An Alternatives Analysis of Restoration Project Concepts across Farm, Fish and Flood Interests: Skagit Hydrodynamic Model Project

Phase 2 Report

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Executive Summary

The Farm, Fish, and Flood Initiative (3FI) aims to create and advance mutually beneficial strategies that support the long-term viability of agriculture and salmon while reducing the risk of destructive floods. As with many places throughout Puget Sound, the Skagit Delta land base is limited and population growth contributes additional pressures on the landscape. In the Skagit River, where salmon are a cornerstone of tribal culture and economy, it was estimated that an additional 1.35 million smolts, approximately 2,700 acres of estuary/delta habitat, are needed for a sustainable Chinook population. The delta also supports a strong agricultural economy and community that faces risks from floods due to aging flood/drainage infrastructure. Climate change is also anticipated to impact estuarine habitat, agriculture, and flooding.

Under the umbrella of 3FI, local representatives from salmon recovery, flood risk reduction, and agricultural groups have worked together on the Skagit Hydrodynamic Modeling (SHDM) Project led by National Oceanic and Atmospheric Administration Restoration Center (NOAA), The Nature Conservancy (TNC) and Washington Department of Fish and Wildlife (WDFW). The SHDM project contributes to 3FI work and is a landscape-scale alternatives analysis with the goal of developing well-supported actions to achieve long-term viability of Chinook salmon and community flood risk reduction in a manner that protects and enhances agriculture and drainage. The geographic focus of the SHDM study is within the tidally-influenced portion of the Skagit Watershed including the Swinomish Channel and southern portion of Padilla Bay.

The SHDM Team was comprised of individuals from 14 organizations representing farm, fish and flood interests, guided the project. The SHDM Team identified twenty-three restoration concepts for evaluation in the alternative analysis. Three types of projects were assessed:

(1) Dike setbacks or removals that restore tidal and riverine inundation and construction of new dikes to protect adjacent lands;

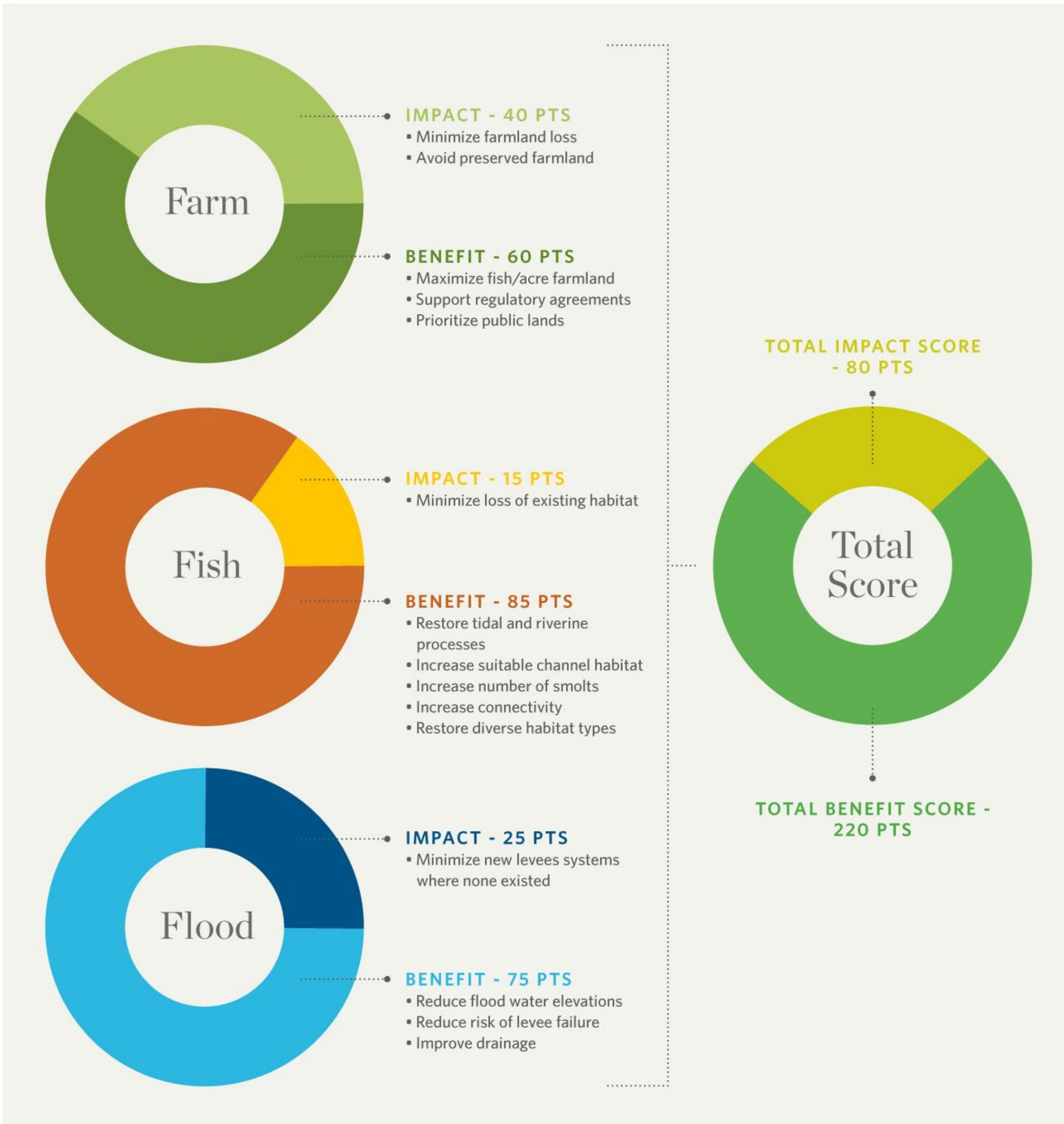
(2) Hydraulic projects that change the flow pattern by excavating new channels to distribute flow; and

(3) Backwater channels where an existing channel waterward of the dikes is altered to increase backwater flow.

Most of these projects were identified and described in the Skagit River Chinook Recovery Plan, some of which include further refinements from later planning processes such as the Puget Sound Nearshore Estuary Restoration Project or individual project sponsor actions. A few projects were pulled from the Skagit River Flood General Investigation or developed by the SHDM Team.

The SHDM Team used a logic framework as the foundation for the alternatives analysis. Representatives from each interest group developed objectives with measurable indicators against which restoration concepts could be assessed. These objectives included benefits to be maximized as well as impacts to be minimized (Figure E-1). Each interest group received 100 points that could be divided between the different objectives allowing for weighting of any high priority objectives. The scores for each interest were then summed for a multiple-interest benefit and multiple-interest impact score. The objectives, indicators, and their weighting assignments were shared with other stakeholders and organizations from the respective interest groups for review and comment. The SHDM Team worked with scientists and technical experts to quantify the indicators hydrodynamic modeling, estimates of habitat connectivity and smolt production, predictions of sediment transport processes, GIS calculations, and local tidal and river flood and drainage knowledge. This work was an iterative process that allowed for input from each interest group to ensure the results are meaningful.

Figure E-1. Skagit Hydrodynamic Model Project logic framework



Using the outputs of the technical analyses, each project concept was assessed to determine how it contributed to each objective. For each indicator, the projects were normalized on a scale of 0-1 and then multiplied by the assigned points for that objective. Project objective scores were summed for a total benefit and impact score at the interest and multiple-interest level. The multiple-interest project scores were graphed in order to identify groupings of projects based on how they provided benefits or minimized impacts (Figure E-2). Five management groups (Figure E-3) were identified with different timelines and recommendations for each group as described below. It is assumed that some project concepts within these groups may move forward faster or slower than the processes described below and that some may never advance due to impacts or other limitations and constraints.

Figure E-2. Multi-Interest Project Benefit and Impact Scores

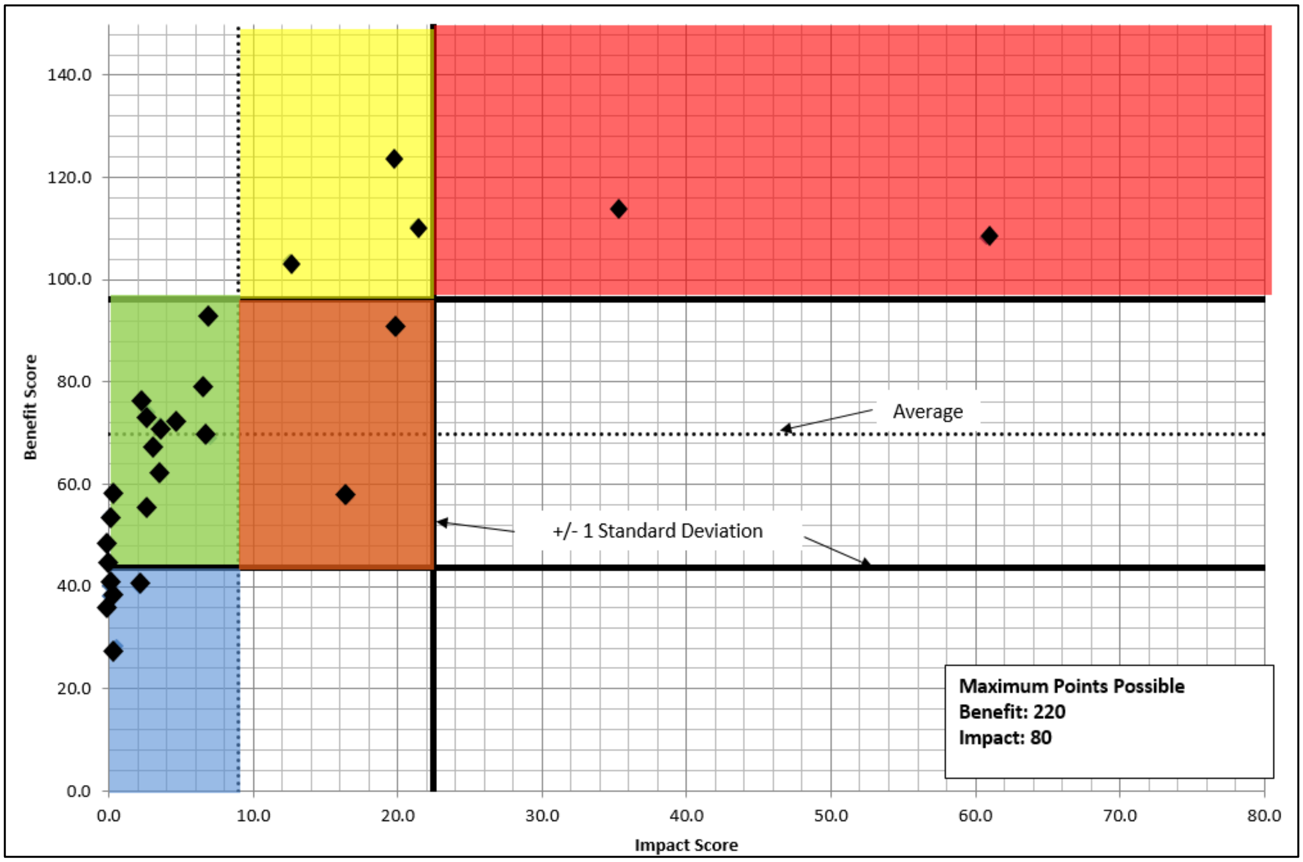


Figure E-3. Five Management Groups

Blue: Low benefits/low impacts – These projects have low multiple-interest benefits or only strong benefits to one interest group and therefore are not recommended to be a focus of future multi-interest work. Due to their low impacts, they may be advanced by one interest should the benefits be high enough for that interest group.

Green: Moderate benefits/low impacts – These projects have moderate benefits with relatively low impacts and are therefore the priority group for advancing. Focus over the next five years should be on engagement of key-stakeholder groups and development of multi-interest partnerships to identify ways to address and offset remaining impacts as well as to ensure that any project advancement is maximizing benefits across the interests.

Yellow and Orange: High benefits/moderate impacts and moderate benefits/moderate impacts – Due to the higher likelihood of impacts from project concepts in these two groups, it is recommended that outreach to key stakeholders and the development of multi-interest partnership not begin for five to 15 years to allow less impactful actions to be implemented and increase our understanding of how projects perform.

Red: High benefits/high impacts – It is recommended that these projects not advance through this process due to the high level of impacts to one or multiple-interests.

Additional hydrodynamic modeling examined cumulative effects if all project concepts except the red group were implemented, and provided an initial assessment of how climate change may affect projects and their benefits. Cumulative effects analyses found no major impacts to flow distribution between the North Fork and South Fork Skagit RIver nor the performance of individual projects. Climate change results can be used to better understand or evaluate how the benefits of projects may change over time. Additional analysis of climate changes, and sediment transport processes should be conducted to address future needs for drainage and diking infrastructure.

This SHDM project report covers the development and application of the technical analyses used to calculate scores and evaluate project concepts. It also describes how project concepts with similar benefits and impacts were grouped and the management recommendations and timelines for each group. Finally, the report summarizes the results from the climate change analysis and how potential future impacts to habitat, coastal flood resiliency, drainage, and irrigation may be impacted.

Acronyms

3FI	Skagit Farm, Fish, and Flood Initiative
AG-NRL	Skagit County Zoning Code for Agricultural Natural Resource Land
GIS	Geographic Information System
NF	North Fork
NOAA	National Oceanic and Atmospheric Administration/Restoration Center
PNNL	Pacific Northwest National Laboratory
PSNERP	Puget Sound Nearshore Estuary Restoration Project
Q2	2-year return frequency discharge rate
QFlood	Discharge rate defined for this analysis to represent a flood event
RCO-SRFB	Recreation and Conservation Office – Salmon Recovery Funding Board
OSRSI	Skagit County Zoning for Public Open Space of Regional/Statewide Importance
RRv	Skagit County Zoning for Rural Reserve
SCRP	Skagit Chinook Recovery Plan
SF	South Fork
SHDM	Skagit Hydrodynamic Model
SLR	Sea Level Rise
SPF	Skagitonians to Preserve Farmland
SRSC	Skagit River System Cooperative
TFI	Skagit Delta Tidegates and Fish Initiative
TNC	The Nature Conservancy
USGS	US Geological Survey
WDFW	Washington Department of Fish and Wildlife
WSE	Water Surface Elevation
WWAA	Western Washington Agricultural Association

Acknowledgements

Many thanks to the SHDM team members who generously volunteered their time or whose organizations supported their involvement. This project would not have happened without them being fully engaged in the conversation, diving into messy technical details, and challenging us to capture what is most important to their respective interest.

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Project Funding

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- Private Donors (Phase 1)
- National Oceanic and Atmospheric Administration Restoration Center (Phase 2)
- Salmon Recovery Funding Board / Recreation and Conservation Office (Phase 2)

1.0 Introduction

The Farm, Fish and Flood Initiative (3FI) aims to create and advance mutually beneficial strategies that support the long-term viability of agriculture and salmon while reducing the risks of destructive floods. 3FI is a landscape-scale effort in the Skagit delta where representatives from a variety of interests have agreed to a common agenda and established partnerships that can bring about breakthroughs in estuary restoration, flood risk reduction, and farmland protection in a way that supports multiple community interests.

The Skagit Hydrodynamic Model (SHDM) Project is supported by and contributes to 3FI. The goal for the SHDM Project is:

> *Using alternative analysis, develop a suite of projects that are well supported to achieve long-term viability of Chinook salmon tidal delta habitat and community flood risk reduction in a manner that protects and enhances agriculture and drainage.*

There have been two distinct phases of the project. Phase 1 began in late 2012 and was completed by early 2014. Phase 1 included the following tasks and is described in more detail in a Phase 1 Report (Appendix A):

- Convened a project team of individuals representing farm, fish, and flood interests
- Developed the project goal, objectives, indicators, means of estimation, and assumptions
- Identified a suite of potential project concepts
- Developed the alternatives analysis framework
- Identified the appropriate analyses to complete the alternatives analysis
- Community stakeholder outreach

Phase 2 began in early 2014 and ended in late 2017. This is the Phase 2 Report which documents the analyses of restoration project concepts developed for Chinook recovery in the Skagit delta using hydrodynamic modeling, GIS analysis and mathematical models, to determine which concepts have the potential for providing multiple-benefits (fish, farm, and flood), and management recommendations for moving forward.

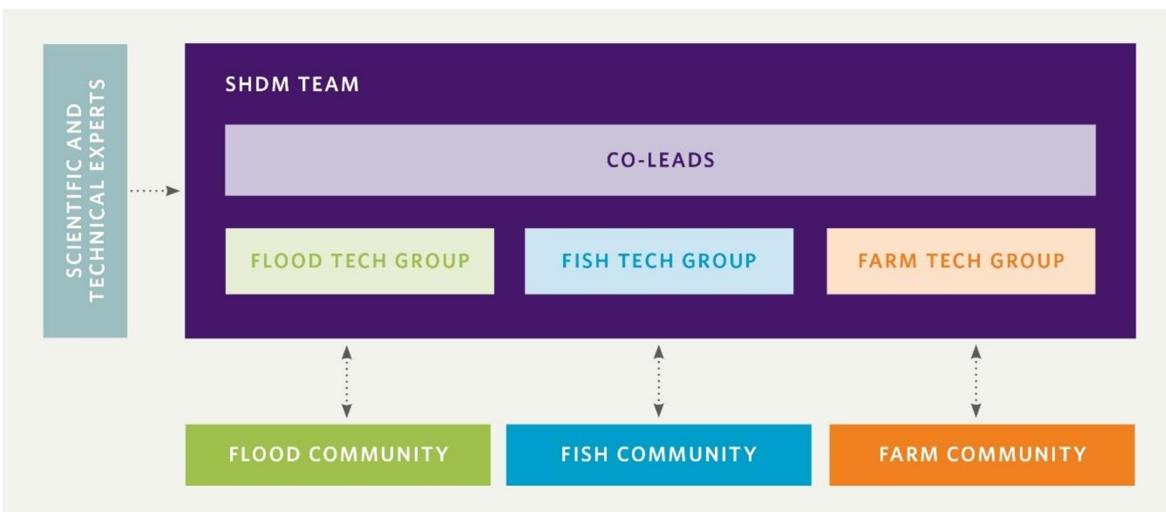
2.0 SHDM Team Members and Outreach Efforts

Project Management Structure and Team Members

Polly Hicks (National Oceanic and Atmospheric Administration/Restoration Center), Jenna Friebel (Washington Department of Fish and Wildlife) and Jenny Baker (The Nature Conservancy) co-managed the SHDM Project. The co-leads oversaw and guided the project, including developing the overall approach, convening the appropriate teams and work groups, managing grants and contracts, interpreting results, providing meeting content, incorporating input, developing and vetting the alternatives analysis framework, and writing up project outcomes.

A diverse team of scientists and key local stakeholders involved in salmon recovery, flood protection, and agriculture called the Skagit Hydrodynamic Modeling (SHDM) Team was convened during Phase 1. In Phase 2, the SHDM Team reviewed and provided input on the overall approach and results. This group was also an important venue for communication that built understanding between interests (Figure 2-1).

Figure 2-1. SHDM Project Team Structure

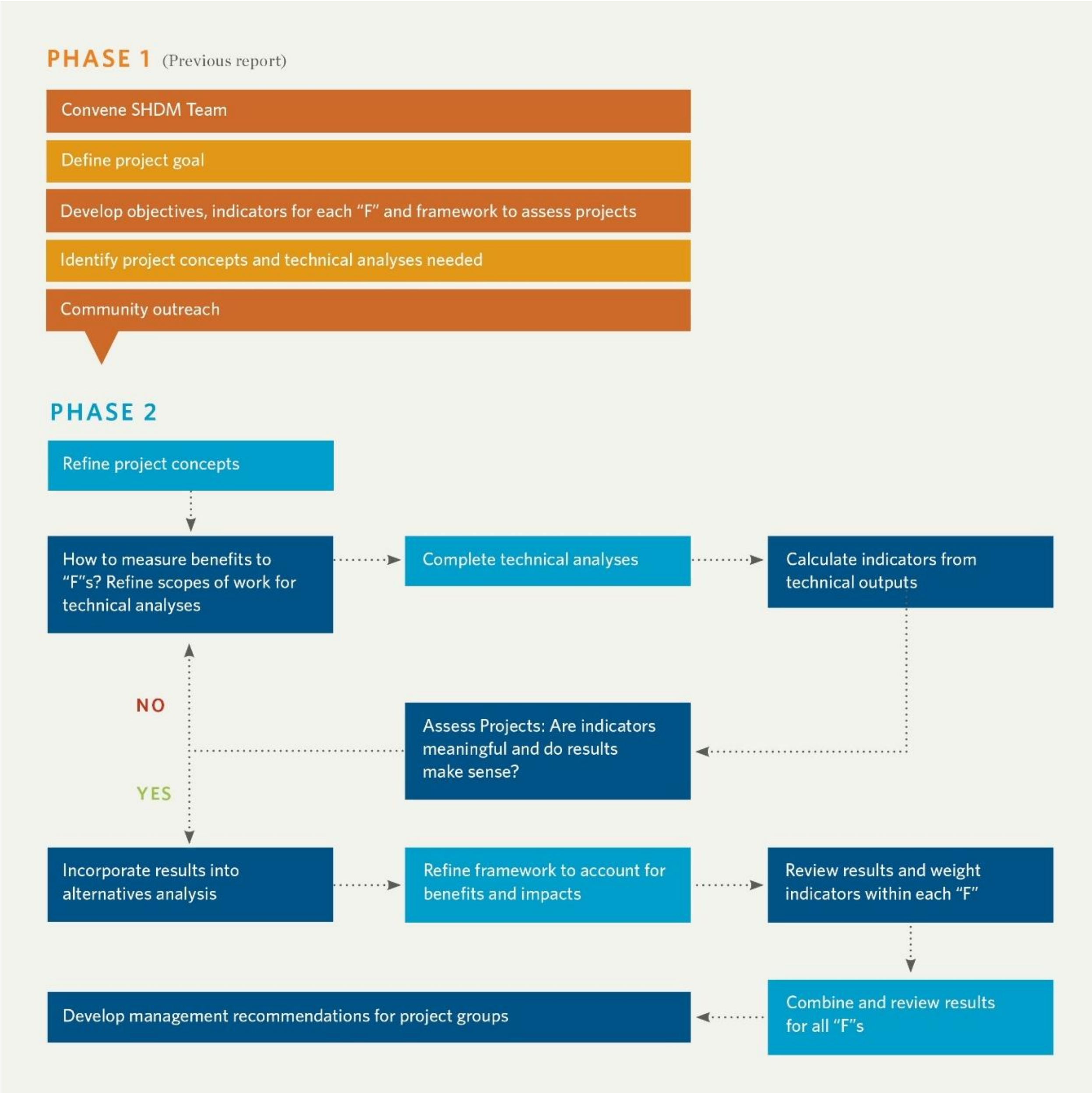


The SHDM Team included members from the following agencies and organizations:

- Skagit County Consolidated Diking Improvement District #22
- Skagit Watershed Council
- Skagit County Dike District #17
- Skagitonians to Preserve Farmland
- Skagit County Dike District #3
- The Nature Conservancy
- NOAA/Restoration Center
- Washington Department of Fish and Wildlife
- Seattle City Light
- Western Washington Agricultural Association
- Skagit Conservation District
- Upper Skagit Tribe
- Skagit County Dike District Partnership
- US Geological Survey

During Phase 2, the SHDM Team also broke into three smaller technical work groups, each comprised of representatives with specific knowledge and experience related to farm, fish, or flood issues. Each technical work group was tasked with refining objectives and indicators, then reviewing the numeric scoring system for each objective and indicator, developing the weighting systems between indicators, and presenting the work to their boards and key community members (Figure 2-2).

Figure 2-2. SHDM Project Process



Technical work group decisions were brought back to the larger SHDM Team for review. The results were combined to understand to what degree project concepts might provide outcomes across farm, fish, and flood interests. The SHDM Team was also involved in development of the management recommendations.

TNC contracted for scientific and technical analyses:

1. Pacific Northwest National Labs developed and ran the hydrodynamic model;
2. US Geological Survey completed a sediment study; and
3. Skagit River Systems Cooperative provided tidal channel and smolt estimates based on numeric models.

A Geographic Information System (GIS) specialist at TNC completed GIS analysis.

SHDM Team Meetings

The co-leads convened a number of meetings throughout Phase 2 of the SHDM Project. SHDM Team meetings were facilitated by David Roberts of Kulshan Services. Meetings were held at key milestones in the project and were used as a way to present draft methods, results, and management recommendations. In addition, meeting presentations, draft technical analyses, and reports were made available to the SHDM Team on a Box site hosted by TNC.

Technical Work Group Meetings

The co-leads met frequently with technical work groups for each interest group. The focus of these meetings was to confirm the objectives and indicators, finalize the methods used to calculate and weight the objectives and indicators, and review draft results.

Outreach

In addition to convening SHDM Team meetings and farm, fish, and flood technical work group meetings, the co-leads reached out to individual SHDM team members over the course of the project to share information and get feedback. SHDM Team members were also tasked with providing updates to and getting feedback from their respective organizations. During the spring and summer of 2017, the co-leads also had direct communication with the following organizations to share initial results and get feedback:

- Skagit Dike District Partnership
- SPF Board
- WWAA Board
- Swinomish Tribe staff/SRSC staff
- Samish Tribe staff
- Skagit Watershed Council Technical Work Group
- Skagit Watershed Council general member meeting

3.0 Restoration Project Concepts

The SHDM project evaluated 26 potential projects (Figure 3-1 and Table 3-1). The project concepts are mostly dike setbacks or dike removals with the potential to increase floodplain and estuary habitat, reduce river flood stage, and result in the construction of new dikes built to a higher standard. Another major group of project concepts were hydraulic projects that change the flow pattern by excavating new channels to distribute flow across the delta. Project concepts also included backwater channels, where existing channels located riverside of levees would be modified to increase backwater flow and fish use.

Figure 3-1. Project concepts included in the SHDM Project

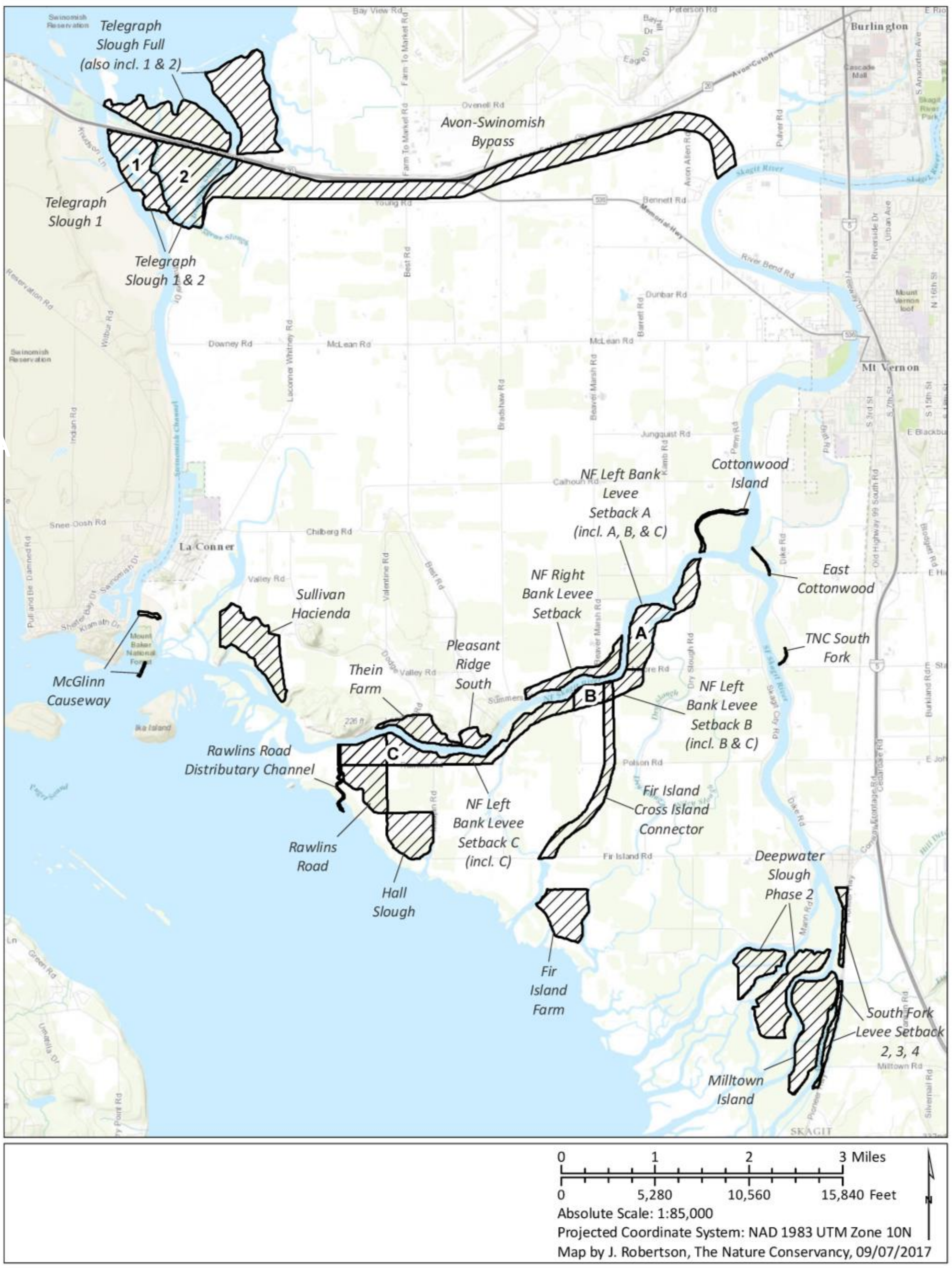


Table 3-1. Project Concepts included in the SDHM Project

Project	Project Type	Total Area (acres)[N1]
Avon-Swinomish Bypass	Hydraulic	1,291
Cottonwood Island	Backwater Channel	15
Deepwater Slough Phase 2	Dike Removal	268
East Cottonwood	Backwater Channel	2
Fir Island Cross Island Connector	Hydraulic	150
Fir Island Farm	Dike Setback	140
Hall Slough	Dike Setback	134
McGlinn Causeway	Hydraulic	7
Milltown Island	Dike Breach	222
NF Left Bank Levee Setback A	Dike Setback	552
NF Left Bank Levee Setback B [N2]	Dike Setback	370
NF Left Bank Levee Setback C	Dike Setback	275
NF Right Bank Levee Setback	Dike Setback	86
Pleasant Ridge South	Dike Setback	30
Rawlins Road	Dike Setback	191
Rawlins Road Distributary Channel	Hydraulic	8
South Fork Levee Setback 2, 3, 4	Dike Setback	56
Sullivan Hacienda	Dike Setback	205
Telegraph Slough 1	Dike Setback	185
Telegraph Slough 1 & 2	Dike Setback	495
Telegraph Slough Full	Dike Setback/Hydraulic	1,048
Thein Farm	Levee Setback	78
TNC South Fork	Backwater Channel	1
McGlinn & TS 1[N3]	Dike Setback/Hydraulic	192
McGlinn & TS 1&2 [N3]	Dike Setback/Hydraulic	501
McGlinn & TS Full [N3]	Dike Setback/Hydraulic	1,055

N1. Acreages listed here are updated to more closely match on-the-ground conditions compared to the acreages listed in Appendix B

N2. Not modeled directly by PNNL, but results interpreted from results from NF Left Bank Levee Setback A and NF Left Bank Levee Setback C

N3. Combo projects to understand how connectivity through McGlinn Causeway affected Telegraph Slough project smolt numbers

A majority of the project concepts were identified and described in the Skagit River Chinook Recovery Plan (SCRP; SRSC and WDFW 2005), which laid out a pathway to help recover threatened Chinook salmon in the Skagit Watershed. The original GIS shape files for these projects were obtained from SRSC. However, some of the restoration concepts had more than one shape file. In these instances, SRSC recommended the correct shape file to use in the SHDM project. Some of the SCRP projects have been further refined or developed through other planning processes such as the Puget Sound Nearshore

Ecosystem Restoration Project (PSNERP)[1] or through individual project sponsor actions as noted in the project summaries (Appendix B). Additional project ideas or expansions of existing CRP project footprints were also pulled from the Skagit River Flood General Investigation[2] process and developed by the SHDM Project Team. To be included in the study, a project concept had to have enough information available to be able to be modeled. Table 3-1 summarizes the projects concepts evaluated.

