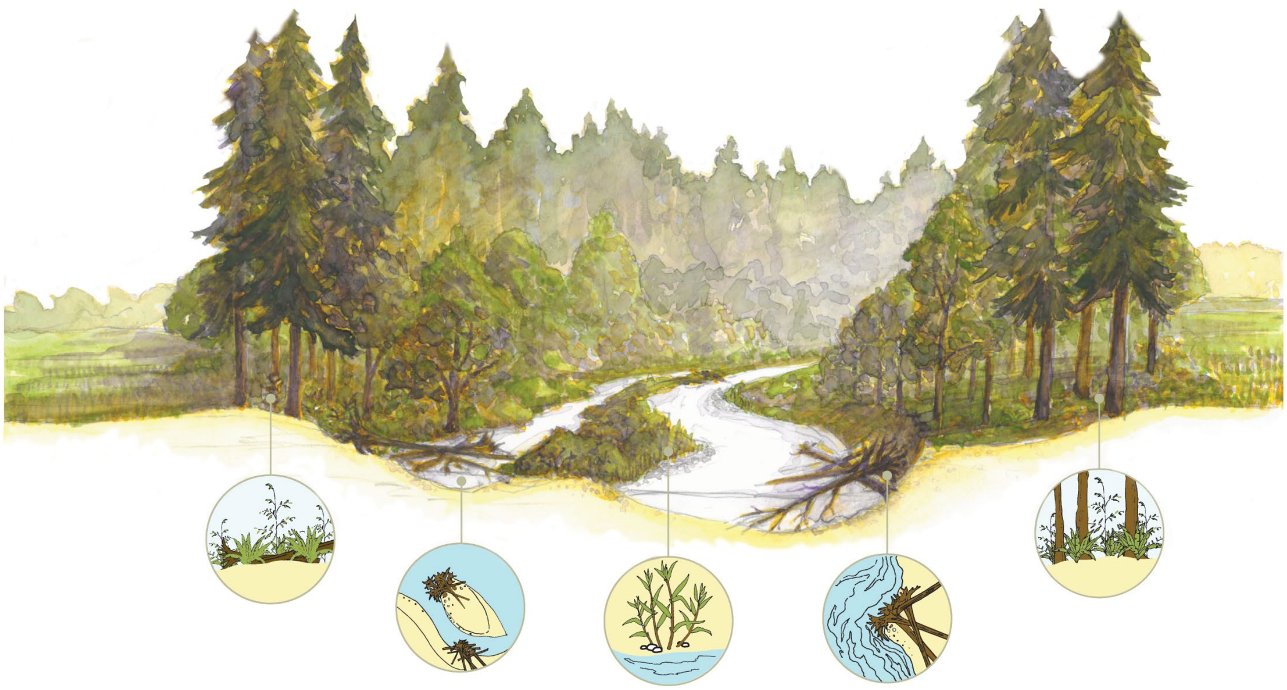

Stillman Creek EAR – Final Design Report

Stillman Creek | Early Action Reach River Mile 0 – 3.3

SUBMITTED TO
Washington Department of Fish and Wildlife

January 2022

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SUBMITTED TO

Washington Department of Fish and Wildlife
Olympia, Washington

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1. Introduction

1.1 OVERVIEW

This report describes the aquatic habitat restoration design for the Stillman Creek (RM 0 – 3.3) Early Action Reach (EAR). The project helps to achieve the goals and objectives of the Chehalis Basin Aquatic Species Restoration Plan (ASRPSC 2017 and WDFW 2019). Enhancement actions address critical habitat limitations and improve aquatic habitat and ecosystem processes within the project reach. The identified actions are guided in large part by the findings of the South Fork Chehalis Sub-basin Reach Assessment (Inter-Fluve 2018a) and by other efforts performed as part of the Chehalis Basin ASRP, which have provided a considerable amount of additional foundational material. The final design plans and this final design report build off of the Restoration Actions Report (Inter-Fluve 2018b) and previous design report iterations at the Concept and Preliminary Design stages.

The restoration actions included in the design have been informed by a range of information sources at multiple spatial scales. These are visualized in Figure 1. At the Geospatial Unit (GSU) scale, limiting factors were identified by the SRT using results from the Chehalis Ecosystem Diagnosis and Treatment (EDT) analysis (ICF 2019). EDT is a fish population and habitat model that models the impact of habitat impairments on life-stage specific fish performance measures. EDT output was also used by Inter-Fluve (IF) at the sub-basin and reach scales to identify habitat limiting factors and the types of actions necessary to address them. For the specific reach and sub-reach scale actions that comprise the final designs, these were further informed by multidisciplinary science and engineering analysis, modeling, and field investigations by Inter-Fluve; methods and results of which are described in this report. The designs also incorporate discussions and feedback from the SRT, Steering Committee, WDFW Engineering, Lewis Conservation District and landowners.

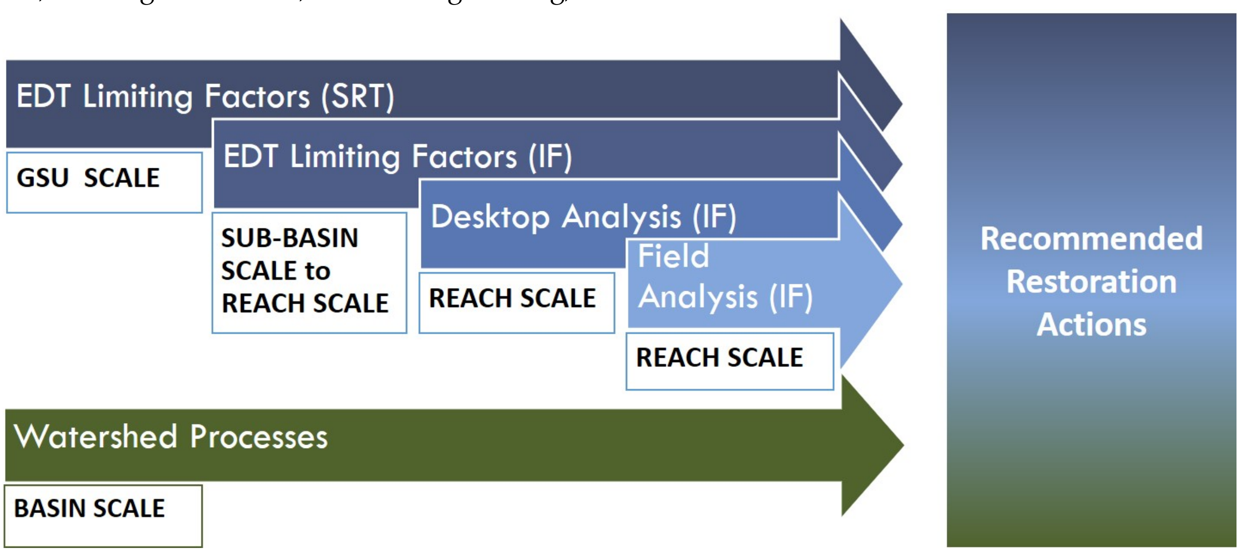


Figure 1: Flow chart indicting process involved moving from limiting factors, through reach and watershed assessment, to restoration actions. All of these stages have been incorporated in developing the designs, and will continue to be incorporated as the design progresses.

1.2 EARLY ACTION REACHES & THE AQUATIC SPECIES RESTORATION PLAN

The intent of the early action reach projects is to begin progress on meeting the goals for aquatic species restoration in the Chehalis Basin. Those goals include the following, sourced from the 2018 Chehalis Basin Strategy and the 2019 Phase I ASRP;

- Improving and protecting critical habitats,
- Restoring ecosystem processes,
- Increasing populations of aquatic and semi-aquatic species
- Creating flood and climate-resilient systems
- Supporting the human needs in the basin

These goals are further defined in the Aquatic Species Restoration Plan Initial Outcomes and Needed Investments for Policy Consideration (ASRP Steering Committee 2017). That document critically states that *"The goal of restoration is not to restore the watershed to its intrinsic conditions, which is not possible."* Rather the *"Restoration aims to restore some part of the lost intrinsic potential in ways consistent with achieving the vision for the ASRP"* (ASRP Steering Committee 2017). The 2019 draft of the ASRP Phase I document reiterates these same goals and provides specific mention of how the Early Action Reaches are intended to begin progress on meeting these goals (WDFW 2019). As such, this project design is intended to align with the ASRP goals.

ASRP Vision Statement

"The vision of the ASRP is to provide for a future where the Chehalis Basin can support healthy and harvestable salmon populations, robust and diverse populations of native aquatic and semi-aquatic species, and productive, self-sustaining ecosystems that are resilient to climate change and anthropogenic stressors, while also honoring the social, economic, and cultural values of the region."
(ASRP Steering Committee 2017)

1.3 SOUTH FORK CHEHALIS DESCRIPTION

The South Fork of the Chehalis sub-basin has its headwaters in the Willapa Hills Region, the northern extent of the Coastal Range before the Olympic Mountains (McConnaha et al. 2017). At its confluence with the mainstem of the Chehalis River, the South Fork Chehalis drains 125 square miles of the Coastal Range within Lewis County in central Washington. The South Fork of the Chehalis contributing basin includes several tributaries such as
Stillman Creek, Lost Creek, Lake Creek, and Halfway Creek. The sub-basin has a long history of logging, wildfires and mass movements within areas of steeper terrain, and agricultural and residential development in the lower elevation valleys. The South Fork Chehalis sub-basin was split into seven diagnostic units for assessment (McConnaha et al. 2017), which were further divided into 163 stream reaches (McConnaha et al. 2017). These stream reaches were delineated using geomorphic characteristics and physical obstructions to flow in 2016 and

South Fork of the Chehalis

The South Fork of the Chehalis River Sub-basin is one of five sub-basins within the Chehalis River Basin identified by the ASRP as high priority for habitat restoration. The study reach selected for this analysis is RM 0 – 3.3 of the Stillman. The study reach sits within a wide agriculturally-developed valley and drains managed and unmanaged forest.

incorporated into the Chehalis EDT model. This effort focuses on the planning reach identified as *RM 0 to 2.5* of Stillman Creek and its adjacent floodplains. However, the actual project assessment and design extents are from RM 0 to 3.3[1]. Stillman Creek, at the confluence with the South Fork Chehalis, drains 39 square miles.

[1] The project assessment, conceptual designs, and draft preliminary design extents were from RM 0 to 3.3. However, changes in landowner participation have reduced the project extent to RM 0 to 2.6, with about a 0.6 river mile gap in the middle of the project reach. See Section 2.8 for more detail on landownership and participation.

2. Existing Conditions for Aquatic Species

2.1 SUMMARY OF LIMITING FACTORS

2.1.1 Watershed

Limiting factors within the South Fork Chehalis River sub-basin (including Stillman Creek) have been identified by the SRT using EDT (Figure 2). The majority of limiting factors have been identified as ones that can be addressed directly using process-based river restoration approaches. Temperature, food index, and fish harvest are limiting factors that are beyond the scope of this project, but may be indirectly improved by the restoration of functional ecosystem and fluvial processes.

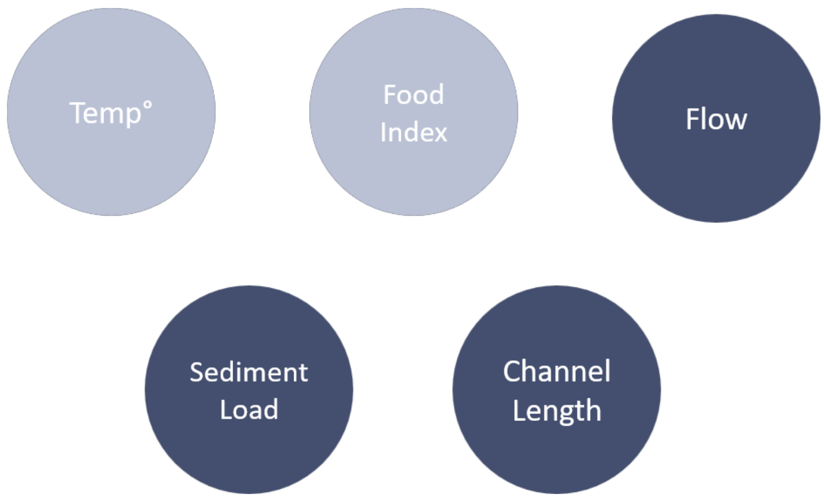


Figure 2: Limiting factors to salmonid target species within the South Fork Chehalis Subbasin identified by the Science Review Team (SRT) using Ecosystem Diagnosis and Treatment (EDT) modeling.

Figure Notes: Light blue circles indicate that these limiting factors were not quantified within the Reach Assessment, and are addressed on a more limited basis with the designs.

2.1.2 Project Reach

The previously conducted reach assessment (Inter-Fluve 2018a) describes the complex geologic and glacial history that carved the landscape and the subsequent legacy of human manipulation and disturbance. The subbasin and reach continue to be significantly influenced by the effects of:

- Large-scale landcover conversion within floodplains (agricultural development);
- Large-scale landcover conversion within headwaters (timber harvesting);
- Channel straightening and manipulation of planform;
- Bank stabilization projects; and
- A loss of old growth forest throughout watershed.

These legacy effects have impaired aquatic habitat function, and are believed to limit the production of salmon and steelhead within the reach. These limiting factors include the following:

- Floodplain disconnection
- Loss of summer and winter habitat quantity and quality
- Disruption of large wood recruitment processes
- Impaired resilience to flooding
- Loss of large wood and persistent large wood accumulation abundance

From a fisheries perspective, Stillman Creek supports anadromous runs of winter steelhead, fall Chinook salmon, spring Chinook salmon, and Coho salmon (Inter-Fluve 2018a). Physical habitat modeling suggests that the primary controls on habitat suitability are the result of:

- Low baseflows, high temperatures and reduced habitat during summer low flows, and
- High velocities and a lack of winter refuge during winter high flows.

Due to the simplified channel and floodplain conditions within the reach, winter refuge habitats where fish can escape high velocities in the main stem are lacking during average winter discharge. Similarly, summer low-flow habitat has been degraded by historical riparian clearing and channel straightening, which has reduced physical habitat while simultaneously increasing water temperatures.

Habitat Limitations by Species

Coho Salmon: Habitat diversity | Habitat composition | Temperature | Limiting habitat discharge range: typical winter flows around 400 cfs.

Steelhead: Summer flow volume | Temperature | Habitat diversity | Limiting discharge range: typical summer low flows.

Fall Chinook: Habitat composition | Habitat diversity | Sediment load | Limiting discharge range: typical late winter flows during early emergence.

Spring Chinook: Habitat composition | Temperature | Habitat diversity | Limiting discharge range: typical late winter flows during early emergence.

From a historic perspective, prior to settlement by early European pioneers, the project reach likely consisted of extensive floodplain wetlands and forests, numerous large wood accumulations, and narrower, multi-threaded channels.

Although certain subreaches of the project reach exhibit characteristics of higher functioning streams, such as mobile beds, and large wood, the reach as a whole remains in a state of suspended degradation. The ability of the channel to “self-heal” is uncertain over timescales relevant to target species recovery (i.e., years to decades). The channel is continually responding to fluctuations in driving process variables (e.g., flow and sediment) and largely lacks those elements that provide resilience to the constant change (e.g., large wood and mature riparian forests). For example, past channel alterations have concentrated flow into primarily a single-thread channel, resulting in higher stream velocities that cause rapid erosion even during common floods (i.e., those that occur every one to two years), especially in areas lacking mature riparian vegetation. Therefore, improvements in stream function, and habitat quality and quantity, will likely need to come from rehabilitation via. reach scale restoration projects. The Reach Assessment (Inter-Fluve 2018a) suggests that improvements in stream function can be obtained from actions such as removing bank armor and reconnecting floodplains, actions that build resilience into the system by reducing flood energy and capturing sediments. These and other actions are mechanisms by which river processes, and associated ecological function and habitat benefits, may be re-established in the project reach.

2.2 LAND USE

The South Fork Chehalis sub-basin has a rich and varied human land use and river history. The Chehalis Tribe extended to many regions within the Chehalis River basin, but primarily traveled through and inhabited the regions along the Chehalis River and out into Grays Harbor (Confederated Tribes of the Chehalis 2009). Their impacts to the land largely consisted of encouraging the growth of berries and camas through prairie burns every two to three years. The arrival of Euro-American settlers to the area and their consumption of natural resources increased pressure on Native American fisheries, reduced available hunting grounds, and altered watersheds through logging, development and agricultural practices.

The first European settlers arrived in 1851 and likely cleared enough land to homestead (as evidenced by Government Land Office maps). The rich soils of the South Fork Chehalis valley, un-scoured by glaciers, provided fertile ground for cultivating crops once cleared of forest. Following clearcutting, the river valley bottoms were converted to agriculture. Crops planted included wheat, oats, barley, corn, and potatoes (Rowe 2018). Agricultural changes also included the raising of livestock, such as cattle, goats, and sheep. The cultivation of crops and expansion of agriculture within the valleys west of the Cascade Range by settlers of European descent conflicted with the land management practices of the tribes native to the land, including the Chehalis Tribe. This included the tribal use of fire as a tool to maintain prairie ecosystems as opposed to settlers clearing land for cultivation. Additionally, the plants and animals that arrived with the increasing numbers of settlers coming from the east did not always coexist with the native plants cultivated and animals raised by the native tribes. The spread of disease, the introduction of noxious weeds and the suppression of wildfire led to dramatic changes in plant communities. This period marks a shift in the ecological and cultural landscape of the South Fork Chehalis and adjacent basins.

Today, much of the former river valley bottom continues to be actively farmed and the modern timber industry continues to manage forests for harvest in most upland areas of the basin. Residential land adjacent to the river has increased as larger parcels have been segmented. The on-going uses as well as the legacy effects of a century of alteration continue to impair aquatic habitat within the project reach and the ecological processes necessary to support it. Additionally, human land use within and outside of the basin have resulted in a comparatively flashier hydrograph, increased high intensity storm events, reduced large wood volumes, and increased sediment loads. These factors, among many others, continue to put pressure on the watershed, channels, and remaining healthy riparian areas, leading to less aquatic habitat than would have otherwise been present.

2.3 WATER QUALITY

The lower reaches of both Stillman Creek and the South Fork Chehalis River generally exceed water quality standards set by the Washington State Department of Ecology (WDOE 2018). Assessed waters are placed into categories that describe the status of water quality based on repeated measurements.

- Category 1 indicates the water body meets tested standards for clean waters.
- Category 2 indicates there may be some evidence of a water quality problem, but not enough to show a continuous problem and continued testing will be necessary.
- Category 3 waters are those with insufficient data and which necessitate continued testing in order to either place the waters into Categories 4 or 5 if the standards are exceeded or to put them into Categories 1 or 2 if they are not.
- Category 4 waters have several sub-categories, depending on how the water quality impairments are being met.
- Category 5 indicates the water body is polluted and exceeding water quality standards.

