed life history stages.
Water Intakes/Diversion Structures									
	Construction and Maintenance Activities								

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Construction equipment operation and materials placement	Increased underwater noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Glochidia larvae; Juveniles; Adults	▪ All life-history stages: The effect of pile-driving sound pressure on California floater and western ridged mussels at any life-history stage is a data gap. Any potential impact would likely occur on the host fish species for the glochidia larvae (California floater= native minnows; western ridge = coldwater stream fish such as trout and salmon).	Avoid pile-driving noise in excess of impact thresholds established by NOAA Fisheries and USFWS in habitats used by species. Limit pile driving to in-water work windows. Use double-confined bubble curtain to reduce sound pressure, or work within confined or dewatered work areas. Encourage use of vibratory hammers and wooden pilings where practicable.	This is a data gap for these species. However, effects on host fish species for glochidia larvae will affect population productivity of this species. This indirect effect applies to all stressors.
		Altered ambient noise levels	During project construction and maintenance activities	Temporary (auditory masking) to short-term (hearing threshold effects)	Interannual to decadal (during project construction and maintenance)	Glochidia larvae; Juveniles, Adults	All life-history stages: The effect of pile-driving sound pressure on California floater and western ridged mussels is a data gap.	Although little is known on the effects of anthropogenic sounds on California floater and western ridged mussels, it is prudent to avoid/minimize cavitation to limit noise intensity. Promote use of equipment equipped with antinoise/ antivibration technology where practicable.	Very little is known of the effects of pile-driving sounds on California floater and western ridged mussels at any life-history stage.
		Bank/shoreline/channel disturbance, resulting in increased sediments	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles, Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of disturbance to the greatest extent practicable. Follow established protocols for erosion control during construction.	See effects for related stressors under Water Quality Modification.
		Exposure to toxic chemicals from accidental spills	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles, Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit spills to the greatest extent practicable. Follow established protocols for erosion control and chemical containment during construction.	See effects for related stressors under Water Quality Modification.
	Flow Bypass, Fish handling and channel rewatering	Fish removal, relocation, and exclusion	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Mortality from dewatering.	River beds containing live freshwater mussels should not be disturbed. If live mussels are encountered during excavation of the bed, operations should immediately cease and should be relocated a minimum of 200 ft away from the mussels.	May affect survival at juvenile and adult life-history stages.
		Entrainment in pumps or impingement on pump screens	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae	Glochidia larvae: Any potential impact would only occur if the glochidia fish host is entrained or impinged.	Install and maintain pump screens consistent with WDFW protocols. Adhere to system-specific in-water work windows; avoid use when glochidia fish host are present.	Any potential impact would only occur if the glochidia fish host is entrained or impinged.
		Altered flow conditions	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	All life-history stages: Potential downstream sedimentation, resulting in decreased downstream habitat suitability, decreased dissolved oxygen levels, reduced food resource availability, and reduced suitable habitat; decreased fitness, growth, and productivity.	Limit alteration of flow conditions to minimal area.	May affect survival in all life stages.
		Streambed disturbance, increased turbidity (associated with site rewatering)	During project construction and maintenance activities	Temporary	Interannual to decadal (depending on activity frequency)	Juveniles; Adults	Juveniles and adults: Mortality from increased sedimentation.	Adhere to system-specific in-water work windows.	May affect survival at juvenile and adult life-history stages.
		Localized alteration in invertebrate abundance	NA	NA	NA	NA	NA	NA	NA