[1] PSNERP is a US Corps of Engineers General Investigation with WDFW as the local sponsor with the goal of evaluating significant ecosystem degradation in the Puget Sound Basin and then recommending a series of actions to help address these problems. - www.pugetsoundnearshore.org/

[2] www.skagitcounty.net/Departments/PublicWorksSalmonRestoration/main.htm

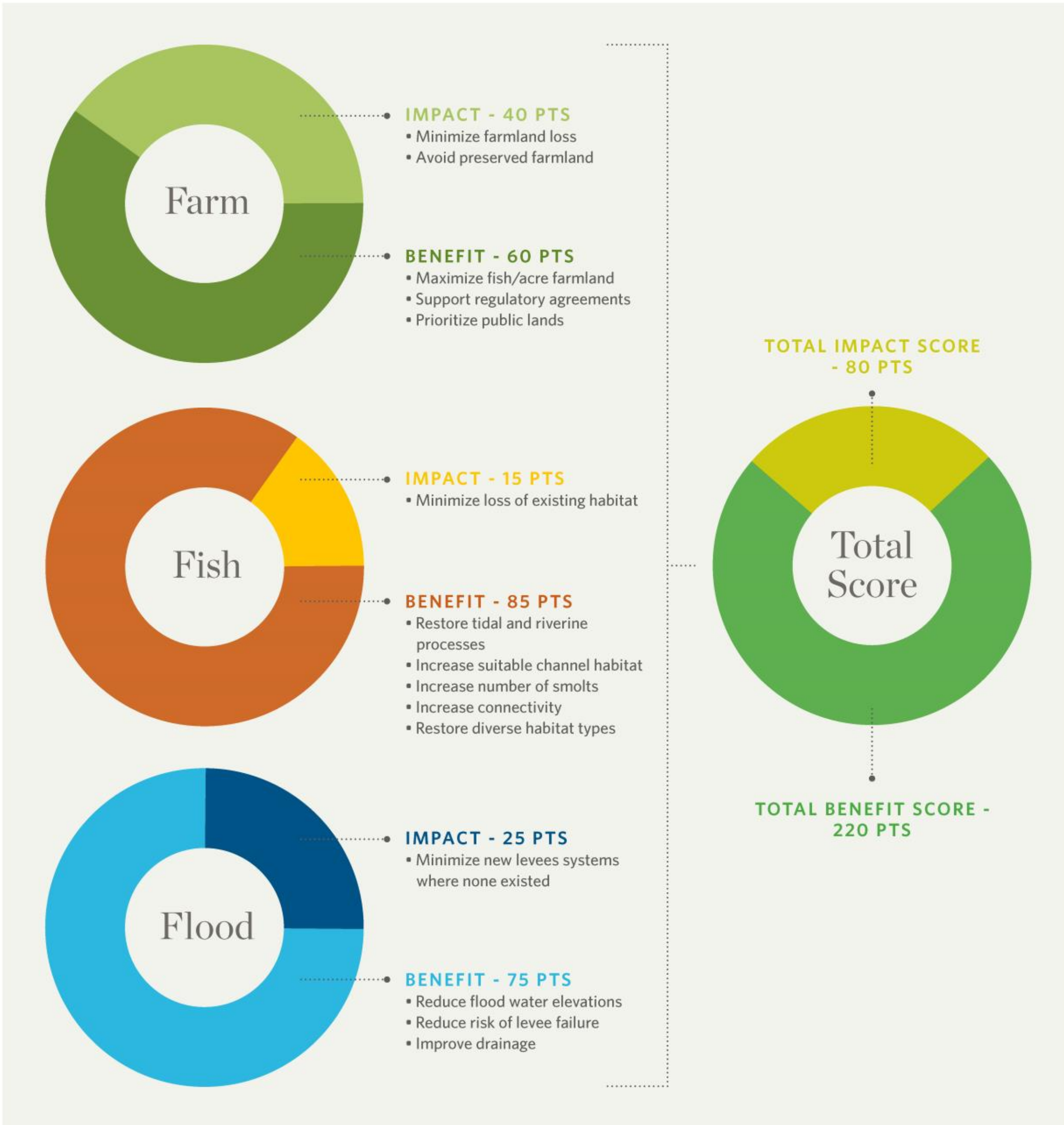
4.0 Alternative Analysis Framework

The SHDM Team used a Logic Framework Approach to develop the alternative analysis. Originally created for international development projects, the Logical Framework Approach is a management tool that helps to guide the design, monitoring and evaluation of projects (Rosenberg, et al. 1970). The approach requires identification of general and specific objectives. Each specific objective has an associated measurable indicator that can be used to gauge how a project contributes to the specific objectives, general objectives, and larger goal.

Guided by the Logic Framework Approach, the SHDM Team established objectives for each interest group: farm, fish, and flood with several measurable indicators for each objective. All of the objectives and indicators support the overall goal of the SHDM Project, which is to develop a suite of projects that are well supported to achieve long-term viability of Chinook salmon tidal delta habitat and community flood risk reduction in a manner that protects and enhances agriculture and drainage and formed the basis for this alternative analysis

Initially, all of the indicators were evaluated using positive scores. Project concepts with higher scores were considered better for each interest group, projects with lower scores were considered worse. However, this approach did not include consideration of the benefits versus the negative impacts from each project concept because it masked impacts as lower benefits. As a result, the logic framework was modified to categorize some objectives and indicators as measuring the benefits (positive) and others measuring the impacts (negative) of project concepts (Figure 4-1).

Figure 4-1. Logic framework used to assess project concepts



Each interest group (farm, fish, and flood) has a different number of objectives and differences in the number of objectives considered either a benefit or an impact. Farm, fish and flood were equally weighted with 100 possible points per group (Figure 4-1). Representatives from each interest group either divided these points evenly between objectives or weighted some objectives more heavily. The total scores for all of the objectives were combined into overall benefit and impact scores for each project concept. These scores were plotted on an x-y axis and used to develop management recommendations for specific groups of projects with similar scores.

Technical Analyses

Several different technical analyses were conducted to characterize and score the indicators developed for each objective. These analyses fell into two broad categories, numerical models and non-modeling analysis. The numeric models used to support this analysis included:

- 3-D Hydrodynamic Modeling (Whiting et al, 2017; Appendix C)
- Tidal Channel Allometry Model and Skagit Chinook Model (Beamer et al, 2016; Appendix D)

Non-modeling analysis included:

- GIS (Robertson, 2017; Appendix E)
- Sediment Analysis (Grossman, In Review, Appendix F)
- Vegetation community predictions

Overview of technical analyses done to support the objectives and indicators is provided below. Detailed results for each objective and indicator are provided in the Results Section of this report.

Numerical Models

3-D Hydrodynamic Modeling

Pacific Northwest National Lab (PNNL) modified the Salish Sea Finite Volume Coastal Ocean Model to increase the resolution of the grid network within the study area (Appendix C). The updated model was called the Skagit Hydrodynamic Model (PNNL Model). These modifications included expanding the grid network to include project concept footprints. PNNL also calibrated the model using data collected by WDFW at five locations within the study area to better characterize the relationship in flow between the north and south forks of the Skagit River and between Freshwater and Steamboat Sloughs. Table 4-1 summarizes the outputs from the PNNL model that were used to support the alternatives analysis.

Table 4-1. PNNL Model Output

Output description	Objectives/indictors supported
Area inundated under high tide/low flow or Q2/low tide (within project and for the whole system)	Restore tidal and riverine processes (Fish) Minimize loss of existing habitat (Fish) Support regulatory agreements (Farm)
Depths of inundation within a project concept	Restore diverse habitat types (Fish)
Duration of WSE over a 3 month period	Increase suitable channel habitat (Fish)
Changes in WSE during flood events	Reduce floodwater elevations (Flood)
Changes in flow balance between forks	Minimize loss of existing habitat (Fish)
Changes in salinity	Not used in alternatives analysis, but provided as additional information for consideration in future phases

Project concepts were grouped into seven different modeling runs to determine the effects of individual projects without being masked by larger effects of other projects (Table 4-2). A comprehensive report on the PNNL Model analyses is in Appendix C.

Table 4-2. Model runs to assess individual project effects

Model Run	Project Name
Small Projects	
1	SF Levee Setback 2, 3, 4
	McGlinn Causeway
	TNC South Fork
	Cottonwood Island
	East Cottonwood
	Pleasant Ridge South
	Hall Slough
	Fir Island Farm
	Telegraph Slough Full
	Sullivan Hacienda
	Rawlins Road Distributary Channel
Major Hydraulic Projects	
2	Fir Island Cross Island Connector
3	Avon-Swinomish Bypass
Major Setback Projects	
4	NF Left Bank Levee Setback C
5	NF Left Bank Levee Setback A
Moderate Setback Projects	
6	NF Right Bank Levee Setback
	Milltown Island
	Telegraph Slough 1
	Thein Farm
7	Deepwater Slough Phase 2
	Rawlins Road
	Telegraph Slough 1&2

N1. NF Left Bank Levee Setback B was not modeled because it is bracketed by NF Left Bank Levee Setbacks A and C; values used to calculate scores for objectives and indicators were interpolated from NF Left Bank Setback A and C.

While McGlinn Island is a major hydraulic project, it was not anticipated to mask the effects of the other projects included in the small project run and therefore was included in modeling run 1 with the small projects. Additional model runs included:

- Model run 8: cumulative effects of selected projects
- Model run 9: climate change without projects
- Model run 10: climate change with selected projects

Tidal Channel Allometry Model

Greg Hood updated the Tidal Channel Allometry Model (Hood, 2007b) and used the allometric model to predict tidal channel areas. The updated allometric model (Beamer et al, 2016) includes expansion of the model into upstream areas with reduced tidal prism, and accounts for wind/storm surge effects. The updated allometric model also includes confidence intervals for tidal channel predictions. The updated model was used to predict tidal channel habitat both within project concepts and potential increases in tidal marsh channel habitat in marsh areas adjacent to the project concept (Appendix D).

Skagit Chinook Model

Skagit River Chinook Model was used to update smolt predictions for the project concepts evaluated for this project (Beamer et al. 2016; Appendix D). Beamer et al estimated changes in smolt predictions based on updated tidal channel predictions from Greg Hood and an analysis of multiple potential pathways for smolts to access a project concept (Beamer and Wolf, 2016b).

SRSC also assessed how the formation of the new distributary channel on the North Fork effects the distribution of juvenile salmon. Currently, the avulsion does not change the distribution of juvenile salmon on the North Fork or Bayfront sites (Beamer and Wolf, 2016a).

Non-modeling Analyses

GIS

GIS analysis was used to understand the spatial relationship of project concept footprints to levee and dike features, PNNL modeling outputs such as change in water surface elevation and wetted area, and parcel information such as land use zoning, ownership, and agricultural easements (Table 4-3). Detailed descriptions of the methods used are in Appendix E.

Table 4-3. Objectives and Indicators supported by GIS analyses

Interest	Objective	Indicator	GIS Method	Data Used
Farm	Minimize conversion of agricultural land	Acres of Skagit County zoned AG-NRL, Skagit County Zoning for Rural Reserve (RRv), or Skagit County Zoning for Public Open Space of Regional/ Statewide Importance (OSRSI) and has a history of farming	Overlay project concepts with land zoned by Skagit County as AG-NRL, RRv, or OSRSI and that have a history of farming and calculate area	Skagit County Comprehensive Plan and Zoning District Shape file
Farm	Prioritize Public Lands	Acres of public land per project concept	Overlay project concepts with Skagit County parcel maps and calculate area in public vs. private ownership	Skagit County Parcel Map and Data
Farm	Avoid conversion of farmland preservation easements	Acres of farmland protection easements	Overlay project concepts with farmland preservation easements and calculate area within easements	Skagit County Database Consortium (Agricultural Easements map and data)
Fish	Increase the area subject to natural tidal and riverine processes in study area	Within project increases in wetted area during a high tide or 2-year flow	For the three backwater channels that were too narrow to be accurately predicted by PNNL's output, calculate additional area inundated	PNNL world files for inundation depth
Fish	Minimize impacts to existing habitats subject to tidal and riverine processes[N1]	Decreases in wetted area during a 2-year flow outside of project concept footprint	Calculate areas outside of the project concepts where increases or decreases in wetted area occurred	PNNL world files for inundation depth
Fish	Maintain or improve existing diversity of tidal marsh habitat along the historical elevation gradient (i.e. mudflat to riverine tidal)	Diversity metric of predicted habitat types within project area based on elevation	Calculate the area within each project concept that falls within each 1-ft elevation bin (NADV 88)	Elevation data created from XYZ coordinates of the PNNL surface model
Flood	Reduce water surface elevation within the study area [N2]	Length of river with reduced water surface elevation during flood event	Calculate length of reduced water surface elevation per elevation bin during a flood event	PNNL world files for reduced water surface elevation and channel centerlines adjusted by TNC from WDNR data
Flood	Reduce risk of levee failure by constructing new engineered levees	Length of replaced river levee or marine dike	Measure the length of replaced river levee or marine dike the overlaps with a project concept	n/a – measurements taken from aerial photos [N2]

N1. Analyses completed to understand the cumulative impacts of selected projects using PNNL model outputs for the cumulative impacts model run

N2. Measurements completed by Jenna Friebel, WDFW

Sediment Analysis

The US Geological Survey (USGS) performed a characterization of past sediment deposition rates and patterns in the lower Skagit River (Grossman in Review; Appendix F). This analysis used recently acquired high-resolution bathymetric and land-surface elevation data to create a digital elevation model for the lower Skagit River. The USGS then compared new bathymetric data with channel cross-sections collected in 1975 and 1999 to characterize increases in bed elevations of the lower Skagit River due to aggradation. Originally, the SHDM Team planned to use the results of this work to evaluate potential benefits of project concepts for flood management and offshore eelgrass beds via increased sediment storage potential. However, through the process of calculating and reviewing results, a suitable method for quantifying sediment storage and effects could not be determined, and the indicators associated with this work were dropped from the final scoring system.

Although sediment could not be incorporated in this landscape-scale analysis, sediment dynamics are an important factor affecting habitat, flooding, and drainage. Additional analysis of sediment transport processes may be important as individual projects advance or could be done at a more comprehensive scale.

Vegetation Community Predictions

In tidal marsh systems, specific vegetation species and plant communities correlate with marsh surface elevation resulting from changes in salinity, inundation frequency and duration, and other factors (Ewing 1986, Bertness and Ellison 1987, and Callaway et al 2012). Predictions of elevations ranges for different vegetation communities were based on literature regarding the distribution of vegetation found on existing habitat within the Skagit Delta (Hood 2007a and Hood 2013) and previous Skagit tidal marsh restoration design reports (Hinton et al, 2005; Tetra Tech, 2007; Shannon and Wilson, 2011). A synopsis of the literature supporting the selected elevation ranges for each vegetation community or vegetation zone is below. Elevations are in NAVD 88.

Mudflat: Elevations below 3ft

Of the 11 dominant marsh vegetation species noted in Hood (2013), none occurred below approximately 3 ft. The Wiley Slough report noted lower emergent ranges from 2.6 – 7.6 ft (Hinton et al, 2005). Therefore, mudflat habitats were predicted to occur below 3 ft in elevation.

Emergent Marsh: 3 – 7.9 ft

Fir Island Farm Restoration Project used a 7 ft elevation as the upper extent of the low marsh habitat classification. Hood (2013) found an overlap of dominant marsh species that are typical of emergent marsh communities (*Carex lynbyei* and *Schoenoplectus tabernaemontani*) and those of shrub or high marsh communities (*Myrica gale*) between 7 ft and 8 ft. *M. gale's* lower elevation range is influenced by its ability to establish on large woody debris found at this lower elevation than other shrub species (Hood 2007). Because the occurrence of *M. gale* depends on woody debris accumulation and not surface elevation, the upper limit of emergent marsh was set at 7.9 ft for this analysis.

Shrub-Scrub: 8 – 9.9 ft

Hood (2013) found some occurrences of *Salix* sp., a common genus that occurs in this vegetation zone, above 10.0 ft; however, other species typical of this zone more frequently occurred below 9.3 ft. Fisher Slough and Fir Island Farm restoration plans had a lower extent to their high marsh habitat ending at 9 ft. Because some shrubs including *Salix* sp. occur at elevation above 9 ft, the shrub-scrub zone was considered to extend to 9.9 ft for this analysis.

Floodplain/Riparian: at or above 10 ft

Due to the vegetation patterns found in the shrub-scrub zone, we set a general riparian/floodplain habitat at elevations above 10 ft.

Methods to Evaluate and Score Objectives and Indicators

The results of the technical analyses were used to quantify indicators for each objective in order to evaluate and compare restoration concepts. During Phase 2, objectives and indicators were reviewed with representatives from each interest group and modified as needed to best represented farm, fish, and flood needs and priorities.

The final indicators are presented in the detailed methods section below. The raw score for each objective was normalized on a scale of 0 to 1. Ultimately, each interest group (farm, fish, and flood) had a total maximum score of 100 points. These points were either evenly divided between each indicator and objective or weighted. The detailed calculations for scoring, normalizing, and weighting for each indicator and objective are provided in the following sections.

Indicators that were dropped

Between Phase 1 and Phase 2, indicators within each interest changed. As new information became available and the SHDM Team assessed the indicators, some data did not differentiate between projects and thus the indicator was not meaningful for the intended purpose. In other cases, through the course of conversation, a new indicator was identified that provided a meaningful way to compare projects. New indicators are discussed in the relevant sections below. Indicators that were dropped are as follows:

- One fish objective and its associated indicator was dropped: Enhance Valued Nearshore Rearing Habitats by Reducing Sediment Impacts. The sediment data was not detailed enough to be able to use. We knew where there were areas of high, medium, and low sedimentation in the river channel, but did not have a clear way to link project implementation to sediment impacts to nearshore habitats. There were too many potential confounding factors so the indicator was dropped.
- Two flood objectives and their associated indicators were dropped. The first was Reduced Risk of Unplanned Levee Overtopping, which was removed because accurate information about levee heights and flood depths was not available for a meaningful analysis. The second indicator removed was Reduce Risk of Levee Failure Associated with Scour Locations. Model results showed that scour locations were affected by project implementation, but based on the modeling output, it was unclear if scour reduced or simply shifted location. In addition, the magnitude of reduction in scour was very small.

More information on changes to the indicators during Phase 2 is included in Appendix G.

5.0 Objectives and Indicators: Evaluation, Scoring and Weighting Methods

Farm Objectives and Indicators

A total of five objectives and measurable indicators were used to evaluate and compare restoration concepts for the farm interest (Table 5-1). Only minor changes were made to the farm objectives and indicators developed during Phase 1.

Table 5-1. Objectives and indicators for the farm interest

Farm Objectives	Farm Indicators	Objective Type
1. Minimize conversion of agricultural land	1. Area of Skagit County zoned AG-NRL, RRv, or OSRSI and has a history of farming that would be converted	Impact
2. Maximize the number of smolts per acre of converted agricultural land	2. Smolts/acre of agricultural land converted	Benefit
3. Support tidegate maintenance through TFI Implementation Agreement	3. Number of TFI credits per project, area inundated at 10.8-ft tide or Q2	Benefit
4. Prioritize Public Lands	4. Area of public land per project concept	Benefit
5. Minimize conversion of farmland preservation easements	5. Area of farmland preservation easements converted	Impact

The following sections summarize the methods used to evaluate, score, and weight each farm objective. Detailed maps and calculations are provided in Appendix H. Throughout this analysis, the farm interest group recognized that agricultural drainage is an important element of agricultural viability. However, the farm interest group and co-leads could not develop methods to objectively measure or evaluate this variable at a landscape scale so it was dropped from the analysis. Farm drainage does have an objective under the flood interest group.

Farm Objective 1: Minimize conversion of agricultural land

GIS was used to determine the area of a project concept that is zoned by Skagit County as AG-NRL, RRv, or OSRSI and has a history of farming. Any conversion of agricultural land was considered an impact to the farming community. The raw score for each project concept was normalized with 1.0 being the concept with the most potential to impact the farm interest group.

Score Farm Objective 1 (FRM_{O1}): A_{Pn}/A_{MAX}

Where:

A_{Pn} = Area converted by project "n" from farmland to habitat (acres)

A_{MAX} = Maximum area converted by a single project concept (acres)

Farm Objective 2: Maximize the number of smolts/acre of converted agricultural land

The number of smolts produced for a project concept (Fish Indicator #4) was divided by the acres of converted farmland (Farm Indicator 1) to estimate the number of smolts produced per acre of converted farmland. Project concepts that do not convert farmland were given a score of 1.0, with 1.0

being the project concept with the most potential farm benefit. All other project concepts were normalized using the flowing equation:

Score Farm Objective 2 (FRM_{O2}): SPA_{Pn}/SPA_{MAX}

Where:

SPA_{Pn} = Smolts per acre of converted farmland by project "n"

SPA_{MAX} = Maximum smolts per acre of converted farmland by a single project concept

Farm Objective 3: Support tidegate maintenance through TFI Implementation Agreement

Farm Objective 3 was calculated using output from the PNNL model, which was used to predict the area inundated under two different scenarios: high tide and low river flow, and low tide with 2-yr return frequency event flow (Q2). These scenarios are consistent with the methodology established in the TFI Implementing Agreement to calculate TFI credits and are the same scenarios used for the calculations of Fish Objective 1. For project concepts dominated by tidal processes the high tide/low flow scenario was used to calculate the area inundated. For project concepts dominated by riverine processes, the Q2/low tide scenario was used. For the Telegraph Slough suite of projects, the total number of credits generated is reduced by 50 percent unless the McGlinn Causeway project is also implemented. The McGlinn Causeway project is necessary to improve connectivity to the Telegraph Slough project concepts to maximize the habitat gains at that location. The raw score for each project concept was normalized with 1.0 being the concept with the most potential farm benefit.

Score Farm Objective 3 (FRM_{O3}): TFI_{Pn}/TFI_{MAX}

Where:

TFI_{Pn} = TFI credits generated by project "n"

TFI_{MAX} = Maximum number of TFI credits generated by a single project concept

Farm Objective 4: Prioritize public lands

Farm Objective 4 places a higher priority on project concepts located on public land. Skagit County parcel data was used to determine whether a project concept is located on land that is publicly or privately owned. Project concepts located on privately-owned land received a score of 0.0, project concepts located on publicly-owned land received a score of 1.0. Scores for concepts comprised of both public and private land ownership were scored using an area-weighted average. The raw score for each restoration concept was normalized with 1 being the concept with the most potential farm benefit, using the following equation:

Score Farm Objective 4 (FRM_{O4}) = $[1-A_{PVTn}/[A_{PVTMAX]} + A_{PUBn}/A_{PUBMAX}]/2$

Where:

A_{PVTn} = Acre of private land converted by project concept "n"

A_{PVTMAX} = Maximum acres of private converted land by a single project concept

A_{PUBn} = Acre of public land converted by project concept "n"

A_{PUBMAx} = Maximum acres of public converted land by a single project concept

Farm Objective 5: Minimize conversion of farmland preservation easements

Farm objective 5 was calculated using GIS. Project concepts were compared to the location of Skagit County or other farmland protection easements to determine if the footprint overlaps with land preserved for farmland. The area of overlap for any project concept was calculated. The raw score for each restoration concept was normalized with 1 being the concept with the most potential to impact the farm interest group.

Score Farm Objective 5 (FRM_{O5}): FLP_{Pn}/FLP_{MAX}

Where:

FLP_{Pn} = Acre of converted protected farmland by project "n"

FLP_{MAX} = Maximum acres of converted protected farmland by a single project concept

Total farm interest score

The farm interest group decided to weight each of the objectives evenly. Since there were five objectives identified for the farming interest group, each objective received 20 points. The benefit and impact scores were then calculated using the following equation:

Farm Interest Benefit Score = FRM_{O2} x 20 + FRM_{O3} x 20 + FRM_{O4} x 20

Maximum Farm Benefit Score = 60

Farm Interest Impact Score = FRM_{O1} x 20 + FRM_{O5} x 20

Maximum Farm Impact Score = 40

Fish Objectives and Indicators

A total of six objectives and seven indicators were used to evaluate and compare project concepts for the fish interest group. Methods for evaluating the indicators and changes made to the objectives or indicators are provided below with a summary of the revised objectives and indicators in Table 5-2.

Table 5-2. Revised fish objectives and associated indicators

Final Fish Objectives	Final Fish Indicators	Objective Type
1. Increase the area subject to natural tidal and riverine processes in the study area	1. Within project increases in wetted area during a high tide or Q2	Benefit
2. Minimize impacts to existing habitats subject to tidal and riverine processes	2. Outside of project area decreases in area wetted during a Q2	Impact
3. Increase the area of tidal and riverine channels suitable for Chinook rearing fry in the study area	3a. Steady state prediction of channel area	Benefit
	3b. Total number of acre-hours that suitable habitat (water depth up to 6 ft) is available	
4. Increase Chinook smolt production	4. Number of additional Chinook smolts estimated	Benefit
5. Increase landscape connectivity of the study area	5. Ratio of existing to improved connectivity to a point downstream of the project	Benefit
6. Maintain or improve existing diversity of tidal marsh habitat along the historical elevation gradient (i.e. mudflat to riverine tidal)	6. Diversity metric of predicted habitat types within project area based on elevation	Benefit

The following sections summarize the methods used to evaluate, score, and weight each fish objective. Detailed maps and calculations are provided in Appendix I.

Fish Objective 1: Increase in area subject to natural tidal and riverine processes in study area

This objective was originally the total net gain of acres within the study area with restored tidal and/or riverine processes. To increase transparency, this objective was split into two; the first being to increase the area subject to tidal or riverine processes (Fish Objective 1) and the second being to minimize reducing areas subject to tidal or riverine processes (Fish Objective 2). A project concept was considered to have processes restored if it was inundated in either the high tide/low flow or Q2/low tide scenario, but was not inundated under either scenario in the baseline model run. These scenarios were selected to be consistent with the TFI and represent habitat types that are inundated frequently enough to provide valuable habitat for salmon.

Fish Objective 1 was calculated in two steps. First, project concepts were classified into three different categories (tidally dominated, riverine dominated or a combination of tidal and riverine) based on the position of the project concept within the study area and the type of project. The PNNL model was then used to calculate the increase in wetted area within a project concept as compared to baseline conditions using the same scenarios as Farm Objective 3. For projects considered tidally dominated, the wetted area under a high tide/low flow scenario was used. For project concepts considered riverine dominated a Q2/high tide scenario was used to calculated the wetted area. Project concepts that are designed to be hydraulic or backwater channels were automatically considered riverine dominated.

If project concept is influenced by both riverine and tidal processes, PNNL's calculations and inundation (water depth) maps were reviewed to determine the total of area inundated under either the high tide or Q2 scenarios and the higher value for wetted area was used to calculate the indictor score. For the three backwater channels that were too narrow to be accurately predicted by PNNL's output, GIS analysis was used to calculate the additional area inundated.

During the analysis of Fish Objective 2, an error in the way that Fir Island Cross Island Connector was digitized was discovered. The polygon did not include the area between Fir Island Road and Brown Slough tidegate. The increase in wetted area (21.1 acres) from that portion of the site was added to the total increase in wetted area for Fir Island Cross Island Connector. The raw score for each restoration concept was normalized with 1 being the concept with the most potential to benefit the fish interest group.