Lower portions of Stillman Creek within the project reach are listed (in Categories 4 and 5) on the 2012 Washington State Department of Ecology 303d list for Temperature. At the confluence of the South Fork and the mainstem Chehalis Rivers has two water quality excursions above TMDL limits: Category 5 listing for Temperature, Category 4A listing for Dissolved Oxygen (up from a Category 3 listing in 2008). In addition, there is a Category 2 listing for Bacteria in the South Fork Chehalis River (WDOE 2018). These conditions are detrimental to aquatic species in the project reach and are considerations relevant to the project design approach.

2.4 GEOMORPHOLOGY

Throughout the project reach, geomorphic characteristics vary by proximity to lateral controls such as infrastructure, intact riparian vegetation, bedrock outcrops, and bank armoring. The channel and active floodplain through the project reach are inset into a modern terrace, formed by both glacial process of the past and human disturbance practices of the present.

The project reach reflects largely conventional downstream geomorphic trends. In the downstream portion of the project reach stream gradient increases from a shallow slope (0.2%) to a moderate grade in the mid reach (0.4%). Sinuosity of the channel ranges between the upstream and downstream segments of the project reach. The upstream half is characterized by larger meander wavelengths and a sinuosity of 1.9. While the downstream half has smaller meander wavelengths and a lower sinuosity of 1.3. Interestingly, the upstream section appears more confined and influenced by bedrock grade control, while the downstream half becomes more alluvial and depositional in nature. However, the channel receives Lost Creek tributary contributions of sediment and discharge which influence it channel form (width) from its confluence at the Lost Valley Road Bridge. Bed forms today are predominantly pool-riffle throughout the channel, with glide habitat present in the intermittent lower gradient sections.

The contemporary channel form of Stillman Creek is governed by the valley morphology, but is largely influenced by plentiful sediment supply pulses, most-recently related to the 2007 flood event (near 500-year recurrence interval). The large sediment supply produced during the 2007 flood event resulted in aggradation (Inter-Fluve 2018a). In some locations, particularly upstream of channel constrictions such as the Lost Valley Road bridge (Inter-Fluve 2018a), aggradation of logs and sediment of 10 to 15 feet was observed. The channel has been subsequently incising through this aggraded floodplain, slowly shifting towards pre-flood dimensions (Nelson and Dube 2015). Channel complexity is limited to areas that contain short split flow or anabranched segments that generally correspond to the presence of large wood accumulations and lateral migration. Bed forms range from pool-riffle sequences through more complex portions of the channel, with lower energy glides occupying the reminder of the channel. The substrate in these locations consisted of relatively clean accumulations of gravels and cobbles. Spawning sized gravels appeared to be retained in the form of mid-channel and point-bar features.

Within the context of modern entrenchment, contemporary channel morphodynamics include creation and development of floodplain and point-bar that are inset below abandoned terrace surfaces. This is a classic channel evolution process described by Schumm et al. (1984, 1986) and built upon by Cluer & Thorne (2013) where incision and entrenchment occur due to changes in discharge and/or sediment regimes. As the channel has adjusted to these changes, it develops a new active floodplain surface that is inset within the historical abandoned terraces. On Stillman Creek, floodplain aggradation related to large-scale sediment inputs, most likely produced by large flood events and landslides, drive this process. In addition to upstream landslide inputs, primary sediment sources observed within the project area are tributary inputs and localized bank erosion.

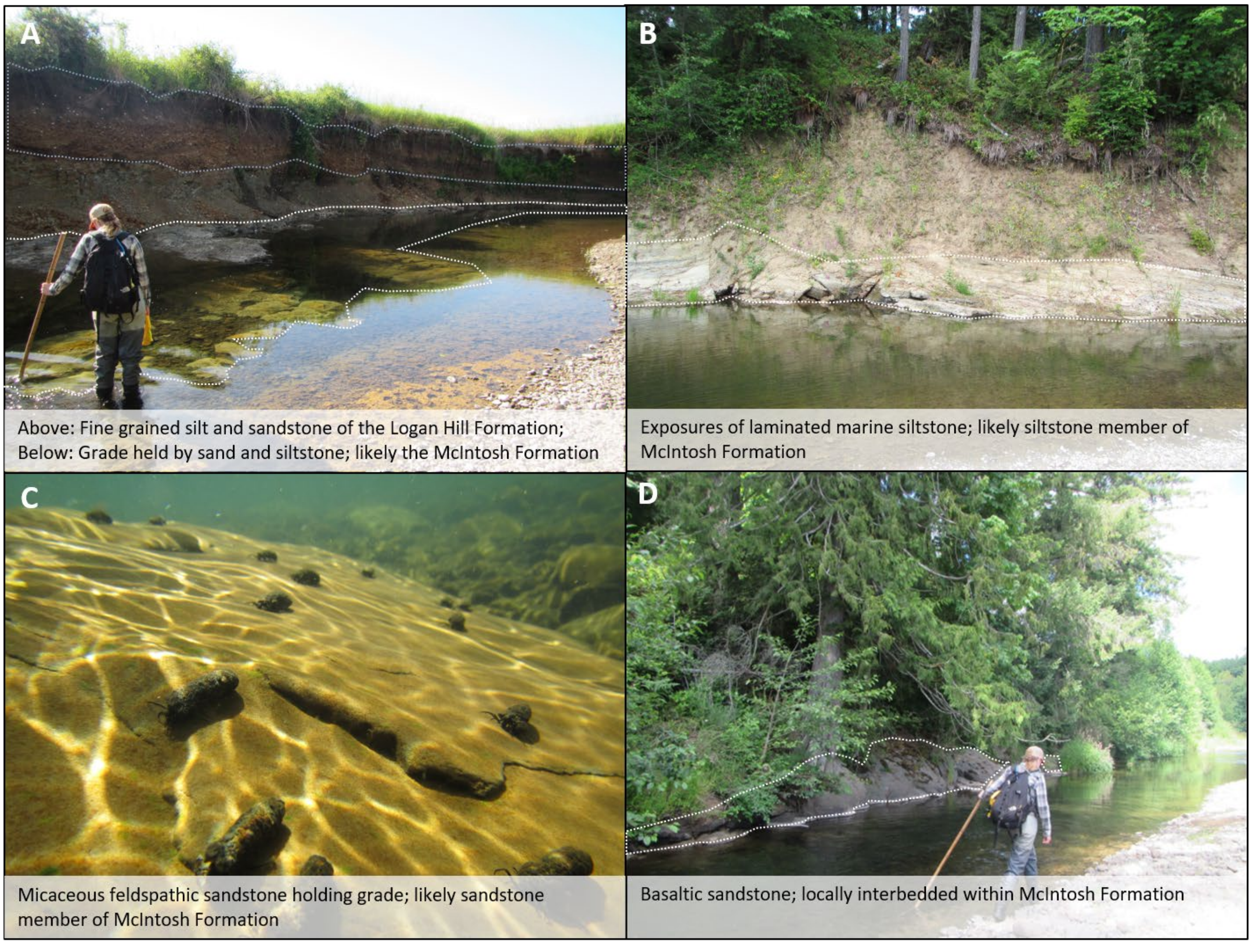
The modern geomorphology of the project reach has been impacted by large-scale anthropogenic disturbances and landcover conversion as previously described. The most effective rehabilitation strategies will need to provide sufficient 'adjustment space' that allows the river to mediate and absorb the effects of on-going changes to the discharge, sediment, and flow regimes, while allowing vegetation conditions to mature over time. Actions such as removing bank armor and removal or alteration of confining features (e.g., riprap, levees) that disconnect the floodplain can be a means to achieve this. However, these actions are often not possible due to infrastructure that is protected by these features or uninterested landowners, and this is the case for several areas within the project reach. In these cases, areas of enhanced floodplain connections can be created through the development of inset floodplains or reactivation of the modern terrace in select low-risk locations. Large wood structures can also help with the reconnection process by aggrading bedload to stop or reverse past channel incision. These structures also provide temporary ecologic (e.g., habitat cover) and geomorphic (e.g., pool scour) benefits in the intervening period.

2.5 GEOLOGY

Within the project reach, Stillman Creek has cut down through the overlying Pleistocene-aged alluvium and colluvium deposits, exposing these sediments at near vertical banks up to 10 feet. These layers, referred to as the Logan Hill Formation, consist of unconsolidated to semi-consolidated clay, silt, sand, and gravel layers and locally contain peat or wood deposits. Decades to centuries of stream incision has exposed the underlying Eocene sedimentary layers at the channel bed (Figure 3A). This exposed bedrock is likely the McIntosh Formation, consisting of laminated marine siltstone in the upper section (Figure 3B) and transitioning to micaceous feldspathic sandstone in the lower section (Figure 3C). Basaltic sandstone, basalt flows and tuff are locally interbedded (Figure 3D) (Washington Division of Geology and Earth Resources 2018).

Landslides, debris flows, and debris avalanches have been mapped along Stillman Creek, West Fork Stillman Creek, and Little Mill Creek, all of which are tributaries to the project reach (Inter-Fluve 2018a). The frequency and aerial extent of landslides within the Willapa Hills region has been attributed to steep slopes and the contact between subsurface bedrock and thin soil. The mass failures mapped within the South Fork Chehalis sub-basin tend to occur along the contact of the subsurface Crescent Formation basalt or unnamed Eocene-aged mafic intrusive rocks with overlying soil (Sarikhan et al. 2008).

The combination of exposed bedrock, lack of large wood, and the periodic nature of sediment delivery results in a system that can see rapid aggradation during major flood events followed by relatively quick degradation back down to the bedrock layers.



Above: Fine grained silt and sandstone of the Logan Hill Formation; Below: Grade held by sand and siltstone; likely the McIntosh Formation

Exposures of laminated marine siltstone; likely siltstone member of McIntosh Formation

Micaceous feldspathic sandstone holding grade; likely sandstone member of McIntosh Formation

Basaltic sandstone; locally interbedded within McIntosh Formation

Figure 3: Site assessment photos of exposed bedrock and recently deposited material along the Stillman Creek project reach.

2.6 HYDROLOGY

Streamflow in the Stillman Creek varies seasonally, with the largest floods typically occurring as a result of heavy rains or rain-on-snow events during late fall and winter. Many of the largest storms in the Chehalis River basin are atmospheric river events, which are long, narrow bands of highly concentrated water vapor typically characterized by large amounts of rainfall and warm atmospheric conditions (Abbe et al., 2016). Given the narrow width of atmospheric rivers, precipitation amounts can vary greatly between adjacent catchments in a single storm. Additionally, due to a larger proportion of basin elevations being suitable for antecedent snow conditions, the Stillman Creek reach is inherently more susceptible to rain-on-snow events than the South Fork Chehalis upstream of the Stillman Creek confluence. The lowest flows in the South Fork Chehalis River basin typically occur in summer months, which is consistent throughout the Chehalis River basin.

Streamflow within the South Fork Chehalis reach is actively measured at the South Fork Chehalis Near Wildwood (USGS Gage# 12020800), which is located immediately downstream of the Wildwood road crossing. The relatively short period of record for the Wildwood gage spans 1996 to 2018, with missing peak flow data in the 2015 water year. The wildwood gage operates seasonally, meaning no data are reported from May 1 through September 30 of each year. There are a number of ephemeral tributaries along the South Fork Chehalis project reach, which likely combine to add a meaningful proportion of the flow within the project reach during peak flow events. The limitations on available data and presence of ungagged tributaries reduce the general confidence in development hydrologic statistics, as described below.

There are currently no streamflow data collected on Stillman Creek, and therefore a combination of methods for estimating streamflow on ungaged streams were used for this analysis. The Stillman Creek project reach consists of 3 major sub-basins; Stillman and Halfway Creeks, which combine near the upstream end of the project reach, and Lost Creek, which combines with Stillman Creek just upstream of the Stillman and Lost Creek confluence.

The results of the peak flow analysis for the South Fork Chehalis Reach are displayed in Figure 4. A representative seasonal hydrograph comprised of daily and monthly mean exceedance flows for Stillman Creek is displayed in Figure 5. A summary of key discharges consisting of peak and seasonal flows is provided in Table 1. Peak and seasonal flows were used in the hydraulic analyses (Section 4.5) which ultimately informs the design process.

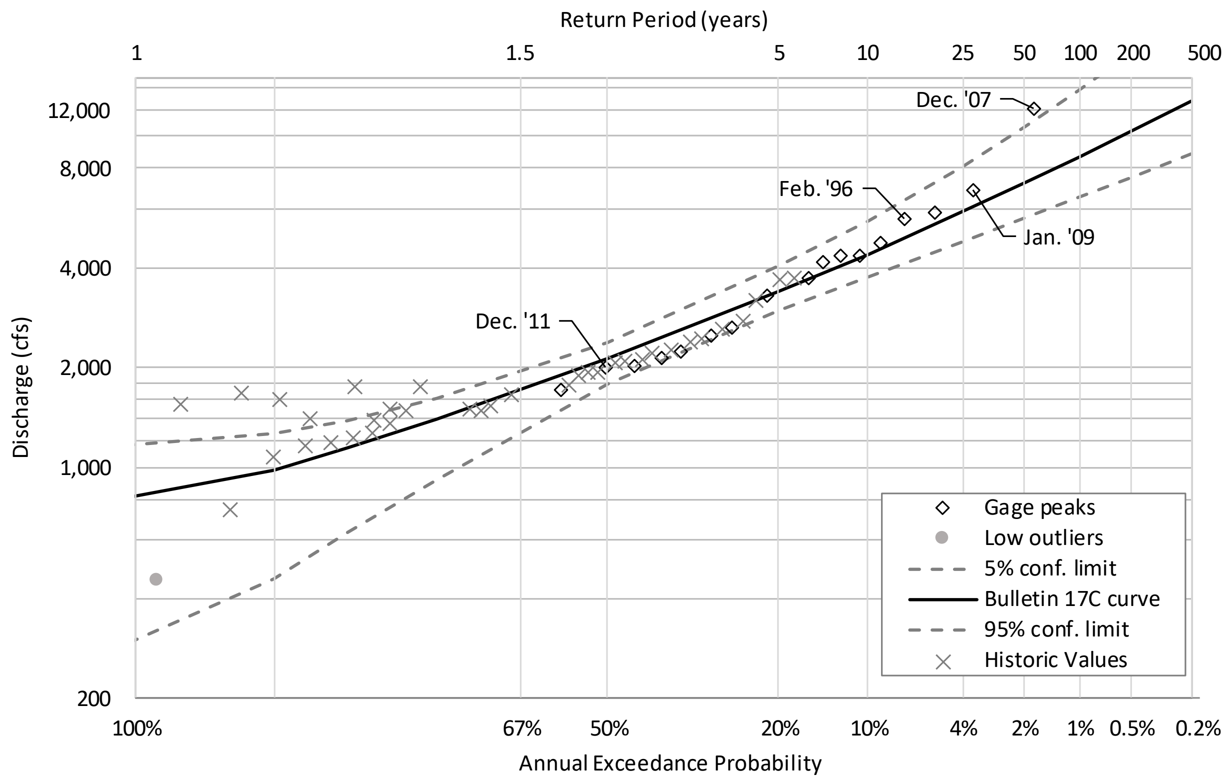


Figure 4. Flood Frequency Curve for the modified Wildwood Gage analysis. Gage peaks are weighted from discharge at the South Fork Chehalis near Wildwood Gage for the available period of record (1996-2018). The historic peaks are estimated from discharge at the South Fork Chehalis near Boistfort, and South Fork Chehalis at Boistfort gages. The 5% confidence, Bulletin 17C curve, and 95% confidence lines are from HEC-SSP version 2.1.

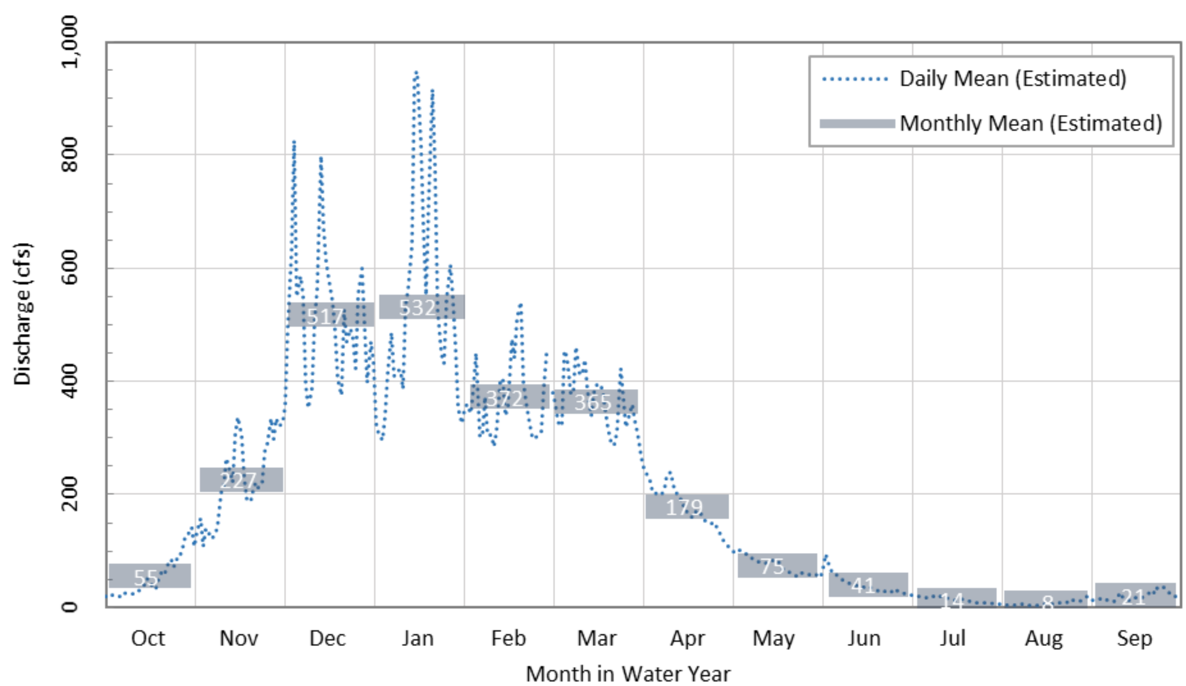


Figure 5. Seasonal Flow statistics for the South Fork Chehalis Project Reach.

Table 1. Stillman Creek project reach discharges of interest.

Discharge Statistic	Discharge (cfs)	Source
Q7,10	18	USGS Regional Low Flow Equations
Summer	8	Scaled from South Fork Chehalis NR Bositfort Gage Record
Winter	532	Scaled from South Fork Chehalis NR Bositfort Gage Record
FEMA 100-year Flow	7,340	Estimated from FEMA Analysis
Recurrence Interval Peaks		
1-year	1,884	Extrapolated from USGS Regional Regression Equations
2-year	2,820	USGS Regional Regression Equations (weighted by South Fork Chehalis NR Boistfort Gage)
5-year	4,100	
10-year	4,990	
25-year	6,160	
50-year	7,060	
100-year	7,990	
500-year	10,300	

2.6.1 Regulatory Flood Comparison

To conform with Lewis County Codes the project will require that a hydraulic analysis be completed that indicates that during a 100-year event the project will not have an adverse impact on insurable structures located on private property in the vicinity of the Project area. This topic is covered in more detail in Attachment D.