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
		Increased suspended solids	During project construction and maintenance activities	Short-term	Interannual to decadal (depending on activity frequency)	Glochidia larvae; Juveniles; Adults	All life-history stages: See responses to related stressors under Water Quality Modification.	Limit area of dewatering to the greatest extent practicable. Follow established protocols for dewatering and rewatering.	See effects for related stressors under Water Quality Modification.
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	During project construction and maintenance activities	Permanent	Interannual-decadal	Glochidia larvae; Juveniles; Adults	All life-history stages: See responses described under Hydraulic and Geomorphic Modification.	Avoid fill or, if unavoidable, restore currently filled or degraded shallow shoreline habitats. River beds containing live freshwater mussels should not be disturbed. If live mussels are encountered during excavation of the bed, operations should immediately cease and should be relocated a minimum of 200 ft away from the mussels.	See effects for related stressors under Hydraulic and Geomorphic Modification.
		Aquatic vegetation removal and delayed recovery	During project construction and maintenance activities	Intermediate-term	Interannual-decadal	Juveniles; Adults	Juveniles and adults: See responses described under Aquatic Vegetation Modification.	Limit dredging-related disturbance of submerged aquatic vegetation to the greatest extent practicable through project siting.	See effects for related stressors under Riparian and Aquatic Vegetation Modification.
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	During project construction and maintenance activities	Temporary to short-term	Interannual-decadal	Glochidia larvae; Juveniles; Adults;	All life-history stages: See responses described for related stressors under Water Quality Modification.	Avoid turbidity effects above background levels.	May affect juvenile growth and fitness. See effects for related stressors under Water Quality Modification.
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, reduced habitat availability and suitability	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	Glochidia larvae: Changes in channel morphology, flow velocity, and substrate composition can affect host fish. Juveniles and adults: As filter feeders, constant water flow is required. Altered channel geometry, flow velocity, and substrate composition can result in decrease habitat suitability and changes in food web complexity. This may limit prey resource availability and foraging opportunities and increase competition for suitable habitats, leading to decreased growth, fitness, and survival.	Carefully evaluate project siting and design and consider the magnitude of impact mechanisms produced by the project. Encourage selection of project designs that minimize effects on channel geometry, flow velocity, substrate composition, and groundwater exchange to the greatest extent practicable.	May affect survival at all life-history stages and affect life-history stages and productivity of host-fish.
	Altered flow regime		Year-round (with stressor exposure occurring during high-flow events, fall through spring)	Permanent	Seasonal				
	Altered substrate composition and stability		Year round	Permanent	Continuous				
	Altered groundwater–surface water exchange		Year-round	Permanent	Continuous				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	Glochidia larvae: Changes in habitat availability may indirectly affect survival through effects on host fish. Juveniles and adults: The structural footprint of intakes and diversions may permanently modify habitat suitable for juveniles and adults, affecting survival and overall population abundance.	Require assessment of the hydraulic effects of the project before permitting and avoid permitting designs that lead to disconnection of floodplain habitat.	May affect survival at all life-history stages and affect life-history stages and productivity of host-fish.

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered habitat complexity under Riparian Vegetation Modification.	No specific recommendations.	May affect juvenile growth and survival, as well as overall population productivity.
	Altered groundwater-surface water exchange	Accumulation of fines will reduce hyporheic exchange, combined with changes in hyporheic flow from alteration in vegetation, flow regime and channel geometry.	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	Mussel responses to altered groundwater-surface water exchange are a data gap.	Encourage intakes and diversions placement in locations where effects on hyporheic exchange will be limited to the greatest extent possible.	Effect of groundwater exchange to mussel health and fitness is a data gap.
	Lacustrine								
	Lateral and longitudinal habitat fragmentation	Fragmentation of lateral connectivity is minimal. If outfalls extend across littoral zone, longitudinal connection will be degraded. This will result in changes in habitat structure and habitat suitability, as well as reduced food web complexity, habitat availability, and suitability	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	Glochidia larvae: Changes in habitat availability may indirectly affect survival through effects on host fish. Juveniles and adults: The structural footprint of intakes and diversions may permanently modify habitat suitable for juveniles and adults, affecting survival and overall population abundance.	Require structures with the minimal footprint necessary to achieve project objectives. Avoid permitting projects in areas where significant cumulative effects are already prevalent.	May affect survival at all life-history stages and affect life-history stages and productivity of host-fish.
	Loss of LWD recruitment	Reduced availability of LWD from drift. Reduced availability of LWD from drift. Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduced organic matter inputs Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Permanent	Continuous	Juveniles; Adults	See responses to altered allochthonous inputs and altered habitat complexity under Riparian Vegetation Modification.	Recommend moving LWD accumulations on the structures to adjacent beaches where they would otherwise be naturally deposited, where appropriate during maintenance.	May affect juvenile survival.
	Riparian Vegetation Modification								
	Riverine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Glochidia larvae; Juveniles; Adults	All life-history stages: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns (including food web supporting host fish). Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival and productivity during all exposed life-history stages.