Score Fish Objective 1 (FSH_{O1}): A_{Pn}/A_{MAX}

Where:

A_{Pn} = Wetted area of project concept "n" (acres)

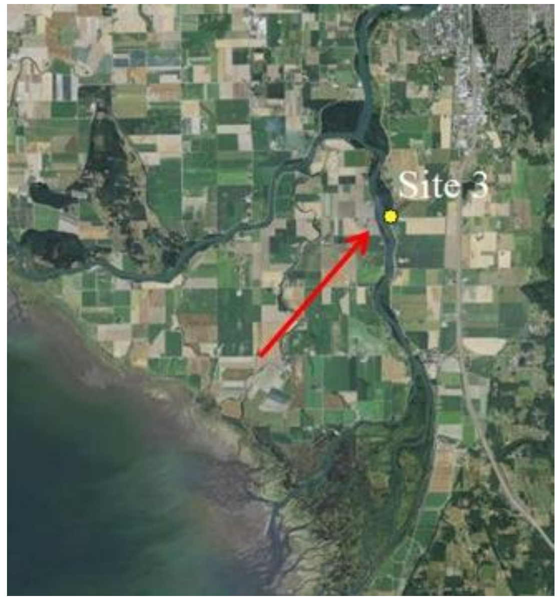
A_{MAX} = Maximum wetted area of a single project concept (acres)

Fish Objective 2: Minimize impacts to existing habitats subject to tidal and riverine processes

Project concepts have the potential to restore processes within a project concept footprint as well as reduce WSE, thus potentially decreasing the area inundated off-site. In particular, the fish interest group was concerned that project concepts could change the distribution of flow between the North and South Forks of the Skagit River and potentially impact existing habitat.

Stage and discharge output from PNNL's model at two locations, one on the North Fork (Site 2) and one on the South Fork (Site 3) was used to evaluate changes in balance of flow between the North and South Forks under baseline and with-project concept scenarios (Figure 5-1).

Figure 5-1. Location of WSE output



If changes were in the balance of flow between the North Fork and South Fork were detected, then the total wetted area predicted by the PNNL model was evaluated to determine if there was a change in total wetted area that could not be accounted for by the project concept footprint(s) alone. This analysis was done for both the high tide/low flow and low tide/Q2 flow scenarios.

For the flow scenarios (high tide/low flow or low tide/Q2) and model runs in which the total wetted area differences were found, GIS analysis was conducted on PNNL's water depth output files to identify and measure areas outside of the project concepts where changes in wetted area occurred. These were summed together to calculate the total reduction in wetted areas outside of a project concept footprint. The raw score for each restoration concept was normalized with 1 being the concept with the most potential to impact the fish interest group.

Score Fish Objective 2 (FSH_{O2}): A_{Pn}/A_{MAX}

Where:

A_{Pn} = Wetted area of lost offsite habitat "n" (acres)

A_{MAX} = Maximum wetted area of lost offsite habitat resulting from a single project concept (acres)

Fish Objective 3: Increase the area of tidal and riverine channels suitable for Chinook rearing fry in the study area.

Fish Objective 3 was calculated using two equally weighted indicators: 1) steady state prediction of channel area and 2) total number of acre-hours of suitable habitat.

Indicator 3a: Steady-state predication of channel area

Steady state channel areas were estimated for 14 project concepts using the allometric model completed by Greg Hood (Appendix D). The allometric model provided a low, mid-point and high estimate for the total channel area to be formed within a project footprint as well as the increase in channel area predicted to occur in adjacent marshes due to the increase in tidal prism from the restored site. The mid-point estimates of channel development rates were used for this indicator. The low and high estimates were based on an 80 percent confidence interval. Rankings among projects did not change whether the low, mid, or high estimates were used.

Channel area estimates for the remainder of the project concepts were estimated using the following methods. Channel area estimates for Cottonwood were obtained from the 2011 design report (Skagit Conservation District, 2011). East Cottonwood's channel and wetland pond area were provided by WDFW in 2017 based on the most recent project design (NHC 2016). Distributary project concepts with no channels created in adjacent marsh habitat were given a score of 0; these include McGlinn Causeway and Fir Island Cross Island Connector. Milltown Island's channel area was taken from PSNERP 2012 Strategic Restoration Conceptual Report (Cereghino, 2012) and Thein Farm was taken from the 2005 Skagit Chinook Recovery Plan. The raw score for each restoration concept was normalized with 1 being the concept with the most potential to benefit the fish interest group.

Score Fish Indicator 3a (FSH_{I3a}): CA_{Pn}/CA_{MAX}

Where:

CA_{Pn} = Channel area of "n" (acres)

CA_{MAX} = Maximum channel area resulting from a single project concept (acres)

Indicator 3b: Total number of acre-hours of suitable habitat

Juvenile Chinook salmon can only use channels that have a water depth ranging from 20 cm (0.66 ft) to 2 m (6.56 ft) with a velocity less than 1.3ft/sec (Beamer et al, 2005). Because the Skagit delta is a tidal system, the total acres of suitable channel habitat available for juveniles fluctuates depending on river flow and tides as well as the surface elevation of the project concept. While the scope of this project did not allow for an analysis of velocity, the spatial and temporal component of suitable water depths were calculated during the out-migration window (March 1 to May 22). This indicator accounts for sites that hold water at depths within the range suitable for Chinook smolts. The longer Chinook can use a site, the more productive that site will be for rearing smolts. This was seen at the Wiley Slough Project where ponded areas acted as channel habitat and therefore increased smolt capacity estimates for the site (Beamer et al, 2016).

To calculate acre*hours, the elevation of each project concept was broken down into 1-ft elevation bins using GIS analysis of the PNNL surface model. The total number of acres within each 1-ft elevation bin were then summed for each project concept. For each project concept, one sample spot was identified waterward of the site at which the water surface elevation was calculated in 15 minute increments from March 1 through May 22 from the PNNL model output. For long linear sites that would experience a variety of tidal ranges, such as the North Fork Left Bank Levee Setback A and B, two or more points were used. For each elevation bin, number of hours that the WSE was at or up to 6-ft above the ground elevation was calculated. That time period of suitable inundation was then multiplied by the total acres within that elevation bin for an acre*hour calculation. The acre*hours of suitable inundation were then summed across all of the elevation bins of a site for the total acre*hours of suitable inundation using the following equation:

$$\sum_{elevation\ x}^{elevation\ z} (hours\ inundated(x\ to\ x + 6ft) \quad * acres\ x)$$

It is beyond the scope of this project to predict the depth of channels across the marsh surface within each elevation band. The elevation bins were at the scale of 1 ft while smolts can use habitat inundated at depths of 0.66 ft and up to 6.56 ft. Therefore, to be conservative, only WSE 1 ft to 6 ft above the ground surface of each restoration concept was included.

East Cottonwood was the only backwater channel project that was expected to have significant ponded areas based on the conceptual design. However, the project team was not able to account for the proposed topographic modifications using the PNNL model; therefore, the inundation time used to calculate this indicator only included channel area and not potential ponded area.

The raw score for each restoration concept was normalized with 1 being the concept with the most potential to benefit the fish interest group.

Score Fish Indicator 3b (FSH_{I3b}): AH_{Pn}/AH_{MAX}

Where:

AH_{Pn} = Acre*Hours of project "n"

AH_{MAX} = Maximum number of Acre*hours resulting from a single project concept

Score Fish Objective 3 (FSH_{O3}): (FSH_{I3a} + FSH_{I3b})/2

Fish Objective 4: Increase Chinook smolt production

The potential increase in Chinook smolts production was calculated using several different methods depending on the project concept (Table 5-2).

Table 5-2. Source of smolt estimates for each project concept

2005 Smolt Estimates Using Chinook Model			
	Fir Island Cross Island Connector		
	McGlinn Causeway		
	Thein Farm		
2016 Smolt Estimates Using Chinook Model			
	Deepwater Slough Phase 2	NF Right Bank Levee Setback	Telegraph Slough 1
	Fir Island Farm	Pleasant Ridge South	Telegraph Slough 1 & 2
	Hall Slough	Rawlins Road	Telegraph Slough Full
	NF Left Bank Levee Setback A	Rawlins Road Distributary	
	NF Left Bank Levee Setback B	SF Levee Setback 2, 3, 4	
	NF Left Bank Levee Setback C	Sullivan Hacienda	
Project Specific Analysis			
	Cottonwood Island	Milltown Island	
	East Cottonwood	Avon-Swinomish Bypass	
	TNC South Fork		

For those project concepts that remained unchanged since the 2005 Skagit Chinook Recovery Plan, the 2005 predictions for smolts were used for this analysis (SRSC and WDFW 2005). Updated estimates were calculated for project concepts that have changed since 2005, or were not evaluated in the Skagit Chinook Recovery plan. Project specific methods were used to estimate smolt production for project concepts outside the geographic boundaries of the Skagit Chinook Model or that had other unique conditions.

Skagit Chinook Model
The Skagit Chinook Model, originally developed to support the SCRP, was used to estimate increases in Chinook smolts for project concepts. The original model took into account the area of channel habitat predicted for each project concept (Fish Indicator 2a) and the connectivity of the project concept.

Updated Skagit Chinook Estimates
As a part of this analysis, SRSC provided smolt estimates for any new project concepts not included in the SCRP. SRSC also provided updated smolt predictions for project concepts that either had a change in predicted tidal channel area based on the updated allometric model, had the potential to increase offsite tidal channel area or had a change in connectivity (Beamer et al. 2016) (Appendix D). Using the confidence intervals provided for the predicted channel area, SRSC also provided a range of fish carrying capacities for each project concept analyzed (Beamer et al. 2016). As with Fish Indicator 3a, we used the mid-point estimate for scoring project concepts.

Project Specific Analysis
Additionally, several estimates provided either in the 2005 SCRP or Beamer et al. 2016 were modified and are explained in the following sections.

Milltown Island
In the 2005 Skagit Chinook Recovery Plan, Milltown Island was estimated to support 57,179 smolts. This project was partially completed since 2005 and its current carrying capacity is estimated at 30,000 smolts (Beamer, 2017 personal communication). A value of 27,179 smolts was used to represent the remaining capacity potential of this project concept and calculate a score for this indicator.

Avon-Swinomish Bypass
To estimate the number of smolts for the Avon-Swinomish Bypass, SRSC calculated potential connectivity for two design options: a 100-ft wide channel and a 500-ft wide channel. For both options, they used the same tidal channel area predicted for Telegraph Slough 1 and 2 because the downstream end of the Avon-Swinomish Bypass includes Telegraph Slough 1 and 2 (Appendix B). Because the project concept includes a control structure that would reduce the connectivity of the 500-ft wide channel option, and based on a hydrologic evolution that suggests that the full 500-ft channel may not be wetted during the outmigration period, the connectivity value for the 100-ft channel was used to predict smolt numbers for this objective. Similar to the methods for Fir Island Cross Island Connector, the smolt estimate did not account for habitat that may be provided by the distributary channel because channel length and sinuosity were not defined in the conceptual design report.

During this project, SRSC raised the concern that the Avon-Swinomish Bypass had the potential to take a significant volume of Skagit River flow, which could result in a large proportion of the Skagit smolts being diverted to Padilla Bay. If there were not enough habitat in Padilla Bay to support those smolts, there would be a negative impact due to smolts being exported from the system. In response to those concerns, additional analyses were completed to estimate the potential volume of water diverted into the bypass during the Chinook outmigration period and to determine whether there would be enough habitat in Padilla Bay to support the projected number of smolts diverted from the river.

Using the output from PNNL's model for the time period of Jan 15 through May 22, Ed Connor (2017) completed a regression analysis to calculate the percentage of flow diverted into the bypass from the Skagit River based upon mean daily flow data during the chinook outmigration. This enabled the analysis to examine for potential impacts during the entire smolt outmigration window from Jan 15 through July 25. The average flow diverted to the bypass was 7.4 percent of the total Skagit River flow. It was assumed that the number of smolts diverted into the bypass channel would be directly proportional to the percentage of total river flow diverted into the channel. Therefore, it was estimated that 7.4 percent of the Chinook smolts in the Skagit would be diverted into the bypass channel throughout the entire outmigration period. During a peak smolt outmigration year of 6 million outmigrants, this would be 444,000 smolts. The remaining 5,556,000 smolts would continue to habitats downstream in the mainstem and forks of the Skagit River. For this analysis, it was assumed that the bypass channel would have an average width of 50-ft during the smolt outmigration period and a mean connectivity of 0.033l. The smolt capacity from the Avon-Swinomish Bypass channel including Telegraph Slough 1 and 2 would support an estimate 364,094 smolts. The remaining 75,600 Chinook smolts diverted to Padilla Bay should be readily supported by the approximate 247 acres of existing habitat (Connor, 2017). Based on this analysis, it was concluded that the Avon-Swinomish Bypass would not divert smolts to an area that would not support them, therefore, the predictions made by SRSC were used for this indicator.

East Cottonwood and TNC South Fork

Cottonwood East and TNC South Fork are located further upstream where the landscape connectivity value is greater than the data set used to create the Skagit Chinook model, which were collected further downstream. As a result, the Skagit Chinook model may significantly overestimate the number of smolts that these project concepts could support. SRSC's recommendation was to use an estimate of 13,150 fish/hectare/year for these sites based on smolt density data measured by SRSC at other long-term monitoring locations closer to the locations of these project concepts.

Cottonwood Island

Feasibility level designs have been completed for Cottonwood Island. The average of the high and low smolt estimates provided in the Project Design Report (Skagit Conservation District, 2011) were used for this site.

McGlinn Island Causeway & Telegraph Slough Project 1, Telegraph Slough 1 and 2 and Telegraph Slough Full

For each Telegraph Slough project concept, Chinook estimates were recalculated using the Chinook Model assuming the McGlinn Island Causeway project has been implemented and connectivity has been improved. The improved connectivity value was obtained from the SCRP. The smolts predicted for the McGlinn project concept were added to the revised Telegraph Slough project concept smolt estimates to get the total smolt production numbers for these combination projects.

The raw score for each restoration concept was normalized with 1 being the concept with the most potential to benefit the fish interest group.

Score Fish Objective 4 (FSH_{O4}): S_{Pn}/S_{MAX}

Where:

S_{Pn} = Number of additional smolts supported by project concept "n"

S_{MAX} = Maximum number of additional smolts from a single project concept

Fish Objective 5: Increase landscape connectivity of the study area

The function of any given habitat depends on its spatial position in the landscape and its relationship to and connection with other habitats. Similar habitats in different locations in the delta have been shown to support different densities of juvenile Chinook. Some project concepts have the potential to increase the connectivity to existing habitat or other proposed project concepts. The landscape connectivity values, following methods detailed in the Skagit Chinook Model (Beamer et al. 2005) and Beamer and Wolf (2011), were used to generate an index of connectivity according to the equation below. Specific landscape connectivity values for each project concept and baseline condition were obtained from the Chinook Recovery Plan and Beamer et al. 2016. The raw score for each restoration concept was normalized with 1 being the concept with the most potential to benefit the fish interest group.

Connectivity Index (CI) = Project Concept Connectivity Value/Baseline Connectivity Value

Where: Connectivity was measured at a point downstream of the project concept

Score Fish Objective 5 (FSH_5): CI_{pn}/CI_{MAX}

Where:

CI_{Pn} = Connectivity Index of project concept "n"

CI_{MAX} = Maximum Connectivity Index resulting from a single project concept

Project concepts with no changes in connectivity received a score of 0.

Fish Objective 6: Maintain or improve diversity of tidal marsh habitat along historical gradient

Using elevation data from the PNNL model, GIS analysis was completed to calculate the areas within each project concept that fall within each 1-ft elevation bin (NAVD 88). Then using the predicted elevation ranges for each vegetation zone, the total area within each vegetation zone was summed for a site (Table 5-3).

Table 5-3. Summary of elevation ranges for vegetation zones

Vegetation Zone	Elevation Range (ft NAVD88)
Mudflat	Less than 3.0
Emergent Marsh	3.0 – 7.9
Shrub	8.0 – 9.9
Floodplain Riparian	Greater than 10

Using the Simpson's Diversity Index, the total acres predicted to occur within each vegetation zone was then used to calculate the habitat diversity for the site. Simpson's Diversity Index is commonly used for calculating species diversity (Ricklefs 1993); however, it can be applied to habitat types, which we are calling vegetation zones. Simpson's Diversity Index takes into account both the richness or total number of different vegetation zones occurring at a site as well as the relative abundance of each zone. A detailed description of the use of Simpson's Diversity Index for habitat types can be found at the National Center for Ecological Analysis and Synthesis website https://groups.nceas.ucsb.edu/sun/meetings/calculating-evenness-of-habitat-distributions.

The raw score for each restoration concept was normalized with 1 being the concept with the most potential to benefit the fish interest group.

Score Fish Objective 6 (FSH_6): SD_{pn}/SD_{MAX}

Where:

SD_{Pn} = Simpson's Diversity Index score of project concept "n"

SD_{MAX} = Maximum Simpson's Diversity Index score resulting from a single project concept

Total fish interest score

The fish interest group decided to weight Fish Objective 4 more than the other objectives, and each of the remaining objectives evenly. The Skagit Chinook Recovery Plan goal defined for the study area is an additional 1.35M smolts annually; therefore, the fish interest group decided to weight this objective more. Objective 4 was given a weight of 25 points and the remaining objectives each received 15 points. The benefit and impact scores were then calculated using the following equations:

Fish Interest Benefit Score = FSH_{O1} x 15 + FSH_{O3} x 15 + FSH_{O4} x 25 + FSH_{O5} X 15 + FSH_{O6} X 15

Maximum Fish Benefit Score = 85

Fish Interest Impact Score = FSH_{o2} x 15

Maximum Fish Impact Score = 15

Flood Objectives and Indicators

During Phase 1, five flood objectives and their associated indicators were identified (Appendix J). However, based on the technical results from the PNNL model and input from the flood interest group, one of the original objectives was dropped resulting in four final objectives and six indicators (Table 5-4).

Table 5-4. Final flood objectives and indicators

Final Flood Objectives	Final Flood Indicators	Objective Type
1. Reduce water surface elevation within the study area	1. Length of river with reduced Water Surface Elevation (WSE) during flood event	Benefit
2. Reduce risk of levee failure by constructing new engineered levees	2a. Length of replaced river levee 2b. Length of replaced marine dike 2c. Overlap with known weakness area	Benefit
3. Avoid creation of new dike infrastructure where none existed previously	3. Length of new levees and/or marine dikes where none currently exist	Impact
4. Improve agriculture flood drainage	4. Overlap with location of drainage outlet	Benefit

The following sections summarize the methods used to evaluate, score, and weight each flood objective. Detailed maps and calculations are provided in Appendix J.

Flood Objective 1: Reduced water surface elevation

The indicator for Flood Objective 1 is a predicted reduction in the WSE during a flood event relative to existing conditions as a result of a project concept. If a project concept results in a reduction in flood WSE, adjacent dikes near the restoration can be assigned a lower risk for over-topping, seepage, and boils. Reduced flood risk results in a benefit to landowners within the area of flood risk and the responsible dike district.

This indictor was calculated using output from the PNNL model of WSE for existing and with-project concept conditions. The model output for the Qflood scenario was used to create georeferenced maps of the change in WSE. The flood flow scenario was defined as a peak discharge rate at the Mount Vernon gage of 93,200 cfs and a spring high tide of 10.4 ft. Under this combination of river flow rate and tidal elevation, the model predicted the WSR to be near the top the river levees; the levee elevations were based on LiDAR data and not more detailed topographic survey.

The georeferenced maps were then used to calculate the length of change in WSE in 1-ft vertical bins. A score for each restoration concept was calculated using the following equation:

$$\text{Flood Objective 1 Score } (FLD_{O1}) = (L_1 \times WSE_1 + L_2 \times WSE_2 + L_n \times WSE_n)$$

The raw score for each restoration concept was normalized with 1 being the concept with the most potential flood benefit.

Flood Objective 2: Reduce risk of levee failure by constructing new engineered levees

Many of the project concepts set back existing dikes or levees. In general, replacement of existing infrastructure was considered a benefit by the flood interest group. This objective was divided into three indicators.

Flood Objective 2: Indicator 1: Length of replaced river levee

Flood Objective 2: Indicator 2: Length of replace marine dike

Flood Objective 2: Indicator 3: Number of known weakness areas within a project concept

Indicators 1 and 2 were calculated by measuring the length of the setback levee or dike using conceptual plans or GIS. Based on input from the flood interest group, it was not necessary to ensure that the linear feet of new dike or levee matched exactly with the length of replace dike or levee. Marine dikes were separated from river levees to allow weighting by the flood technical group, although they ended up being weighted equally.

Indicator 3 was calculated using information about the locations of known problem areas in dikes and river levees provided by dike district commissioners. Problem areas include weaknesses such as boils, seepage, or areas that experience overtopping or require frequent rock placement. The raw score for each restoration concept was normalized with 1 being the concept with the most potential flood benefit.

Flood Objective 2: Indicator 1 (FLD_{I1}) = length of replace river levee (ft)/maximum length of replaced river levee (ft)

Flood Objective 2: Indicator 2 (FLD_{I2}) = length of replaced dike (ft)/maximum length of replaced dike (ft)

Flood Objective 2: Indicator 3 (FLD_{I3}) = number of problem areas overlapping a project concept

Flood Objective 2 Score (FLD_{O2}) = ($FLD_{I1} + FLD_{I2} + FLD_{I3}$)/3

Flood Objective 3: Avoid creation of new infrastructure where none currently exists

The flood interest group agreed that any project concept that would require an expansion of dike/levee infrastructure would be an impact to the flood group. The flood interest group considered this objective as an impact because any new dike/levee system would have unknown risks to drainage, increased landowner assessments for long-term operation and maintenance, and it would introduce new flood fighting liability where none currently exist. The raw score for each restoration concept was normalized with 1 being the concept with the most potential flood impact.

Flood Objective 3 Score (FLD_{O3}) = length of new levee created by project concept “n” (ft)/ maximum length of new levee (ft) by a single project concept

Flood Objective 4: Improve agricultural flood drainage

Many of the projects concepts would overlap with existing outfall locations. The flood interest group agreed that any project concept that overlaps with an existing or proposed flood return structure that would be upgraded or added as part of a project would be a benefit. This objective was scored as a simple yes or no; projects concepts that would have the potential to include a flood return structure were given a high score of 1. The raw score for each restoration concept was normalized with 1 being the concept with the most potential flood benefit.

Flood Objective 4 Score (FLD_{O4}) = Flood Return Structure Yes/No

Total flood interest score

The flood interest group decided to weight each of the objectives evenly, since there were four objectives identified for the flood interest group, each objective received 25 points. The benefit and impact scores were then calculated using the following equation:

Flood Interest Benefit Score = FLD_{O1} x 25 + FLD_{O2} x 25 + FLD_{O4} x 25

Maximum Flood Benefit Score = 75

Flood Interest Impact Score = FLD_{O3} x 25

Maximum Flood Impact Score = 25

Multiple Interest Project Concept Scoring and Weighting Methods

The weighted benefit and impact scores from each interest group were combined into a total benefit and total impact score for each project concept:

Project Concept Benefit Score = [FRM_{O2} x 20 + FRM_{O3} x 20 + FRM_{O4} x 20] + [FSH_{O1a} x 15 + FSH_{O2} x 15 + FSH_{O3} x 25 + FSH_{O4} X 15 + FSH_{O5} X 15] + [FLD_{O1} x 25 + FLD_{O2} x 25 + FLD_{O4} x 25]

Maximum Benefit Score = 220

Project Concept Impact Score = FRM_{O1} x 20 + FRM_{O5} x 20+ FSH_{O1b} x 15 = FLD_{O3} x 25

Maximum Impact Score = 80

The total benefit and impact scores for each project concept were then plotted on an x-y axis.

Cumulative Effects Analysis Methods

PNNL's model was used to evaluate potential cumulative effects if all of the selected project concepts were implemented. The selected projects included all of the project concepts except the NF Levee Setback A and Avon-Swinomish Bypass. The cumulative effects analysis focused on the following analyses:

- Potential changes in WSE for flood flows;
- Potential changes in on-site and off-site habitat; and
- Potential changes in salinity.

Results from the cumulative effect analysis were not used for additional ranking or weighting of project concepts. Instead, these analyses were developed to determine the potential for significant effects that cannot be identified when modeling the project concepts in isolation.

Methods to evaluate cumulative effects on WSE during a flood

Potential changes in WSE during a Qflood scenario were evaluated by comparing WSE under the cumulative model run as compared to baseline water surface elevations with no project concepts. The Qflood scenario was defined as a discharge rate of 93,200 cfs and high tide of 10.4 ft and was developed using flow data from the Mount Vernon USGS gage during the 1995 flood. Maps of the extent and magnitude of predicted WSE from the PNNL model were exported to GIS. The length of river with reduced WSE was measured and tabulated in 0.5 ft vertical bins. Changes less than +/- 0.3 ft were within the modeling error and not calculated. In addition, after reviewing the results of the model, the flood interest group decided that reductions in WSE less than 1.0 ft were not significant because the analysis only represented a single flood scenario and did not address the duration of flooding; therefore, reductions in WSE less than 1.0 ft were dropped from the analysis of flood benefits.

Methods to evaluate cumulative effects on habitat

Potential changes in wetted area within each project concept was evaluated using the same methods as Fish Objective 1. The wetted area within each project concept was calculated under the cumulative scenario and compared to the results from isolated project runs.

Potential changes to existing (off-site) habitat were evaluated using the same methods as Fish Objective 2. First, stage and discharge output from the PNNL model was used to evaluate changes in balance of flow between the North and South Forks under baseline and selected project concept scenario. If changes were detected, then changes in the wetted area under baseline and selected projects were calculated for the low tide/Q2 model flows using GIS. Areas outside of the project polygons and within the riverine portion of the site that either became wetted or became dry with the selected projects were tallied for a net change in off-site habitat.

Methods to evaluate cumulative effects on salinity

The PNNL model was used to evaluate potential changes to salinity levels within the study area to get a general understanding of potential system-wide changes to the extent and magnitude under the cumulative scenario. PNNL model outputs are available to inform future outreach efforts but were not analyzed for this report. The salinity analysis was limited to changes, but the scope of work did not include an evaluation of potential impacts associated with different magnitudes of change.

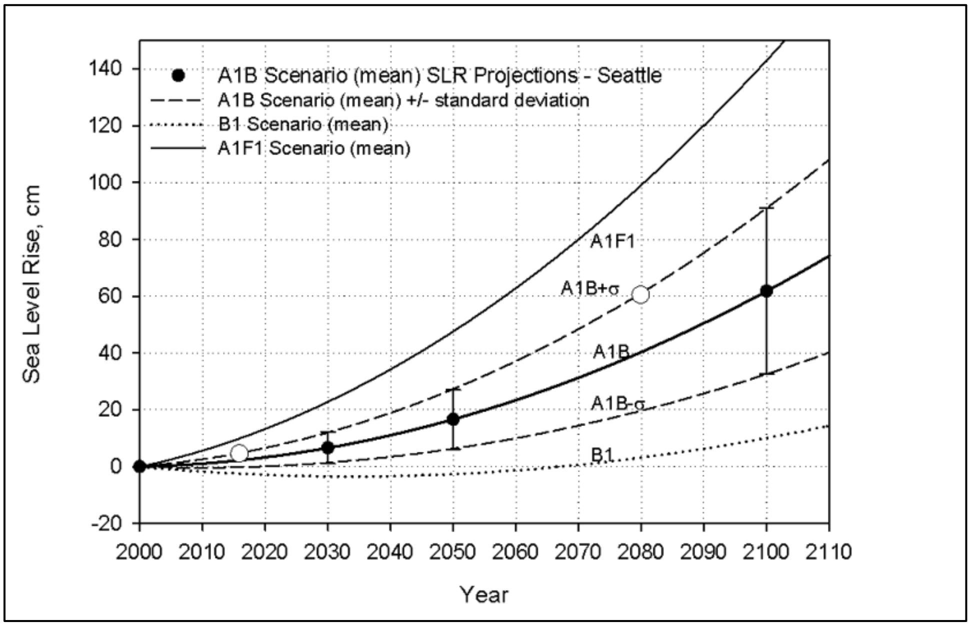
Climate Change Analysis Methods

PNNL's model was used to evaluate climate change scenarios with and without the selected projects. The selected projects included all of the project concepts except the NF Levee Setback A and Avon-Swinomish Bypass. This climate change analysis was performed to evaluate the following:

- Changes in WSE under a future high tide and a future Q2 flood event;
- Changes in WSE due to implementation of selected projects under future flood scenario;
- Changes in the WSE habitat predictions for projects concepts; and
- Potential for changes in the height of low tides to affect drainage.

For this analysis, changes in sea level rise (SLR) were based on predictions for 2080 under the A1B emissions scenario (IPCC 2007). The A1B Scenario reflects a balance of energy sources, not an emphasis on fossil fuels and is a moderate future scenario (Figure 5-2).

Figure 5-2. Projected SLR for Salish Sea (Seattle, WA) region of the Pacific Northwest for the A1B, B1, and A1F1 scenarios (Source: NRC 2012)



SLR projections were developed by Khangaonkar et al and were adjusted for the 2080 timeframe (Khangaonkar et al. 2016). This analysis used an elevation of 12.7 ft NAVD88 to represent the future high spring tide and - 1.4 ft NAVD88 for the future low tide. In addition, this analysis also included a modified hydrograph and a predicted future value for the 2-year return frequency flood event. The modified hydrograph was based on an analysis performed by Lee et al. (2016). Lee et al. used five global climate models to predict a range of future 2-yr floods at the Mount Vernon Gauge. For this analysis, the forecasted Q2 discharge rate from the five models was averaged and a flow rate of 103,237 cfs at the Mount Vernon Gauge was used for the future 2-year event.

Predicted changes to flood protection infrastructure and the management of floodwaters upstream of the study area were outside of the scope of this project. This analysis is only one prediction for future changes. Therefore, additional work during feasibility or in a more comprehensive and inclusive form is recommended to better understand a broader range of potential climate change effects.

Results from the climate change analysis were not used for additional ranking or weighting of project concepts. They are intended to provide additional information for partners to support discussions related to infrastructure, design, improvements, feasibility, and long-term collaboration.

Methods to evaluate effects of sea level rise and future Q2

Change in WSE and inundated areas between current baseline and future baseline were evaluated under two scenarios: one to isolate SLR and one to evaluate higher future flows. SLR was isolated using a high spring tide, the current low flow rate of 12,000 cfs was kept constant and the high spring tide elevation was modified to the 12.7 ft NAVD88 (Khangaonkar et al. 2016) (Table 5-5).