2.7 CLIMATE CHANGE

The climate of the South Fork Chehalis sub-basin generally consists of warm and relatively dry summers and cold, wet winters. Oceanic influence provides slightly warmer winters and cooler summers than counterparts on the eastern side of the Cascades. The majority of the precipitation throughout the basin falls as rain in the winter and spring. However, the annual precipitation received varies across the basin from headwaters to river outlet (Figure 6). The headwaters of Stillman Creek, located in close proximity to the heart of the Coastal Range, receive over 91 inches of precipitation on average annually. The outlet of Stillman Creek, at the confluence with the South Fork Chehalis, receives over 70 inches of precipitation on average annually. Average daily air temperatures in the summer months (June – August) typically fluctuate between 60-70°F (PRSIM Climate Group and Oregon State University 2017). Average air temperatures in the winter months decrease slightly upstream as elevation increases, but generally stay between 30-40°F.

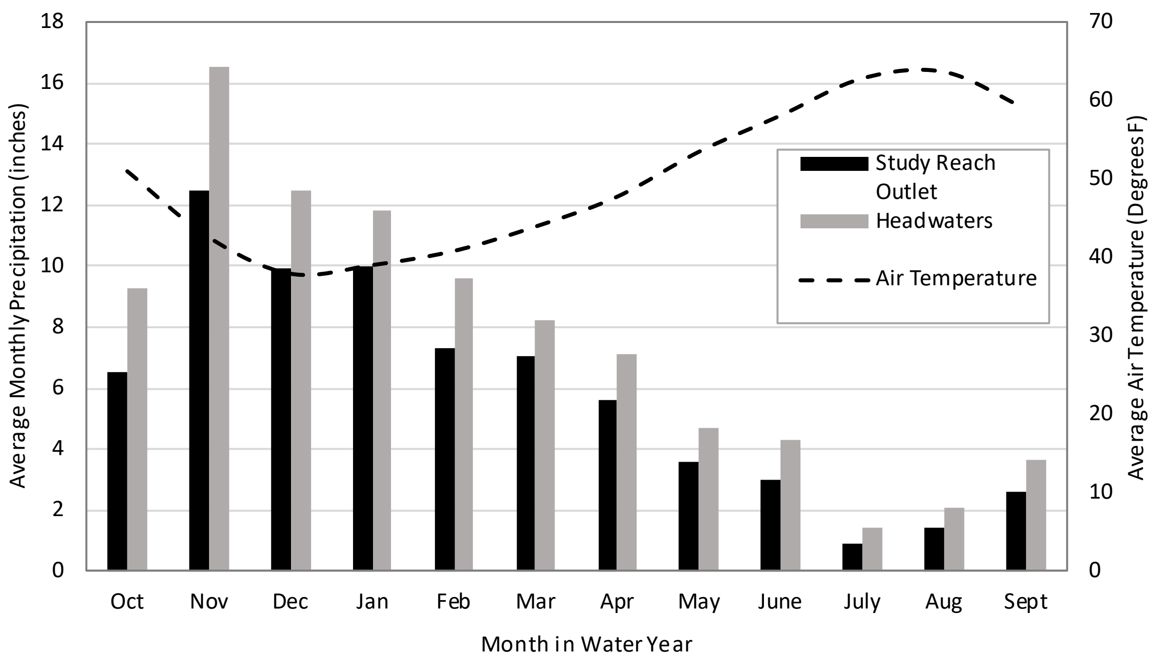


Figure 6: Precipitation and temperature at the outlet and headwaters of the Stillman Creek project reach (PRISM Climate Group and Oregon State University 2017).

Global climate models used to accurately capture the 1.4°F warming measured in the Pacific Northwest over the 20th century have been applied to predict future climate trends (Srinivasan et al., 2007). These models predict an average increase in annual temperature of 2.0° F by the 2020s, 3.2° F by the 2040s, and 5.3°F by 2080 (Mote & Salathé, 2010). Climate simulations indicate precipitation and streamflow in the Pacific Northwest will respond to a changing climate through increased intensity of winter storm events resulting in higher winter streamflow, and decreased summer precipitation resulting in longer periods of and decreased, low streamflow (Mantua et al, 2009). They also predict that summer temperatures currently associated with eastern Washington will begin to encroach into western Washington by the 2080s.

The South Fork Chehalis watershed (including Stillman Creek), a rain dominated watershed, is predicted to see an increase in summer streamflow temperatures associated with the increase in atmospheric temperature and prolonged periods of low flow. This increase in stream flow temperature within Western Washington has been predicted to increase by 2.5°F by the 2040s, resulting in 16% more stream locations with weekly summer temperatures that exceed 67°F, the threshold of salmonid stress (NWIFC 2016). These temperature increases will make cool water refuge areas, such as deep pools with cover, key to helping sustain salmon populations. It is also predicted that the frequency and magnitude of peak floods will increase, a trend found to correlate with low chinook productivity in adjacent Western Washington streams (NWIFC 2016).

2.8 LAND OWNERSHIP

Landownership along the project reach is summarized in Table 2 below.

Table 2. Landowners along the Project Reach

Landowner Name	River Mile | River Side	Parcel ID Num.	In Project LOD [1]
Ethan Allen	3.3 - 3.1 | River Right	16197002006	No
Barry Panush	3.3 – 2.8 | River Right & River Left	16197001006 16186003000 16186002001	No
Jane Trieber	3.0 - 2.6 | River Right	16186002002	No
Weyerhaeuser Don Schuh	2.6 - 1.6 | River Left	16188000000 16182000000 16176000000 16189004000 16176001000	Yes
Vikki Harr	2.6 - 2.4 | River Right	16183004008	Yes
Mary Mallonee	2.2 – 2.4 | River Right	16181001000	No
Loren Torgerson (Lindelof)	2.2 – 1.9 | River Right & River Left	16175000000	Yes
Christopher and Shari Johnson	1.9 – 1.5 | River Right	16146011006	No
Kelly and Marty McGreal	1.9 – 1.5 | River Right & River Left	16146011005	No
Brenda & Stillman Wood (Banjuh's)	1.5 – 0.7 | River Right & River Left	16150000000 16148000000	Yes
Liz Senderak	1.2 – 0.9 | River Right & River Left	16147000000 16151022001	Yes
Capital Land Trust	0.7 – 0.0 | River Right & River Left	16025002000	Yes

Notes:

1. Landowners are listed whose properties are along the project reach. Not all properties along the project reach are in the project limits of disturbance (LOD).

3. Alternatives

3.1 OVERVIEW OF ACTION EVALUATION AND SELECTION

The suite of actions that comprise the designs were developed through a step-wise consideration of the efficacy of the actions and a host of socio-economic and site constraints. This section briefly summarizes this process and the considerations that resulted in the suite of actions included in the designs.

Natural Process Limiting Factors

- Floodplain connectivity
- Large wood
- Riparian conditions
- Natural bank migration rates
- Watershed conditions

Actions were originally identified that addressed the habitat limiting factors in the project reach. As described in detail in sections 2.1.1 and 2.1.2, the Stillman Creek project reach continues to respond to legacy impacts from logging, agriculture, and residential development. This has resulted in:

- A loss of floodplain connectivity, resulting in reduced habitat during late winter flows;
- A loss of in-channel and floodplain complexity, resulting in reduced habitat during all flows;
- A reduction in large wood processes (both on a reach and watershed scale), resulting in reduced abundance and longevity of large wood accumulations and associated habitat diversity and composition; and
- Impaired riparian vegetation, altering natural bank migration rates and lateral large wood recruitment.

Numerous potential actions were originally developed as a means to address the habitat and river process impairments. These are presented in the Restoration Actions Report (Inter-Fluve 2018b) and many are described in Section 4.4. Although they are presented individually, these restoration[2] actions have a cumulative impact. Many of them provide opportunities to begin to restore processes that have been affected by a legacy of alteration; however, their efficacy is achieved through their integration and interaction.

Due to the complexity of landowner and stakeholder interests and scale of study reach, a variety of options were presented within the Restoration Actions Report (Inter-Fluve 2018b), which were further culled down to concepts presented within the Concept Design Report (Inter-Fluve 2019). A framework for identifying, prioritizing, and selecting restoration actions was developed and utilized in-lieu of a more traditional alternatives analysis. The approach draws from past experience of what has worked well in other systems and also draws from regional guidance for restoration planning. The framework is described in the following section.

[2] The term 'restoration' is used as a broad catch-all when referring to recommended actions; however, it's acknowledged that many of the actions are not restoration in the true sense of the word, and would be more appropriately labeled as enhancement or creation (Beechie et al. 2010).

3.2 STRATEGY PRIORITIZATION

It's well documented that working with natural channel processes is often the most effective strategy for restoring and maintaining aquatic species habitat (Beechie 2008, Beechie et al. 2010, Krueger 2017). As such, the strategy prioritization follows the guidelines of 1) protection, 2) reconnection and restoration, and 3) enhance and create. These priorities have been tailored to the reach as described in the following sections.

3.2.1 Protection

Protection strategies for restoration focus on preserving properly functioning or naturally recovering areas. They generally provide the opportunity for continuation of natural processes to maintain aquatic habitat. They can include actions such as:

- Land use protection measures (land use conversion incentive programs, conservation easements, and acquisitions by restoration focused entities), or
- Adjacent (upstream, downstream, or lateral) actions to reduce or eliminate potential sources of impairment (e.g., upstream fine sediment source reduction, downstream headcut mitigation, and run-off erosion reduction).

Protection strategies should be monitored for performance over time as conditions in the reach and watershed change. Adaptive management may be needed to address new risks to the protected areas to improve their long-term potential for supporting aquatic species restoration.

Protection strategies, requiring long-term landowner collaboration and watershed-scale project extents, have not been presented at this phase in the project. Opportunities to explore this strategy may arise as landowner relationships evolve, as the spatial scale of the ASRP projects expand, and as part of on-going monitoring and adaptive management of constructed restoration projects.

3.2.2 Reconnect and Restore

Reconnection and restoration strategies focus on actions that remove impairments to natural processes and establish conditions for sustaining those processes in the long run. In general, they provide immediate partial restoration with the long-term potential to achieve full restoration. As described in Section 4.4, some examples might include:

- **Fish passage restoration:** culvert replacement or removal, weir removal, and dam removal
- **Floodplain reconnection:** Levee removal.
- **Off-channel reactivation:** Remove unnatural blockages.
- **Riparian vegetation management and planting:** Removal of invasive species and replanting with native species.
- **Large wood structures for bed aggradation or channel forcing:** Install large wood structures in mainstem and off-channel habitats; for example, to mimic beaver dams in small channels, to cause bed aggradation to reconnect floodplains, or to divert flow into off-channel habitats.

Reconnection and restoration strategies should be monitored for performance over time as conditions in the reach and watershed change. Adaptive management may be needed to address new risks to the reconnected and restored areas to improve their long-term potential for supporting aquatic species restoration.

3.2.3 Enhance and Create

Enhancement and creation strategies focus on actions that provide immediate habitat benefits while applying the process-based principles to improve their suitability, function, and persistence (Beechie et al. 2010). Enhancement and creation actions are often included as components of reconnect and restore projects to provide more immediate habitat features while the longer-term processes recover. As described in Section 4.4 they can include the following action types:

- **Floodplain roughness:** Large wood placements on the floodplain emulating large downed trees that would have been part of a healthy mature floodplain forest.
- **Off-channel habitat creation:** Side channel or alcove excavation that emulates the conditions left following a channel avulsion or progressive migration.
- **Floodplain lowering:** Excavate floodplain areas that emulate the conditions left by lateral channel migration and bar growth.
- **Large wood structures:** Install large wood structures that emulates the accumulation of large wood on the outside of a meander bend or at the apex of a bar.

Enhancement and creation strategies should be monitored for performance over time as conditions in the reach and watershed change and as the design life of created structural elements is approached. Adaptive management may be needed to address the long-term limitations of structural enhancements and support the reestablishment of natural processes (e.g., vegetation growth monitoring and replanting) in order to support aquatic species restoration.

3.3 STRATEGY CONSTRAINTS

The restoration strategy within the reach is constrained by a number of factors both at the reach and watershed scale. They include, but are not limited to:

- **Project extents** are limited to the reach restricting the ability to change watershed conditions such as land use or impact channel and floodplain processes outside the project reach;
- **Landowner willingness** is limited in areas like a) conversion of agricultural or forestry land into the ecological corridor, b) selling property to have easements applied to the parcels, and c) a general overall moderate interest in helping salmon populations recover;
- **Pre-project distribution of valuable and sensitive species** such as the presence of fresh water mussels in the river bed and mature conifers in the riparian especially along the banks that could limit access to the river for construction;
- **Physical site constraints**, for example, locations where there is practical construction access or where existing structures or roads are to be maintained;
- **Regulatory conditions**, such as the County's FEMA no-rise code, extent of work below ordinary high water, and regulations on conversion of wetlands to waters;
- **Public safety**, including things like recreation uses (swimming, boating, fishing);
- **Limiting changes to infrastructure** (bridges, roads, structures, etc.) risks; and
- **Cost effectiveness and overall costs** relative to likely available implementation funding.

3.4 LANDOWNER INPUT

Restoration goals and potential actions have been discussed with landowners at each stage of project development, beginning in August 2018 and most recently in April through July and September and October of 2021. This landowner feedback has been incorporated into the final designs while continuing to take into consideration the project's primary objectives of natural process based aquatic habitat restoration. Prior to finalizing the designs, landowners whose properties are directly impacted by the project were asked to review and approve the preliminary designs, provide their signature in Part 4 of the Joint Aquatic Resources Permit Application (JARPA), and sign a landowner agreement (LOA) with the project sponsor. However, it should be noted that it has been explained to landowners that applying for permits and singing a LOA does not fully authorize or guarantee construction of the proposed aquatic habitat restoration project on their properties. Additionally, it has also been explained to landowners that they reserve the right to request changes to the design following the application for permits through a final review of the final design before they are issued for soliciting construction bids.

Key landowner concerns and interests factored into the development of designs since 2018 include the following:

- Uncertainty in the administrative aspects of the ASRP program (e.g., agreements, compensation/ incentive options, landowner legal liability limitations, etc.).
- An interest in maintaining management/rental rates on existing CREP areas while completing the habitat project.
- Maintaining personal access to entire property, including driving down onto the floodplain.
- Maintaining farm operations.
- Varying levels of interest in easements or purchases.
- Project visual aesthetics during and following construction.

3.5 PREFERRED RESTORATION ALTERNATIVE

The restoration strategy behind the project design was created by combining prioritized actions and project constraints to develop a comprehensive and realistic collection of restoration actions on the landscape. The final combination of actions was selected by drawing from the “toolbox” of actions as presented in the Restoration Action Report (Inter-Fluve 2018b). The final combination of actions make up what we call the Restoration Action Landscape.

The Restoration Action Landscape in the designs contain a mix of partial restoration and habitat creation actions, with components of both the Reconnect and Restore actions as well as the Enhance and Create actions as described in 3.2. Given the strategy constraints described above (Section 3.3), especially the reach-scale limitation of the project, the prospect of full restoration is not believed to be possible with this effort alone. However, as additional aquatic habitat restoration and watershed management work is completed within the sub-basin, the reach scale projects are expected to respond favorably and support a trajectory towards more complete restoration. In the meantime, the reach-based aquatic habitat restoration strategy presented here will support a balance between active land uses in the valley and natural channel processes that sustain viable salmonid and other aquatic species populations.

4. Design

4.1 PROJECT SURVEY

Topobathymetric LiDAR (light detection and ranging) data were acquired in March of 2017 along the project reach (Quantum Spatial 2017). This effort was conducted to provide of channel morphology data to support the environmental and habitat restoration efforts within the Chehalis Basin. These data were incorporated into the pre-project surface. Additionally, ground LiDAR collected in 2012 by Watershed Sciences and sourced from Puget Sound LiDAR Consortium and ground surveyed topographic and bathymetric data were collected by Inter-Fluve in October and November 2018 in areas where supplemental data was needed for advancing designs. These areas of supplemental survey included areas where the topobathymetric LiDAR did not provide sufficient coverage or where significant channel change since the LiDAR acquisition was suspected. The ground-based survey also provided data to confirm that the overall accuracy of the LiDAR was sufficient for use in project design. The comparison ground and bathymetric survey points to the LiDAR is shown in Figure 7 and Figure 8. The comparison indicates that the general accuracy of the LiDAR is sufficient for this type of habitat restoration project with the average difference between the LiDAR and surveyed elevations less than 1-foot. The slightly negative average difference between the LiDAR and the ground survey points is typical for LiDAR that does not always reflect off the ground but rather the dense layer of vegetation near the ground surface. The small average difference between the LiDAR and the bathymetric survey points indicates that the LiDAR techniques and post processing methods used by Quantum Spatial were appropriate. In September 2021 additional ground surveyed topographic and bathymetric data were collected by Inter-Fluve for a portion of the project reach downstream of the Lost Valley Road Bridge. The 2021 survey represents the major channel changes that have occurred in that area since 2018. These major channel changes include a meander avulsion, progressive channel migration, gravel bar development, and changes in the pool-riffle sequence and locations. Given the overall condition of the portion of the project reach downstream of the Lost Valley Road Bridge it is expected that it will continue to change quickly during high winter flows and peak flow events. The designs may need to be adjusted to fit the conditions at the time of construction. These efforts would be considered field engineering and would be supported by Inter-Fluve in order to maintain consistency with the design intent.

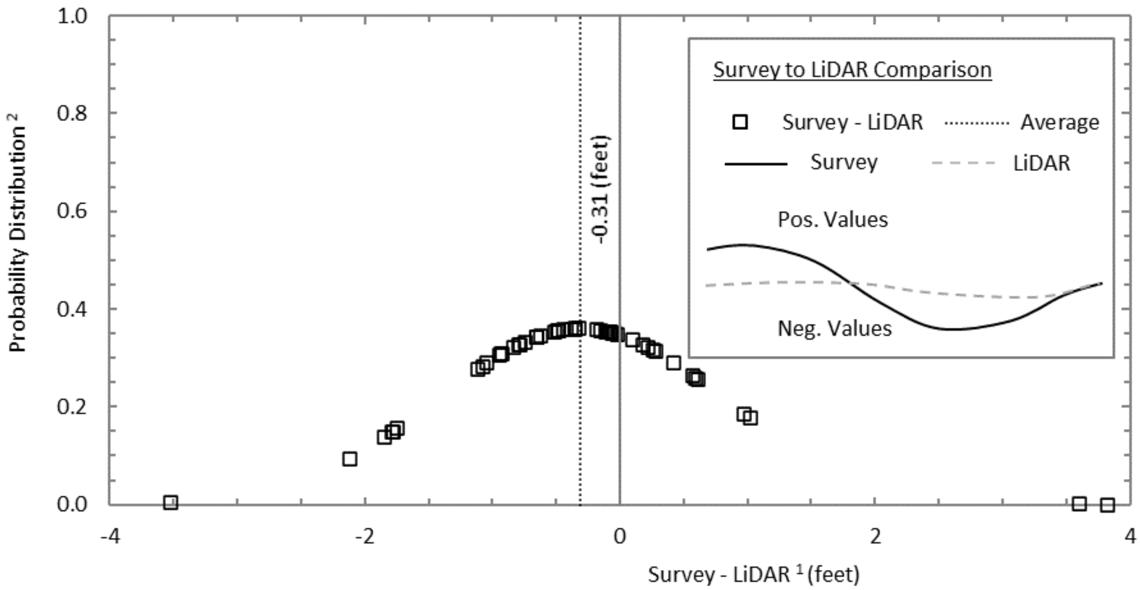


Figure 7. Survey v. LiDAR Ground Elevations.