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered stream bank and shoreline stability	Increased suspended solids; decreased area of suitable habitat; reduced habitat complexity (e.g., filling of pools)	Year-round (with specific stressors prominent during high flow conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Glochidia larvae; Juveniles; Adults	All life-history stages: Decreased food resource availability, leading to increased competition and resulting effects on growth and fitness for mussels and host fish. Decreased suitable habitat, injury, or mortality caused by excessive turbidity or resulting smothering by burial.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult fitness and survival of mussels and host fish.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	Year-round	Permanent	Continuous	Glochidia larvae	Mussel dependence upon allochthonous input is a data gap. However, could affect host fish.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect productivity.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available habitat (freshwater)	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Decreased habitat availability and food availability, leading to increased competition and resulting effects on growth and fitness, including health of host fish.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival overall population productivity.
	Altered groundwater–surface water exchange	Reduced available suitable habitat; reduced gravel dissolved oxygen	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	Mussel responses to groundwater exchange are a data gap.	Avoid disturbance of vegetation along stream.	Effect of groundwater exchange to mussel health and fitness is a data gap.
	Lacustrine								
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round, (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts)	Seasonal	Glochidia larvae; Juveniles; Adults	Glochidia larvae: Host-fish of the California floater and Western ridged mussel may be affected by increased temperatures, which may lead to mortality or increased thermal stress and decreased fitness of host fish. Juveniles and adults: Mortality due to increased temperatures.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect survival of all life-history stages.
	Altered shoreline stability	Increased suspended solids; secondary effects on habitat complexity (e.g., through change in substrate composition, smothering of aquatic vegetation)	Year-round (with primary stressor prominent during high wave energy conditions)	Intermediate-term to long-term (dependent on time required for riparian recovery)	Continuous to seasonal (dependent on specific stressor)	Juveniles; Adults	Juveniles and adults: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness for mussel host-fish.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult survival.
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources. Reduced aquatic food web productivity due to reduction of organic matter inputs.	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	All life-history stages: Mussel dependence on allochthonous inputs from shoreline riparian vegetation is a data gap. This could be a stressor to host fish.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible.	May affect juvenile and adult growth, fitness, and productivity.
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Short-term to permanent (dependent on nature of activity)	Continuous	Glochidia larvae; Juveniles; Adult	All life-history stages: Decreased refuge habitat availability and foraging opportunities, leading to increased competition and resulting effects on growth and fitness.	Encourage project designs that limit permanent alteration of high-quality habitat features.	May affect juvenile survival and productivity, as well as overall population productivity.