Table 5-5. Modeling Scenarios to evaluate changes in WSE under a future high tide scenario

Run	Discharge (cfs)	Tide Elevation (ft)
Existing Baseline	Low Flow Q = 12,000	High Spring Tide = 10.8
Future Baseline SLR	Low Flow Q = 12,000	High Spring Tide = 12.7

A second modeling scenario evaluated the potential effect WSE and areas inundated under Q2 by increasing both the magnitude of the flood event and the height of the low tide to reflect climate predictions for increases sea levels and changes to the hydrograph (Table 5-6). Both WSE and areas inundated under each modeling scenario were compared to baseline to determine potential changes under future conditions.

Table 5-6. Modeling Scenarios to evaluate changes in WSE under a future 2-yr flood

Run	Discharge (cfs)	Tide Elevation (ft)
Existing Baseline Q2	Q2 = 62,000	Low Tide = -3.3
Future Baseline Q2	Q2 = 103,237	Low Tide = -1.4

Methods to evaluate effects under a future flood scenario

The PNNL model was also used to evaluate changes in WSE under a future flood condition. This analysis used the PNNL model to calculate the reduction in WSE under existing and future conditions with and without the selected projects implemented. The future Q2 was modeled with a future high tide instead of a larger flow rate because of the uncertainty predicting future flood stages and future flood protection efforts (Table 5-7).

Table 5-7. Modeling Scenarios to evaluate future flood scenarios

Run	Discharge (cfs)	Tide (ft)
Existing Baseline Flood	Qflood = 93,200	High Tide = 10.4
Existing w/ projects Flood		
Future Flood Baseline	Future Q2 = 103,237	SLR High Tide = 12.7
Future Flood w/projects		

Methods to evaluate effects to habitat under future conditions

Potential effects to habitat under future conditions was evaluated using magnitude of the increase in WSE. The PNNL hydrodynamic model was used to generate cumulative frequency plots of WSE between March 1 and May 22 for the following scenarios:

- R1-7: Existing baseline with individual projects
- R8: Existing baseline with selected projects
- R9: Future conditions with no projects
- R10: Future conditions with selected projects

The cumulative frequency plots showed that for the tidally dominated project concepts, the increase in WSE was approximately 1.9 ft. This value was then used to predict changes in habitat types by adjusting the habitat zone categories by 1.9 ft to see if projects have the potential for shifts in the habitat zones predicted to occur. Sediment accumulation rates, vegetation colonization rates and effects of storm surges are all unknown, but would also will influence what habitat zones are ultimately formed and can be sustained within a site. An analysis of all of these factors was beyond the scope of work for this project and should be considered during feasibility analyses. The magnitude of change in WSE for riverine influenced project concepts was more complex and was not considered for this evaluation.

Methods to evaluate effects to drainage

The study area included approximately 65,000 acres of farmland. The farmland is drained through a system of open ditches, tidegates, and pumps. This analysis used cumulative frequency plots to evaluate potential changes in the magnitude and duration of low tides under future conditions. Changes in the duration and magnitude of low tides were evaluated in terms of potential impacts to the efficiency of gravity drainage.

Methods to evaluate future changes in salinity

The PNNL model was used to evaluate potential changes to salinity levels in the water column within the study area to get a general understanding of potential system wide changes to the extent and magnitude of salinity under climate change scenarios. PNNL model outputs are available to inform future outreach efforts but were not analyzed as part of this report. The salinity analysis was limited to changes, but the scope of work did not include an evaluation of potential impacts associated with different magnitudes of change.

6.0 Alternatives Analysis Results

As described in the methods section, several different technical analyses were performed to quantify objectives and indicators for each project concept. For each project concept, scores for indictors under each interest group were then combined and weighted. This resulted in a total benefit and total impact score for each project concept for each interest group. These were then combined for a total multi-benefit score for each project concept.

Farm Objectives and Indicators Scores

Farm Objective 1: Minimize impacts to farmland (Impact Score)

The project concept that had the greatest impact to farmland, as measured by Farm indicator 1, was the Avon-Swinomish Bypass, followed by Telegraph Slough Full, which would convert 1,171 acres and 940 acres of land to estuary, respectively (Table 6-1).

Table 6-1. Farm Objective 1 results: impacts to farmland

Project Concept Area Name	Land zoned AG-NRL + OSRSI (acres)	Normalized Score	
Avon-Swinomish Bypass	1,170.9	1.00	IIIIIIIIII
Cottonwood Island	0.0	0.00	
Deepwater Slough Phase 2	268.4	0.23	II
East Cottonwood	0.0	0.00	
Fir Island Cross Island Connector	149.9	0.13	I
Fir Island Farm	139.2	0.12	I
Hall Slough	133.8	0.11	I
McGlinn Causeway	0.0	0.00	
Milltown Island	0.0	0.00	
NF Left Bank Levee Setback A	553.4	0.47	IIIII
NF Left Bank Levee Setback B	371.4	0.32	III
NF Left Bank Levee Setback C	275.7	0.24	II
NF Right Bank Levee Setback	85.9	0.07	I
Pleasant Ridge South	29.4	0.03	
Rawlins Road	191.8	0.16	II
Rawlins Road Distributary Channel	0.0	0.00	
South Fork Levee Setback 2, 3, 4	0.0	0.00	
Sullivan Hacienda	205.2	0.18	II
Telegraph Slough 1	161.4	0.14	I
Telegraph Slough 1 & 2	398.9	0.34	III
Telegraph Slough Full	940.0	0.80	IIIIIIII
Thein Farm	64.9	0.06	I
TNC South Fork	0.0	0.00	
McGlinn & TS 1	161.4	0.1	I
McGlinn & TS 1&2	398.9	0.3	III
McGlinn & TS Full	940.0	0.8	IIIIIIII

Projects that are located waterward of existing dikes and levees had the least impact to farmland and included Cottonwood Island, East Cottonwood, McGlinn Causeway, Milltown Island, Rawlins Road Distributary Channel, South levee Setback 2,3,4, and TNC South Fork.

Farm Objective 2: Maximize smolts per acre of converted agricultural land (Benefit Score)

Project concepts that had either high numbers of smolts per acre of farmland converted (Fir Island Cross Island Connector) or that took no farmland out of production (Cottonwood Island, East Cottonwood, McGlinn Causeway, Milltown Island, Rawlins Road Distributary Channel, South levee Setback 2,3,4, and TNC South Fork) received the highest scores for this objective. The lowest scoring projects were the Telegraph suite of project concepts without McGlinn Causeway (Table 6-2). The NF Right Bank Levee Setback and Pleasant Ridge South also scored low for this objective because of their low estimate for smolt production (Table 6-2).

Table 6-2. Farm Objective 2 Results: Smolts/Acre

Project Concept Area Name	smolts/acre	Normalized score	
Avon-Swinomish Bypass	141.5	0.08	IIIIIIII
Cottonwood Island	0.0	1.00	IIIIIIIIII
Deepwater Slough Phase 2	597.7	0.34	III
East Cottonwood	0.0	1.00	IIIIIIIIII
Fir Island CIC	1,763.7	1.00	IIIIIIIIII
Fir Island Farm	465.3	0.26	III
Hall Slough	171.2	0.10	I
McGlinn Causeway	0.0	1.00	IIIIIIIIII
Milltown Island	0.0	1.00	IIIIIIIIII
NF Left Bank Levee Setback A	154.4	0.09	I
NF Left Bank Levee Setback B	176.8	0.10	I
NF Left Bank Levee Setback C	194.8	0.11	I
NF Right Bank Levee Setback	94.3	0.05	I
Pleasant Ridge South	82.8	0.05	I
Rawlins Road	260.5	0.15	II
Rawlins Road Distributary Channel	0.0	1.00	IIIIIIIIII
SF Levee Setback 2, 3, 4	0.0	1.00	IIIIIIIIII
Sullivan Hacienda	1,072.9	0.61	IIIIII
Telegraph Slough 1	75.4	0.04	IIIIIIIIII
Telegraph Slough 1&2	124.0	0.07	I
Telegraph Slough Full	98.1	0.06	I
Thein Farm	383.1	0.22	II
TNC South Fork	0.0	1.00	IIIIIIIIII
McGlinn & TS 1	347.6	0.2	II
McGlinn & TS 1&2	307.8	0.2	II
McGlinn & TS Full	219.0	0.1	I

Farm Objective 3: Restoration acres that support TFI credits (Benefit Score)

The project concept that scored highest for this objective was Telegraph Slough Full in combination with McGlinn Causeway (Table 6-3). This project provides a large area of restored estuary and the McGlinn Causeway improves connectivity to the restored habitat resulting in the greatest number of TFI credits generated. The lowest scoring project concepts were those that had small wetted areas at high tide or Q2, or were on the river side of existing dike/levee infrastructure and therefore would not generate TFI credits.

Table 6-3. Farm Objective 3 Results: Restoration Concepts that Support TFI

Project	Area inundated during Q2 or 10.8ft tide (acres)	TFI Credit Factor	TFI credits	Normalized Score	
Avon-Swinomish Bypass	1,204.4	50%[1]	602.2	1.00	IIIIIIIIII
Cottonwood Island	7.4	0%	0.0	0.00	
Deepwater Slough Phase 2	268.3	100%	268.3	0.45	IIII
East Cottonwood	0.5	0%	0.0	0.00	
Fir Island CIC	138.0	100%	138.0	0.23	II
Fir Island Farm	139.2	100%	139.2	0.23	II
Hall Slough	132.7	100%	132.7	0.22	II
McGlinn Causeway	1.7	0%	0.0	0.00	
Milltown Island	6.0	0%	0.0	0.00	
NF Left Bank Levee Setback A	546.2	100%	546.2	0.91	IIIIIIIII
NF Left Bank Levee Setback B	370.2	100%	370.2	0.61	IIIIII
NF Left Bank Levee Setback C	275.5	100%	275.5	0.46	IIIII
NF Right Bank Levee Setback	82.2	100%	82.2	0.14	I
Pleasant Ridge South	27.4	100%	27.4	0.05	I
Rawlins Road	191.7	100%	191.7	0.32	III
Rawlins Road Distributary Channel	0.8	0%	0.0	0.00	
SF Levee Setback 2, 3, 4	50.1	0%	0.0	0.00	
Sullivan Hacienda	205.0	100%	205.0	0.34	III
Telegraph Slough 1	164.2	50%	82.1	0.14	I
Telegraph Slough 1&2	446.2	50%	223.1	0.37	IIII
Telegraph Slough Full	1,047.0	50%	523.5	0.87	IIIIIIIIII
Thein Farm	64.3	100%	64.3	0.11	I
TNC South Fork	0.0	0%	0	0.00	
McGlinn & TS 1	164.2	100%	164.2	0.16	II
McGlinn & TS 1&2	446.2	100%	446.2	0.43	IIII
McGlinn & TS Full	1,047.0	100%	1,047	1.00	IIIIIIIIII

N1. The TFI credits were reduced by 50 percent because at the conceptual design stage it is unclear how the proposed control structure would limit fish access to the project area.

Farm Objective 4: Restore public land first (Benefit Score)

Project concepts located primarily on public land scored the highest for this indicator. These project concepts include Deepwater Slough Phase 2, Milltown Island, and Fir Island Farm. The lowest scoring project concepts were primarily located on private lands and had large footprints (Table 6-4).

Table 6-4. Farm Objective 4 Results: Restore Public lands

Project Concept Area Name	Private (acres)	Public + District (acres)	Normalized score	
Avon-Swinomish Bypass	1,110.4	95.6	0.18	II
Cottonwood Island	4.9	4.5	0.51	IIIII
Deepwater Slough Phase 2	0.0	262.4	1.00	IIIIIIIIII
East Cottonwood	0.1	1.8	0.50	IIIII
Fir Island Cross Island Connector	147.8	1.8	0.44	IIII
Fir Island Farm	2.3	135.8	0.76	IIIIIIII
Hall Slough	133.8	0.0	0.44	IIII
McGlinn Causeway	0.0	2.9	0.51	IIIII
Milltown Island	0.0	216.2	0.91	IIIIIIIII
NF Left Bank Levee Setback A	525.2	23.0	0.31	III
NF Left Bank Levee Setback B	351.8	19.3	0.38	IIII
NF Left Bank Levee Setback C	260.1	15.3	0.41	IIII
NF Right Bank Levee Setback	78.0	8.0	0.48	IIIII
Pleasant Ridge South	29.8	0.0	0.49	IIIII
Rawlins Road	187.6	4.3	0.42	IIII
Rawlins Road Distributary Channel	0.2	7.1	0.51	IIIII
South Fork Levee Setback 2, 3, 4	28.6	26.0	0.54	IIIII
Sullivan Hacienda	203.5	0.0	0.41	IIII
Telegraph Slough 1	158.6	1.8	0.43	IIII
Telegraph Slough 1 & 2	398.1	9.9	0.34	III
Telegraph Slough Full	920.3	34.9	0.15	II
Thein Farm	77.7	0.1	0.47	IIIII
TNC South Fork	0.0	0.1	0.50	IIIII
McGlinn & TS 1	158.6	4.7	0.4	III
McGlinn & TS 1&2	398.1	12.6	0.3	III
McGlinn & TS Full	920.3	37.8	0.2	II

Farm Objective 5: Minimize conversion of protected farmland parcels (Impact Score)

Project concepts that scored highest for this objective were those that overlapped the largest areas of protected farmland and included NF Left Bank Levee Setback A and Hall Slough (Table 6-5). Many project concepts do not overlap protected farmland and received a score of zero.

Table 6-5. Farm Objective 5 Results: conversation of protected farmland

Project Concept Area Name	Farmland easements (acres)	Normalized Score	
Avon-Swinomish Bypass	7.4	0.04	
Cottonwood Island	0.0	0.00	
Deepwater Slough Phase 2	0.0	0.00	
East Cottonwood	0.0	0.00	
Fir Island Cross Island Connector	43.9	0.23	II
Fir Island Farm	0.0	0.00	
Hall Slough	132.8	0.71	IIIIIII
McGlinn Causeway	0.0	0.00	
Milltown Island	0.0	0.00	
NF Left Bank Levee Setback A	187.0	1.00	IIIIIIIIII
NF Left Bank Levee Setback B	29.6	0.16	II
NF Left Bank Levee Setback C	0.0	0.00	
NF Right Bank Levee Setback	10.0	0.05	I
Pleasant Ridge South	0.0	0.00	
Rawlins Road	0.0	0.00	
Rawlins Road Distributary Channel	0.0	0.00	
South Fork Levee Setback 2, 3, 4	2.4	0.00	
Sullivan Hacienda	0.0	0.01	
Telegraph Slough 1	0.0	0.00	
Telegraph Slough 1 & 2	1.8	0.00	
Telegraph Slough Full	35.8	0.19	II
Thein Farm	0.0	0.00	
TNC South Fork	0.0	0.00	
McGlinn & TS 1	0.0	0.00	
McGlinn & TS 1&2	1.8	0.01	
McGlinn & TS Full	35.8	0.19	II

Total farm interest score

The 100 points for the farming interest group was evenly divided between each of the 5 objectives, resulting a maximum of 20 points for each objective. This resulted in a maximum potential benefit score of 60 points and impact score of 40 points. Table 6-6 summarizes the total benefit and impact farm scores for each project concept.

Table 6-6. Total farm benefit and impact scores

Project Concept	Farm Benefit Score				Farm Impact Score		
	Farm #2:	Farm #3:	Farm #4:	Total	Farm #1:	Farm #5:	Total
	Max. smolts per acre	Support TFI	prioritize public land		Min. farmland loss	Avoid preserved farmland	
Total possible points	**20**	**20**	**20**	**60**	**20**	**20**	**40**
Avon-Swinomish Bypass	1.6	20.0	3.6	**25.2**	20.0	0.8	**20.8**
Cottonwood Island	20.0	0.0	10.1	**30.1**	0.0	0.0	**0.0**
Deepwater Phase 2	6.8	8.9	20.0	**35.7**	4.6	0.0	**4.6**
East Cottonwood	20.0	0.0	10.1	**30.1**	0.0	0.0	**0.0**
Fir Island CIC	20.0	4.6	8.7	**33.3**	2.6	4.7	**7.3**
Fir Island Farm	5.3	4.6	15.2	**25.1**	2.4	0.0	**2.4**
Hall Slough	1.9	4.4	8.8	**15.1**	2.3	14.2	**16.5**
McGlinn Causeway	20.0	0.0	10.1	**30.1**	0.0	0.0	**0.0**
Milltown Island	20.0	0.0	18.2	**38.2**	0.0	0.0	**0.0**
NF LB Levee Setback A	1.8	18.1	6.1	**26**	9.5	20.0	**29.5**
NF LB Levee Setback B	2.0	12.3	7.6	**21.9**	6.3	3.2	**9.5**
NF LB Levee Setback C	2.2	9.1	8.2	**19.6**	4.7	0.0	**4.7**
NF RB Levee Setback	1.1	2.7	9.6	**13.4**	1.5	1.1	**2.5**
Pleasant Ridge South	0.9	0.9	9.7	**11.6**	0.5	0.0	**0.5**
Rawlins Road	3.0	6.4	8.5	**17.8**	3.3	0.0	**3.3**
Rawlins Rd Dist. Channel	20.0	0.0	10.3	**30.3**	0.0	0.0	**0.0**
SF Levee Setback 2, 3, 4	20.0	0.0	10.7	**30.7**	0.0	0.3	**0.3**
Sullivan Hacienda	12.2	6.8	8.2	**27.1**	3.5	0.0	**3.5**
Telegraph Slough 1	0.9	2.7	8.6	**12.2**	2.8	0.0	**2.8**
Telegraph Slough 1 & 2	1.4	7.4	6.8	**15.6**	6.8	0.2	**7.0**
Telegraph Slough Full	1.1	17.4	3.0	**21.5**	16.1	3.8	**19.9**
Thein Farm	4.3	2.1	9.3	**15.8**	1.1	0.0	**1.1**
TNC South Fork	20.0	0.0	10.0	**30.0**	0.0	0.0	**0.0**
McGlinn & TS 1	3.9	3.1	8.7	**15.8**	2.8	0.0	**2.8**
McGlinn & TS 1&2	3.5	8.5	6.9	**18.9**	6.8	0.2	**7.0**
McGlinn & TS Full	2.5	20.0	3.2	**25.6**	16.1	3.8	**19.9**

No project concept received the maximum potential impact or benefits points. NF LB Levee Setback A had the highest impact score of 29.5 points with Avon-Swinomish Bypass and Telegraph Slough Full (by itself and in combination with McGlinn Island Causeway) being the next closest projects with ~20 points each. Hall Slough had 16.5 impact points and all remaining project had less than 10 points.

Milltown Island was the highest ranking benefit project for the farm interest followed by Deepwater Phase 2 and Fir Island Farm Cross Island Connector (Table 6-6). All project concepts that improve habitat waterward of the dike had benefit scores ~30 points with zero impact points.

Fish Objectives and Indicators Scores

Fish Objective 1: Increase the area subject to natural tidal and riverine processes (Benefit Score)

The project concepts had a wide range of increased area subject to tidal and riverine processes. The three backwater channel projects and Milltown Island had the smallest increases in habitat because these project concepts are areas already subject to some level of tidal and riverine inundation (Table 6-7). The largest increases in area came from sites with the largest footprints, Avon-Swinomish Bypass and Telegraph Slough Full.

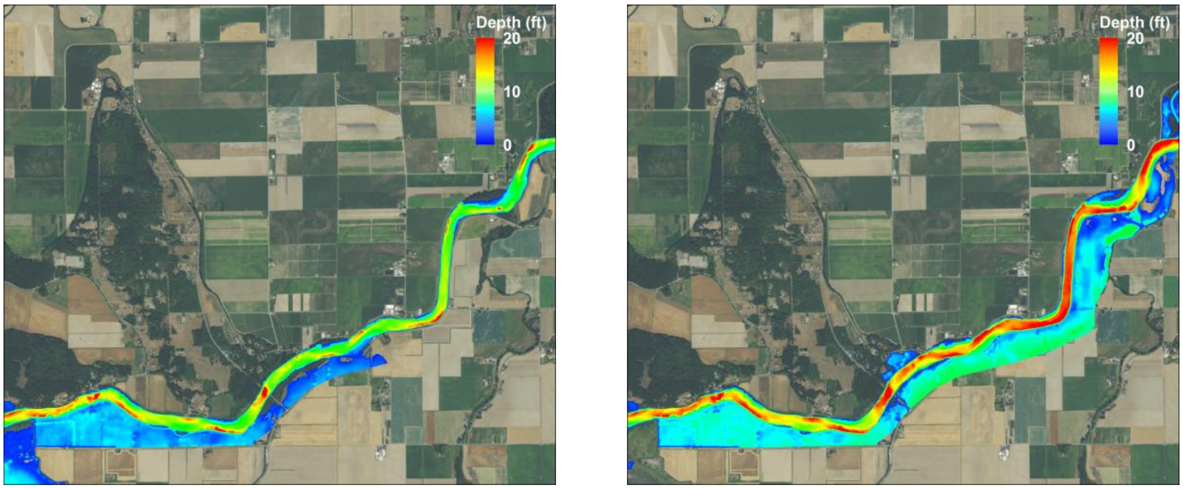
Table 6-7. Fish Objective 1 Results: Increase in area subject to riverine and tidal processes

Project Concept	Increased Wetted Area (acres)	Normalized Score	
Avon-Swinomish Bypass	1,204.4	1.00	IIIIIIIIII
Cottonwood Island[N1]	7.4	0.01	
Deepwater Slough Phase 2	268.3	0.22	II
East Cottonwood[N1]	0.5	0.00	
Fir Island CIC	138.0	0.11	I
Fir Island Farm	139.2	0.12	I
Hall Slough	132.7	0.11	I
McGlinn Causeway	1.7	0.00	
Milltown Island	6.0	0.00	
NF Left Bank Levee Setback A	546.2	0.45	IIIII
NF Left Bank Levee Setback B	356.7	0.30	III
NF Left Bank Levee Setback C	275.5	0.23	II
NF Right Bank Levee Setback	82.2	0.07	I
Pleasant Ridge South	27.4	0.02	
Rawlins Road Distributary Channel	0.8	0.00	
Rawlins Road	191.7	0.16	II
SF Levee Setback 2, 3, 4	50.1	0.04	
Sullivan Hacienda	205.0	0.17	II
Telegraph Slough 1	164.2	0.14	I
Telegraph Slough 1&2	446.2	0.37	IIII
Telegraph Slough Full	1,047.0	0.87	IIIIIIIII
Thein Farm	64.3	0.05	I
TNC South Fork[N1]	0.0	0.00	
McGlinn & TS 1	165.9	0.1	I
McGlinn & TS 1&2	447.9	0.4	IIII
McGlinn & TS Full	1,048.7	0.9	IIIIIIIII

N1. The area inundated was calculated using GIS analysis of georeferenced maps produced by PNNL.

In general, project concepts subject to both tidal and riverine processes had similar inundation areas under high tide and Q2. However, the North Fork Right Bank Setback and North Fork Levee Setback A were exceptions because they were more influence by riverine processes. Figure 6-1 shows the difference between in wetted area under each scenario.

Figure 6-1. North Fork Right Bank Levee Setback A inundation comparison

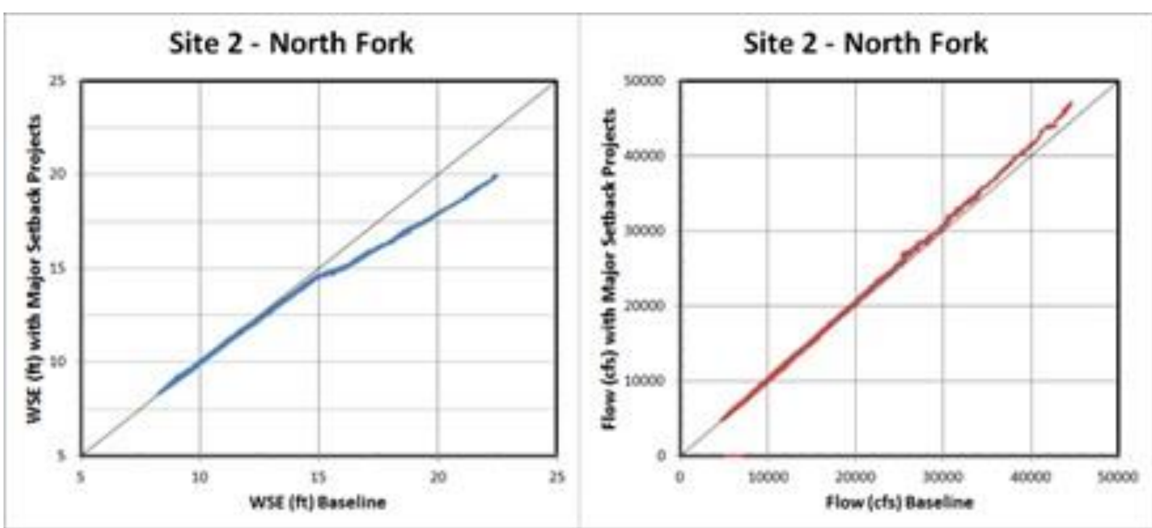


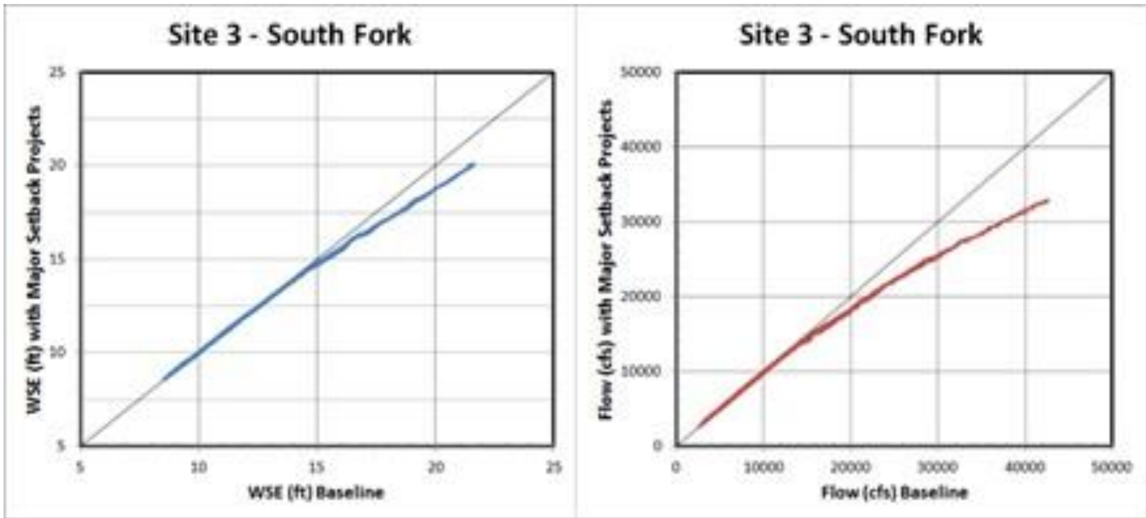
Left: Area inundated during a high tide; Right: Area inundated under Q2

Fish Objective 2: Minimize impacts to existing habitat (Impact Score)

Several project concepts resulted in a change in the balance of flow between the North and South Forks and reduced WSE. It is important to note that these changes generally occurred at discharge rates greater than 20,000 cfs (Figure 6-2, Appendix X). No differences in wetted area under the high tide/low flow scenario were found.

Figure 6-2. Changes in the balance of flow and WSE for the NF Levee Setback A project





Seven projects had a net decrease in offsite wetted areas during the Q2/low tide flow scenario (Table 6-8). There were no projects with a net increase in habitat outside of the project footprint. Thein Farm and NF Right Bank Levee Setback were identified as the sources of offsite losses because they opened up the North Fork channel causing a slight reduction in WSE and flow in the South Fork and mainstem during Q2. The off-site habitat losses were divided evenly between the two projects.

Table 6-8. Fish Objective 2 Results: impacts to existing habitat

Project Concept	Net reduction in wetted area (acres)	Normalized Score	
Avon-Swinomish Bypass	336.4	1.00	IIIIIIIIII
Fir Island CIC	97.6	0.29	III
NF Left Bank Levee Setback A	132.5	0.39	IIII
NF Left Bank Levee Setback B	68.3	0.20	II
NF Left Bank Levee Setback C	40.8	0.12	I
NF Right Bank Levee Setback	23.3	0.07	I
Thein Farm	23.3	0.07	I

The largest off-site reductions in wetted area during a Q2 came from Avon-Swinomish Bypass with over twice the area reduced than any other project. Off-site losses in habitat were located within the existing levees and occurred primarily around the areas just downstream of Edgewater Park, Cottonwood Island and East Cottonwood, North Fork Bridge, the original South Fork Levee Setback and where the South Fork splits. All of these losses were predicted for a Q2/low tide scenario and therefore may not occur during a higher river flows or higher tides.

Fish Objective 3: Increase the area of channels suitable for Chinook rearing (Benefit Score)

Fish Object 3 was calculated using two indicators. Indicator 3a is a steady state prediction of tidal channel area based on Hood 2015. Indicator 3b is an estimate of time each project concept would have water depths suitable for juvenile chinook smolts.

Indicator 3a: Steady-state predication of channel area

Total increase in channel habitat from each project concept did not always correlate with the size of the project concept due to differences in the location of the project on the landscape and tidal range or storm wave forces experienced on-site, (Table 6-9, (Hood, 2015). Telegraph Slough Full, which was the second largest project, had the largest channel area increase of 80.2 acres. In addition, some restoration concepts were also credited with off-site increases in tidal channel area in adjacent marsh habitat due to predicted increases in tidal prism resulting from a project (Figure 6-3). These include Sullivans Hacienda (205-acre site; 34.7 acres of channels) and Deepwater Phase 2 (268.3-acre site; 22.5 acres of channels). Others had small channel area predictions relative to the project size because of location further up the river where there is reduced tidal prism, such as North Fork Dike Setback A (553 acre-site) and C (275 acre-site) with only 6 and 4.5 acres of predicted channel area, respectively.