Figure Notes: [1] Difference in elevation is the October - November 2018 survey point elevation minus the 2017 LiDAR from Quantum Spatial bare earth elevation for the raster cell containing the survey point. [2] Probability distribution calculated using 258 upland ground survey points with a standard deviation of 0.31-feet.

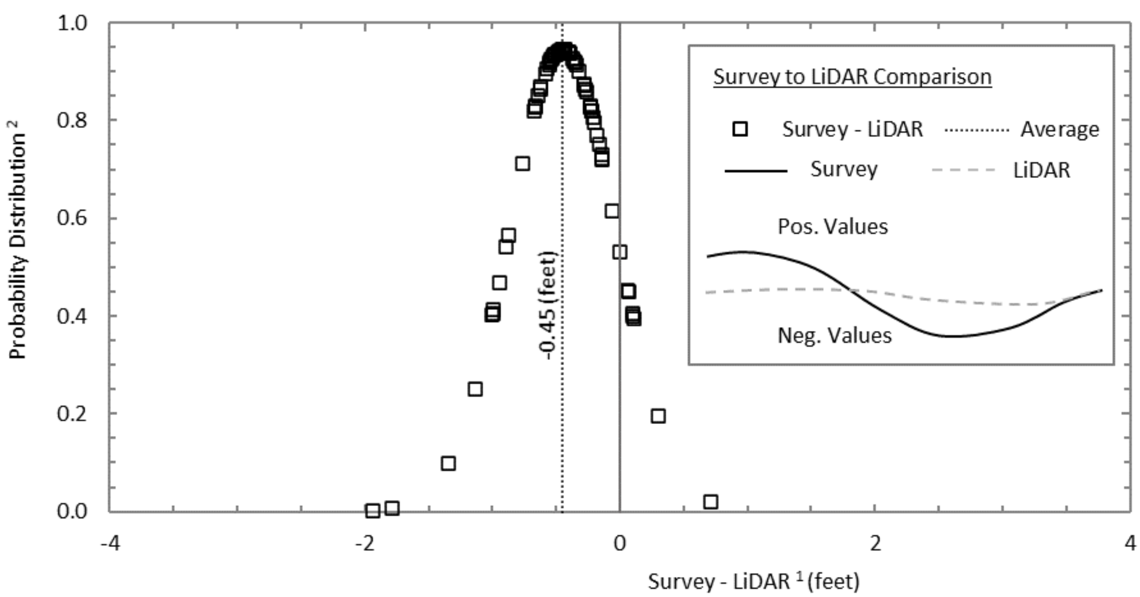


Figure 8. Survey v. LiDAR Bathymetric Elevations.

Figure Notes: [1] Difference in elevation is the October - November 2018 survey point elevation minus the 2017 LiDAR from Quantum Spatial bare earth elevation for the raster cell containing the survey point. [2] Probability distribution calculated using 1241 bathymetric survey points with a standard deviation of 0.45-feet.

4.2 SITE ACCESS

The site is approximately 12 miles from Chehalis, Washington. Access to the upper and middle areas of the project are available from Boisfort Road, Lost Valley Road, Roundtree Road, and Pe Ell McDonald Road. The majority of construction staging and temporary access will occur within the properties of Capitol Land Trust, Banjuh Family LLC, Senderak, Norvel Lindelof Credit TST, and Harr.

4.3 DESIGN CRITERIA

To address reach and watershed limitations as well as regulatory requirements and landowner input, the designs have been developed with consideration of the below design criteria. It is expected these will be reviewed and refined as the designs process continues.

Regulatory and Landowner Criteria:

- Avoid increasing water surface elevation within the project area to meet Lewis County code requirements related to work in a regulated floodway (i.e., no adverse impact) as discussed in section 2.6.1.
- Avoid removal of or damage to large mature trees during construction (to the extent determined by the project sponsor). Although tree removal is unavoidable in many work areas, the available LiDAR data was used to visualize locations of taller trees and the project designs and limits of disturbance were set to avoid unnecessary impacts to those areas. A visualization of treed areas is presented on the Habitat Suitability Maps (Attachment E).
- Reuse materials on-site such as cleared wood and vegetation where feasible. Specifically, all the large wood structures include the use of slash (branches and small logs) and many of the large wood structures include the reuse of whole trees within the structure.
- Balance landowner interests with the aquatic habitat restoration objectives to promote and maintain voluntary landowner participation.

Habitat and Hydraulic Connectivity Criteria:

- Increase habitat complexity and availability during the summer within reach. This is accomplished by the addition of large wood to existing pools and the creation of new pools associated with apex large wood structures. These large wood structures also help promote and maintain beneficial geomorphic process such as pool scour.
- Increase suitable habitat areas and inundation of the floodplain during average winter high flows within the reach. This is accomplished by the development of side channels, alcoves, floodplain benches, and the installation of associated large wood structures.
- Protect and improve suitable habitat areas within the floodplain during peak flows (e.g., the 2-year return period event) within the reach. This is accomplished by planting open floodplain areas with woody species and installing floodplain large wood structures.
- Increase wood loading and retention processes. This is accomplished by the installation of a range large wood structure types with various configurations, intents, and sizes. The goal for large wood structure density follows the recommendations of the leading science recommendations for addition of key large wood pieces to restore degraded systems (Fox

and Bolton 2007). The large wood density in the final designs is similar to the preliminary designs (Inter-Fluve 2021b), though it is still lower than the concept designs (Inter-Fluve 2019). The final design large wood density falls within published ranges of large wood density for functioning systems (Fox and Bolton 2007).

- Increase wood-driven geomorphic processes, such as localized scour, deposition and sediment sorting. This is accomplished by the installation of a range large wood structure types at a range of locations relative to the channel planform and hydraulics.
- Improve riparian habitat function through increasing hydraulic connectivity, riparian management and planting of native species.
- Remove or reconfigure riprap where possible to eliminate sources of long-term restrictions to channel processes. Given the landowner interests within the project reach this accomplished in two ways: 1) Through the replacement of riprap bank toes with periodic individual large wood structures where woody riparian vegetation is already established in the channel migration direction. 2) Through the replacement of riprap bank toes with large wood based bioengineered bank treatments (log cribs and densely planted fabric encapsulated soil lifts) where young or newly established woody vegetation is present in the channel migration direction.
- Encourage water quality improving processes such as riparian shading and nutrient infiltration. This is accomplished by native plantings to convert agricultural land into forested riparian areas over time. Additionally, the installation of large wood based bioengineered bank treatments along more rapidly eroding banks is intended to provide time for the associated riparian plantings to mature take over management of channel migration rates and fine sediment yield from eroding banks.

4.4 PROJECT DESIGN FEATURES

The following sections describe the various types of habitat elements that are included in the final designs (Attachment A). In some cases, example photographs are included from other projects and natural conditions to help describe project features.

4.4.1 Large Wood Structures

Large wood structures will be used throughout the project to provide complexity to the main channel and to influence geomorphic processes such as pool scour, bedload aggradation, and split flow. They are generally located in areas where wood would naturally accumulate. For example, accumulation frequently occurs along the outside of bends, at the apex of bars, or at the upstream end of riffles. Locations have been selected where the large wood will be maintained by the existing stream hydrology and geomorphology. Some placements will be configured to collect and retain additional fluvial-transported wood.

Large wood structures within the designs span a variety of forms and functions in order to support project objectives. Multi log structures (i.e., pool, floodplain, and habitat wood) will be used as habitat features and placed alongside pools or within side channels to provide cover and refuge. Habitat wood is used to provide key refuge from high velocities associated with average winter flows (See Inter-Fluve 2019 and 2018b). Floodplain wood will be used to increase hydraulic roughness on the floodplain and habitat complexity and refuge opportunity during high flows. Backwater large wood will be used to encourage inundation of alcove features during target flows. Apex structures will serve to encourage split flow conditions that enhance side channel formation and function, as well as geomorphic process such as scour pool and gravel bar development. Additionally, bank large wood structures are used to deflect flow away from vulnerable banks.

Large wood structures have been designed to provide key habitat associated with the limiting factors described in section 2.1. Specifically, in-channel structures have been designed to encourage velocity dissipation and hydraulic complexity, pool scour, habitat cover, and habitat complexity that will provide key habitat during low summer flows. Side channel, floodplain, apex, and backwater structures have been designed to provide hydraulic variability, off-channel habitat, and refuge at high winter high flows.

Additional information on the location, configuration, stability and risk assessment for large wood structures are provided in Attachment A –Design Drawings and Attachment G – Large Wood Structure Memo. Examples of existing conditions large wood and related constructed project structure examples are provided in Figure 9 - Figure 13.

Figure 9. Examples of a natural large wood **accumulations observed along the Stillman Creek project reach.**

Figure 10: Example of an apex large wood structure at the head of a forested island. The Apex large wood structure influences the geomorphology to help promote and maintain flow down side channels along with providing deep pool habitat at its front and sides. | Dry Creek, CA

Figure 11: Example of a wood structure in a side channel. Large wood structures in side channels influence geomorphology to help maintain initial side channel geometry along with providing habitat complexity over a range of flows. | Clackamas River, OR

Figure 12: Example of a bank wood structure in a side channel. The large wood structures along channel banks and in side channels influence geomorphology to help maintain initial side channel form along with providing habitat complexity over a range of flows. | Methow River, WA

Figure 13. Example of a large wood structure installed to maintain scour pools and encourage side channel formation and floodplain reconnection | Whatcom Creek, Whatcom County, WA

4.4.2 Floodplain Reconnection

This restoration action addresses issues associated with the reduction in low-lying floodplain surfaces activated at regular intervals (e.g., seasonal to 2-year recurrence flows). This approach is intended to increase connection to and inundation frequency of low-lying floodplains, while not significantly altering or increasing the surface area activated at a 100-year or greater flood (as required by regulatory agencies such as FEMA and the County government, in addition to landowners' aversion to increases in flooding of structures including houses and barns). See section 2.6.1 and Attachment D for more detail related to floodplain regulation. Floodplain reconnection is applied to areas that have the potential for an increase in habitat quality and a reestablishment of dynamic processes through their reconnection. The creation of winter refuge habitats through floodplain reconnection will entail excavation to achieve desired grades relative to targeted winter water surface elevations. This restoration action is focused on restoring the processes associated with sediment, nutrient, and habitat connectivity within the system. Examples of existing floodplain conditions where floodplain reconnection and floodplain large wood roughness are designed along with related constructed project examples are provided in Figure 14 through Figure 17.

Figure 14. Example of an existing disconnected floodplain area lacking significant roughness. | Stillman Creek, WA

Figure 15: Example of a floodplain reconnection though grading (photo is just after construction). Note the distribution of floodplain and other large wood structures to provide roughness and habitat. | Whatcom Creek, WA

Figure 16: Example of a floodplain reconnection though grading (photo is 2.5 years after construction). Note the thick growth of willows and alders providing roughness and additional habitat values including shading. | Whatcom Creek, WA

Figure 17: Complex inundated floodplain at bankfull flow, an example of healthy riparian connectivity | Methow River, WA

4.4.3 Off-Channel Habitat

Off-channel habitat features are prioritized in areas with minimal channel complexity where there are high velocities during winter flows. Construction of these areas will entail excavation to achieve desired grades for the particular activation flow, and include placement of large wood at appropriate locations, planting of aquatic and riparian vegetation, and management of existing surrounding vegetation. The placement of features has been selected to reduce the likelihood of main channel capture or large-scale avulsion.

Off-channel features have been incorporated in order to restore processes that have been impaired. Examples of these processes include dissipating energy during flood events, provide low-velocity refuge to aquatic species during winter high water, encourage accumulation of nutrients needed to support healthy and functioning riparian vegetation.

These features have been included in order to provide key habitat associated with the limiting factors described in section 2.1. Specifically, features have been designed to provide off-channel habitat and refuge at average January high flows. Elevations associated with these constructed features have been designed to activate at a range of target flows. Some areas are designed to be functional for salmonids year-round while other areas are designed to activate during winter high flows. Additional discussion on the identification of target flows can be found in the Reach Assessment and Restoration Actions Reports (Inter-Fluve 2018a and 2018b). Examples of related constructed projects are provided in Figure 18 through Figure 21.

Figure 18: Example of an alcove in the summer providing habitat for a number of aquatic species, including amphibians. Note the large wood within the alcove providing aquatic habitat in addition to the growth of vegetation. | Clackamas River, OR

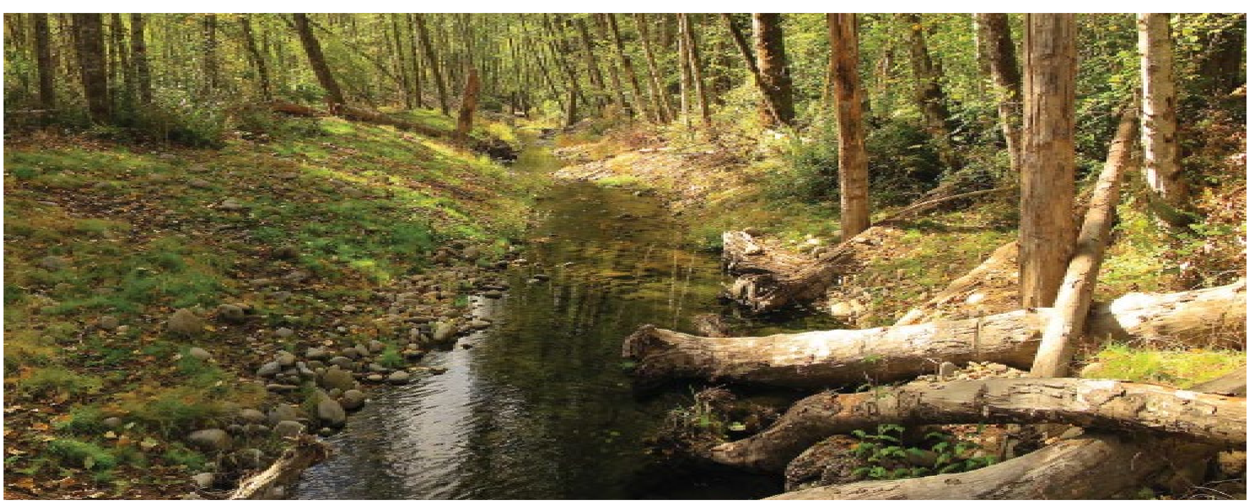


Figure 19: Example of a graded side channel (photo is 2.5 years after construction). Note this side channel was design to flow year-round whereas this project's side channels are designed to flow during typical fall and winter high flows. | Clackamas River, OR

Figure 20: Example of a graded high flow side channel project before construction (left) and after construction (right). Note the clear, lower velocity, flow in the side channel after construction. | Clackamas River, OR

Figure 21: Example of off-channel habitat with large wood placements | Clear Creek, OR

4.4.4 Riparian and Upland Treatments

Restoration actions are focused on restoring native riparian vegetation communities in order to reestablish natural levels of stream stability, stream shading, nutrient exchange, and future large wood recruitment. Riparian restoration areas are located where native riparian vegetation communities have been significantly impacted by anthropogenic activities such that riparian functions and connections with the stream are compromised. The locations of riparian restoration projects will be prioritized in areas where there is very little existing vegetation adjacent to the channel, where there are high concentrations of invasive or non-native plant types, or where the existing vegetation is likely to be disturbed by other restoration actions or temporary construction impacts such as within access and staging areas. Riparian restoration is an integral component of the restoration project, particularly within the disturbance limits of the project. Areas within the project reach that are currently enrolled in the Conservation Reserve Enhancement Program (CREP) have generally been avoided to maintain the integrity of those areas. However, there are some locations where project actions will overlap with CREP areas. In those cases, the continued enrollment of the area will be maintained by replacing the plantings disturbed during construction and limiting the conversion of planted areas to open water. This approach is consistent with the project specific approval provided by the USDA Farm Service Agency (FSA 2020) for these disturbances.

As such, riparian and upland treatments have been incorporated into the final designs to assist in the restoration of processes that have been impaired, and thus have contributed to the limiting factors described in detail in Section 2.1. Immediate benefits will include increased channel bank and floodplain roughness, increased native plant seed sources, a reduction in the presence of non-native and invasive species, and increased diversity of riparian vegetation species in managed areas. Over time, however, the development of mature woody riparian vegetation will provide a potential source of large trees to the floodplain and recruitment into the channel that are capable of reestablishing the natural large wood cycle. Additionally, as tree heights increase overtime, channel shading continues to improve, helping to maintain cooler water temperatures.

Figure 22. Example of riparian plantings atop a large wood structure and in a reconnected floodplain | Whatcom Creek, WA

Figure 23. Example of riparian plantings near a wetland (A) and in an open area (B).

4.5 HYDRAULIC ANALYSIS

A two-dimensional (2D) hydraulic model was developed in the U.S. Army Corps of Engineers HEC-RAS 6.0 software (USACE 2016), which can compute hydraulic properties related to the physical processes governing water flow through natural rivers and other channels. An existing conditions 2D hydraulic model was developed to assess the current channel/floodplain dynamics as well as assess the overall impacts of a wide range of flows on the existing landscape. Similarly, a proposed conditions 2D hydraulic model was used to assess the functionality of the design, as well as the relative changes between existing and proposed condition hydraulics within the project reach.

4.5.1 Model Capabilities and Limitations

HEC-RAS 6.0 software has the capacity to model the complex flow patterns, on-site water storage, bridge routines, and temporally variable boundary conditions. The 2D hydraulic model calculates depth averaged water velocities (including magnitude and direction), water surface elevation, and mesh cell face conveyance throughout the simulation. Other hydraulic parameters, such as depth, shear stress, and stream power, can be calculated after the simulation. The model does not simulate vertical variations in velocities or complex three-dimensional (3D) flow eddies.