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure					Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Stressor	When	Duration	Frequency	Life-history Form			
	Loss of groundwater input	Reduced aquatic food web productivity; secondary effects on habitat complexity (e.g., through alteration of aquatic vegetation)	Year-round (stressor exposure occurs during nearshore rearing period in spring and summer)	Permanent	Continuous	Juveniles; Adults	Juveniles and adults: Mussel dependence on groundwater inflow is currently a data gap.	Avoid disturbance of vegetation along shoreline	Effects of the action resulting from this impact mechanism are unknown.
	Aquatic Vegetation Modification								
	Riverine and Lacustrine								
	Altered autochthonous production	Reduced food web productivity	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Continuous	Juveniles	Juveniles: Reduced prey availability due to decreased food web productivity, decreased growth and fitness of host fish. Although effects specific to altered autochthonous inputs for the California floater and Western ridged mussels are a data gap, alterations could be expected to affect prey resource availability.	Design: Limit project structural footprint to minimize shading of aquatic vegetation to the greatest extent practicable. Construction: Avoid/minimize disturbance of aquatic vegetation during project construction.	May affect all life-history stages.
		Altered dissolved oxygen levels due to reduced photosynthesis	Year-round (most pronounced in spring and summer when vegetation growth is most extensive)	Permanent	Seasonal	Juveniles; Adults	Juveniles and adults: Require high levels of dissolved oxygen. See related stressor responses under Water Quality Alteration. Effects include effects to shot fish.		See effects for related stressors under Water Quality Modification.
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	Year-round	Short-term to permanent (dependent on nature of activity)	Continuous	Juveniles; Adults	Juveniles and adults: Reduced prey resources due to decreased food web productivity, decrease growth and fitness of the California floater and Western ridged mussel prey and host fish. Altered autochthonous could be expected to effect prey resource availability.		May affect all life stages.
	Water Quality Modification								
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	Year-round (pronounced in winter/summer during solar radiation and ambient temperature extremes)	Long-term to permanent (dependent on nature of riparian impacts).	Seasonal	Glochidia larvae; Juveniles; Adults	All life-history stages: Altered growth and productivity caused by temperatures outside optimal growth range, and alteration of food web patterns (including food web supporting host fish). Adults and juveniles: Direct mortality caused by exposure to temperatures in excess of tolerance thresholds.	Avoid/minimize disturbance of riparian vegetation. Maintain system-appropriate riparian buffer widths to the greatest extent possible. Ensure that appropriate instream flows necessary to regulate temperature and other habitat parameters are maintained.	May affect survival, growth, and fitness during all exposed life history stages.
		Altered dissolved oxygen levels	Dependent on contributing mechanism of impact	Temporary to short-term (e.g., contaminant spill or discharge) to seasonal (e.g., reduced submerged aquatic vegetation productivity due to changes in ambient light patterns), dependent on contributing mechanism of impact	Intermittent to permanent (dependent on contributing mechanism of impact)	Glochidia larvae; Juveniles; Adults	All life-history stages: Mortality in acute low dissolved oxygen events due to asphyxiation. Effects to host-fish could be stressor to these mussels. Juveniles and adults: A physiological response to exposure at toxic levels, causing mortality or injury leading to reduced fitness is a data gap.	Avoid sediment pulses. Limit nutrient inputs. Other mechanism specific measures as appropriate.	May affect survival of larvae. May affect juvenile survival and adult survival and productivity.

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Increased suspended solids	Dependent on contributing mechanism of impact	Temporary to short-term (dependent on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Effects depend on the magnitude of increased suspended solids. Turbidity sufficient to cause fine sediment embeddedness may bury these mussels and lead to direct mortality and decreased population survival.	Ensure project design avoids and/or minimizes habitat alterations leading to chronic bank instability. Avoid short-term turbidity effects above background levels to greatest extent practicable. Adhere to established protocols for managing sediment and turbidity.	May affect juvenile and adult survival.
		Altered pH levels	Dependent on contributing mechanism of impact	Temporary to short-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Juveniles; Adults	Juveniles and adults: Physiological responses to pH levels outside of optimal thresholds, causing mortality or injury leading to reduced fitness.	Limit nutrient inputs. Avoid in-water curing of concrete or discharge of concrete leachate to surface waters.	May affect survival and fitness of juveniles and adults.
		Altered nutrient cycling	Year-round	Permanent	Continuous	Glochidia larvae; Juveniles; Adults	Nutrient increases will lead to reduction in dissolved oxygen levels. See responses under altered dissolved oxygen levels.	No specific recommendations.	May affect survival, growth and fitness at all exposed life history stages.
		Introduction of toxic substances	Dependent on contributing mechanism of impact	Temporary to long-term (depending on contributing mechanism of impact)	Intermittent to interannual–decadal (dependent on contributing mechanism of impact)	Glochidia larvae; Juveniles; Adults	All expose life history stages: Intakes and diversions construction may lead to introductions of toxic substances through accidental spills or other pathways. Exposure to toxic substances may lead to direct mortality, or physiological injury limiting to survival, growth and fitness.	Employ appropriate BMPs during construction to avoid accidental spills and/or minimize their extent. Encourage improved management of recreational uses to limit introductions of toxic substances from these sources.	May affect survival, growth and fitness at all exposed life history stages.
Tide Gates									
	Construction and Maintenance Activities								
	Construction equipment operation and materials placement	Increased underwater noise levels	NA	NA	NA	NA	▪ NA	NA	This species does not occur in habitats suitable for tide gate development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered ambient noise levels	NA	NA	NA	NA	NA	NA	
		Bank/shoreline/channel disturbance, resulting in increased sediments	NA	NA	NA	NA	NA	NA	
		Exposure to toxic chemicals from accidental spills	NA	NA	NA	NA	NA	NA	
	Flow Bypass, fish handling and channel rewatering	Fish removal, relocation, and exclusion	NA	NA	NA	NA	NA	NA	
		Entrainment in pumps or impingement on pump screens	NA	NA	NA	NA	NA	NA	
		Altered flow conditions (riverine)	NA	NA	NA	NA	NA	NA	
		Streambed disturbance, increased turbidity (associated with site rewatering)	NA	NA	NA	NA	NA	NA	