Table 6-9. Fish Indicator 3a Results: increase in channel area

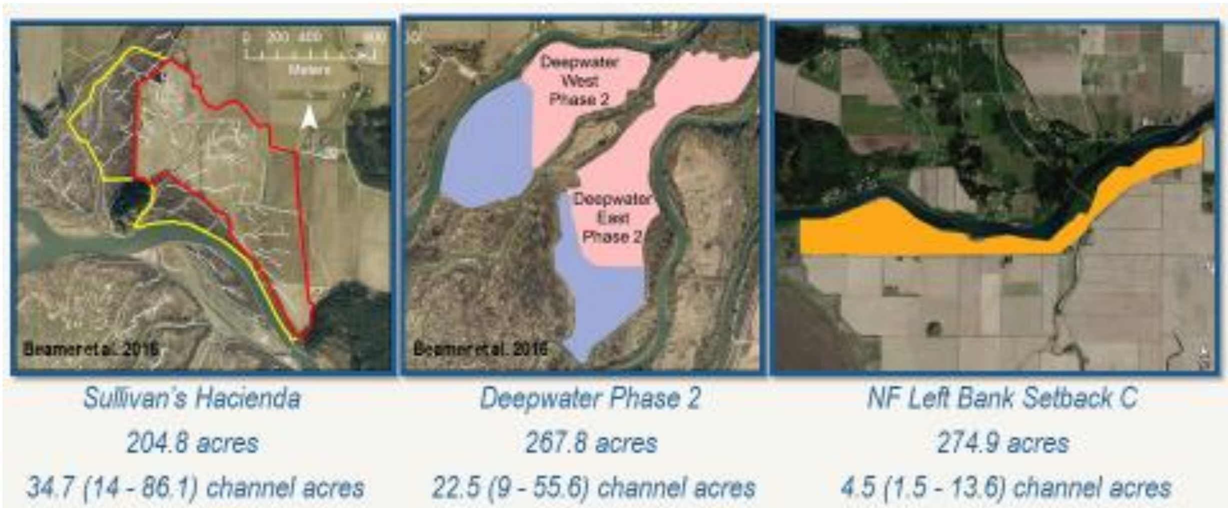
Project	Project Area (acres)	Estimated Channel Area (acres)	Normalized Score	
Avon-Swinomish Bypass	1,292.6	41.3	0.51	IIIII
Cottonwood Island[N1]	15.4	9.4	0.12	I
Deepwater Slough Phase 2	268.3	22.5	0.28	III
East Cottonwood[N1]	1.9	7.8	0.10	I
Fir Island CIC[N2]	150.0	0.0	0.00	
Fir Island Farm	139.7	17.4	0.22	II
Hall Slough	133.7	6.7	0.08	I
McGlinn Causeway[N2]	6.9	0.0	0.00	
Milltown Island[N1]	221.9	2.6	0.03	
NF Left Bank Levee Setback A	553.1	6.0	0.08	I
NF Left Bank Levee Setback B	370.0	5.1	0.06	I
NF Left Bank Levee Setback C	275.5	4.5	0.06	I
NF Right Bank Levee Setback	86.0	0.5	0.01	
Pleasant Ridge South	30.1	0.2	0.00	
Rawlins Road	8.4	9.4	0.12	I
Rawlins Road Distributary	191.7	1.0	0.01	
SF Levee Setback 2, 3, 4	56.5	0.4	0.01	
Sullivan Hacienda	205.0	34.7	0.43	IIII
Telegraph Slough 1	185.0	9.2	0.12	I
Telegraph Slough 1&2	494.8	41.3	0.51	IIIII
Telegraph Slough Full	1,048.5	80.2	1.00	IIIIIIIIII
Thein Farm[N3]	78.3	2.6	0.03	
TNC South Fork	1.1	1.0	0.01	
McGlinn & TS 1	191.9	9.2	0.12	I
McGlinn & TS 1&2	501.7	41.3	0.51	IIIII
McGlinn & TS Full	1,055.4	80.2	1.00	IIIIIIIIII

N1 had their channel areas pulled from design report and feasibility studies

N2 are distributary concepts with no habitat restoration components and were assigned a score of 0

N3 denotes concepts for which channel area estimates were pulled from SCRP

Figure 6-3. Channel area estimated from three different sites located across the Skagit Bayfront



Indicator 3b: Total number of acre-hours of suitable habitat

Both the size of the project concept and the duration of time areas were inundated were used to calculate this indicator (Table 6-10). The largest scoring project Telegraph Slough Full as a stand-alone and in combination with McGlinn have the second largest footprint and have relatively low elevation ranges across the site, resulting in significantly higher acre*hours levels. The acre*hours for these two projects are twice that for the next highest project. The backwater project concepts had the lowest scores.

Table 6-10. Fish Indicator 3b results: Acre*hours of suitable habitat

Project	Acre*hours available	Normalized Score	
Avon-Swinomish Bypass	449,027	0.40	IIII
Cottonwood Island[N1]	29,222	0.03	
Deepwater Slough Phase 2	280,722	0.25	III
East Cottonwood[N2]	1,847	0.00	
Fir Island CIC[N3]	0	0.00	
Fir Island Farm[N5]		0.00	
Hall Slough	70,194	0.06	I
McGlinn Causeway[N3]	0	0.00	
Milltown Island[N4]	43,609	0.04	
NF Left Bank Levee Setback A	424,059	0.38	IIII
NF Left Bank Levee Setback B	370,732	0.33	III
NF Left Bank Levee Setback C	302,832	0.27	III
NF Right Bank Levee Setback	36,692	0.03	
Pleasant Ridge South	7,547	0.01	
Rawlins Road	142,035	0.13	I
Rawlins Road Distributary	0	0.00	
SF Levee Setback 2, 3, 4	11,577	0.01	
Sullivan Hacienda	187,234	0.17	II
Telegraph Slough 1	170,188	0.15	II
Telegraph Slough 1&2	449,027	0.40	IIII
Telegraph Slough Full	1,122,487	1.00	IIIIIIIIII
Thein Farm	82,753	0.07	I
TNC South Fork	2,217	0.00	
McGlinn & TS 1	170,188	0.15	II
McGlinn & TS 1&2	449,027	0.40	IIII
McGlinn & TS Full	1,122,487	1.00	IIIIIIIIII

N1. Channel area is from the 2011 Design Report
N2. Channel estimate is from design analysis by WDFW and includes wetland ponds. A specific breakdown of the ponded area elevation by 1-ft bins was not provided; therefore, the inundation time only includes channel area and not the ponded area
N3. Distributary projects with no habitat creation elements included are given a score of 0
N4. From PSNERP May 2012 Strategic Restoration Conceptual Report
N5. Fir Island Farm was under construction at the time that this analysis was conducted with a high level of elevation modification occurring. Therefore, it was not included in this analysis.

Fish Objective 3: Total Score

The total score for Fish Objective 3 is the sum of the equally weighted scores from indicators 3a and 3b divided by 2. Telegraph Slough Full with lower elevations (and therefore greater acre*hours of suitable habitat) and largest predicted channel area was the highest scoring project (Table 6-11). Project concepts that would excavate channels, including Fir Island CIC, McGlinn Causeway, Rawlins Road Distributary and TNC South Fork, had the lowest scores for this objective.

Table 6-11. Fish Objective 3 results: increase in area of channels suitable for chinook rearing

Project	Indicator 3a	Indicator 3b	Total Score
Avon-Swinomish Bypass	0.51	0.40	0.46
Cottonwood Island[N1]	0.12	0.03	0.07
Deepwater Slough Phase 2	0.28	0.25	0.27
East Cottonwood[N2]	0.10	0.00	0.05
Fir Island CIC[N3]	0.00	0.00	0.00
Fir Island Farm	0.22	0.00	0.11
Hall Slough	0.08	0.06	0.07
McGlinn Causeway[N3]	0.00	0.00	0.00
Milltown Island[N4]	0.03	0.04	0.04
NF Left Bank Levee Setback A	0.08	0.38	0.23
NF Left Bank Levee Setback B	0.06	0.33	0.20
NF Left Bank Levee Setback C	0.06	0.27	0.16
NF Right Bank Levee Setback	0.01	0.03	0.02
Pleasant Ridge South	0.00	0.01	0.00
Rawlins Road	0.12	0.13	0.12
Rawlins Road Distributary	0.01	0.00	0.01
SF Levee Setback 2, 3, 4	0.01	0.01	0.01
Sullivan Hacienda	0.43	0.17	0.30
Telegraph Slough 1	0.12	0.15	0.13
Telegraph Slough 1&2	0.51	0.40	0.46
Telegraph Slough Full	1.00	1.00	1.00
Thein Farm	0.03	0.07	0.05
TNC South Fork	0.01	0.00	0.01
McGlinn & TS 1	0.12	0.15	0.13
McGlinn & TS 1&2	0.51	0.40	0.46
McGlinn & TS Full	1.00	1.00	1.00

N1. Channel area is from the 2011 Design Report
N2. Channel estimate is from design analysis by WDFW and includes wetland ponds. A specific breakdown of the ponded area elevation by 1-ft bins was not provided; therefore, the inundation time only includes channel area and not the ponded area
N3. Distributary projects with no habitat creation elements included are given a score of 0
N4. From PSNERP May 2012 Strategic Restoration Conceptual Report

Fish Objective 4: Increase Chinook smolt production (Benefit Score)

The predicted annual carrying capacity of smolts for each project concept ranged from approximately 2,500 smolts/yr for the Pleasant Ridge South project concept to 264,000 smolts/yr from the Fir Island Cross Island Connector project concept (Table 6-12). In addition, for some project concepts smolt predications changed between the 2005 SCRP and the updated 2016 work and some projects have had site-specific estimates developed as part of the feasibility and/or design work as discussed in the methods section.

Table 6-12. Summary of juvenile Chinook Smolt estimates for each project concept

Project	Smolt Prediction[N1]				
	2005 SCRP smolt estimates	2016 updated estimates			Project Specific
		low	mid	high	
Avon-Swinomish Bypass	--	71,057	**182,844**	470,139	--
Cottonwood Island	10,148	8,370	**13,695**	19,020	--
Deepwater Slough Phase 2	95,516	63,967	**160,334**	403,226	--
East Cottonwood	--	--	--	--	**41,509**
Fir Island CIC	**264,486**	--	--	--	--
Fir Island Farm	--	--	--	--	**65,000**
Hall Slough	--	7,714	**22,889**	68,416	--
McGlinn Causeway	**40,898**	--	--	--	--
Milltown Island	57,179	--	--	--	**27,179**
NF Left Bank Levee Setback A	625,032	28,079	**85,239**	259,946	--
NF Left Bank Levee Setback B	--	21,811	**65,468**	199,243	--
NF Left Bank Levee Setback C	--	17,937	**53,476**	161,883	--
NF Right Bank Levee Setback	--	2,650	**8,119**	25,245	--
Pleasant Ridge South	--	933	**2,488**	7,776	--
Rawlins Road	95,000	18,742	**49,936**	133,686	--
Rawlins Road Distributary	--	--	**9,268**		--
SF Levee Setback 2, 3, 4	--	883	**3,027**	8,940	--
Sullivan Hacienda	36,517	88,694	**219,936**	545,304	--
Telegraph Slough 1	25,000	5,560	**13,956**	34,963	--
Telegraph Slough 1&2	56,573	23,848	**61,365**	157,787	--
Telegraph Slough Full	--	40,197	**102,855**	263,000	--
Thein Farm	**30,000**	--	--	--	--
TNC South Fork	--	--	--	--	**5,326**
McGlinn & TS 1[N26]	--	--	**66,716**	--	--
McGlinn & TS 1&2[N26]	--	--	**154,426**	--	--
McGlinn & TS Full[N26]	--	--	**231,183**	--	--

N1. The bold values were the values used to calculate this indicator

N2. The relevant Telegraph Slough chinook estimates were recalculated using the mid-channel estimates provided by SRSC (2016) and by adjusting the connectivity values due to improvements through the McGlinn Causeway as estimated in the SCRP.

For each of the project concept that combines the McGlinn Causeway and Telegraph Slough project concepts, the increase in smolt carrying capacity was over double that of the individual Telegraph Slough project concepts due to increased connectivity between the NF Skagit River and the Swinomish Channel. Table 6-13 summarizes the value for estimated smolts for each project concept and the normalized score for fish objective 4.

Table 6-13. Fish Objective 4 Results: increase Chinook smolt production

Project	Predicted Smolt Estimate	Normalized Score	
Avon-Swinomish Bypass	182,844	0.69	IIIIIII
Cottonwood Island	13,695	0.05	I
Deepwater Slough Phase 2	160,334	0.61	IIIIII
East Cottonwood	41,509	0.16	II
Fir Island CIC	264,486	1.00	IIIIIIIIII
Fir Island Farm	65,000	0.25	III
Hall Slough	22,889	0.09	I
McGlinn Causeway	40,898	0.15	II
Milltown Island	27,179	0.10	I
NF Left Bank Levee Setback A	85,239	0.32	III
NF Left Bank Levee Setback B	65,468	0.25	III
NF Left Bank Levee Setback C	53,476	0.20	II
NF Right Bank Levee Setback	8,119	0.03	
Pleasant Ridge South	2,488	0.01	
Rawlins Road	49,936	0.19	II
Rawlins Road Distributary	9,268	0.04	
SF Levee Setback 2, 3, 4	3,027	0.01	
Sullivan Hacienda	219,936	0.83	IIIIIIII
Telegraph Slough 1	13,956	0.05	I
Telegraph Slough 1&2	61,365	0.23	II
Telegraph Slough Full	102,855	0.39	IIII
Thein Farm	30,000	0.11	I
TNC South Fork	5,326	0.02	
McGlinn & TS 1	66,716	0.25	III
McGlinn & TS 1&2	154,426	0.58	IIIIII
McGlinn & TS Full	231,183	0.87	IIIIIIIII

Fish Objective 5: Increase landscape connectivity (Benefit Score)

Four stand-alone project concepts had some level of increase in connectivity as shown by the change in connectivity value at a point downstream of the site (Table 6-14).

Table 6-14. Fish Objective 5 Results: increased connectivity

Project	Change in Downstream Connectivity Value	Normalized Score	
Avon-Swinomish Bypass	3.11	1.00	IIIIIIIIII
Fir Island CIC	2.10	0.68	IIIIIII
McGlinn Causeway	1.84	0.59	IIIIII
Rawlins Road Distributary	1.13	0.36	IIII
McGlinn & TS 1	1.84	0.59	IIIIII
McGlinn & TS 1&2	1.84	0.59	IIIIII
McGlinn & TS Full	1.84	0.59	IIIIII

The three combination projects had the same change in connectivity value as McGlinn Causeway as that was the only portion of the projects that would result in increased connectivity to existing habitats. All of other project concepts had no effect on downstream connectivity values and were therefore assigned a score of 0.

Fish Objective 6: Diversity of tidal marsh habitat (Benefit Score)

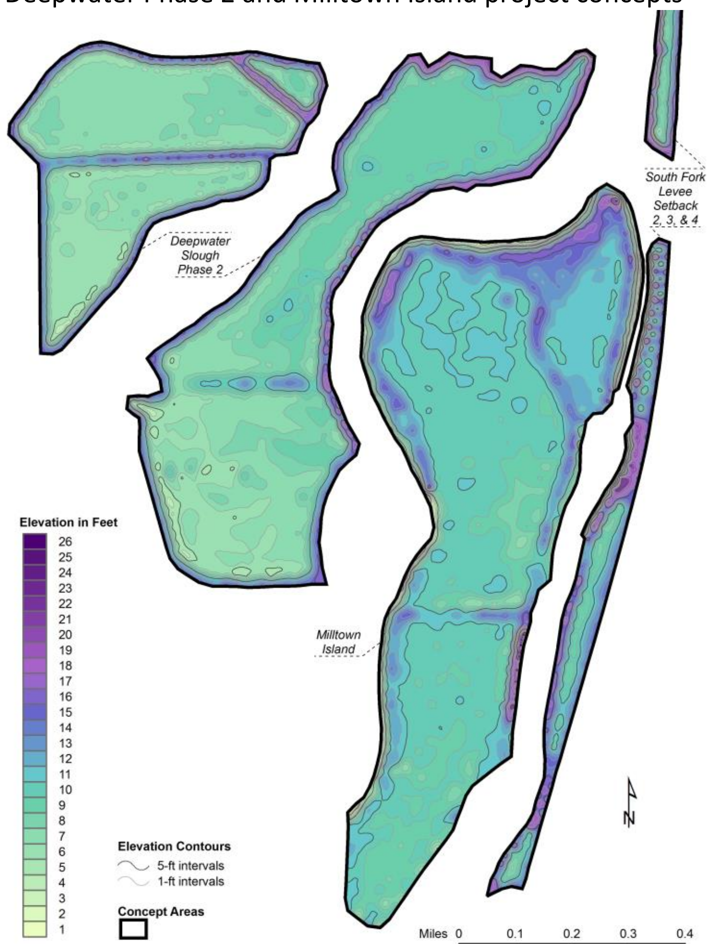
The diversity of habitats for each project concept was represented by a Simpson's Diversity Index score. The highest score for any project concept was 2.79 and the lowest was 1.0 (Table 6-15).

Table 6-15. Fish Objective 6 Results: maintain or improve diversity of tidal marsh habitat

Project	Acres mudflat or submerged	Acres emergent marsh	Acres shrub/ scrub	Acres floodplain/ riparian	Habitat Diversity Score	Normalized Score	
Avon-Swinomish Bypass	72.0	696.3	43.1	480.0	2.31	0.83	IIIIIIII
Cottonwood Island	0.1	0.1	0.1	14.9	1.00	0.36	IIII
Deepwater Slough Phase 2	0.0	149.1	66.6	52.1	2.44	0.88	IIIIIIIII
East Cottonwood	0.0	0.0	0.0	1.9	1.00	0.36	IIII
Fir Island Cross Island Connector	0.0	119.1	24.3	6.1	1.00	0.36	IIII
Fir Island Farm	0.6	133.2	1.8	3.9	1.10	0.39	IIII
Hall Slough	0.0	122.8	3.4	7.4	1.18	0.42	IIII
McGlinn Causeway	0.3	4.3	0.7	1.5	1.00	0.36	IIII
Milltown Island	2.5	15.6	114.2	89.2	2.31	0.83	IIIIIIII
NF Left Bank Levee Setback A	0.0	174.3	125.2	252.6	2.77	1.00	IIIIIIIIII
NF Left Bank Levee Setback B	0.0	169.6	112.3	88.5	2.79	1.00	IIIIIIIIII
NF Left Bank Levee Setback C	0.0	166.3	70.2	38.4	2.22	0.80	IIIIIIII
NF Right Bank Levee Setback	0.1	9.3	14.0	62.3	1.76	0.63	IIIIII
Pleasant Ridge South	0.1	0.8	15.6	13.6	2.11	0.76	IIIIIIII
Rawlins Road	0.0	168.6	10.5	12.5	1.28	0.46	IIIII
Rawlins Road Distributary Channel	0.0	3.6	3.7	1.0	1.00	0.36	IIII
South Fork Levee Setback 2, 3, 4	0.3	6.3	15.0	34.5	2.16	0.78	IIIIIIII
Sullivan Hacienda	6.2	175.2	8.3	15.1	1.35	0.49	IIIII
Telegraph Slough 1	27.8	143.4	3.8	9.8	1.59	0.57	IIIIII
Telegraph Slough 1 & 2	68.0	396.0	14.5	16.0	1.51	0.54	IIIII
Telegraph Slough Full	172.5	794.6	33.9	46.8	1.65	0.59	IIIIII
Thein Farm	1.1	51.2	6.0	19.9	2.00	0.72	IIIIIII
TNC South Fork	0.0	0.0	0.0	1.0	1.00	0.36	IIII
McGlinn & TS 1	28.1	147.7	4.6	11.3	1.61	0.58	IIIIII
McGlinn & TS 1&2	68.3	400.3	15.3	17.5	1.52	0.54	IIIII
McGlinn & TS Full	172.8	798.9	34.6	48.3	1.66	0.59	IIIIII

Project concepts, such as the three North Fork Left Bank Levee Setbacks concepts, that stretched along the river had the highest habitat diversity scores because of the large elevation gradient. Project concepts with greater topographic relief such as. Deepwater 2 and Milltown Island had higher diversity scores (Table 6-15, Figure 6-4).

Figure 6-4. Elevation of Deepwater Phase 2 and Milltown Island project concepts



Deepwater Phase 2 project concept is shown in the two left polygons outlined in black. Milltown Island project concept is shown in the middle polygon outlined in black. 1-ft elevation bands shown as tan lines and 5-ft elevation bands shown as brown lines. Lighter green shades are higher elevations and teal are lower elevations.

Bayfront projects with low elevations and little topographic variation had lower diversity scores. Only the Telegraph Slough project concepts had relatively large components of mudflat habitat predicted on site.

Total fish interest score

The 100 points for the fish interest score were not evenly divided between the 6 objectives. The fish interest group assigned a weight of 25 points to Fish Objective 4. The recovery goal for Chinook salmon in the delta is an additional 1.35M smolts; therefore, the fish interest group decided that weighting Objective 4 higher was appropriate. After several meetings, the fish interest group decided to weight the remaining objectives evenly with 15 points each. As a result, the maximum fish benefit score is 85 points and the maximum impact score is 15 points.

No project concepts achieve the maximum benefit score of 85 points. The highest scoring project concept was the combination project of Telegraph Slough Full and McGlinn Island Causeway with a benefit score of 67.7 points followed by the Avon-Swinomish Bypass with 66.6 points. The Avon-Swinomish Bypass received the maximum impact score.

Table 6-16. Total fish benefit and impact scores

Project Concept Area Name	**Fish Benefit Score**						**Fish Impact Score**	
	Fish #1	Fish #3	Fish #4	Fish #5	Fish #6	**Total**	Fish #2	**Total**
	Restore habitat process	Increase channels	Increase smolt production	Increase connectivity	Increase or maintain habitat		Min. loss of existing habitat	
Total possible points	15	15	25	15	15	**85**	15	**15**
Avon-Swinomish Bypass	15.0	6.9	17.3	15.0	12.4	**66.6**	15.0	**15.0**
Cottonwood Island	0.1	1.1	1.3	0.0	5.4	**7.8**	0.0	**0.0**
Deepwater Phase 2	3.3	4.0	15.2	0.0	13.1	**35.6**	0.0	**0.0**
East Cottonwood	0.0	0.7	3.9	0.0	5.4	**10.1**	0.0	**0.0**
Fir Island CIC	1.7	0.0	25.0	10.1	5.4	**42.2**	4.4	**4.4**
Fir Island Farm	1.7	1.6	6.1	0.0	5.9	**15.4**	0.0	**0.0**
Hall Slough	1.7	1.1	2.2	0.0	6.3	**11.3**	0.0	**0.0**
McGlinn Causeway	0.0	0.0	3.9	8.9	5.4	**18.1**	0.0	**0.0**
Milltown Island	0.1	0.5	2.6	0.0	12.4	**15.6**	0.0	**0.0**
NF LB Levee Setback A	6.8	3.4	8.1	0.0	14.9	**33.2**	5.9	**5.9**
NF LB Levee Setback B	4.7	3.0	6.2	0.0	15.0	**28.8**	3.0	**3.0**
NF LB Levee Setback C	3.5	2.4	5.1	0.0	11.9	**22.9**	1.8	**1.8**
NF RB Levee Setback	1.1	0.3	0.8	0.0	9.5	**11.6**	1.0	**1.0**
Pleasant Ridge South	0.3	0.1	0.2	0.0	11.3	**11.9**	0.0	**0.0**
Rawlins Road	2.4	1.8	4.7	0.0	6.9	**15.8**	0.0	**0.0**
Rawlins Rd Dist. Channel	0.0	0.1	0.9	5.5	5.4	**11.8**	0.0	**0.0**
SF Levee Setback 2, 3, 4	0.6	0.1	0.3	0.0	11.6	**12.6**	0.0	**0.0**
Sullivan Hacienda	2.6	4.5	20.8	0.0	7.3	**35.1**	0.0	**0.0**
Telegraph Slough 1	2.1	2.0	1.3	0.0	8.6	**14.0**	0.0	**0.0**
Telegraph Slough 1 & 2	5.6	6.9	5.8	0.0	8.1	**26.3**	0.0	**0.0**
Telegraph Slough Full	13.1	15.0	9.7	0.0	8.9	**46.7**	0.0	**0.0**
Thein Farm	0.8	0.8	2.8	0.0	10.8	**15.2**	1.0	**1.0**
TNC South Fork	0.0	0.1	0.5	0.0	5.4	**6.0**	0.0	**0.0**
McGlinn & TS 1	2.1	2.0	6.3	8.9	8.7	27.9	0.0	0.0
McGlinn & TS 1&2	5.6	6.9	14.6	8.9	8.2	44.1	0.0	0.0
McGlinn & TS Full	13.1	15.0	21.9	8.9	8.9	67.7	0.0	0.0

Flood Objectives and Indicators Scores

Flood Objective 1: Reduced water surface elevation (Benefit Score)

Levee setback and distributary project concepts all resulted in some level of reduced WSE within the study area (Table 6-17). The Avon-Swinomish Bypass would divert the largest amount of water from the Skagit River and would have the greatest reduction in WSE in the mainstem, north fork and south fork of the Skagit River during a flood, affecting the river for 106,270 feet, and reducing WSE in some places by more than five vertical feet.

Table 6-17. Flood Object 1 Results: Reduced WSE

Project	reduced WSE (linear feet)	Normalized Score	
Avon-Swinomish Bypass	106,270	1.00	IIIIIIIIII
Cottonwood Island	0	0.00	
Deepwater Slough Phase 2	21,585	0.20	II
East Cottonwood	0	0.00	
Fir Island Cross Island Connector	24,010	0.23	II
Fir Island Farm	0	0.00	
Hall Slough	0	0.00	
McGlinn Causeway	0	0.00	
Milltown Island	0	0.00	
NF Left Bank Levee Setback A	50,660	0.48	IIIII
NF Left Bank Levee Setback B	43,568	0.41	IIII
NF Left Bank Levee Setback C	17,310	0.16	II
NF Right Bank Levee Setback	0	0.00	
Pleasant Ridge South	0	0.00	
Rawlins Road	12,200	0.11	I
Rawlins Road Distributary Channel	0	0.00	
SF Levee Setback 2, 3, 4	6,660	0.06	I
Sullivan Hacienda	0	0.00	
Telegraph Slough 1	0	0.00	
Telegraph Slough 1&2	0	0.00	
Telegraph Slough Full	0	0.00	
Thein Farm	0	0.00	
TNC South Fork	0	0.00	
McGlinn & TS 1	0	0.00	
McGlinn & TS 1&2	0	0.00	
McGlinn & TS Full	0	0.00	

Many projects did not reduce WSE because of their relatively small size or because their location relative to the river did not provide increased storage or conveyance capacity.

Flood Objective 2: Reduce risk of levee failure by constructing new engineered levees (Benefit Score)

NF Left Bank Levee Setback A and NF Left Bank Levee Setback B received the highest scores for this indicator (Table 6-18). These project concepts would have the longest sections of replaced river levee and would also address known problem areas over much of their length.

Table 6-18. Flood Objective 2 Results: Reduced Risk of Levee Failure

Project Concept Name	Length Replaced Levee (ft)	Length Replaced Dike (ft)	# Problem Area Addressed	Normalized Score	
Avon-Swinomish Bypass	0	0	--	0.00	
Cottonwood Island	0	0	--	0.00	
Deepwater Slough Phase 2	0	0	--	0.00	
East Cottonwood	0	0	--	0.00	
Fir Island CIC[N1]	0	0	1	0.25	III
Fir Island Farm	0	5,800	1	0.49	IIIII
Hall Slough	0	7,567	--	0.32	III
McGlinn Causeway	0	0	--	0.00	
Milltown Island	0	0	--	0.00	
NF Left Bank Levee Setback A	27,408	0	2	1.00	IIIIIIIIII
NF Left Bank Levee Setback B	15,586	0	2	0.78	IIIIIIII
NF Left Bank Levee Setback C	12,830	0	1	0.48	IIIII
NF Right Bank Levee Setback	6,435	0	1	0.37	IIII
Pleasant Ridge South	2,535	0	--	0.05	I
Rawlins Road	0	10,745	--	0.45	IIIII
Rawlins Road Distributary Channel	0	0	--	0.00	
SF Levee Setback 2, 3, 4	9,346	0	1	0.42	IIII
Sullivan Hacienda	0	11,942	--	0.50	IIIII
Telegraph Slough 1	0	5,036	--	0.21	II
Telegraph Slough 1&2	0	5,036	--	0.21	II
Telegraph Slough Full*	0	5,036	--	0.21	II
Thein Farm	1,000	0	--	0.02	
TNC South Fork	0	0	--	0.00	
McGlinn & TS 1	0	5,036	--	0.21	II
McGliin & TS 1&2	0	5,036	--	0.21	II
McGlinn & TS Full	0	5,036	--	0.21	II

N1. Fir Island Cross Island Connector addresses a problem area by removing levee in a project location; however, it replaces that levee with new levee infrastructure and is accounted for in Flood Objective 3.

Other project concepts that would address problem areas and replace existing river levee or marine dike also scored relatively high and included Fir Island Farm, NF Left Bank Levee Setback C, NF Right Bank Levee Setback, and SF Levee Setback 2, 3, 4. Several projects do not have the potential to address known problems but do replace significant lengths of existing marine dike or river levee and include Sullivan's Hacienda and Rawlins Road. Projects that do not involve replacing a marine dike or river levee and did not address a problem area received a score of 0 for this indicator.

Flood Objective 3: Avoid creation of new dikes and levees where none exist (Impact Score)

The Avon-Swinomish Bypass and the Fir Island Cross-Island Connector were the only project concepts that would create new levees (Table 6-19). Both of these projects add levees where none currently exist, adding management of new infrastructure to the existing flood protection system. All other projects would not introduce new levees or dikes to the system and received a score of 0 for this objective.

Table 6-19. Flood Objective 3 Results: Length of New Levee

Project Concept Name	(LF)	Normalized Score	
Avon-Swinomish Bypass	77,088	1.00	IIIIIIIIII
Fir Island CIC	30,000	0.39	IIII

Flood Objective 4: Improve agricultural flood drainage (Benefit Score)

About half of the project concept footprints overlap with an existing outfall or location of a flood return structure identified by local flood managers that could potentially be upgraded or improved as part of a project (Table 6-20).