HEC-RAS allows the user to choose between solving the full momentum or diffusion wave simplification of the shallow water equations, with the appropriate application varying from project to project. The primary goals of the hydraulic analysis are to assess the relative changes in hydraulic properties between existing and proposed conditions, as well as the overall timing and distribution of flows relative to the various proposed features at the design reach scale. As such, the diffusion wave equation set was selected for this modeling effort, given the overall size of the reach and the associated computational demands and long model run times that are required when using the full momentum equations.

4.5.2 Model Extent and Terrain

The Stillman Creek model domain extends from approximately 700 feet upstream of the South Fork Chehalis confluence to approximately 0.75 miles upstream of the Pe Ell McDonald Road crossing, and spans from the western valley wall to the ridge separating Stillman Creek and the South Fork Chehalis. Existing terrain data as discussed in section 4.1 was added to model existing conditions. Proposed features were added to the model terrain using final design TIN surfaces generated in CAD software.

4.5.3 Model Geometry

The computational mesh consists of grid cells ranging from 5 to 30 feet, with the smallest grid cells utilized along the main channel corridor to provide higher resolution results. Breaklines were added along road centerlines and topographic high points, to align cell faces along high ground and appropriately represent the underlying terrain. Additional refinements were made to the computational for proposed conditions, to represent the configuration of proposed side channels, alcoves, and large wood structures.

4.5.4 Model Roughness

A spatially varying roughness layer was developed from canopy heights associated with the 2012 LiDAR data. The canopy heights were grouped into vegetation classes and assigned a corresponding roughness (Manning's n) coefficient as outlined in Table 3. Land cover was classified with respect to characteristics that relate to hydraulic roughness, as opposed to the more generalized classifications that are provided in the NLCD dataset. Additional roughness polygons representing the main channel, gravel bars, and roads were developed in ArcGIS software based on aerial imagery and topography data and were added to the composite roughness layer. Proposed conditions roughness values for final design features were assumed using professional judgement, assuming a post-construction condition where vegetation is not fully mature. Manning's n values ranged from 0.014 to 0.2 within the computational domain.

Table 3. Summary of hydraulic roughness values assigned to land cover classifications

Description	Manning's n
Channel	0.028
Gravel or Cobble Bar	0.035 – 0.038
Vegetated Gravel Bar	0.05
Large wood accumulation	0.15
Riparian Vegetation	0.065 - 0.15
Bare Bank	0.025
Coarse Riprap	0.042
Riprap w/Logs or Vegetation	0.06 - 0.075
Grassy Bank	0.055
Groundcover (<1 foot)	0.03
Vegetation 1-4 feet	0.05
Vegetation 4-6 feet	0.14
Vegetation 6-12 feet	0.2
Vegetation 12-20 feet	0.10
Forest (>20 feet)	0.08
Proposed LWS	0.15 - 0.17
Proposed Alcove	0.08
Proposed Side-Channel	0.07
Proposed Riparian Enhancement	0.065

4.5.5 Model Discharges and Boundary Conditions

The modeled discharges of interest included all the flows listed in Section 2.6 These discharges were incorporated into a synthetic "stepped" hydrographs that contain gradual rising limbs between discharges of interest (i.e., 100-year flow) to simulate quasi steady-state flow conditions. The discharges of interest remain unchanged for a period of time long enough to allow the model to reach a steady-state, before rising to the next step (Figure 24). It's worth noting that allowing the model to reach a steady state during large flood events provides conservative flooding results, as floodplain storage throughout the model domain must reach capacity to achieve steady-state conditions. Also, the receding limb of a typical flood hydrograph is not represented when using this methodology. For the project objectives and risk assessment needs investigating the effects of a receding hydrograph on channel-floodplain interactions was not seen as warranted.

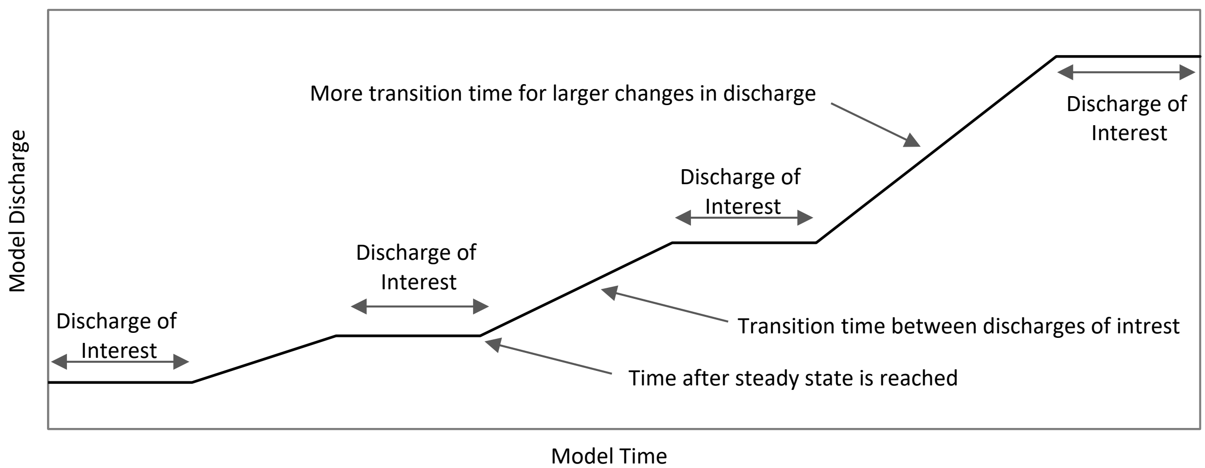


Figure 24. Demonstrative "stepped" flow input hydrograph

Input flows in the Stillman Creek reach are divided between three large drainage areas (Stillman, Halfway, and Lost Creeks) with separate input hydrographs specified for each. The steady flow peaks were assumed to occur simultaneously. The downstream boundary was set as normal depth, with an assumed friction slope of 0.00124 ft/ft. Tributary inputs were proportioned using area-weighting (Section 2.6) and were assigned for peak flows as well as seasonal flows, given that flow was observed entering the reach from the tributaries during field reconnaissance that was conducted in June of 2018.

4.5.6 Model Output

Various hydraulic model outputs were analyzed to assess the overall functionality of the proposed project features at low to intermediate flows, as well as the relative changes between existing and proposed conditions during peak flow events. Model results for seasonal flows were primarily assessed through the HSI analysis, which is discussed in greater detail in Section 4.6. Model outputs are provided in Attachment E. These results demonstrate the increase in off channel low velocity areas during intermediate high flow and larger flood events, with peak flood inundation patterns that remain similar between existing and proposed conditions. The analysis of pre- and post-project conditions during the modeled 100-year flood event, is provided in Attachment D.

4.5.7 Model Validation

The model was verified at medium flows (approximately 61.5 cfs) using water surface elevations recorded during the October 2018 survey compared to modeled water surface elevations. Water surface elevations within the channel survey surface extent compared well to the model results. A 0.19 ft root mean square error was found between measured and modeled water surface elevations. Sensitivity testing indicated that the model results do not vary substantially with changes in roughness values at such low flows.

4.6 HABITAT SUITABILITY MODELING

Fisheries habitat modeling evaluates how suitable habitat area changes seasonally with river discharge, and how proposed restoration actions are expected to change habitat area immediately after construction. This effort focuses on juvenile rearing habitat area within the Stillman Creek project reach, and evaluates suitable habitat under both existing and proposed conditions. Habitat suitability is calculated by combining depth and velocity preference curves for target species with 2-D hydraulic model outputs. Habitat was analyzed for juvenile Coho Salmon, steelhead, and Chinook Salmon. Attachment E contains mapping of modeled habitat suitability within the project reach at the mean August discharge (8 cfs), mean December discharge (517 cfs), and the 1.01-year event (1,884 cfs).

4.6.1 Methods

Methods for modeling physical habitat are consistent with those presented in Appendix E of the *South Fork Chehalis Sub-basin Reach Assessment Report* (Inter-Fluve, 2018). This document should be referenced for more details on numerical methods and preference curves utilized. Steelhead and Coho Salmon habitat was calculated for fifteen flows, from low summer discharge (8 cfs) through the 1.01-year recurrence flood (1,884 cfs) under both existing and proposed conditions. Results were mapped for mean August discharge (8 cfs), mean December discharge (517 cfs), and the 1.01-year event (1,884 cfs). Juvenile Chinook Salmon habitat was calculated for eight flows, from mean February discharge during early emergence (372 cfs) through outmigration in July (15 cfs). Habitat was mapped for mean February (372 cfs), April (179 cfs), and July (14 cfs) discharges.

This analysis only evaluates habitat suitability based on water depth and velocity, while considering when juveniles are most likely to be present in the reach as inferred from work done on the S. Fork Newaukum R. (Winkowski, Walther, and Zimmerman 2018). Large wood structures are included in the proposed conditions model as either roughness patches or topography, and therefore the interstitial spaces and micro-habitats provided by large wood are not fully reflected in the analysis. Therefore, this analysis is expected to provide a conservative estimation of how the proposed project is expected to improve habitat conditions.

4.6.2 Results

Mapping of suitable habitat area under existing and proposed conditions is included in Appendix E. Results are color-coded to visually display where suitable habitat is located, and the quality of that habitat based on the combined depth and velocity criteria. Four categories are displayed, ranging from areas that are not suitable, to those that are highly preferred (Table 4). The appendix should be referenced to identify where suitable habitat is being created under proposed conditions, and how habitat suitability of project elements changes with varying river flows. Suitable habitat area was plotted against discharge to evaluate how habitat area changes with discharge for each species under both existing and proposed conditions. The charts in the following sections utilize the aggregated habitat areas (low, medium, and high) to look at habitat quantity more broadly.

Table 4. Suitability score and rating for visualization purposes.

Suitability score	Rating
0	Not suitable
0 > to 0.33	Low preference
0.33 - 0.66	Medium preference
0.66 - 1	High preference

Coho Salmon

Under existing conditions, Coho Salmon habitat peaks during summer low flow conditions, and shows a minimum during winter flows from 300 to 600 cfs that are typical from December through March (Figure 26). Habitat area increases at higher flows as more off-channel habitats become available. The decline in habitat area during winter months is attributable to high water velocities in the main channel. Flows are primarily contained within the banks, and few off-channel areas are connected. Habitat area increases at higher flows as the floodplain becomes inundated, and loss of main channel rearing habitat due to high velocity is offset by an increase in suitable habitat within adjacent floodplain areas.

Under proposed conditions, habitat area increases for modeled discharges particularly at flows higher than 200cfs. Increased margin roughness in the main channel and side channels increase the availability of habitat at high flows. The largest increase in available habitat is above 500 cfs as proposed side channels begin to wet up.

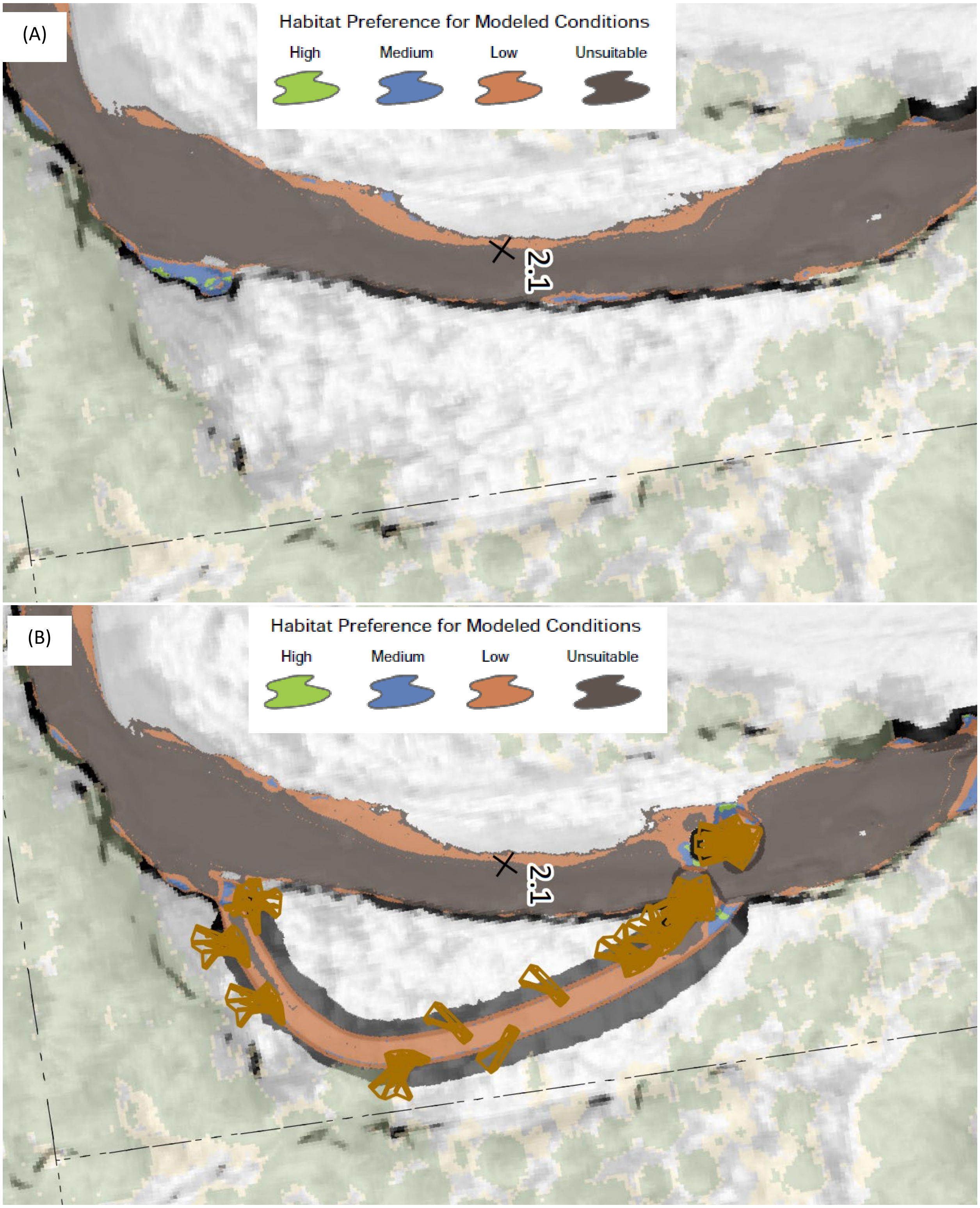


Figure 25. Example of suitable habitat area mapping for juvenile Coho Salmon at 516 cfs under existing (A) and proposed conditions (B) showing side-channel functioning.

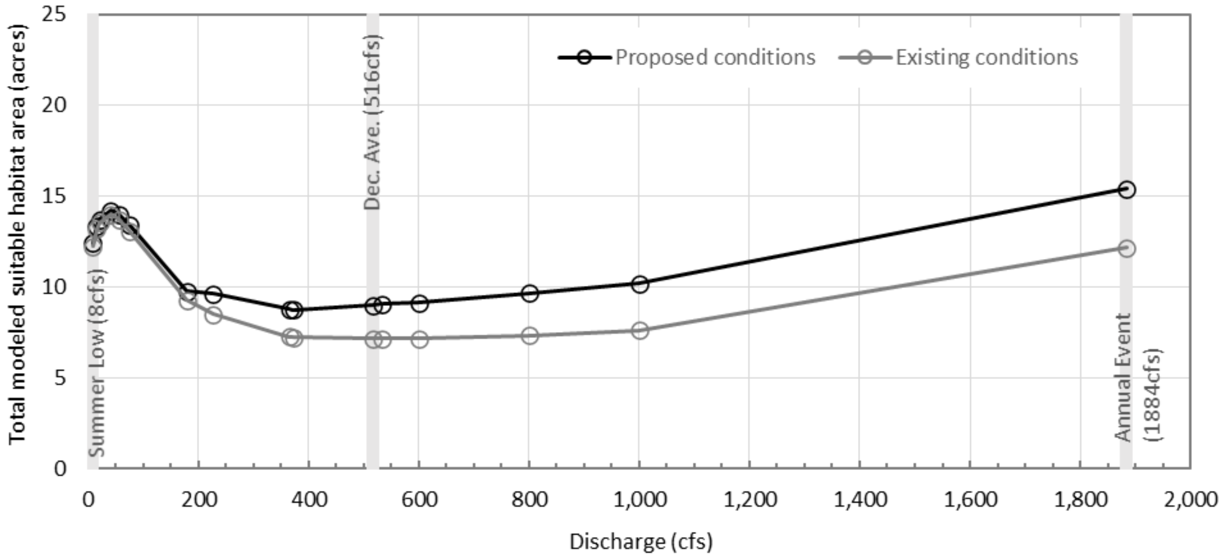


Figure 26. Suitable habitat area for juvenile Coho Salmon under existing and proposed conditions, plotted against flow from August low flow to the annual flood event. The December average flow is a low point in the suitable habitat area that the project aims to improve conditions during.

<u>*Steelhead*</u>

Under existing conditions, steelhead habitat peaks around 400cfs, and shows a minimum during summer low flow conditions, with another dip around 1,000 cfs
(

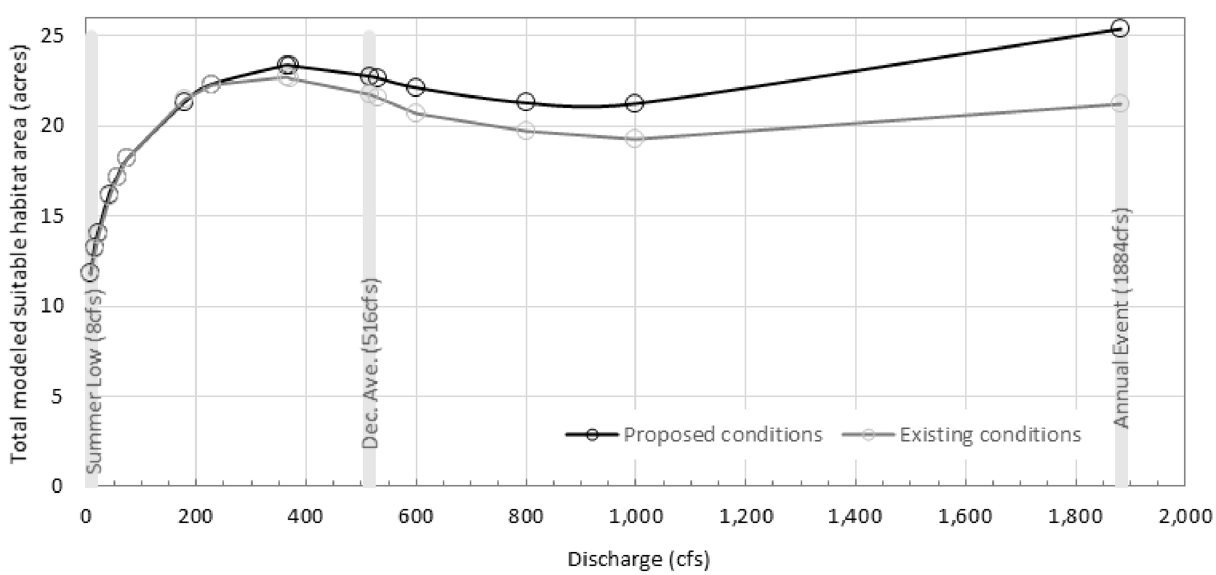


Figure 28). The decline in habitat area during summer low flow conditions is attributable to a reduction in wetted channel area and low water velocities, while relatively low habitat area during the 1,000cfs winter high flow is attributable to high water velocities in the main channel.