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Localized alteration in invertebrate abundance	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Loss of habitat, stranding from dewatering (during construction, maintenance, and removal)	NA	NA	NA	NA	NA	NA	
	Construction/maintenance dredging	Alteration of bathymetry and substrate characteristics	NA	NA	NA	NA	NA	NA	
		Aquatic vegetation removal and delayed recovery	NA	NA	NA	NA	NA	NA	
		Entrainment of benthic organisms, increased suspended solids, resuspension of contaminated sediments	NA	NA	NA	NA	NA	NA	
	Hydraulic and Geomorphic Modification								
	Riverine								
	Altered channel geometry	Change in habitat structure and habitat suitability, reduced food web complexity, habitat availability and suitability	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for tide gate development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered flow regime		NA	NA	NA				
	Altered substrate composition and stability		NA	NA	NA				
	Altered groundwater–surface water exchange		NA	NA	NA				
	Ecosystem Fragmentation								
	Riverine								
	Lateral and longitudinal fragmentation of habitat	Fragmentation of side channel and floodplain habitat; fragmentation of upstream-downstream habitat; change in habitat structure, availability, and suitability; reduced food web complexity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for tide gate development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Loss of LWD recruitment	Sequestration of LWD, preventing downstream recruitment. See altered habitat complexity stressors under Riparian Vegetation Modification	NA	NA	NA	NA	NA	NA	
	Riparian Vegetation Modification								
	Riverine								

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
	Altered shading, solar input and ambient air temperature	Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for tide gate development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
	Altered stream bank and shoreline stability	Increased suspended solids;; decreased area of suitable habitat; reduced habitat complexity (e.g., filling of pools)	NA	NA	NA	NA		NA	
	Altered allochthonous inputs	Reduced recruitment of terrestrially derived prey resources; reduced aquatic food web productivity due to reduction in organic matter inputs	NA	NA	NA	NA		NA	
	Altered habitat complexity	Reduced recruitment of large woody debris, affecting habitat structure, hydraulic and substrate complexity, and availability of organic substrate; reduced food web productivity, reduced foraging opportunity, reduction in available cover, reduction in available habitat (freshwater)	NA	NA	NA	NA		NA	
	Altered groundwater–surface water exchange	Reduced available suitable habitat; reduced gravel dissolved oxygen	NA	NA	NA	NA		NA	
	Aquatic Vegetation Modification								
	Riverine								
	Altered autochthonous production	Reduced food web productivity	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for tide gate development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels due to reduced photosynthesis	NA	NA	NA	NA	NA		
	Altered habitat complexity	Reduced food web productivity, reduced foraging opportunity, reduction in available cover	NA	NA	NA	NA	NA		
	Water Quality Modification								

Table A-25 (continued). HPA HCP Flow Control Structures Exposure and Response Matrix for California Floater and Western Ridged Mussel.

Sub-activity Type	Mechanism of Impact	Exposure: Stressor	Exposure: When	Exposure: Duration	Exposure: Frequency	Exposure: Life-history Form	Response to Stressor	Minimization Measures	Resulting Effects of the Submechanism
		Expansion of thermal regime (i.e., increased summer temperatures, decreased winter temperatures)	NA	NA	NA	NA	NA	NA	This species does not occur in habitats suitable for tide gate development; therefore, there is no potential for exposure to construction-related impact mechanisms and related stressors.
		Altered dissolved oxygen levels	NA	NA	NA	NA	NA	NA	
		Increased suspended solids	NA	NA	NA	NA	NA	NA	
		Altered pH levels	NA	NA	NA	NA	NA	NA	
		Altered salinity	NA	NA	NA	NA	NA	NA	
		Altered nutrient cycling	NA	NA	NA	NA	NA	NA	
		Introduction of toxic substances (metals from changes in oxygen and pH; toxics from accidental spills during construction and maintenance)	NA	NA	NA	NA	NA	NA	