Table 6-20. Flood Objective 4 Results: Potential for Flood Return Structures

Project Concept Name	Flood Return Structure (yes/no)	Normalized score	
Avon-Swinomish Bypass	NO	0.0	
Cottonwood Island	NO	0.0	
Deepwater Slough Phase 2	NO	0.0	
East Cottonwood	NO	0.0	
Fir Island CIC	YES	1.0	IIIIIIIIII
Fir Island Farm	YES	1.0	IIIIIIIIII
Hall Slough	YES	1.0	IIIIIIIIII
McGlinn Causeway	NO	0.0	
Milltown Island	NO	0.0	
NF Left Bank Levee Setback A	YES	1.0	IIIIIIIIII
NF Left Bank Levee Setback B	YES	1.0	IIIIIIIIII
NF Left Bank Levee Setback C	YES	1.0	IIIIIIIIII
NF Right Bank Levee Setback	YES	1.0	IIIIIIIIII
Pleasant Ridge South	NO	0.0	
Rawlins Road	YES	1.0	IIIIIIIIII
Rawlins Road Distributary Channel	NO	0.0	
SF Levee Setback 2, 3, 4	NO	0.0	
Sullivan Hacienda	NO	0.0	
Telegraph Slough 1	YES	1.0	IIIIIIIIII
Telegraph Slough 1&2	YES	1.0	IIIIIIIIII
Telegraph Slough Full	YES	1.0	IIIIIIIIII
Thein Farm	NO	0.0	
TNC South Fork	NO	0.0	
McGlinn & TS 1	YES	1.0	IIIIIIIIII
McGlinn & TS 1&2	YES	1.0	IIIIIIIIII
McGlinn & TS Full	YES	1.0	IIIIIIIIII

Total flood interest scores

The 100 points for the flood interest score was evenly divided between the 4 objectives, resulting in each objective having maximum of 25 points (Table 6-21). This resulted in a maximum potential benefit score of 75 points and impact score of 25 points.

Table 6-21. Total flood benefit and impact scores

Project Concept	Benefit Score				Impact Score	
	Flood #1	**Flood #2**	**Flood #4**	**Total**	**Flood #3**	**Total**
	Reduce flood WSE	Reduce risk of levee failure	Improve flood drainage		Avoid new levees where none existed	
Total possible points	25	25	25	**75**	25	**25**
Avon-Swinomish Bypass	25.0	0.0	0.0	**25.0**	25.0	**25.0**
Cottonwood Island	0.0	0.0	0.0	**0.0**	0.0	**0.0**
Deepwater Slough Phase 2	5.1	0.0	0.0	**5.1**	0.0	**0.0**
East Cottonwood	0.0	0.0	0.0	**0.0**	0.0	**0.0**
Fir Island Cross Island Connector	5.6	6.3	25.0	**36.9**	9.7	**9.7**
Fir Island Farm	0.0	12.3	25.0	**37.3**	0.0	**0.0**
Hall Slough	0.0	7.9	25.0	**32.9**	0.0	**0.0**
McGlinn Causeway	0.0	0.0	0.0	**0.0**	0.0	**0.0**
Milltown Island	0.0	0.0	0.0	**0.0**	0.0	**0.0**
NF Left Bank Levee Setback A	11.9	25.0	25.0	**61.9**	0.0	**0.0**
NF Left Bank Levee Setback B	10.2	19.6	25.0	**54.9**	0.0	**0.0**
NF Left Bank Levee Setback C	4.1	12.1	25.0	**41.2**	0.0	**0.0**
NF Right Bank Levee Setback	0.0	9.2	25.0	**34.2**	0.0	**0.0**
Pleasant Ridge South	0.0	1.2	0.0	**1.2**	0.0	**0.0**
Rawlins Road	2.9	11.2	25.0	**39.1**	0.0	**0.0**
Rawlins Road Distributary Channel	0.0	0.0	0.0	**0.0**	0.0	**0.0**
SF Levee Setback 2, 3, 4	1.6	10.5	0.0	**12.1**	0.0	**0.0**
Sullivan Hacienda	0.0	12.5	0.0	**12.5**	0.0	**0.0**
Telegraph Slough 1	0.0	5.3	25.0	**30.3**	0.0	**0.0**
Telegraph Slough 1&2	0.0	5.3	25.0	**30.3**	0.0	**0.0**
Telegraph Slough Full	0.0	5.3	25.0	**30.3**	0.0	**0.0**
Thein Farm	0.0	2.2	0.0	**2.2**	0.0	**0.0**
TNC South Fork	0.0	0.0	0.0	**0.0**	0.0	**0.0**
McGlinn & TS 1	0.0	5.3	25.0	30.3	0.0	0.0
McGlinn & TS 1&2	0.0	5.3	25.0	30.3	0.0	0.0
McGlinn & TS Full	0.0	5.3	25.0	30.3	0.0	0.0

No project concept received the potential maximum benefit points. NF LB Levee Setback A, B and C had the highest benefit scores with Setback A and B scoring high in all three flood benefit objectives and Setback C high in all but Flood #1. Eleven projects had a benefit score in the 30's and the rest were below 13 points. Only Avon-Swinomish Bypass and Fir Island Cross Island Connector had a flood impact score with Avon-Swinomish Bypass having the maximum of 25 points and the Fir Island Cross Island Connector at 9.7 points.

Multiple-Interest Scores

The total benefit and impact scores farm, fish and flood scores for were added together for each project concept to calculate a multiple-interest score (Table 6-22). By normalizing the results from the technical analyses, each restoration concept could be evaluated relative to the other concepts. The maximum benefit score possible for a project concept was 220 points and the maximum impact score was 80 points. The multiple-benefit scores ranged from 123.6 to 24.4. Multiple-impact scores ranged from 60.8 to 0 points.

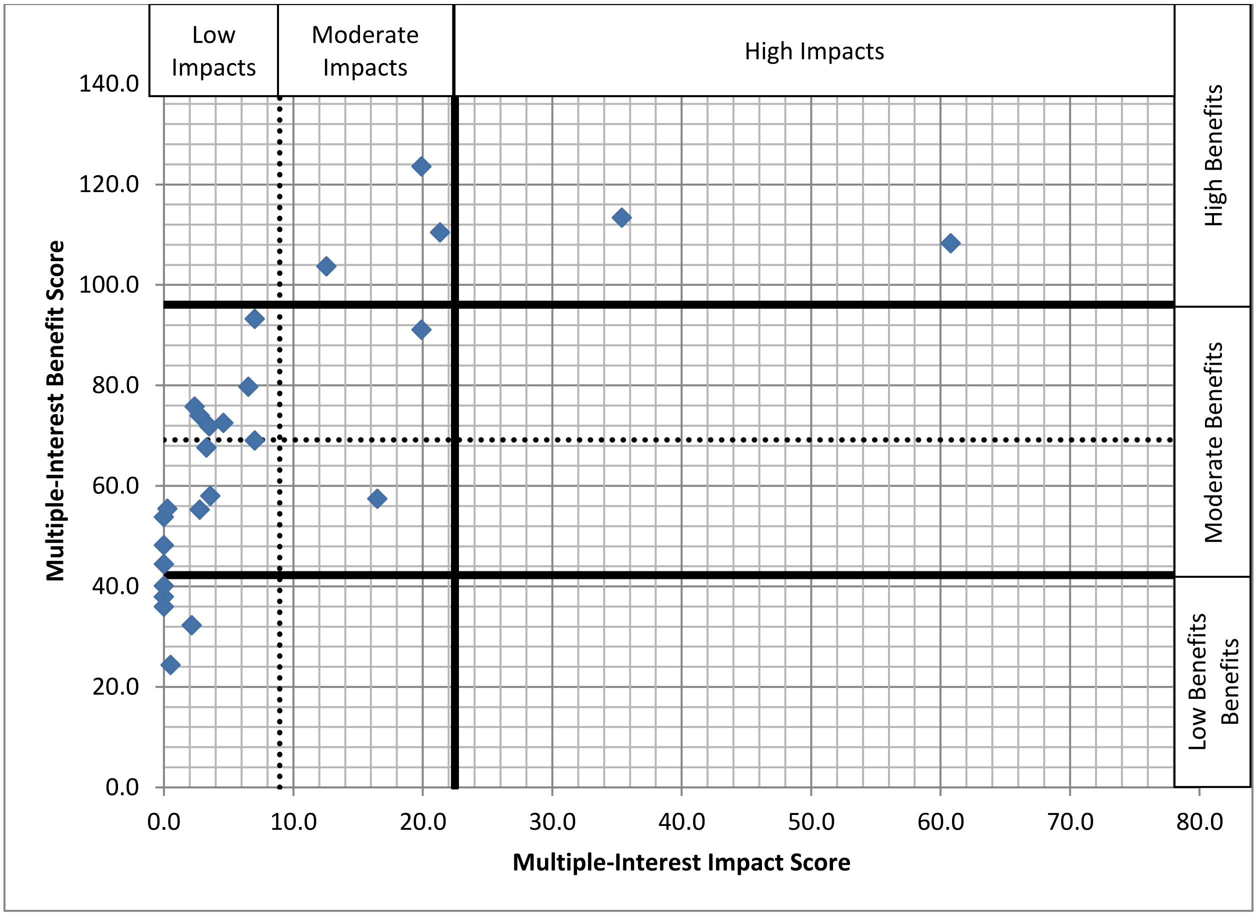
Table 6-22. Multiple-Interest scores

	Farm Interest Score		Fish Interest Score		Flood Interest Score		Multi-Interest Score	
Project Concept	**Benefit**	**Impact**	**Benefit**	**Impact**	**Benefit**	**Impact**	**Benefit**	**Impact**
Total possible points	**60**	**40**	**85**	**15**	**75**	**25**	**220**	**80**
Avon-Swinomish Bypass	16.8	20.8	66.6	15.0	25.0	25.0	108.3	60.8
Cottonwood Island	30.1	0.0	7.8	0.0	0.0	0.0	38.0	0.0
Deepwater Slough Phase 2	31.9	4.6	35.6	0.0	5.1	0.0	72.6	4.6
East Cottonwood	30.1	0.0	10.1	0.0	0.0	0.0	40.1	0.0
Fir Island Cross Island Connector	31.4	7.3	42.2	4.4	36.9	9.7	110.5	21.3
Fir Island Farm	23.1	2.4	15.4	0.0	37.3	0.0	75.8	2.4
Hall Slough	13.3	16.5	11.3	0.0	32.9	0.0	57.4	16.5
McGlinn Causeway	30.1	0.0	18.1	0.0	0.0	0.0	48.2	0.0
Milltown Island	38.2	0.0	15.6	0.0	0.0	0.0	53.8	0.0
NF Left Bank Levee Setback A	18.3	29.5	33.2	5.9	61.9	0.0	113.4	35.4
NF Left Bank Levee Setback B	16.6	9.5	28.6	3.0	58.5	0.0	103.7	12.6
NF Left Bank Levee Setback C	15.7	4.7	22.9	1.8	41.2	0.0	79.8	6.5
NF Right Bank Levee Setback	12.2	2.5	11.6	1.0	34.2	0.0	58.0	3.6
Pleasant Ridge South	11.2	0.5	12.0	0.0	1.2	0.0	24.4	0.5
Rawlins Road	15.1	3.3	13.4	0.0	39.1	0.0	67.6	3.3
Rawlins Road Distributary Channel	30.3	0.0	14.2	0.0	0.0	0.0	44.5	0.0
South Fork Levee Setback 2, 3, 4	30.7	0.3	12.7	0.0	12.1	0.0	55.5	0.3
Sullivan Hacienda	24.3	3.5	35.1	0.0	12.5	0.0	71.9	3.5
Telegraph Slough 1	11.1	2.8	13.9	0.0	30.3	0.0	55.3	2.8
Telegraph Slough 1 & 2	12.5	7.0	26.3	0.0	30.3	0.0	69.1	7.0
Telegraph Slough Full	14.2	19.9	46.6	0.0	30.3	0.0	91.1	19.9
Thein Farm	14.9	1.1	15.2	1.0	2.2	0.0	32.3	2.1
TNC South Fork	30.0	0.0	6.0	0.0	0.0	0.0	36.0	0.0
McGlinn & TS 1	15.8	2.8	27.9	0.0	30.3	0.0	74.0	2.8
McGlinn & TS 1&2	18.9	7.0	44.1	0.0	30.3	0.0	93.3	7.0
McGlinn & TS Full	25.6	19.9	67.7	0.0	30.3	0.0	123.6	19.9

Avon-Swinomish Bypass had the largest impacts score of 60.8 point, which was 2 times as large as the next highest impact score, North Fork Left Bank Levee Setback A. Five project concepts had multiple-interest scores above 100 points with the exception of NF LB Setback B, these projects also had the highest impact scores.

The multiple-interest scores were graphed as a scatter plots with the impact score on the y-axis and the benefit score on the x-axis (Figure 6-5). A standard deviation was calculated for the total benefit and impact scores to better understand significant differences in relative benefit and impact between project concepts. The higher the standard deviation the larger the discrepancy between the scores for each category. The solid black lines represent 1 standard deviation and the dotted lines are the average multiple-interest benefit (horizontal line) and impact (vertical line) scores across all project concepts. This allows project concepts with similar scores to be grouped into a simple matrix. Standard deviation and average scores were used to create high, medium and low rankings of projects. These rankings allowed for the sorting of the project into five different groupings with similar benefit and impact scores, as shown in the matrix.

Figure 6-5. Multiple impact score plots



These groupings enable one to quickly understand the potential for a restoration concept to provide benefit or cause impacts in comparison to other concepts. The project concept groups defined using this matrix were then used to develop appropriate management recommendations based on estimated benefits and impacts Figure 6-6).

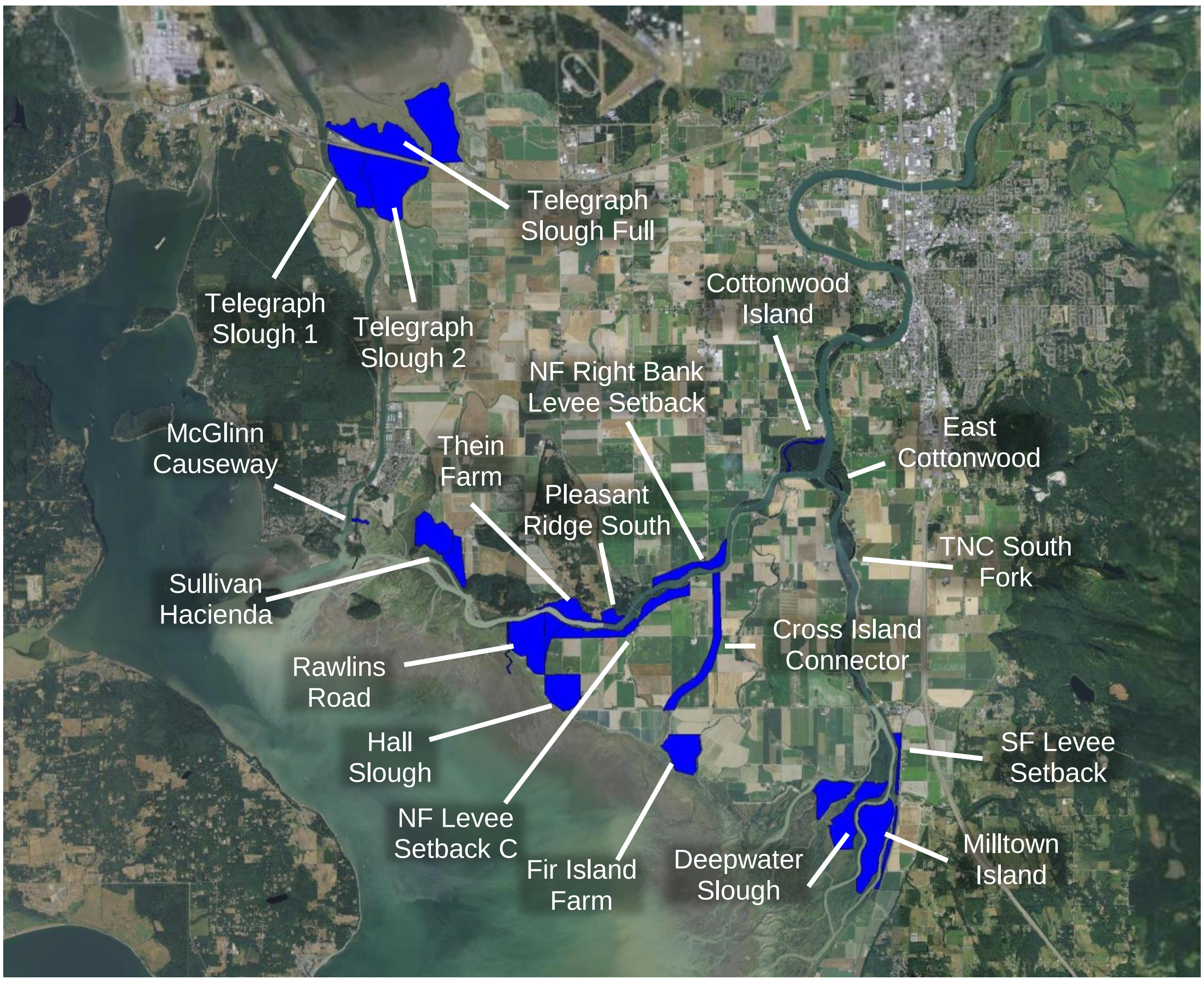
Figure 6-6. Plot of project concepts based on the multiple-interest benefit and impact scores

		Impact: Low	Impact: Moderate	Impact: High
Benefit	High		McGlinn & Telegraph Slough Full Fir Island Cross Island Connector North Fork Left Bank Levee Setback B	North Fork Levee Setback A Avon-Swinomish Bypass
Benefit	Medium	McGlinn & Telegraph Slough 1 and 2 North Fork Left Bank Setback C Fir Island Farm McGlinn & Telegraph Slough 1 Deepwater Slough #2 Sullivan Hacienda Telegraph Slough 1 Milltown Island McGlinn Causeway	Telegraph Slough Full Hall Slough	
Benefit	Low	Rawlins Road Distributary Channel East Cottonwood Thein Farm TNC South Fork Pleasant Ridge South		

7.0 Cumulative Effects Analysis Results

Given the significant potential impacts from Avon-Swinomish Bypass and the NF LB Setback A, the SHDM Team decided not to advance these two projects further through this process. A cumulative impact analysis was completed by modeling the remaining project concepts together (Figure 7-1). The exception for this is NF LB Levee Setback B because it had not been included in the initial modeling analyses. The goal of this analysis was to determine cumulative benefits or impacts at either the project specific level or system-wide if all of the project concepts were implemented.

Figure 7-1. Map of selected projects included in cumulative impacts analyses



Cumulative effects on WSE during a flood

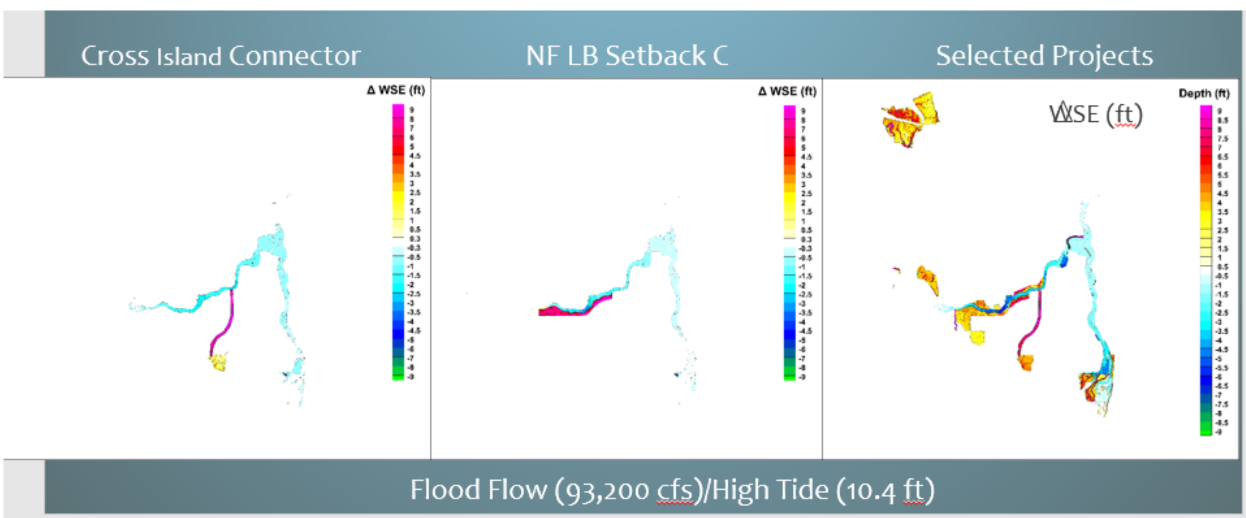
Results from the PNNL model show that implementation of multiple project concepts would reduce WSE during flood flow and that the predicted reduction in WSE is greater than the effects of either the Fir Island Cross Island Connector or the NF Left Bank Levee Setback C, which were the two largest projects considered in the cumulative effects analysis (Table 7-1).

Table 7-1. Cumulative effects on WSE during a flood from selected projects

Change in magnitude of WSE (ft)	Length of River effected by project concept(s) (LF)		
	Fir Island Cross Island Connector	NF Levee Setback C	Selected Projects
-0.3 to -1.0 (dropped)	40,750	30,915	7,098
-1.0 to -1.5	7,130	7,650	19,303
-1.5 to -2.0	10,180	5,240	8,014
-2.0 to -2.5	6,220	2,380	11,624
-2.5 to -3.0	480	570	7,320
-3.0 to -3.5		1,470	6,981
-3.5 to -4.0			9,377
-4.0 to -4.5			4,652
-4.5 to -5.0			2,493
-5.0 to -5.5			2,376
-5.5 to -6.0			1,797
-6.0 to -6.5			130
Total > -1.0	24,010	17,310	74,067

The primary difference of the cumulative effects of selected project concepts was an increase in the magnitude of the reduced WSE in the range of -1.0 to 2.0; however, the effects on WSE included reductions as high as -6.5 feet, and extended further upstream as compared to individual projects (Figure 7-2).

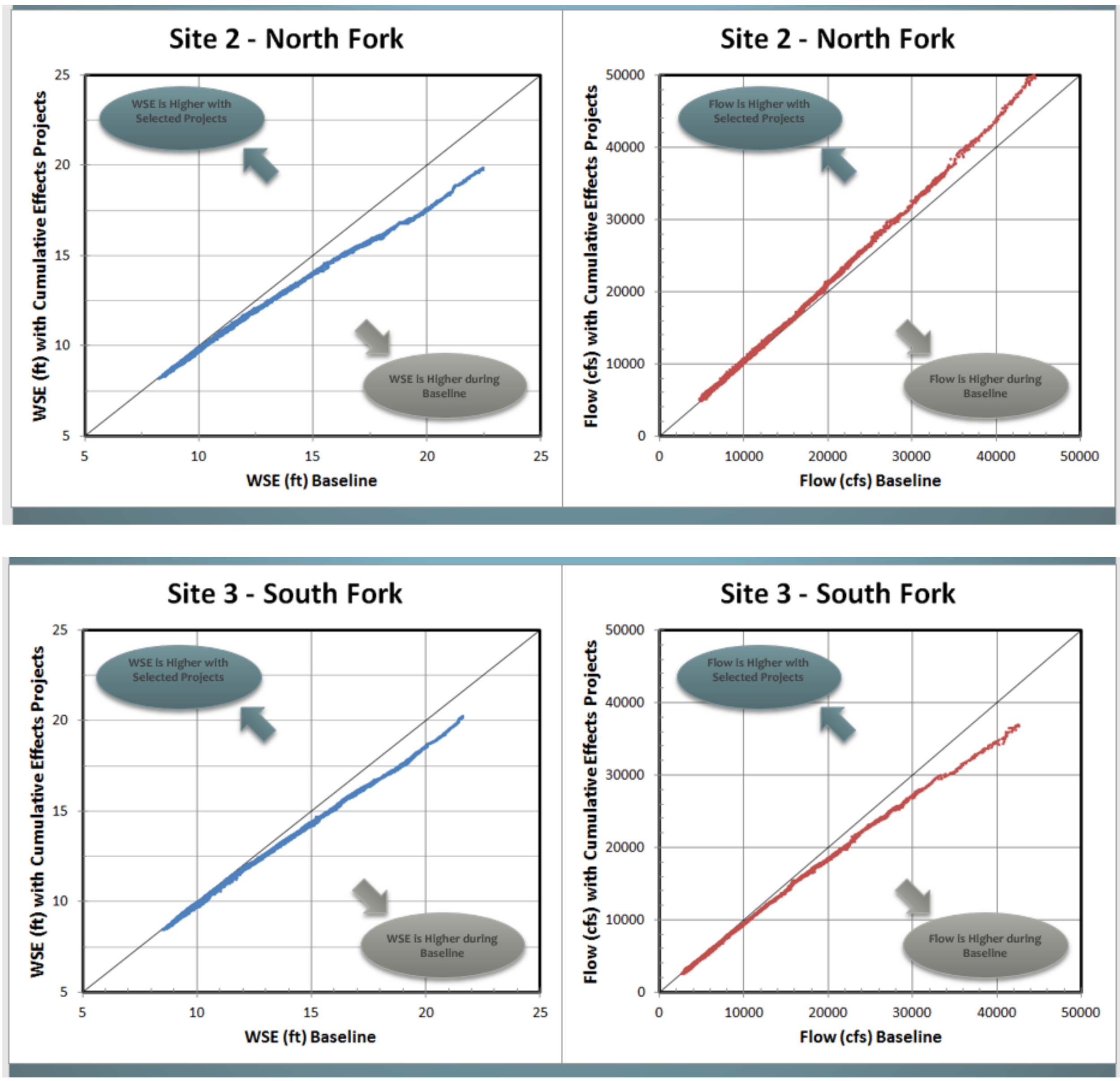
Figure 7-2. Change in WSE with projects as shown (Fir Island Cross Island Connector, NF Left Bank Levee Setback C and cumulative impacts of all selected projects



Cumulative effect to habitat

The cumulative effects analysis also predicted changes to both on-site and off-site areas of habitat. The PNNL model predicted a reduction in WSE in both the North Fork and South Fork due to increases in storage and conveyance capacity across the system. In addition, there was an increase in the volume of flow in the North Fork and a corresponding decrease in the South Fork as compared to baseline, if all of the selected projects are implemented (Figure 7-3).

Figure 7-3. WSE in the N Fork and S Fork with all selected projects vs. baseline



Cumulative effects to off-site habitat

The reduced WSE in the North and South Forks also resulted IN reduction of the offsite habitat wetted during a Q2/low tide scenario as compared to baseline conditions (Figure 7-3).

Table 7-2. Offsite habitat loss due to cumulative effects of selected projects

Project Concept	Net Off-site Habitat Loss (acres)
Selected Projects	123
Cross Island Connector	98
NF LB Levee Setback C	41
Thein Farm and NF RB Levee Setback	47

The magnitude of the off-site impacts to existing habitat is less than the sum of individual project impacts because individual project concepts affected the same areas of off-site habitat. The reductions in off-site habitat were located lower in the system and may be wetted during higher tide or higher river conditions.

Cumulative effects to on-site habitat

The predicted decrease in WSE resulted in reduced wetted area during a Q2/low tide when compared to baseline for the Milltown Island project concept (Table 7-3).

Table 7-3. Summary of reduced project area habitat under cumulative effects

	Single Project Effects		Cumulative Effects	
	Within Project Habitat Changes (acres)		Within Project Habitat Changes (acres)	
Project Concept	Tidal	Q2	Tidal	Q2
Milltown Island	6.0	4.0	8.5	- 81.0
NF Right Bank Setback	–	82.2	–	77.2
Pleasant Ridge South	–	27.4	–	21.9

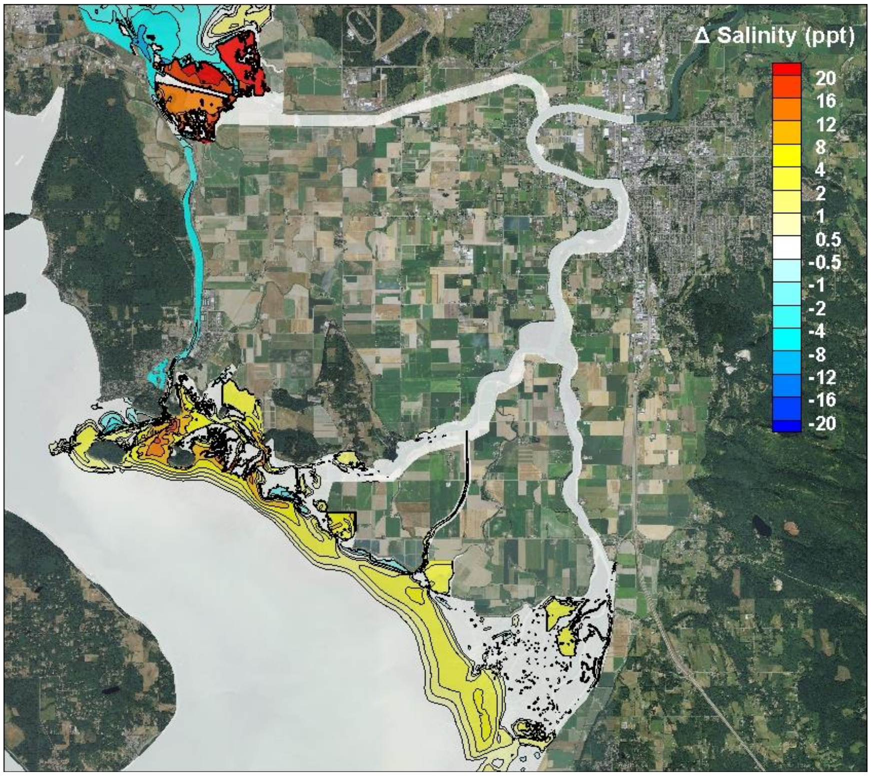
Milltown would have a net gain in habitat under the high tide/low flow scenario in both the selected project and single project model runs. This can be attributed to the reduced WSE during flood conditions in the South Fork due to the increase conveyance and flood storage capacity in the North Fork. Milltown Island is a high elevation site located far down in the system. Its floodplain habitat no longer overtops from flood waters during the Q2/low tide scenario due to the reduced WSE in the South Fork. However, during a high tide it is still inundated by tidal waters.