Under proposed conditions, habitat has increased for all modeled discharges, with more notable increases at higher flows. Increased margin roughness in the main channel and pools associated with large wood structures connected at low flow increase the availability of habitat at all flows. The largest increase in available habitat is above 850 cfs as proposed side channels become activated, and more floodplain connectivity is occurring.

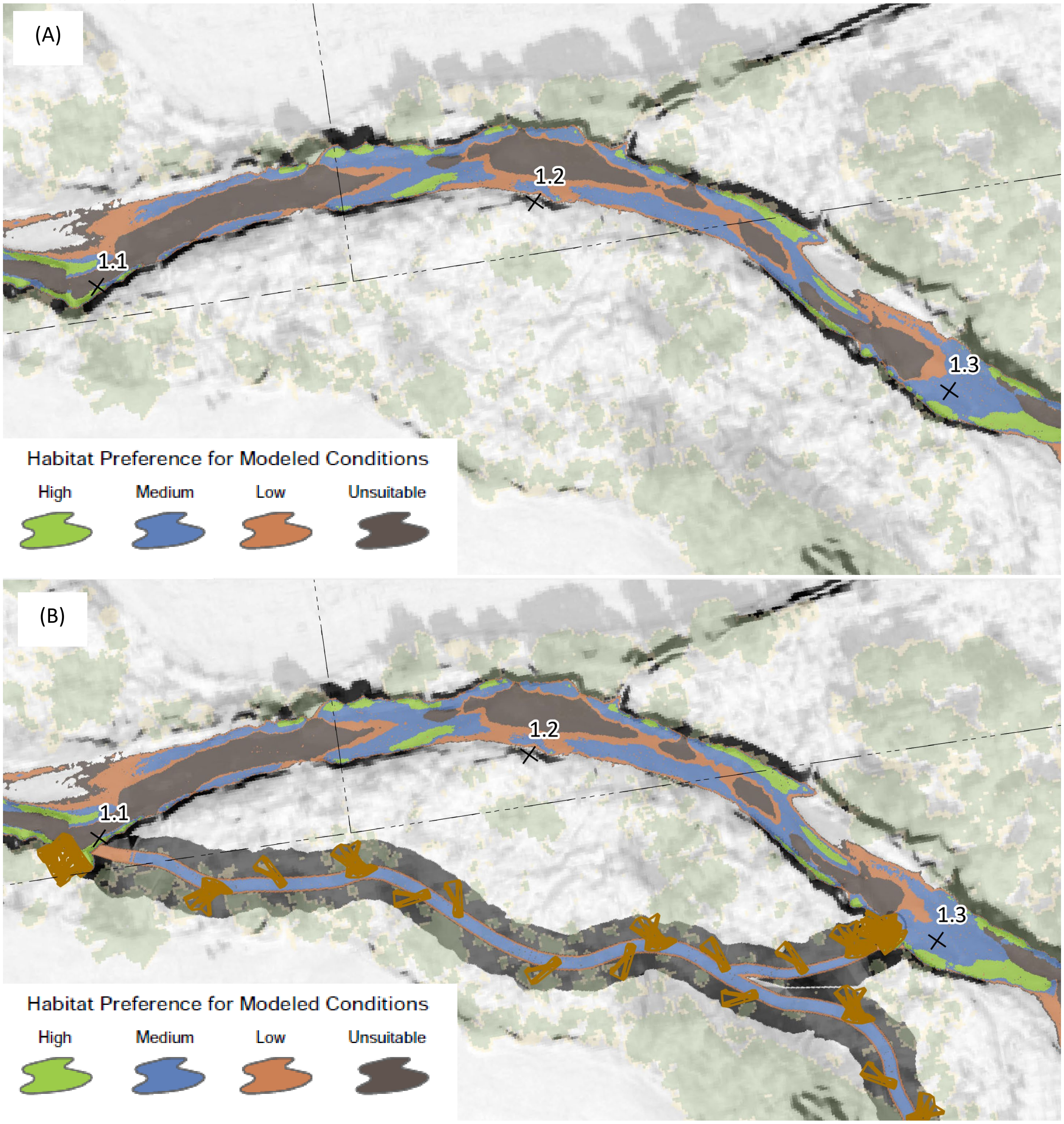


Figure 27. Example of suitable habitat area mapping for juvenile steelhead at 516cfs under existing (A) and proposed conditions (B) showing side-channel functioning.

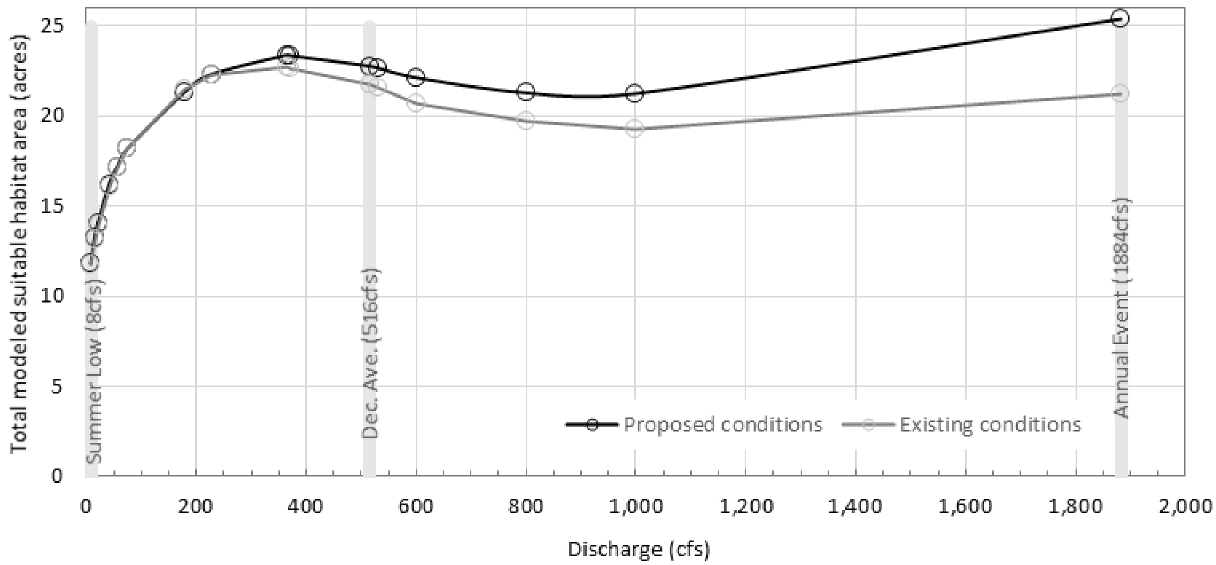


Figure 28. Suitable habitat area for juvenile steelhead under existing and proposed conditions, plotted against flow from August low flow to the annual flood event. Discharges above the December average are one area where the project aims to improve conditions.

Chinook Salmon

Under existing conditions, fingerling Chinook Salmon habitat is lowest during the early emergence and rearing period (higher flows) and greatest during late out-migration (lower flows) (

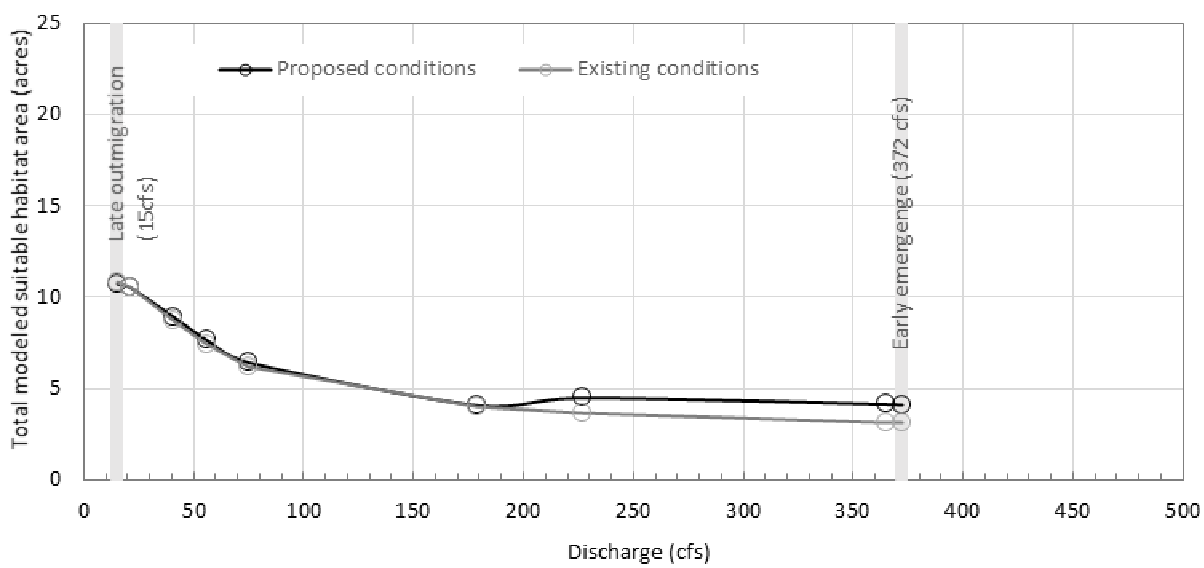


Figure 30). Swimming ability limits suitable habitat to off-channel areas or channel margins where velocities are low.

Under proposed conditions, habitat increases at all flows, with the largest increase observed at higher flow as more side channels inundate, providing shallow, slow water habitat for these fish.

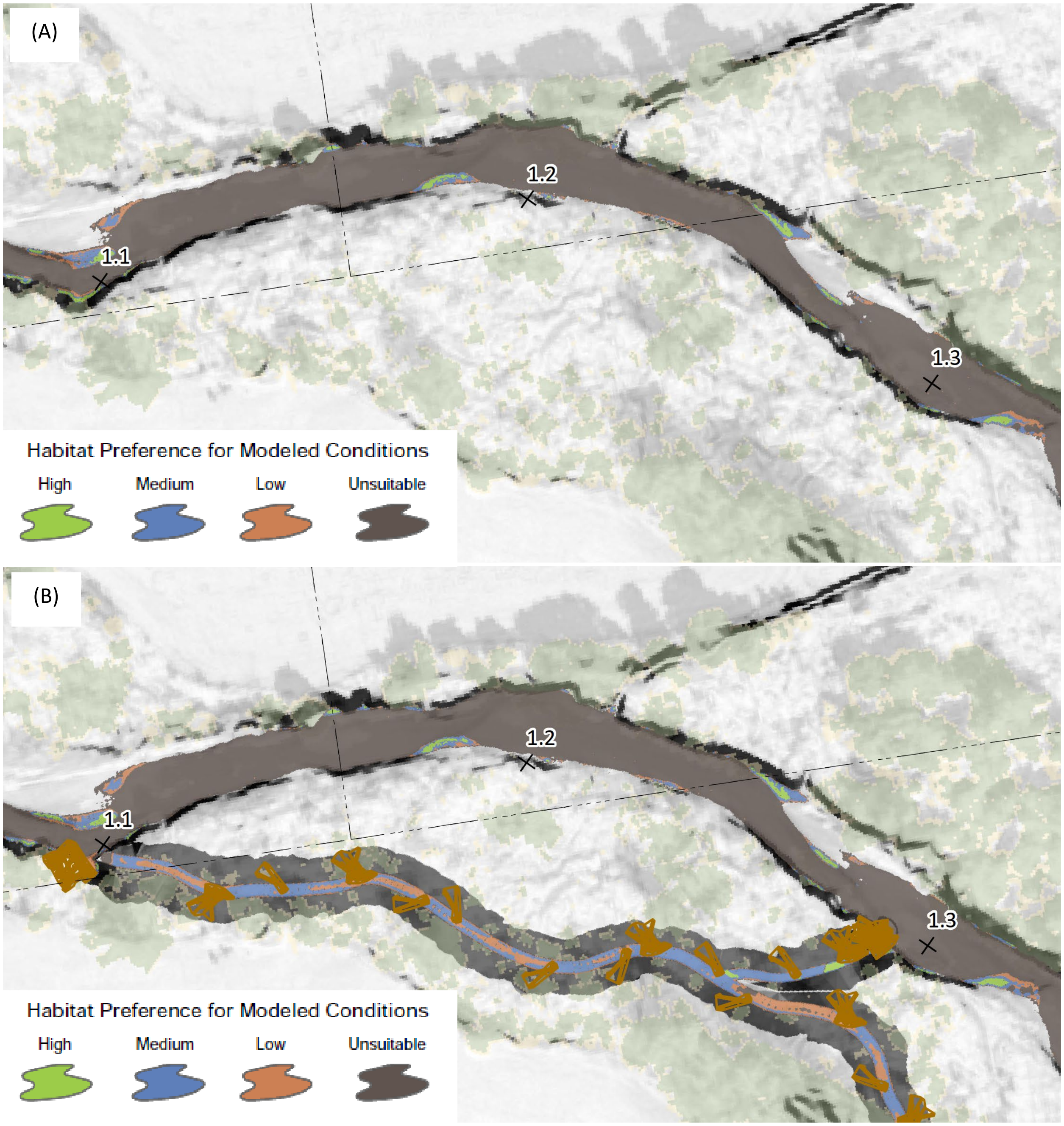


Figure 29. Example of suitable habitat area mapping for fry and fingerling Chinook Salmon at 372 cfs under existing (A) and proposed conditions (B) showing side channel functioning and downstream effect of large wood structures.

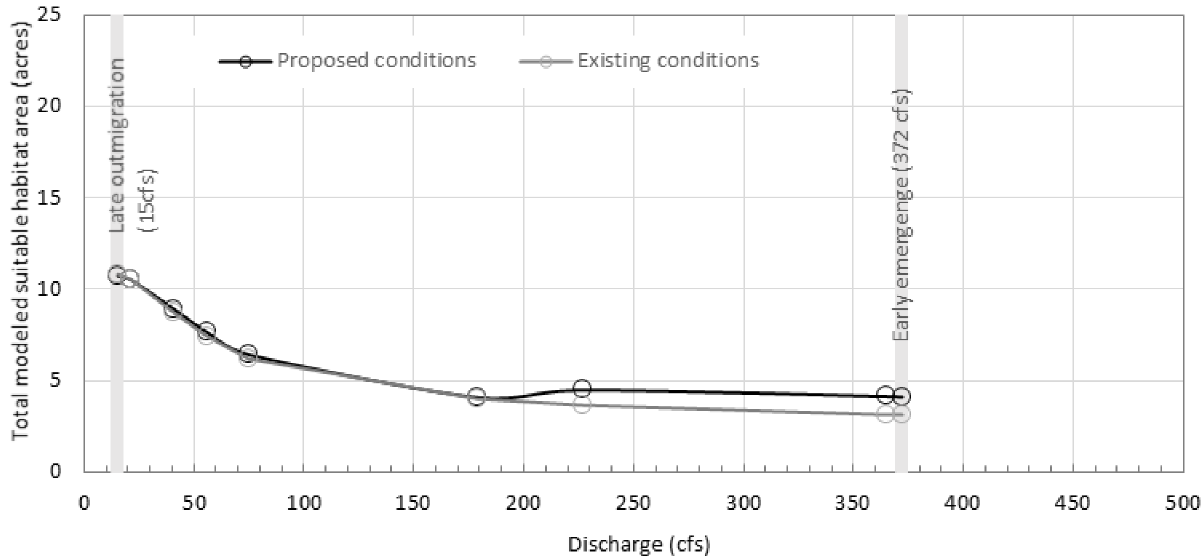


Figure 30. Suitable habitat area for fry and fingerling Chinook Salmon under existing and proposed conditions, plotted against flows experienced from emergence in February to outmigration in July.

4.6.3 Discussion

The proposed project has modeled increases in habitat area for target species at most flows (Figure 31). Maximum increases in available area occur for fingerling Chinook during early emergence in March with a nearly 33% increase, and for juvenile Coho Salmon and steelhead rearing during typical high winter flows with a roughly 25% to 30% increase, respectively. Generally, the largest increases in habitat occur during typical winter high flows, as the project grading plan creates new off-channel habitats that are active at these flows while also increasing the inundation frequency of existing floodplain habitat.

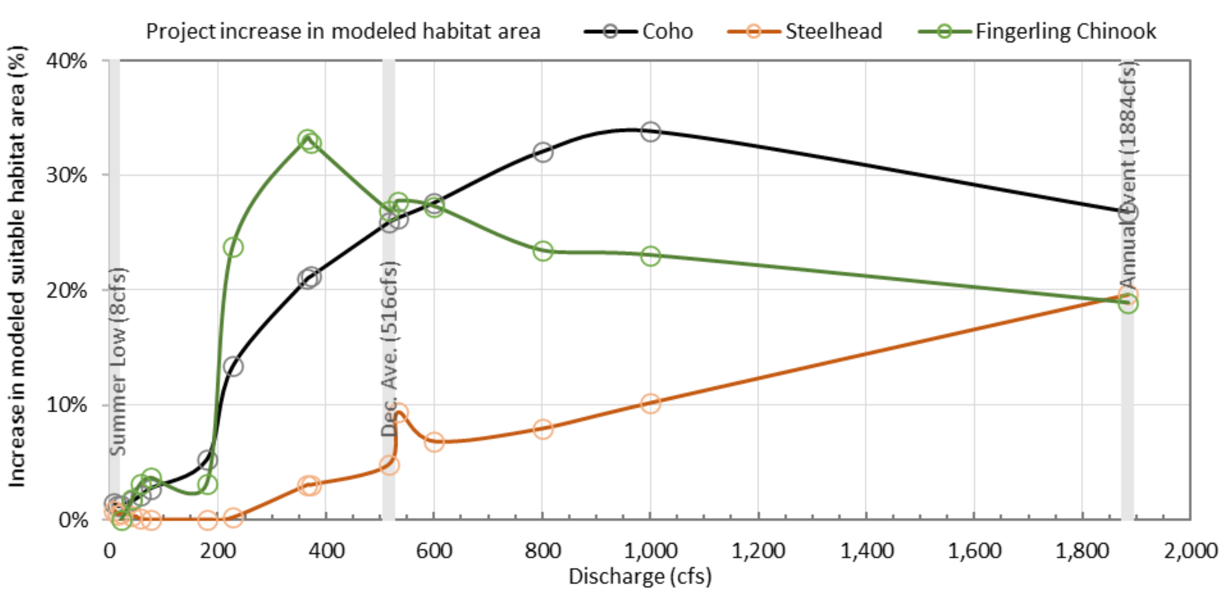


Figure 31. Change in suitable habitat area for target species as a percentage of existing habitat area.