Additionally, the NF Right Bank Setback and Pleasant Ridge South project concepts had less wetted area under the cumulative projects run than in the individual project runs (Table 7-3). The slight reduction in wetted area is due to the reduced WSE seen in the North Fork under the cumulative effects project run. Habitat area for the tidally influenced project concepts did not change under the cumulative run.

Cumulative Effects Salinity Results

In general, cumulative effects of selected projects to the location of salinity were evaluated by comparing the distribution of salinity from the PNNL model to baseline conditions. The most notable changes in salinity were predicted within the footprint of each project concept evaluated due to salt water being introduced into new areas as a result of a dike/levee setback (Figure 7-4). Minor changes in salinity were predicted along the edge of Skagit Bay, particularly near the McGlinn Causeway at the mouth of the NF Skagit River as compared to baseline conditions.

Figure 7-4. Cumulative effects of selected project concepts on salinity at high tide and low flow as compared with baseline (no projects)



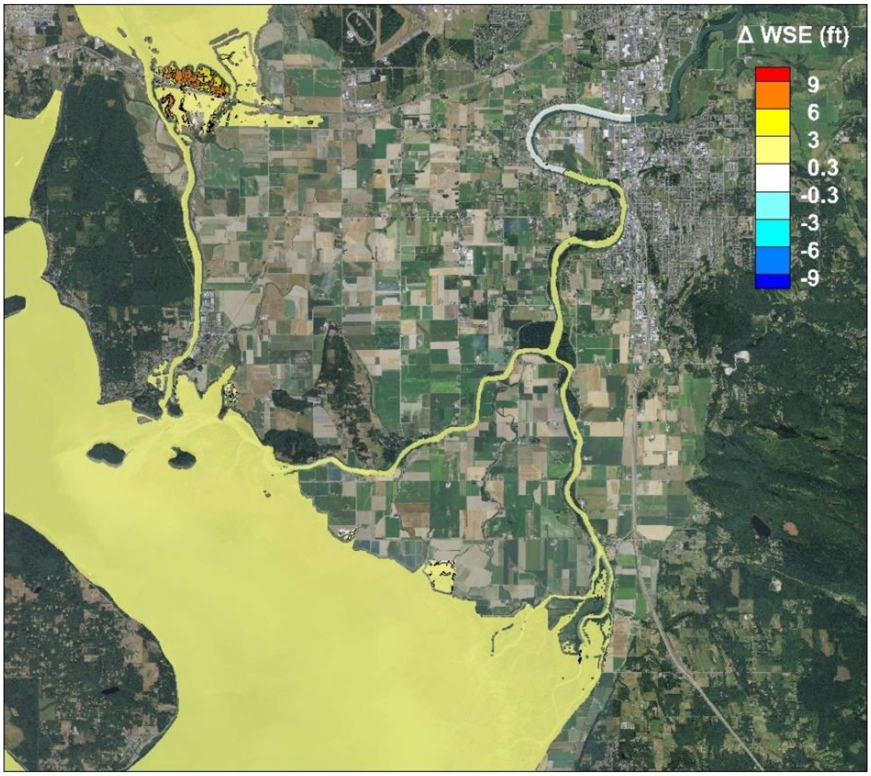
Climate Change Analysis Results

This analysis was designed to build an understanding of where change WSE and the extent of inundation may change between current conditions and in future conditions under SLR. This analysis also evaluated potentially changes WSE and extent of inundation under future conditions. This analysis was not intended to evaluate flood risk under future conditions.

Changes in the WSE under a future high tide and a future 2-year flood event

Potential changes in WSE under a future high tide scenario were evaluated using the PNNL model and running a future high tide and low flow scenario. The 1.9 ft modeled increase in future high tide elevation is predicted to affect WSE across the system extending up to Mount Vernon (Figure 7-5).

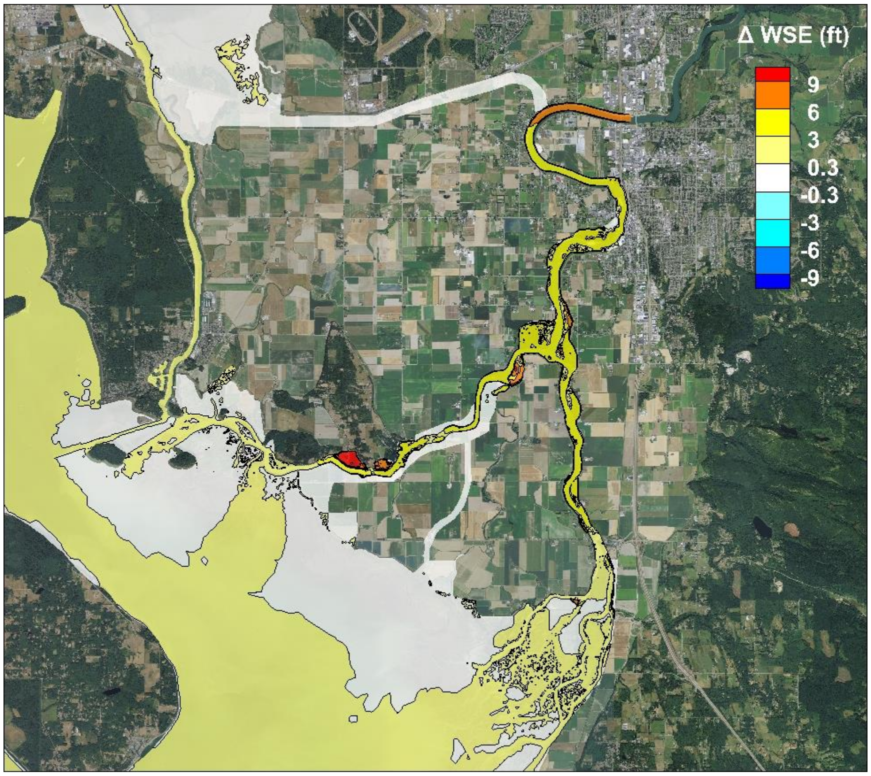
Figure 7-5. Change in WSE between current high spring tide (10.8 ft)/low flow (12,000 cfs) and future high spring tide (12.7 ft)/ low flow (12,000 cfs) scenarios



It is important to note that Figure 7-5 shows increases in WSE in areas in some areas that are currently protected by marine dikes. This result is due to calculated WSE that would be greater than the elevation used to represent the dikes in the PNNL model. Evaluating potential flood risk was outside the scope of work for this project. Analysis of flood risks under future conditions should be evaluated with studies that use site-specific survey data, a finer resolution modeling grid, site-specific water surface elevation data for model validation, and more detailed analysis of wave and wind effects.

Potential changes in WSE under a Q2 scenario was evaluated using the PNNL model by comparing current Q2/low tide with the potential future Q2 flow future low tide. This analysis also showed system wide increases in WSE (Figure 7-6).

Figure 7-6. Change in WSE between current modeled Q2 flow (62,000 cfs)/ low spring tide (-3.3 ft) and modeled future Q2 flow (103,237 cfs)/ future Low Spring Tide (-1.43 ft)



Similar to the scenario that focused on SLR, it is important to note that Figure 7-6 also shows increases in WSE in areas currently protected by marine dikes. Evaluating potential flood risk was outside the scope of work for this project. Any potential flooding under future conditions should be evaluated with studies that use site-specific survey data of levee heights and additional site-specific data.

Changes in the WSE due to implementation of selected projects under future flood scenario

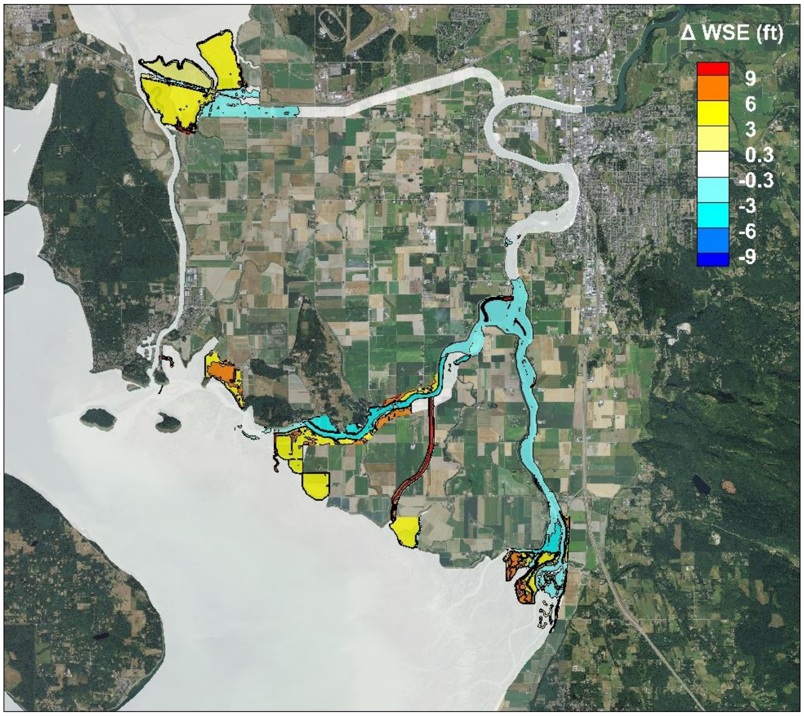
The PNNL model showed that project concepts were predicted to reduce future WSE across the lower portion of the river. The reductions in WSE and extents under this future flood scenario are not as great as in existing conditions likely due to the effect of the higher tidal heights (Table 7-4).

Table 7-4. Comparison of the effect of selected projects to reduced WSE during current and future flood flows

Change in magnitude of WSE (ft)	Length of River effected by project concept(s) (Linear Ft)	
	Selected Projects Flow (93,200 cfs)/ High Spring Tide (10.4 ft)	Selected Projects Future Q2 Flow (103,237 cfs) High Spring Tide (12.67 ft)
-0.5 to -1.0 (dropped)	7,098	8,210
-1.0 to -1.5	19,303	17,195
-1.5 to -2.0	8,014	6,544
-2.0 to -2.5	11,624	6,536
-2.5 to -3.0	7,320	5,435
-3.0 to -3.5	6,981	7,762
-3.5 to -4.0	9,377	3,824
-4.0 to -4.5	4,652	3,806
-4.5 to -5.0	2,493	958
-5.0 to -5.5	2,376	1,721
-5.5 to -6.0	1,797	0
-6.0 to -6.5	130	0
Total > -1.0	74,067	53,780

However, there is still substantial potential reductions across the lower portion of the river in these predicted larger and more frequent flood flows as a result of all of the selected projects being implemented. Reductions in WSE within the project concepts of Thein Farm and Pleasant Ridge South (Figure 7-7) are due to the fact that these were inundated during the without project future Q2/ high tide flood scenario and with the implementation of all of the selected projects the WSE elevation in the NF decreased due to widening of the channel area and flow through Fir Island Cross Island Connector.

Figure 7-7. Change in WSE across study area between with and without selected project concepts under future Q2 (103,237 cfs)/ future high spring tide (12.67ft) scenario



Analyses of the WSE between existing baseline and future scenarios from locations in Skagit and Padilla Bay showed a consistent increase of 1.9 ft in WSE under the future tide elevations. Figure 7-8 illustrates the cumulate frequency of water surface elevations under baseline conditions and under future conditions. Figure 7-8 also shows that implementation of individual and selected project has little effect on the WSE for project concepts that are tidally dominated under the future scenario.

For project concepts located further upstream showed, the PNNL model predicted less of an increase in WSE under the future scenario for sites where both riverine and tidal processes influence WSE (Figure 7-9).

Figure 7-8. Cumulative frequency plot of WSE under baseline and future scenarios at a tidally dominated location

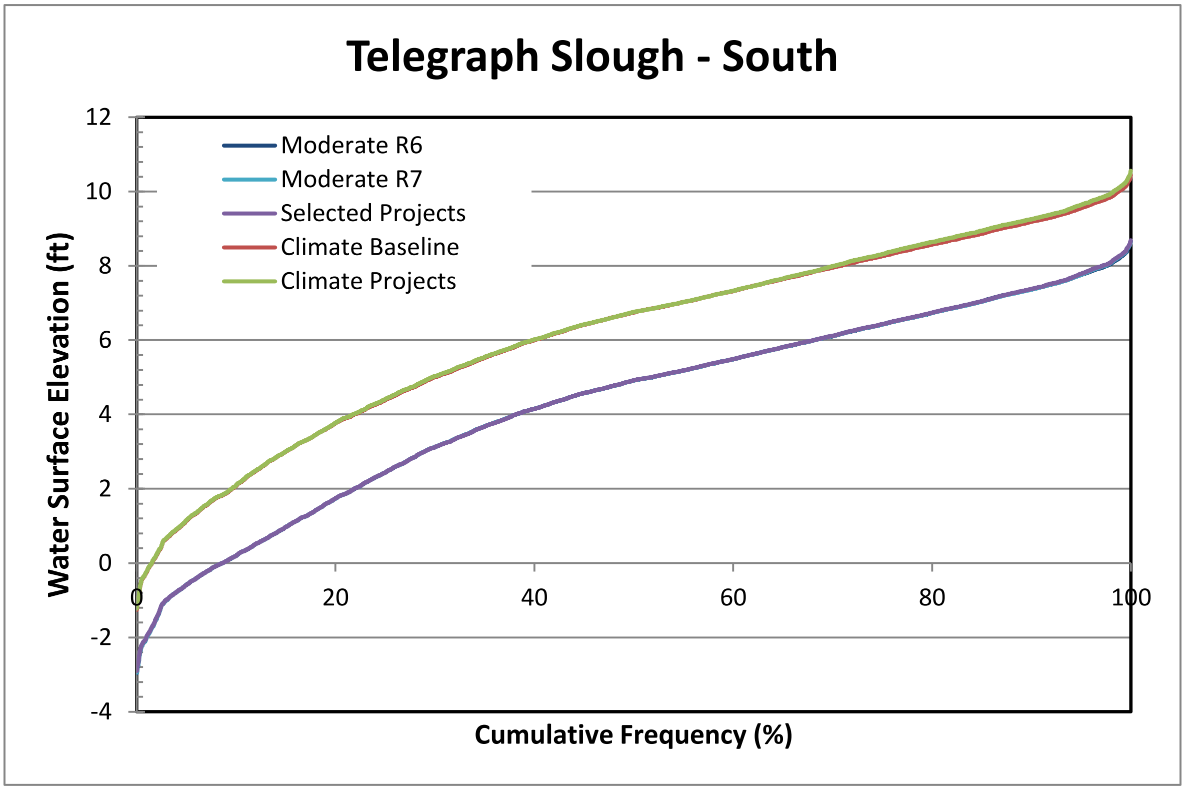
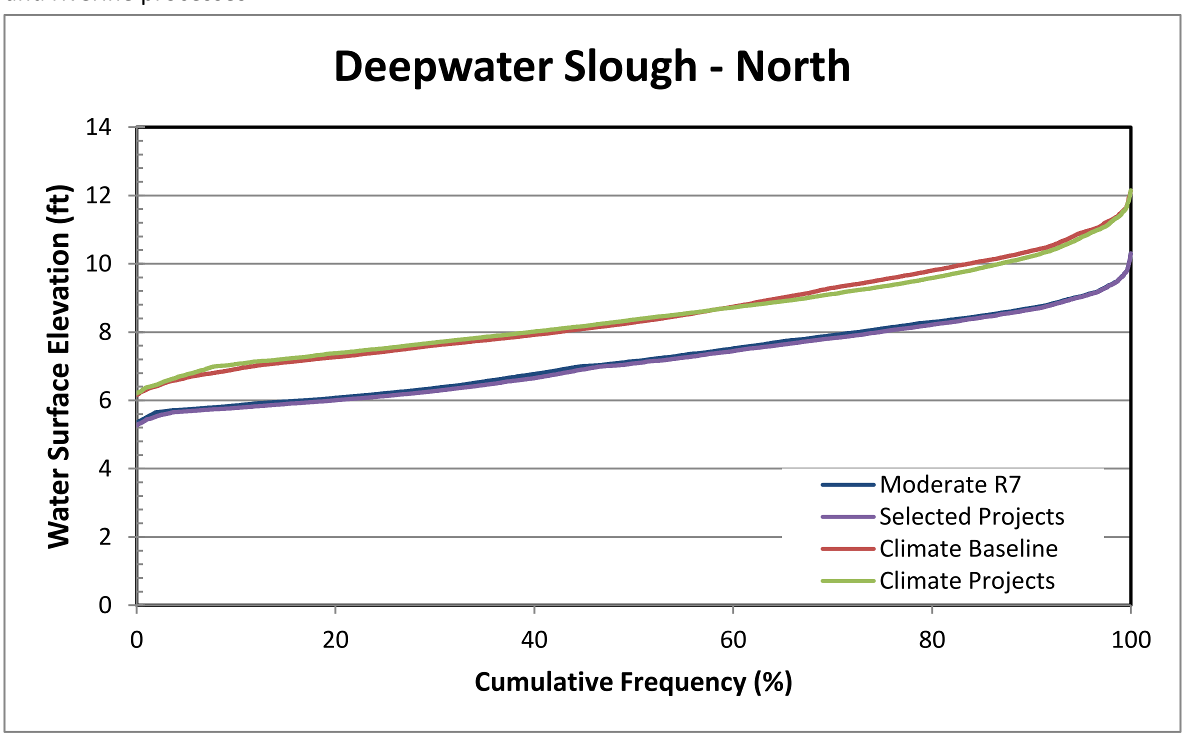


Figure 7-9. Cumulative frequency plot of WSE under baseline and future scenarios at a location influenced by tidal and riverine processes



As shown in Figure 7-9, implementation of the selected project concepts does not greatly affect WSE under the future scenario.

Vegetation zones were predicted for 1-ft elevation bins. To account for increased inundation under the future scenario, 1.9 ft, was added to the elevations predicted to support each community type. In other words, where emergent marsh vegetation was predicted at 3 ft to 7.9 ft under current conditions, it was rounded up and estimated to occur at 5 to 9.9 ft under future conditions. Table 7-5 shows how vegetation communities are predicted to change under the future conditions for each tidally dominated project concept.

Table 7-5. Acres of habitat predicted to be within each vegetation zone under current and 2080 tidal inundation levels

	Current Condition				Future (2080) Condition			
	mudflat/ channel	emergent	shrub	floodplain / riparian	mudflat/ channel	emergent	shrub	floodplain/ riparian
Project Concept	< 3-ft	3 - 7.9 ft	8 - 9.9 ft	10 ft plus	< 3-ft	3 - 7.9 ft	8 - 9.9 ft	10 ft plus
Deepwater Phase 2	0.0	149.1	66.6	52.1	3.9	211.8	16.8	35.3
Fir Island Farm	0.6	133.2	1.8	3.9	15.2	120.5	2.1	1.7
Hall Slough	0.0	122.8	3.4	7.4	0.2	125.9	2.9	4.5
Milltown Island	2.5	15.6	114.2	89.2	5.6	126.8	57.0	32.3
Rawlins Road	0.0	168.6	10.5	12.5	0.1	178.9	4.0	8.4
Sullivan Hacienda	6.2	175.2	8.3	15.1	21.3	168.5	6.3	8.8
Telegraph Slough 1	27.8	143.4	3.8	9.8	89.8	85.2	3.3	6.5
Telegraph Slough 1&2	68.0	396.0	14.5	16.0	215.2	263.3	8.3	7.7
Telegraph Slough Full	172.5	794.6	33.9	46.8	455.8	545.2	29.2	17.6
Thein Farm	1.1	51.2	6.0	19.9	2.9	55.3	4.1	15.7

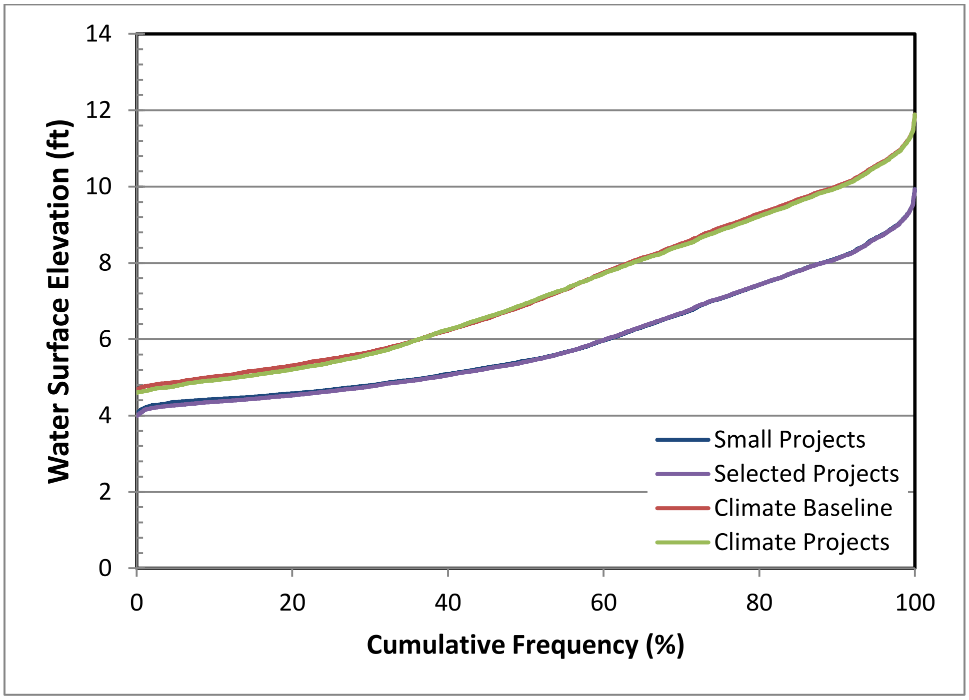
All three versions of Telegraph Slough had a large shift from emergent marsh to mudflat habitat with three times as many mudflat acres predicted under the future scenario. This is the same for the combination project concepts of McGlinn Causeway with the three versions of Telegraph Slough. In contrast, Milltown Island has the potential to have approximately 100 acres shift from shrub vegetation to emergent marsh habitat. Deepwater Slough Phase 2 had a smaller potential increase in the emergent marsh zone. The other sites have fairly similar ranges of acres across each of the vegetation zones.

This analysis is a starting point for understanding potential impacts from sea level rise as it is a static analysis. Marshes with high sediment supply may keep pace with SLR and experience relatively little change in the predicted amount of habitat types seen across the site. Alternatively, those sites with low sedimentation rates or that experience additional subsidence prior to restoration may have additional shifting. This analysis is design to identify sites where there may be a higher potential for changes in vegetation communities due to increased tidal inundation. Additional investigation during project feasibility stage is needed.

Do predicted changes in the height of low tides have the potential to affect drainage outlets?

Based on the output from the PNNL model, the duration of time of WSE is predicted to change under future conditions (Figure 7-10).

Figure 7-10. Cumulative Frequency Plot of WSE under baseline and climate change scenarios



As shown in Figure 7-10, the restoration projects have little influence on predicted WSE for tidally influenced projects concepts. It is likely that the duration of time of lower water levels will decrease under future conditions.

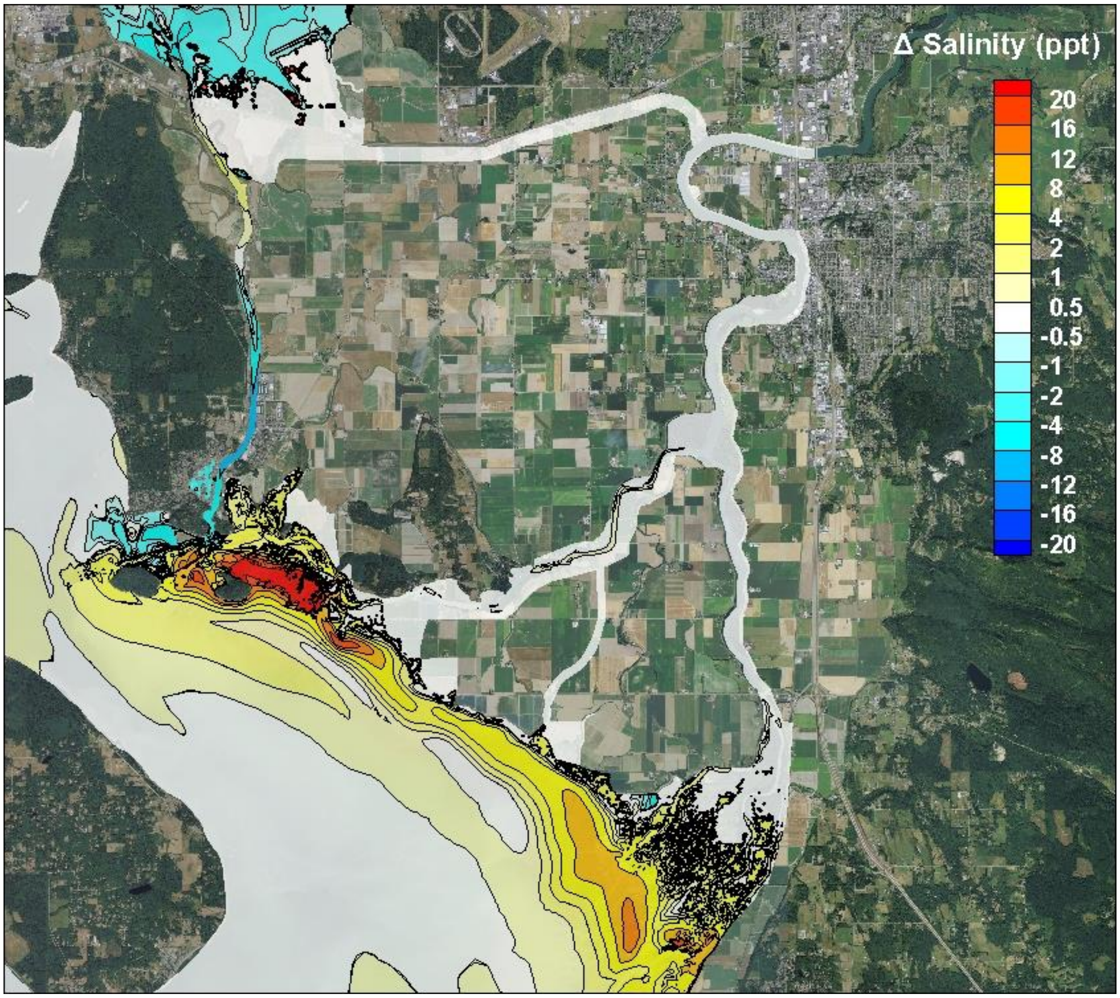
Climate Change Salinity Results

Under future conditions, SLR is expected to change salinity levels in the lower Skagit River (

Figure 7-11). However, the PNNL model had limitations for modeling salinity and uncertainty associated with the predicted magnitude and location of salinity changes (Appendix X). As shown in

Figure 7-11, in general, salinity is anticipated to increase most in the lower extents of the NF Skagit River as compared to existing baseline conditions.

Figure 7-11. Change in salinity from baseline to future conditions during a low-flow and high spring tide scenario



8.0 Management Recommendations

The SHDM Team defined five distinct management groups based on the distribution of projects in the x-y plot (Figure 8-1). These groups represent restoration concepts with significant differences in the relative level of benefits and/or impacts.

Figure 8-1. Project concept management groups

The SHDM team developed an overall framework for project concept implementation with six distinct steps (Figure 8-2). This overall framework was then used to develop specific implementation strategies for each management group using input from members of the SHDM team. The implementation strategies developed for each management group are tailored to that group based on its specific benefit and impact ranges. Some project groups may not have all steps included and others have more protracted time period in which to work on a specific step. Additionally, not every project within a group is expected to advance through the implementation timeline at the same pace. However, it is anticipated that at a minimum one to two projects will meet the implementation timeline. In addition, some projects with willing landowners are already undergoing feasibility or design and therefore may move at a faster pace. In addition, as restoration project concepts are implemented, monitoring fish utilization post-restoration is an important feedback loop that will inform future project selection and design.

Figure 8-2. Project Implementation Flow Chart showing all steps of project implementation required from the initial engagement with key interest groups through monitoring

Project concepts with low impact scores still reflect an impact, and for many project concepts, those impacts fall within the farm indicators. Moving forward a significant effort will be needed to work with the local agricultural community to determine how project impacts can be offset, and with agency and private partners to develop mechanisms to implement offset actions.

The SHDM Project evaluated a variety of project concepts. Not all project concepts will be implemented, but the intention is that the implementation strategy will be used to select project concepts with the highest multiple benefits and use monitoring data as a way to pace implementation of projects consistent with the Skagit delta Chinook recovery goal of 1.35 million additional smolts and timelines established by both the TFI and SCRP.

Blue Management Group: Implementation strategy

The restoration concepts in the Blue Management Group have multiple interest scores that reflect little or no impacts and relatively low benefits.

The project concepts in this group include:

- East Cottonwood
- Cottonwood Island
- Thein Farm
- TNC South Fork
- Pleasant Ridge South
- Rawlins Road Distributary Channel

If these project concepts have a project proponent, willing landowner(s) and receive funding, the project concepts are likely to move forward outside of an established collaborative multi-stakeholder process.