Habitat capacity at low discharges that occur from July through September is only slightly improved or maintained with the proposed project. However, fish are not expected to utilize this reach heavily during these low-flow conditions. Studies on the nearby South Fork Newaukum have shown that stream-type juveniles migrate to cooler headwater reaches to rear in the summer and escape high water temperatures (Winkowski, Walther, and Zimmerman 2018). The downstream migration of juvenile spring and fall Chinook, which both express an ocean-type life history, also coincides with rising water temperatures, as fish seek to outmigrate before temperatures become unsuitable (Winkowski and Zimmerman 2017). While summer rearing habitat may present a physical habitat limitation for target species, that limitation is most likely occurring upstream of the project area where these fish typically spend the summer months, and is therefore outside of the scope of this analysis. In summary, the proposed project is expected to improve rearing habitat area for target species during flows that were previously identified as habitat-limited for these fish (Inter-Fluve 2018a).

4.7 LARGE WOOD STRUCTURE DESIGN

Large wood structures (LWS) in this project are required under Washington State Law to be "designed to withstand one hundred year floods" (House Bill 1194, 2013). The LWS are also designed to maintain their intended geomorphic and habitat functions during a range of flows, including flood events, while balancing management of public safety and property damage risk. This is especially true for the near-term before planted riparian vegetation will have a chance to mature and thereby provide hydraulic roughness and contribute to LWS stability. The LWS design drew from a number of publish guidance documents including: a) the USBR's Large Wood Material Risk Based Design Guidelines (Knutson et. al. 2014), b) the National Large Wood Manual (USBR & ERDC 2015), c) the State of Washington's Integrated Streambank Protection Guidelines (Cramer 2003), and d) the State of Washington's Stream Habitat Restoration Guidelines (Cramer 2012). Additionally, project site specific knowledge and professional judgement gained from experience in design, implementation, and monitoring the large wood habitat restoration projects was used to guide and tailor the designs to meet the site-specific habitat needs and project constraints.

4.7.1 Mobility Considerations

Mobility is defined here as displacement of placed wood by buoyant and hydrodynamic forces. The target level of service with regards to mobility of placed woody materials is achieved through ballasting, which may generally be provided by full or partial embedment, mechanical anchorage (timber piles, aka vertical snags), and/or entrapment within existing woody vegetation. Mobility of project large wood pieces presents a risk of causing property damage, and thus the potential for movement of these pieces must be limited. This consideration is particularly important within the project as all placements of large wood materials are proposed on private property. Relocation of large wood materials from participating properties onto other properties is subject to liability issues that landowners and project partners want to avoid.

4.7.2 Longevity (Design Life) Considerations

Placed wood is subject to decay in riverine riparian environments, and depending on the location decay can be rapid or slow. Additional longevity considerations include wood material size, type and the frequency of wetting and drying cycles. Smaller sizes decay faster for a given species and some tree species are naturally decay resistant (e.g., Douglas fir) whereas others lose their strength rapidly (e.g., cottonwood). LWS are designed such that site and species characteristics allow for appropriate design life.

As an example, wood materials placed in areas that are continuously saturated often have very slow decay rates as does wood placed in very arid conditions that see little seasonal wetting, with some species-specific exceptions (e.g., cottonwood). Whereas, locations that see frequent wet and dry cycling are subject to the most rapid decay rates. Therefore, the location domain for wood placement is an important consideration (Scherer 2004). Location domains (wet, wet/dry and dry) for placed woody materials can be determined using the same hydraulic modeling tools used to determine mobility considerations, in combination with professional judgment and field observations.

Location domains for large wood structures have been established and were used to refine the acceptable wood species and material dimensions.

Decay resistance of various wood materials can be determined from a variety of sources (for example see Bilby et. al. 1999). Longevity considerations for placed wood address features whose functional objectives range from protection of growing vegetation (floodplain wood) to forming the foundations for structural elements (apex structures & bank treatments). A decay life of 10 to 15 years may be acceptable for materials placed on a restored floodplain surface because successful growth of woody vegetation will replace the function of the placed woody materials over a relatively short time. Conversely, woody materials used as foundation materials for structural stream bank treatments and specific habitat function should have a design life in excess of 25 years. Note that the general planning horizon for design of Stillman Creek Early Action Reach enhancements has been assumed to be at least 20 years to be consistent with the project implementation and monitoring timelines described in the Aquatic Species Enhancement Plan (WDFW 2019).

For the project location coniferous species native to Washington State, such as Douglas Fir, Western hemlock, Mountain Hemlock, Silver fir, Grand fir, Engelmann spruce, Sitka spruce, and Western redcedar are preferred for sourcing logs and rootwads to be used in large wood structures. The use overuse of Western redcedar should however be avoided as it is more buoyant than other species and can thereby reduce the initial LWS stability factor of safety. Field engineering is recommended to track and address the use of Western redcedar in construction.

For constructability and strength reasons piles used in the large wood structures should come exclusively from Douglas fir. The acceptable tree species for various large wood materials and applications are described in the project specifications. Additionally, it is not advised to take delivery of these materials too far in advance to avoid significant decay and weakening of materials before construction. It's been observed that decayed wood that has been stored for more than 2 years can be easier for the contractor to damage during handling / installation, which results in a compromised service life. Our recommendation is for the large wood material to be procured and stockpiled near the project no less than 6 months before construction and installed within 2 years of harvest. At this time, it's understood that WDFW is pursuing early procurement of a portion of the large wood materials for the project. The large wood materials procured by WDFW will be made available to the general construction contractor at a designated stockpile location.

4.7.3 Design Stability Computations

Stability analysis and computations for project elements followed professional practice guidelines for large wood design (Knutson et. al. 2014 and USBR/ERDC 2016), stream habitat restoration (Cramer 2012), bank treatments (Cramer 2003), and institutional knowledge combined with professional judgment for the design of specific project elements.

For the evaluation of property damage risk is recommended that the overall project setting be evaluated, including the entire project extent and areas downstream (USBR 2014). For the project reach this includes:

- Two bridges with piers in the project reach (Lost Valley Road Bridge at RM 0.7 and Pe Ell McDonald Road Bridge at RM 2.6).
- Multiple downstream bridges along the South Fork Chehalis River (Beaver Creek Road approx. 2.5 miles downstream, a residential bridge crossing approx. 3.4 miles downstream, and Boistfort Road bridge approx. 4 miles downstream).
- Several agricultural structures within the project reach on the floodplain.
- Many homes and other structures on the floodplain within 2 miles downstream of the project reach.
- Tens of acres of active agricultural land on the floodplain within the project reach.
- The small town of Curtis, Washington
- Many more acres of active agricultural land on the floodplain within 2 miles downstream of the project reach.

Given this setting, the project large wood structures are designed assuming a 'high' property damage risk level.

The reach use characteristics were evaluated with the understanding gained from landowners that the project reach on the Stillman is not highly used by recreational boaters. Site and reach accessibility were evaluated based on site observations and the proposed project design. All of the property along the project reach is privately owned, thereby limiting accessibility. The project's structure characteristics relative to public safety were evaluated using professional judgment. Given these use trends, access conditions, and the structure safety characteristics the project large wood structures are designed assuming a 'moderate' public safety risk level.

Assuming these risk levels results in recommended minimum factors of safety in the horizontal and vertical directions of 1.75 and 2.0, respectively, to maintain a stable structure under design conditions (Knutson et. al. 2014). It should be noted that the factor of safety values for large wood structures evaluated at a 'high' property damage risk level do not change with changes in the selected public safety risk level. As such, and given the moderate reach level risk, the evaluation of large wood structure public safety risk by location groups within the project reach was not completed.

Proposed conditions 2D hydraulic model outputs for the 100-year peak flow event were used to determine conservative design velocities upstream of each structure type, and conservative assumptions relative to the sizes of individual log members were made in accordance with the design drawings. The computed factor of safety equals or exceeds the recommended factors of safety for each structure type, suggesting that the structures can be considered stable for the assumed risk tolerance. The results of the stability analysis are summarized in Table 5.

Stabilization for the LWS is provided by a combination of native backfill and timber piles. The various LWS types are designed with timber piles installed to depth of 13- to 15-feet below the bottom of the LWS, depending on the type of structure. To accommodate potential variability in pile installation depths, pile locations, pile diameters, and pile testing results due to the presence of shallow and exposed siltstone and sandstone bedrock, an Inter-Fluve engineer will be onsite during LWS construction to provide field engineering services. These services will help ensure that the minimum design factors of safety are met for all the LWS as they are constructed. Additional information on the design assumptions, risk evaluation, and the stability analysis can be found in Attachment G - Large Woody Structure Analysis Memo.

Table 5. Summary of large wood stability analysis results.

Large Wood Structure Type	Recommended (A) Factors of Safety		Calculated Factors of Safety					Stable Under Design Conditions
	Net Horizontal Friction & Piles	**Net Vertical** Pile & Ballast	**Horizontal** Friction (B)	**Horizontal** Timber (C)	**Vertical** Piles Only (D)	**Vertical** Ballast Only (E)	**Net Vertical** Piles & Ballast (F)	
Floodplain	1.75	2	1.8	5.6	2.5	0.3	2.7	Yes
Pool	1.75	2	1.8	4.5	2.9	0.0	2.9	Yes
Backwater	1.75	2	3.1	2.9	1.5	0.5	2.0	Yes
Habitat	1.75	2	1.8	5.4	2.4	0.0	2.4	Yes
Bank	1.75	2	1.8	2.7	1.9	1.2	3.1	Yes
Apex	1.75	2	1.8	1.8	2.2	0.5	2.8	Yes
Apex-Wider	1.75	2	1.8	1.7	2.5	0.5	3.0	Yes
Side Channel	1.75	2	1.8	1.6	1.6	0.7	2.3	Yes

Table Notes: *(A) Knutson et. al., 2014 | | (B) This is the vertical snag (piles) soil strength and bed friction factor of safety. | (C) This is the vertical snag (timber) factor of safety against breaking. | (D) This is the vertical snag (pile) only buoyancy factor of safety, assumes that only the piles are acting to provide vertical restraint against the driving forces. | (E) This is the backfill only buoyancy factor of safety, assuming that only the backfill are acting to provide vertical restraint against the driving forces. | (F) This is the net vertical factor of safety including the contributions of the vertical snags (piles) and backfill.*

4.8 DESIGN COST ESTIMATE

A cost estimate, also known as an Opinion of Probable Construction Costs (OPCC), for the Project was developed based on the final design and on review of construction costs for similar items on other similar projects, consultation with construction contractors and material suppliers, and applicable reference cost data. The costs are divided into a number of groups by project element and cost category. The individual line items are set up to be as standard as possible to allow comparison of similar activities in other projects and be used eventually as unit bid items. The actual cost of implementation of the project may vary from the cost opinion based on a number of factors including; changes to the design during construction, construction timing and phasing, variations in the heavy construction market, and other unforeseen factors. To account in part for these uncertainties, and also for necessary field design changes during construction (which are presently unknown), a 10% cost contingency has been included in the cost opinion. The 10% contingency is representative of the current infrastructure construction market trends and the expectation that the project would not be bid until 2022. Table 6 shows a summary of the probable construction costs and an estimate for the engineering design consultants construction quality assurance and field engineering services during construction. Attachment F includes a more detailed OPCC table showing items, units, quantities, unit costs and total costs. The table also provides estimates for the number of pieces of large wood and other construction materials related to the LWS. Estimates of the numbers of plants can be found on the Drawings (see Attachment A).

Table 6. Summary of Probable Construction Costs

Construction Sub-Total	*10% Contingency [4]*	*7.8% Sales Tax*	**Construction Total**
$ 4,693,500	*$ 171,900*	*$ 379,500*	$ 5,244,900
Construction Quality Assurance and Field Engineering			$ 483,200

Notes:

1. See Attachment F for additional notes on assumptions and limitations to this opinion of probable construction costs.
2. These costs do not include construction contract management. This would typically include time for the Sponsor/Contracting Agency or Construction Management Consultant to facilitate initiation of the construction contract, process pay requests, review the contractor's schedule, coordinate other on-site work not under the general contractor's control (e.g., plantings, aquatic species salvage).
3. These costs do not include environmental compliance. This would typically include time and expense for work such as aquatic species salvage, and turbidity monitoring that may not be part of the general contractors bid.
4. This is the contingency in addition to two explicit contingency items listed in the OPCC. See OPCC notes.

Based on the final design project cost estimates, restoration of the project reach is estimated at around $2.3 to $2.7 million per mile. It should be noted that the cost per mile is figured on the actual length of main channel within the project reach (approx. 2.0 miles) and not the ASRP pilot project administrative river mile reach designations (e.g., RM 0-2.5). Additionally, it's worth noting that the project restoration cost per mile is near the high end of the estimates reported in Section 8 and detailed in Appendix D of the ASRP Phase I document (WDFW 2019).

To make construction of this project more feasible, given the short expected permitted in-water work window, multiple construction years (phases) are recommended. These phases should be structured in consultation with the design engineer to avoid unnecessary issues arising from completing particular portions of the design without other interdependent portions of the design being completed during the same construction season (see Section 4.10.7). It is highly recommended to complete any phases in consecutive years to minimize the total time temporary construction impacts are experienced in the area (staging areas in agricultural fields, temporary access route development, noise from construction, turbidity, etc.). The construction phases should also be structured to limit the need to re-establish access through restored areas in subsequent phases. Phasing the project does have an impact on the estimated construction costs as activities like mobilization, temporary site restoration, and demobilization would happen multiple times. However, these costs are generally small relative to the overall construction costs. Additionally, the multiple phases (years of construction) could allow potential cost-saving design revisions to be incorporated based on interim monitoring results and adaptive management decisions.

4.9 PERMITTING CONSIDERATIONS

The proposed project will require a number of permit authorizations from different agencies. A summary of these authorizations is included in Table 7. WDFW has been in contact with permitting authorities to establish and refine permit requirements. WDFW submitted permit applications based on the preliminary design package (Inter-Fluve 2021a & 2021b). It is expected that WDFW will wait to issue project plans and specifications for bidding/construction until permits are received. Should permit terms conflict with the design or the general anticipated construction approach the project team may either: 1) make changes to the design via revisions to the final Plans and Specifications, or 2) request modifications to the permit terms to accommodate the design as-is, the construction considerations (Section 4.10), and the implicit construction approach assumptions.

Table 7. Permit authorizations that are likely to be required to implement the proposed project.

Agency	Authorization/Permits	Contact	Email
Washington Department of Fish and Wildlife	Hydraulic Project Approval (HPA)*	Madeline Nolan	Madeline.Nolan@dfw.wa.gov
	Executive Order 21-02**	Celina Abercrombie	Celina.Abercrombie@dfw.wa.gov
Washington Department of Ecology	Section 401 Water Quality Certification	Zach Meyer	zmey461@ecy.wa.gov
US Army Corps of Engineers	Section 404 Removal/Fill Permit***	Evan Carnes	evan.g.carnes@usace.army.mil
	Section 106 Historic Preservation Act	Lance Lundquist	lance.a.lundquist@usace.army.mil
Lewis County	Fill and Grade Permit, and Floodplain Development Permit	Doyle Sanford	doyle.sanford@lewiscountywa.gov

Notes

**It is understood that a fish habitat enhancement HPA will not be available as a result of the type and scale of restoration actions. The project may not be exempted from the SEPA checklist and local permits.*

*** WDFW is the lead agency on cultural resources consultation at the state level, and will consult with DAHP, and the Chehalis, Cowlitz, Nisqually, Quinault, Shoalwater Bay, Squaxin, and Grand Ronde tribes.*

****Assumed to be permitted through Nationwide 27.*

4.10 CONSTRUCTION AND LANDOWNER CONSIDERATIONS

Construction planning for Stillman Creek EAR requires integrating an understanding of land use, infrastructure and in-water work window constraints in addition to other regulatory constraints. Various considerations for construction are presented in the sections below.

4.10.1 Limits of Disturbance Considerations

For purposes of determining limits of disturbance, as shown on the Drawings (Attachment A), number of factors have been considered:

- The cultural resources area of potential effects sets an outer limit for the limits of disturbance.
- The excavation footprint and the ground extent of large wood structures sets a minimum limit of disturbance.
- Access routes and staging areas are also included in the limits of disturbance. Access routes are assumed to be sufficiently wide to allow for mobilization of heavy equipment and large wood materials to the work areas.
- For side channels and alcoves, the "in-side out" construction approach (where the work is completed largely from within the excavation extent) was assumed and used to set the limits of disturbance along those type of features. This approach limits disturbance of riparian areas providing for faster site recovery and naturalization after construction.
- Planting areas outside the excavation footprint and the ground extent of large wood structures were also included in the limits of disturbance. The level of disturbance allowed in this planting-only area will be limited by the project technical specifications developed for final design.

It should be noted that the locations of project features may be adjusted to fit field conditions at the time of construction, thus flexibility in determining final limits of disturbance boundaries is recommended so this can be accommodated within necessary protocol.

4.10.2 Access and Staging

Proposed alignments of ingress/egress, access corridors and staging areas are shown on the final design drawings. These proposed corridors will need to be reviewed by the Contracting Agency and the landowners to verify consistency with agricultural and timber operations and other landowner constraints.

Additionally, prior to construction the general contractor will be required to submit a site access, staging, and sequencing plan in conformance with the general notes found on the final design drawings (see Attachment A) and the forthcoming permit conditions. The plan will be reviewed and approved by the Contracting Agency (WDFW's Capital Asset Management Program) prior to the contractor beginning work on the site. Site access will be off of public roads and through private properties as shown on the final design drawings. The staging area will be on private properties in the locations shown on the drawings. The staging areas will be entirely above the ordinary highwater elevation, and in most cases outside the extent of the regulatory 100-year flood event (See Attachment D).

4.10.3 Erosion and Pollution Control Plan

Prior to construction, the general contractor will be required to submit an erosion and pollution control plan in conformance with the general notes found on the final design drawings (see Attachment A), the forthcoming permit conditions, as well as applicable State and local regulations. The drawings show a number of recommended erosion and pollution control measures; however, the final plan will be developed by the construction contractor for review and acceptance by the contracting agency. The construction contractor will be responsible for adherence to and implementation of the accepted plan.

Examples of various BMP measures for temporary erosion and sedimentation control (TESC) that are expected to be required include:

- Straw wattles or silt fence installed on the downslope sides of staging areas in the event of wet weather during construction.
- Depending on site conditions during construction, a stabilized rock construction entrance installed at the access point off public roads or private drives to minimize tracking of fine sediment off site.
- Other BMPs as required by the permit conditions.

4.10.4 Construction Equipment and Fuels Management

The construction contractor may be required to provide a list of proposed equipment and a fuel management plan for review and acceptance by the contracting agency. The equipment brought onto the site and fuel management plan prepared by the construction contractor will be in conformance with the general notes found on the final design drawings (see Attachment A) and the forthcoming permit conditions. The contractor will also be responsible for development and implementation of a spill prevention, control, and counter measures plan that conforms to the general notes found on the final design drawings (see Attachment A), the forthcoming permit conditions, as well as applicable State and local regulations. The plan will be reviewed and accepted by the contracting agency prior to mobilization. The construction contractor will be responsible for adherence to and implementation of the accepted plan. In general, it’s expected that construction equipment could include; tracked excavators, wheeled loaders, tracked log loaders, off-highway haul trucks, on-road dump trucks, chain saws, gas, electric, or air powered drills, gas powered abrasive cut-off saws, excavator mounted hydraulically driven side grip vibratory pile driver, work trucks, and other small power/hand tools. Equipment will be stored in the primary upland staging areas, outside the ordinary high-water line, while not in use.

4.10.5 Timing and Duration of Construction

It understood that the in-water work window for the Stillman Creek will be July 1 to August 31. If necessary, this period could be potentially extended, dependent on year and circumstances of the work. In order to maximize the available construction window within the in-water work period, mobilization and site preparation efforts may commence around or before June 1. Prior to construction, it will be necessary to identify whether there are other periods during which construction work would adversely impact agricultural or business operations. If necessary, the available work window will be further constrained or other restrictions placed on work activities (e.g., limited working hours/days, quiet operations, etc.) to accommodate agricultural and business operations. The anticipated total duration of construction will likely require use of the entire in-water work period, plus shoulder periods on either end of the in-water work period that may be used to complete upland work.

4.10.6 Sequencing

The general sequencing of construction is typical for this type of river restoration project. The general sequence of on-site work at a high level is expected to be the along the lines of the following:

1. Pre-construction site visit
2. Initial construction layout and limits of disturbance marking
3. Pre-construction conditions verification survey
4. Mobilization of heavy equipment and materials
5. Access route development, staging area improvements, and protections (e.g., erosion control)
6. Detailed construction layout and limits of disturbance marking
7. Clearing and grubbing
8. Invasive vegetation control
9. Off-channel area excavation, including control of water
10. Large wood structures, including control of water
11. Revegetation
12. Staging and access route restoration
13. As-built survey
14. Demobilization

Beyond these general recommendations, it is expected that the contracting agency (The Washington Department of Fish and Wildlife Capital Assessment Management Program [*WDFW CAMP]*), the general contractor, and the landowners will coordinate the order in which work areas are constructed, and the specific sequence of work tasks needed to meet the project requirements. It is expected that the contractor will be required to submit a detail work plan for approval prior to mobilization that describes their intended sequencing. Changes to this plan during construction would also be expected to reviewed and approved by WDFW CAMP in consultation with the landowners.

4.10.7 Project Feature Interdependencies

There are a number of interdependencies between project features. Some of these are relatively straightforward while others are more subtle. Some examples of straightforward interdependencies include:

- Construction of an off-channel area (side channel, alcove, floodplain bench, etc.) needs to be completed in a single summer/fall construction season, as disturbed ground should not be left unfinished over the winter.
- Large wood structures in constructed off-channels need to be installed in the same construction season as the excavation is done.
- Plantings in disturbed areas need to be done in the same summer/fall construction season and prior to the first highwater or hard frost in the fall.
- Upland planting in specific areas should be completed last to avoid disturbing newly planted areas.

There are a number of more subtle interdependencies between project features that could be important considerations in approving the contractors proposed schedule and work plan. Although it's recommended the designer be consulted during review of the contractor's schedule and work plan the following are some of the more significant interdependent and prioritized design features by location:

- RM 0 – 0.7, Sites A and B. The project elements downstream of the Lost Valley Road bridge are designed to work together to restore this portion of the project reach. These elements should be constructed in the same season. It also recommended that at least one other large site (e.g., Site D) be constructed in the same season as A and B to supply fresh slash and whole trees salvaged from that site for use in Sites A and B.
- All other Sites. Each site is designed to work best with all elements in a site constructed in the same season. The order of site construction is not critical from a geomorphic process perspective. Other considerations, such as landowner preferences, may control what sites are constructed in what order.

4.10.8 Stream Diversion and Dewatering

Prior to construction, the general contractor will be required to submit a stream diversion and dewatering plan that's in conformance with the general notes found on the final design drawings (see Attachment A) and the forthcoming permit conditions. The plan will be reviewed and approved by the Contracting Agency (WDFW's Capital Asset Management Program) prior to the contractor beginning work on the site. Work areas in the wetted channel during construction will be isolated from surface water flow and aquatic species salvage operations will be completed by qualified personnel prior to excavation, pile driving, and large wood placement. Surface water isolation measures may include bulk bag, sheet pile, or concrete block coffer dams. Turbidity curtains and fish exclusion nets may be used on their own in slack water areas to isolate the work areas where dewatering is not needed or in conjunction with coffer dams as needed to further limit turbidity releases and exclude fish from the work area. Work requiring dewatering will be kept pumped down to below the working level. Water from dewatering pumping is expected to be turbid and will be discharged to an upland location for infiltration. The drawings show recommended typical work area isolation measures; however, a final plan showing the extents of the measures selected by the construction contractor will be developed by the construction contractor for review and acceptance by the contracting agency. The construction contractor will be responsible for adherence to and implementation of the accepted plan.

The expected river flow during the in-water wort period is relatively low (see Section 2.6 and Figure 5). However, the river is not regulated by reservoirs or other means and is subject to variations in flow throughout the year. The construction contractor will be advised to review the available hydrology data and make preparations for range of flows during construction. Additionally, the native materials within the project areas are in many cases highly transmissive, necessitating tactical sequencing of work to complete elements that require construction below the river water level.

It should be noted that on other similar project it's been shown to be logistically challenging to keep work areas completely clear of water using bulk bag cofferdams (see Attachment A). In comparison, it's been observed that the use of interlocking sheetpiles (also shown on the Final Design Drawings, Attachment A) can be more effective at isolating work areas and reducing water in-flow, thereby improving the ability to sufficiently dewater the work area. Additionally, the use of sheetpile cofferdams reduces the impact to the channel bed and the overall working footprint. Given the extensive distribution of mussel beds within the project area selection of a work area isolation method that minimizes the channel bed disturbance could reduce the need for timing consuming mussel salvage (see General Notes on the Final Design Plans and Section 4.10.9). The extensive presence of shallow clay and siltstone layers in the project reach is not expected to necessarily limit the use of sheetpiles. The clay and siltstone layers have been observed to be deformable and it's expected that sheetpile could be driven far enough into the layers and combined with the sheetpile linked together, the use of burlap gravel bags, and plastic sheeting, provide work area isolation.

4.10.9 Work Area Aquatic Species Salvage

Total channel diversions and temporary channels crossings are not anticipated to be required for construction of the project. Therefore, aquatic species salvage efforts are anticipated primarily with installation of coffer dams, and other temporary control of water provisions which obscure a portion of the main channel or other habitats where fish and other aquatic species such as mussels and lamprey may reside. For additional information, see publications from the Methow Salmon Recovery Foundation, the US Fish and Wildlife Service, and the Lamprey Technical Workgroup Best Management Guidelines for Native Lampreys During In-Water Work (LTW 2020).

4.10.10 Site Reclamation and Restoration Plan

General site reclamation and restoration following construction of the aquatic habitat aspects of the project will be in conformance with the general notes found on the final design drawings (see Attachment A) and the forthcoming permit conditions. General site restoration includes:

construction materials cleanup, short term erosion control measures, decompaction, revegetation, and temporary access route decommissioning (see Figure 32).

Figure 32: Example of a floodplain roughness large wood used in the decommissioning a temporary construction access route. | Clackamas River, OR

4.10.11 Working Hours

Given the large scope of enhancement work contemplated, the project partners and landowners may wish to consider extended working hours to maximize the daily rate of production, to minimize the overall duration of construction and project cost. If feasible, expanded working hours that allow two shifts per day during the extended summer daylight hours may reduce overall project cost and impact.

4.11 SUMMARY OF SPATIAL METRICS FOR DESIGN

A summary of project design metrics is provided in Table 8. These metrics are described in detail in the Concept Design Report (Inter-Fluve 2019) and are all tied to physical measurements of project actions and extents. These metrics provide stakeholders and regulators with an overview for the design's key impacts or outcomes. The metrics compiled provide a tabulation of quantitative values for evaluating and measuring the project design relative to pre-project conditions. For reference the metric values of the conceptual designs are also included in the table along with a calculation of the percent change relative to the concept designs.

A summary of EDT metrics directly affected by the proposed project are included in Table 9. Other EDT metrics are likely to be improved by the proposed project, however predicting the magnitude of uplift will require post project monitoring and additional analysis. Category, EDT attribute, EDT definition, and existing and proposed classification scheme are derived from Lestelle (2005).

Table 8: Stillman Creek Early Action Reach Project Metrics

Project Metrics					
In-Stream Structures		Original Concepts	Final Designs	Unit	Percent Change
	Number of In-Stream Structures Added *	202	113	Structures	-44%
	Number of Large Wood Pieces	1,093	748	Pieces	-32%
	Number of Large Wood Key Pieces	153	110	Pieces	-28%
	Total Large Wood Volume	2,314	1,556	Cubic yards	-33%
	Rootwad Large Wood Volume	1,607	1027	Cubic yards	-36%
	Log Large Wood Volume	707	527	Cubic yards	-24%
Stream Miles Treated					
	In-Stream Miles Treated*	3.3	2.0	Miles	-39%
Riparian and Upland Treatments					
Riparian Zone	Total Riparian Acres Treated*	24.8	10	Acres	-60%
	Riparian Vegetation Acres Treated	21.7	6.2	Acres	-71%
	Riparian Side Channel and Alcove Area Created	3.1	3.8	Acres	22%
	Riparian Miles Treated *	3.0	1.8	Miles	-40%
Upland Zone	Total Upland Acres Treated*	36.1	45	Acres	25%
	Upland Vegetation Area Treated	35.6	45	Acres	26%
	Upland Side Channel and Alcove Area Created	0.4	0.0	Acres	-100%
Off-Channel Metrics	Side Channel Miles Created	0.7	0.5	Miles	-29%
	Side Channel Area Created	2.5	3.0	Acres	19%
	Side Channel Miles Enhanced	0.4	0.1	Miles	-64%
	Side Channel Area Enhanced	1.3	0.8	Acres	-41%
	Alcove Miles Created and Enhanced	0.1	0.0	Miles	-57%
	Alcove Area Created or Enhanced	1.1	0.1	Acres	-95%
	Total Off-Channel Miles Created	1.2	0.7	Miles	-42%
	Total Off-Channel Area Created	4.8	3.8	Acres	-21%
Other Metrics					
	Agricultural Land Area Converted to Riparian/Upland Trees	20.4	23.3	Acres	14%
	Number of Trees Planted	10,397	6,321	Trees	-39%
	Floodplain Area Reconnected	4.0	3.8	Acres	-5%

*Habitat Work Schedule identified project metrics applicable to this project.
** Number of large wood pieces does not include the estimated 626 timber piles to be installed to support the LWS.

Table 9. Stillman Creek EDT metrics directly affected by the proposed project.

Category	EDT attribute	EDT definition	Measurement method	Existing	Proposed
Channel morphometry	Channel width (high flows)	Average width of the wetted channel during high flow month.	Calculated average channel width as wetted area at mean January discharge (532 cfs) divided by main channel length.	61.9 feet	65.9 feet
	Channel width (low flows)	Average width of the wetted channel during low flow month.	Calculated average channel width as wetted area at mean September discharge (21 cfs) divided by main channel length.	31.3 feet	31.3 feet
Habitat type	Off-channel habitat factor	A multiplier used to estimate the amount of off-channel habitat compared to in-channel habitat.	Calculated as off-channel wetted area divided total reach wetted area at mean January discharge (532 cfs). Side channels classified as main channel habitat.	10.8% (3.4 acres off channel and 28.2 acres main channel)	14.1% (4.6 acres off channel and 28.2 acres main channel)
Riparian & channel integrity	Riparian function	A measurement of riparian function that has been altered within the reach.	Qualitative assessment of riparian function.	Index 2* (50.5% functional attributes present)	Index 2** (68.5% functional attributes present)
	Wood	The amount of wood within the reach.	Wood count from habitat assessment compared to design.	Index 3 (0.6 pieces per channel width)	Index 0 (6.4 pieces per channel width)

Notes

**Score represents future condition, assuming land use does not change over time.*

***Score represents future condition with the proposed project.*

5. Design Support Materials

Attachment A: Final Design Drawings

Attachment B: Technical Specifications

Attachment C: Plant Supplier List

Attachment D: Floodplain Impacts Memo

Attachment E: Habitat Suitability Analysis Maps

Attachment F: Opinion of Probable Construction Costs

Attachment G: Large Wood Structure Memo

6. Limitations

This report was prepared for the Washington Department of Fish and Wildlife for use in documenting development of the final design for natural process based aquatic species habitat restoration in the project reach. It should be noted that the physical conditions and landownership within the project reach may change prior to project implementation. Also, additional scientific and engineering information may become available. Significant changes in landownership, site conditions, or the available information may require reassessment of both existing conditions and the proposed project designs.

Additionally, the designs presented have been reviewed with the landowners to varying degrees. Efforts were made to communicate with each landowner along the project reach whose property would be directly impacted by the restoration actions presented in the designs. Communications with landowners varied from detailed in-person meetings to email and phone correspondence. Many of the landowners have signed landowner agreements and they are on file with WDFW. Landowner feedback continues to be incorporated into the designs while balancing the project's primary objectives of natural process based aquatic habitat restoration. As the project moves forward into the construction phase the project team will continue to engage with landowners to keep them updated. Prior to mobilization for construction landowners whose properties are directly impacted by the project will be notified. However, it has also been explained to landowners that they reserve the right to request changes to the design prior to construction and that they are not obligated to allow construction of the project until they sign the landowner agreements.

Furthermore, the designs may be subject to revision based on a number of items yet to be determined including but not limited to: specific permitting conditions, and major changes in pre-project conditions such as a channel avulsion or significant channel migration. Revisions made to address these items will be made prior to issuing the plans and specifications for construction.

7. Summary and Next Steps

This final design report, along with the reach assessment, restoration actions, and concept and preliminary design Reports (Inter-Fluve 2018a, 2018b, 2019, and 2021a), provides the foundational material to move forward towards restoration project implementation in the reach. The understanding developed from these efforts of the physical, biological, and cultural conditions within the watershed and the reach, combined with continued landowner outreach efforts, have helped make the final designs presented in this report ready for project implementation.

7.1 NEXT STEPS

The Stillman Creek EAR will next be moved into the implementation phase (Figure 33). In this phase of the project, the designs presented in this report will used to solicit bids from general contractors and then used throughout construction. Construction is expected to begin in 2022 and be completed by the end of 2023. Construction work is expected to be primarily during the permitted in-water work window months of July and August each year. Construction activities above the ordinary high water line may occur during other times of the year, contingent on other permit conditions and landowner authorizations.

Any revisions to the design documents during bidding and construction will be and identified with standard revision tracking conventions so the changes are clear to all parties (i.e., construction contractor, WDFW, Engineer, landowners, etc.) Revisions will continue to take into consideration a number of factors including: 1) consistency with natural process, 2) landowner willingness, 3) biological limiting factors, 4) physical opportunities and constraints, 5) regulatory conditions, 6) public safety, 7) cost effectiveness, and 8) contracting & schedule impacts.

During construction it's expected that WDFW will act as the Contracting Agency and designate a Project Manager to oversee construction management. Additionally, it's expected that WDFW will retain the design consultant for services during construction such as: submittal and request for information review, field engineering, on-site construction quality assurance and documentation, and verification of as-built conditions.

Following construction, it's expected that the ASRP monitoring plan for the Early Action Reaches will continue to be implemented and adaptive management measures considered as appropriate. Should adaptive management measures be considered it's expected that the design consultant would have the opportunity to be involved as appropriate.

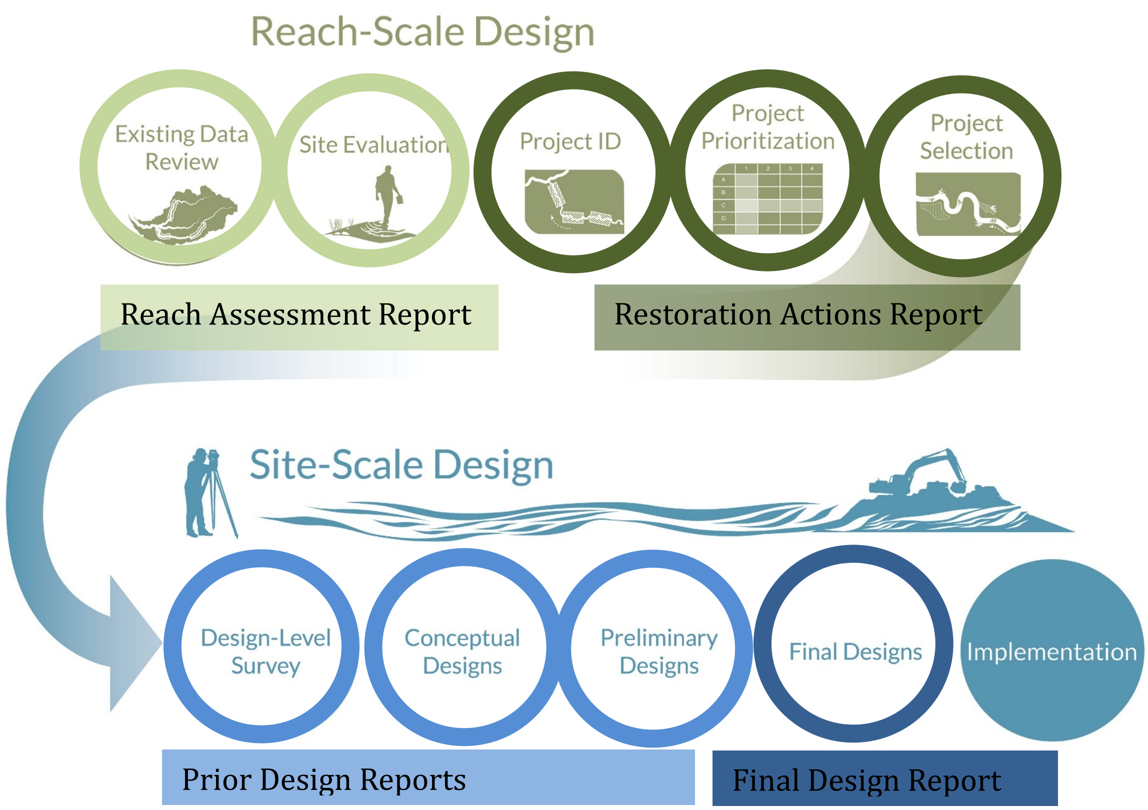


Figure 33. Illustration of the project design and implementation process.

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