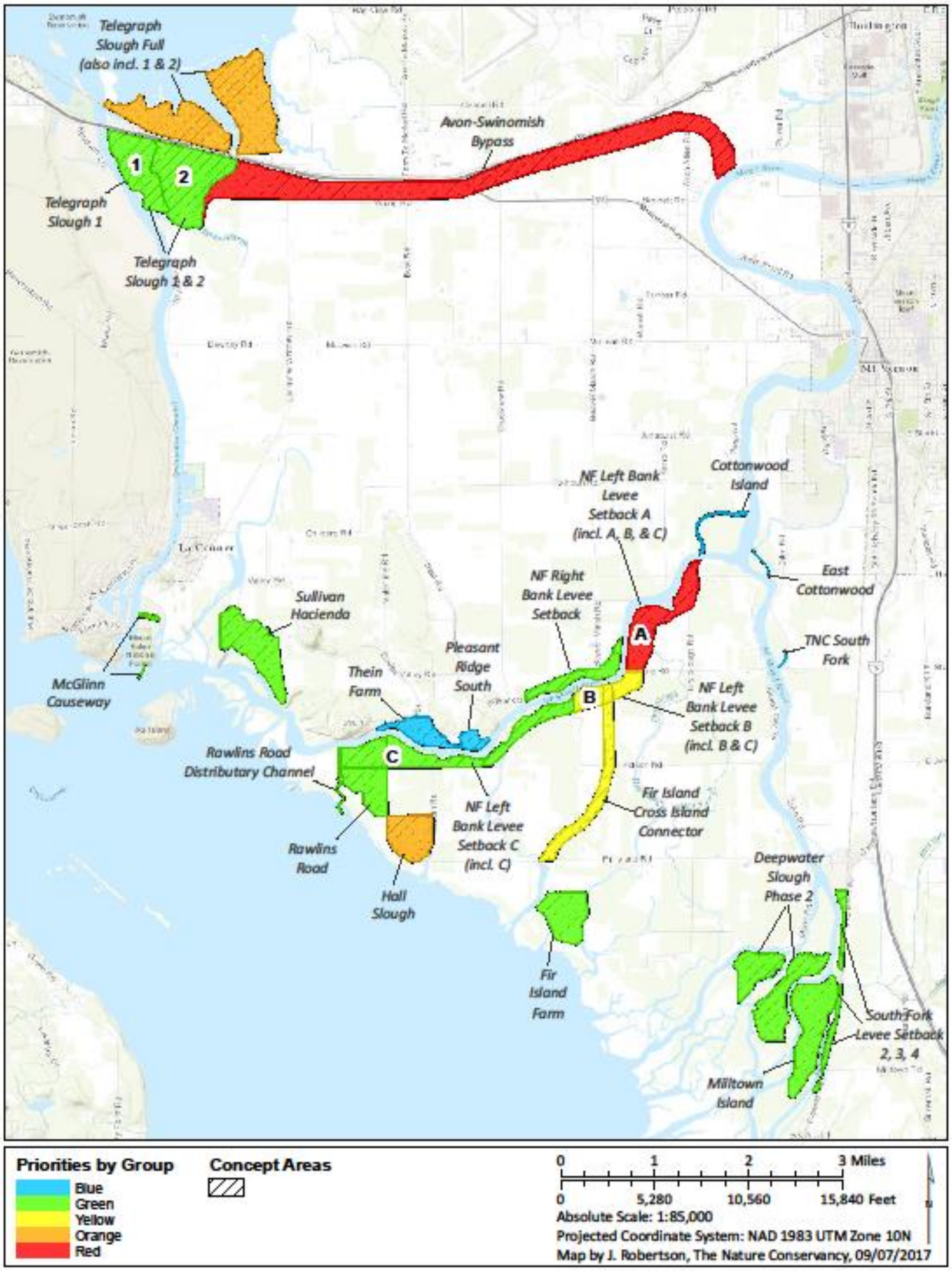
The steps recommended for project concepts in the Blue Management Group are:

- Identify project proponent
- Landowner outreach
- Feasibility
- Final design and implementation

Initial outreach with Dike, Drainage, and Irrigation District Commissioners is not needed for this low impact/low benefit group. Instead, the first step will be to determine if there are interested project proponents who then will contact the landowners, then the commissioners. It is also anticipated that a long phase of community outreach is not required; however, some direct communications with impacted stakeholders will be needed. The timeline for implementing specific project concepts will be influenced by the landowner outreach and feasibility. As a result, advancement of projects concepts through the project implementation flow chart will be staggered as some projects move forward to implementation and others are delayed. In general, Blue Group projects are expected to be on a timeline for completion in approximately 10 years.

Of the five projects in this category, two are already in the feasibility or design phase including Cottonwood Island and East Cottonwood. As part of the overall implementation plan, the SHDM team work within the local community to reach out to potential project proponents for project concepts in the blue category. Figure 8-3 depicts the location of the project concepts in this management group.

Figure 8-3. Project Concept and Management Group Map



Green Management Group: Implementation strategy

The restoration concepts in the Green Management Group have multiple interest scores that reflect low impacts and relatively moderate benefits. The project concepts in this group include:

- McGlinn, Telegraph Slough 1 and 2
- North Fork Left Bank Setback C
- Fir Island Farm (completed)
- McGlinn, Telegraph Slough 1
- Deepwater Slough #2 (an alternatives analysis to determine if WDFW will be the project proponent has been funded for 2018)
- Sullivan Hacienda
- Telegraph Slough 1 and 2
- Rawlins Road
- North Fork Right Bank Levee Setback
- South Fork Levee Setback 2,3 and 4
- Telegraph Slough 1
- Milltown Island (feasibility)
- McGlinn Causeway

The SHDM Team has prioritized advancement of the Green Project Concepts because of their potential to achieve more significant benefits while having relatively low impacts. These projects all tend to be larger in size than the Blue Group and, with a few exceptions, will impact multiple landowners. The timeline for this implementation strategy reflects that priority by focusing multiple-interest efforts on this group of restoration concepts.

The recommended implementation steps for project concepts in the Green Management Group are:

- Key stakeholder outreach and partnership development
- Identify project proponent
- Landowner outreach
- Community outreach
- Feasibility
- Final design and implementation

These project concepts will require significant collaboration with the key stakeholders and Skagit County Drainage and Irrigation Districts. The twelve districts are signatory to the Skagit Tidegate and Fish Initiative (TFI), a framework by which to balance between estuary restoration for Chinook salmon recovery and the need to maintain critical drainage such that the pace of restoration off-sets the impacts of maintaining drainage infrastructure (WWAA, NOAA, WDFW 2010). In the TFI, these districts agreed to work with the restoration community to make the landowner contacts necessary to secure the permissions, easements or ownerships to implement the restoration projects as well as work with landowners to understand habitat restoration goals. Additionally, Skagit Dike, Drainage and Irrigation District commissioners are themselves key landowners as they maintain and own the infrastructure that will need to be removed or realigned. They also have crucial knowledge of the complex diking and drainage systems that needs to be brought into the design of restoration projects to ensure that multiple benefits are achieved.

The SHDM Team recommends working with key stakeholders and Skagit Drainage and Irrigation Districts to strengthen relationships and develop partnerships for project concepts in the green management category. This effort may address social, political, and economic elements of project concepts that have not been addressed by the SHDM Project. By continuing to work through a collaborative and multiple benefit approach, it is likely that project concepts will be modified to address concerns related to climate change, agricultural drainage, coastal resiliency, and offsite impacts that were too detailed and complex to include in the SHDM Project. Partnerships will develop a framework for engaging private landowners and focus on ways for restoration practitioners and the Districts to work together to advance projects from concept stage to design and implementation to ensure multiple benefits are achieved.

Because of the need for further coordination early in the planning process, project concepts in the Green Management Group will likely need a longer timeline. In general, Green Group Projects are expected to be on a timeline for completion in approximately 20 years, but individual project timelines will be staggered as some projects move forward to implementation and others are delayed. The timeline for implementing projects concepts will be influenced both by the approved TFI schedule and monitoring feedback loops that inform progress toward Chinook recovery goals for the Skagit delta. As a result, advancement of projects concepts through the project implementation flow chart will be staggered as some projects move forward to implementation and others are delayed. Currently, two projects within this group have started feasibility. Outreach to district commissioners and to the local community will be incorporated throughout the feasibility process. These projects are advancing because a willing landowner and a project proponent have already been identified. Figure 8-3 depicts the location of the project concepts in this management group.

Yellow and Orange Management Groups: Implementation strategy

The restoration concepts in the Yellow Management Group have multiple interest scores that reflect moderate impacts and relatively high benefits. The project concepts in the yellow group include:

- McGlinn & Telegraph Slough Full
- Fir Island Cross Island Connector
- North Fork Left Bank Levee Setback B

The restoration concepts in the Orange Management Group have multiple interest scores that also reflect moderate impacts and but only have relatively moderate benefits. The project concepts in this group include:

- Telegraph Slough Full
- Hall Slough

Because these projects anticipate moderate levels of impacts, it is likely that projects will be considered on a longer timeline as compared with the green project concepts. Therefore, discussing these project concepts with the district commissioners is delayed as compared to project concepts in the green management category. These project concepts will likely need more connection to monitoring feedback loops to gain community support and more extensive evaluation of potential off-site impacts. In general yellow group projects are expected to be on a timeline where feasibility is completed in approximately 20 years and feasibility for projects in the orange group occurs in 30 years or more. As with all projects included in each management group, individual project timelines will be staggered as some projects move forward and others are delayed. Figure 8-3 depicts the location of the project concepts in these management groups.

The steps recommended for project concepts in the Yellow and Orange Management Groups are:

- Key stakeholder outreach and partnership development
- Identify project proponent
- Landowner outreach
- Community outreach
- Feasibility

Red Category Management Group: Implementation strategy

The restoration concepts in the Red Management Group have multiple interest scores that reflect high impacts and relatively high benefits. The project concepts in this group include:

- Avon-Swinomish By-pass
- North Fork Left Bank Levee Setback A

Due to the high level of potential impacts, these project concepts are not being considered for implementation at this time. Figure 8-3 depicts the location of the project concepts in this management group.

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10.0 Appendices

Appendix A: Phase 1 Report

Appendix B: Restoration Project Concepts

In addition to the 22 project concepts described in Appendix B, we assessed four additional projects:

- NF Left Bank Levee Setback B, which is a portion of NF Left Bank Levee Setback A, but larger than NF Left Bank Levee Setback C, and
- Telegraph Slough 1, Telegraph Slough 1&2 and Telegraph Slough Full in combination with McGlinn

Appendix C: Battelle Report

Appendix D: Beamer et al 2016 Report

Appendix E: GIS tech notes and maps

Appendix F: USGS Report

Appendix G: Changes to Objectives and Indicators During Phase 2

Appendix H: Farm Objectives Calculations

Appendix I: Fish Objectives Calculations

Appendix J: Flood Objectives Calculations

Appendix A: Phase 1 Report

Skagit Delta Hydrodynamic Model Project
Final Report
March 13, 2014

Introduction

The Farms, Fish and Floods Initiative (3FI) aims to create and advance mutually beneficial strategies that support the long-term viability of agriculture and salmon while reducing the risks of destructive floods. 3FI is a landscape scale effort in the Skagit Delta where representatives from conservation and agricultural interests have agreed to a common agenda and established partnerships that can bring about breakthroughs in estuary restoration, flood risk reduction and farmland protection in a way that supports multiple community interests.

The Skagit Delta Hydrodynamic Model Project (SHDP) is supported by and contributes to the goals of 3FI. Funding from the National Estuary Program (NEP) was provided to support SDHP Team (Team) develop a scope of work for hydrodynamic modeling and alternatives analysis that can be used to identify and advance mutually beneficial large scale flood risk reduction and estuarine habitat restoration projects to achieve the Skagit Chinook Recovery Plan 2005 (Recovery Plan) goal. This report summarizes the SDHP process and the deliverables required under the NEP award. The complete deliverables are included as attachments to this report.

SDHP Team

In the fall of 2012, Team members were recruited from the salmon recovery, flood-risk reduction, and agricultural communities. Twenty individuals were invited to participate and over the course of the first few meetings a core group of fourteen team members emerged (Table 1). This core Team worked on the analysis and modeling scope of work throughout the award period. We also had occasional participation from additional staff from NOAA and Skagit County as well as representatives from Seattle City Light and Skagitonians to Preserve Farmland.

Table 1. SDHP Team members and affiliations

Name	**Organization**
Brian Williams (co-chair)	Washington Dept. of Fish and Wildlife
Polly Hicks (co-chair)	NOAA Restoration Center
Brandon Roozen	Western Washington Agricultural Association
Bob Barnard	Washington Dept. of Fish and Wildlife
Bob Warinner	Washington Dept. of Fish and Wildlife
Dan Berentson	Skagit County
Daryl Hamburg	Dike District #17/Dike District Partnership
Dave Olsen	Dike District #3
Eric Grossman	USGS
Jenny Baker	The Nature Conservancy
Kara Symonds	Skagit County
Kris Knight	The Nature Conservancy
Stan Nelson	Dike and Drainage District #22
Tom Slocum	Skagit Conservation District

Because the Team was comprised of a diverse group of individuals from different backgrounds, we conducted a series of meetings where presentations were given on salmon recovery; flood-risk reduction and the Skagit Flood General Investigation (GI); agricultural needs including drainage and irrigation; and climate change predictions and their impacts for the Skagit Watershed. These presentations enabled the team members to have a shared understanding of the different stakeholder interests as we developed our work products.

Goal and Objectives
As a first step in our process, the Team developed the following project specific goal that worked for all members.

> *Using alternative analysis, develop a suite of projects that are well supported to achieve long-term viability of Chinook salmon tidal delta habitat and community flood risk reduction in a manner that protects and enhances agriculture and drainage.*

The Team decided to follow a Logic Framework Approach for developing the scope of work for the hydrodynamic model and for developing the alternative analysis. Originally created for international development projects, the Logic Framework Approach is a management tool that helps to guide the design, monitoring and evaluation of projects. The approach requires the identification of general and specific objectives. Each specific objective has an associated measurable indicator that can be used to gauge how a project contributes to the specific objectives, general objectives and larger goal. The Logic Framework Approach provided process structure for our Team and ensured that we were crafting the correct tools to achieve our goal without letting a single interest or perspective drive our scope of work. An overview of how the Logic Framework Approach was adapted for our process is included in Appendix A.

Guided by the Logic Framework Approach, the Team established general objectives, specific objectives and measurable indicators for each interest – Farm, Fish and Floods (Appendix B). The general objectives, specific objectives and indicators were developed by representatives within a particular interest group and then shared and modified with input from the larger Team to ensure that all of the team members understood and supported the objectives and their indicators. During this process the Team also identified the means to estimate or measure the indicators as well as critical assumptions about the estimates or measurements that need to be considered. The completed tables of general objectives, specific objectives, indicators, means of estimation and assumptions for the fish, farm and flood interests is included in Appendix B.

The draft goal, general objectives, specific objectives, indicators, means of estimation and assumptions were then vetted with the larger Skagit Delta community and trustees in the summer of 2013. No comments were received. Since that time, the Team decided to remove the specific drainage objective and indicator from the farm objectives. Though we recognize that drainage is very important to the agricultural community, we were unable to identify a measurable indicator for the specific drainage objective. The Team will continue to work with Eric Grossman at USGS to try and identify a measurable drainage indicator in the next phase. The Team also agreed that all future restoration projects should have a drainage analysis incorporated into their designs process to ensure that projects are maintaining the existing drainage capacity of agricultural lands in proximity to the restoration projects. After the objectives were reviewed, WWAA introduced an additional specific objective, which was to minimize the conversion of protected farmland parcels.

Study Area and Project Identification

The SHDP study area was originally identified as the areas of dike districts 1, 3, 9 and 22. This study area was distributed for community input at the same time as the draft goals and objectives noted above. Per the recommendation of the Skagit River System Cooperative (SRSC), the study area was extended north to Highway 20 in order to increase the potential for flood and salmon benefits (Figure 1 and Appendix C).

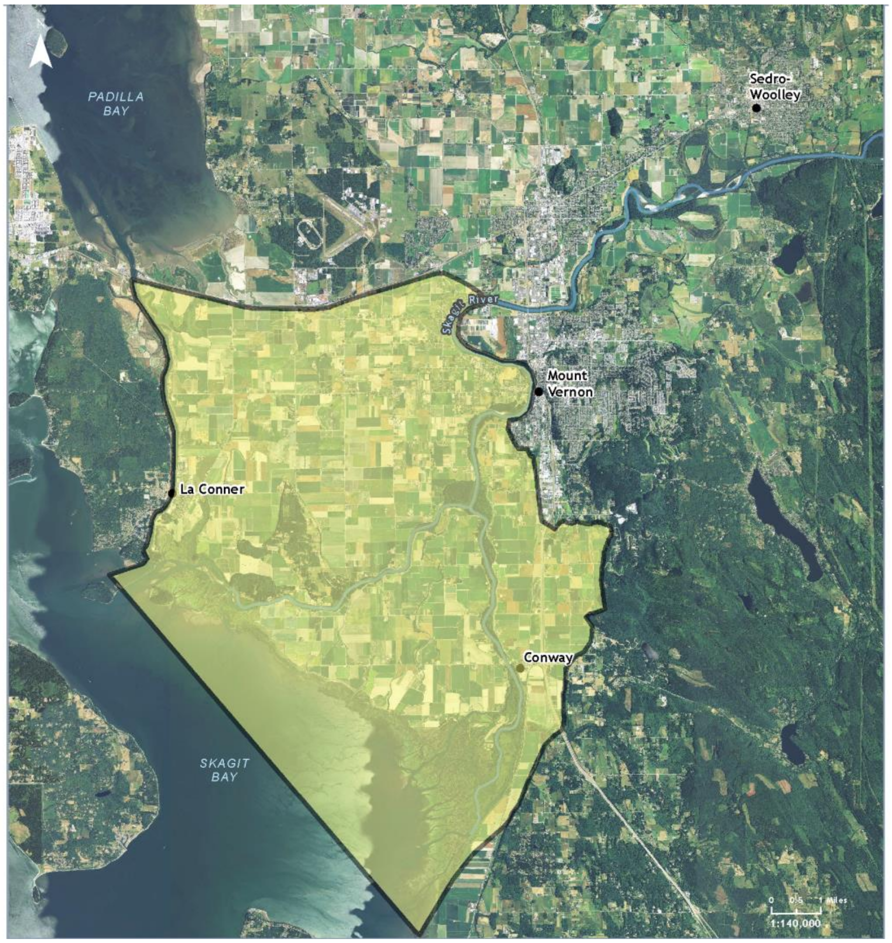


Figure 1. Study Area for SDHP. Study area is shaded in yellow.

The Team compiled all of the existing and proposed habitat restoration projects from the Recovery Plan as well as the proposed flood risk reduction projects from the Skagit Flood General Investigation (Skagit GI) within the study area. It should be noted that the project polygons from the Recovery Plan displayed in Appendix C were drawn by Washington Department of Fish and Wildlife (WDFW) and have some discrepancies with the original polygons from the Recovery Plan. The Team is continuing to work with SRSC to obtain and use the original polygons to ensure consistency with the Recovery Plan. For Recovery Plan projects that have subsequently been adjusted through project feasibility and design processes, such as Fir Island Farm and Cottonwood Island, updated polygons were used to reflect the current version of these projects.

As the Skagit GI progressed and the alternatives considered by the County were refined or eliminated, the list of proposed flood risk reduction projects within the study area was adjusted to reflect the current state of the Skagit GI. Only one project still under consideration in the Skagit GI process is within the study area – Swinomish Bypass, also known as the Avon Bypass. The focus of the Skagit GI is solely on flood-risk reduction for the larger Skagit watershed and for actions that achieve a specific cost-to-benefit ratio. Benefits to other interests are not considered during the calculation of the cost-to-benefit ratio. Agricultural lands and their associated infrastructure do not meet the Army Corps of Engineer's threshold cost-to-benefit ratio and therefore, are not a focus of the Skagit GI. At the local level there is a desire to provide improved flood-risk reduction to the agricultural lands and infrastructure within the study area. The SHDM Project focus for providing flood-risk reduction to this area of the agricultural landscape is seen as an unmet need of importance.

The Team identified eleven new or expanded project concepts within the study area that have the potential to benefit more than one interest. To inform this effort, Daryl Hamburg and Kara Symonds worked with the local diking districts to identify sections of river dikes where there are known weaknesses including seepage, scour or boils. This information was digitalized by the County's GIS staff and added to a map of historic dike breaches for use in this process as well as in other flood-risk reduction efforts. Kara Symonds also worked with Stan Nelson to map known sites where existing marine dikes are overtopped during high tides and winter storms. The Team reviewed the restoration projects identified in the Corps 2002 Skagit River Flood Mitigation Study and new restoration projects in the delta where feasibility studies are proposed or ongoing. Some of the eleven new projects expand the footprint of existing project concepts in order to increase the potential for multiple benefits while others are new stand-alone projects. For several projects, the former Skagit GI alternative known as the levee setback option was used to help identify potential inland boundaries for some of the new or expanded projects.

Maps of the known river dike weaknesses, Recovery Plan projects, Skagit GI projects, new and expanded project concepts in the study area are included in Appendix C. Descriptions for all of the projects are also included in Appendix C though it should be noted that the project numbering for the descriptions correspond to the project numbering in the Alternative Analysis tool and not the maps.

The Team recognizes that the projects presented on the maps in Appendix C are concepts and that the project boundaries are conceptual. Though the Team recognizes that not all projects will be necessary to achieve our stated goals, in the interest of increasing the potential to identify projects that maximize benefits across the farms, fish and flood interests, a comprehensive list of projects is included.

Alternative Analysis

The general objectives, specific objectives and their measurable indicators developed earlier in the SHDP process became the basis for the Alternative Analysis Tool (Alternative Analysis) developed by the Team. The Alternative Analysis is an analytical tool designed to measure how individual projects or groups of projects contribute to salmon recovery and flood risk reduction while minimizing impacts to agriculture. The Alternative Analysis is included in Appendix D. As a tool, the alternative analysis is sufficiently robust to accommodate changes to the existing specific objectives and indicators, the addition of new specific objectives and indicators and the addition of new projects.

In the Alternative Analysis, each interest category (farms, fish and flood) are equally weighted, thus allowing us to understand how individual project or group of projects contributes to each interest category as well as understand its multiple benefits across categories. The Alternative Analysis was designed to allow individual indicators within an interest category to be weighted so that key indicators contribute more to an interest category's total score. Regardless of whether weighting is used, the total number of points for any interest category remains 100 points. The need for weighting within a specific interest category is something that will be evaluated and discussed in the next phase of this work. Summary tables were developed and linked to the Alternative Analysis table that automatically populate and allow the Team to review how projects are ranked by an individual interest category score or by their multiple benefit score. Using the multiple benefit rankings for the individual or grouped projects in combination with how these projects contribute to the objectives of each interest category, the Team will identify priority multiple benefit projects in the next phase of work. Appendix D includes the Alternative Analysis, a full description of the Alternative Analysis methodology, a detailed description of the indicators and examples of the summary tables.

The Team evaluated the draft Alternative Analysis tool by gathering as much non-modeling data as possible and calculating draft scores. This draft run let us refine the tool; however, it is important to note that without the hydrodynamic modeling data, scores from the alternative analysis are considered very preliminary. In the next phase of work, the Team will obtain the original GIS files for the Recovery Plan projects from SRSC, update the project polygons, and correct the non-modeling data fields. In addition, the Team will work with SRSC to update the Chinook smolt production estimates that are the data inputs for the fish specific objective #3. The original Chinook model did not take into account additional channel development outside of the restoration footprint that occurs in adjacent marshes resulting from increased tidal flow. Therefore, for some projects, the model underestimates the Chinook benefit. In phase 2, we will work with Greg Hood at SRSC to develop a tool for estimating habitat formed in adjacent marshes. This revised channel area estimate will be used for all relevant new project as well as relevant Chinook Recovery Plan projects to produce improved estimates for Chinook benefit. A Scope of Work for these analysis and tool development is included in Appendix E. The Team will also work with USGS to obtain habitat diversity data for the fish specific objective #6.

Modeling Framework

The indicators for four specific objectives in the Alternative Analysis require modeling to calculate the indicator data. These indicators include:

- Change in net area subject to tidal and riverine processes (fish specific objective #1);
- Total number of acre-hours suitable habitat area is inundated (fish specific objective #2);
- Change in local flood stage relative to existing conditions (flood specific objective #1); and
- Predicted levee scour under exiting conditions removed by project actions (flood specific objective #4).

Additionally the Team identified four potentially significant landscape-level effects that could result from implementing a large number of the projects. The landscape-level effects include:

- Changes to the North Fork-South Fork distribution of water flow;
- Changes to the distribution of sediment;
- Changes to salinity mixing zone and location of the salt wedge; and
- Changes to existing habitats.

The Team considered a variety of model types that could be employed to provide data for these indicators ranging from 1-D to 3-D models. It was determined that for some of the indicators and the landscape level effects, a 3-D model would be needed to estimate the data. The approach includes updating the existing Skagit model with current data and efficient modeling through the use of project groupings and an elimination process to identifying causes of landscape-level and local affects. The Team recognized the potential for future predicted climate changes to affect the performance and function of the identified projects and included a modeling phase designed to specifically evaluate these affects. The scope of work for the modeling process is described and illustrated in Appendix E of this report. The estimated budget to implement the modeling process is also included in Appendix E.

Community Stakeholder Outreach

The Team made a concerted effort to solicit community stakeholder input at numerous point in the process. In addition to ongoing coordination between Team members and their respective organizations, strategic community stakeholder outreach was implemented at approximately the midpoint of the process after the SHDM study area, goal, general objectives, specific objectives and indicators were completed and during the later stages of the process when the Alternative Analysis and modeling scope of work were completed. Meetings were convened with representatives from affected diking districts, Skagit Diking District Partnership, and the Skagit Watershed Council. NOAA updated and solicited input from the Swinomish Tribe and SRSC through regular phone calls. Our draft work products were distributed to the appropriate leadership of all 3FI member organizations, Skagit Watershed Council and its Technical Committee, Samish Tribe, Upper Skagit Tribe, the Sauk-Suiattle Tribe and other parties from the various interests. Materials supporting outreach efforts are included in Appendix F. Stakeholder comments and Team responses to stakeholder comments were recorded in the SHDP Comment Tracking Table which is included in Appendix F.

Nest Steps

WDFW, NOAA and TNC are working to secure funds to conduct the modeling work and finish the non-modeling data collection for the alternative analysis. A grant to the Skagit Watershed Council for Salmon Recovery Funding Board funds has been submitted and additional requests will be made to the Floodplains by Design and other funding sources. The Team members will be asked to participate in the next phase when funding for the work is secured. Once the modeling and remaining non-modeling data is collected and input into the Alternative Analysis, the Team will work with the Alternative Analysis to prioritize individual and grouped projects. Based on this prioritization, the SDHP Team intends to conduct feasibility or project development work for one or two high priority projects. To help advance these efforts in a timely manner, the 3FI Oversight Team is working to secure feasibility funds for priority projects identified through this process. The 3FI Oversight Team is also exploring a potential early action restoration and flood-risk reduction project around the North Fork Bridge replacement in combination with preserving agricultural lands outside of that project footprint.

Skagit Delta Hydrodynamic Model Project

APPENDIX A
Logic Framework

SHDM LOGIC FRAMEWORK PROCESS

TASKS	ACTIVITIES	WORK MONTHS
Task 1. Goal	Draft SHDM Goal	January 2013
Task 2. Objectives	Define General Objectives with indicators, data sources and assumptions	February
	Define Specific Project Objectives with indicators, data sources and assumptions	
	Make preliminary list of tools needed to measure the identified indicators for each objectives	
Task 3. Study Area/Baseline	Define study area	April
	Define baseline conditions (presentations, catalogue information). Develop a short description of each interest status (flood, fish and farms).	
	Outreach – Share goals and objectives with Oversight Team and key constituents for feed back	
Task 4. Prelim ID of Projects	Assemble projects and suites of projects that lead to meeting the general and specific objectives from existing lists	May
	Seek out new project ideas	
Task 5. New Project Course Screening	Identify course project screening criteria (look for fatal flaws/qualitative)	June
	Apply course screening criteria to new projects	
	Identify all viable new projects	
Task 6. Develop Projects List	Combine existing and new viable projects into a single list	June
Task 7. Develop Alternative Analysis	Identify detailed evaluation criteria (quantitative). Anticipate that this will be fed, in part, by the indicators for each objective.	July - September
	Complete a preliminary analysis of the projects against the evaluation criteria	
	Identify for which evaluation criteria modeling or other analysis is needed	
	Make final decision on tools needed to complete alternatives analysis	
Task 8. Develop modeling contract	Develop scope of work for project modeling and/or any additional project analysis needed	September - December
	Outreach – Share alternatives analysis and evaluation criteria with Oversight Team and key constituents	January – March 2014
Task 9. Complete modeling	Model viable projects, suites of projects and timing of projects to determine feasibility and estimate outcomes	2015
Task 10. ID Priority Projects	Complete alternatives analysis with additional data from modeling & other analyses	
	Prioritize project or suites of projects based on alternative analysis ranking	

Note: Task 8 is final work product under this contract with TNC.

Skagit Delta Hydrodynamic Model Project

APPENDIX B
Goal, Objectives and Indicators Tables

TASK 1 - HDM GOAL
Using alternative analysis, develop a suite of projects that are well supported to achieve long-term viability of Chinook salmon tidal delta habitat and community flood risk reduction in a manner that protects and enhances agriculture and drainage.

Task 2 - OBJECTIVES

FISH

GENERAL OBJECTIVES	**ASSUMPTIONS**
Restore sufficient estuary habitat in the Skagit River delta to achieve the Skagit Chinook Recovery Plan estuarine goal.	Skagit Chinook Recovery Plan Habitat Relationships (aka Skagit Chinook Model) provides a good estimate of the number of new Chinook smolts produced annually in the Skagit estuary to achieve recovery.

SPECIFIC OBJECTIVES	**INDICATORS**	**MEANS OF ESTIMATION**	**ASSUMPTIONS**
Increase the area subject to natural tidal and riverine processes in the study area.	Total project area with restored tidal and riverine processes.	hydrodynamic model	Model assumptions.
Increase the area of tidal and riverine channels suitable for Chinook rearing fry in the study area.	Total number of acre-hours that suitable* channel habitat is available as predicted by model. *suitable channels have a depth of 20 cm to 2 m with a velocity below 1.3ft/sec. Steady state prediction of channel area and if possible a steady state prediction that incorporates sea level rise	hydrodynamic model – at a minimum a 2-D model is required to be run over a specific time period to capture velocity and depths Greg Hood's Skagit Island Marsh Model	The area of restored channel habitat at project(s) sites can be estimated using GIS and Greg Hood's Island Marsh Model.
Increase Chinook smolt production in the study area.	Number of additional Chinook smolts estimated to be produced	Skagit Chinook Model	Chinook smolt production can be estimated using the Skagit Chinook Model.
Increase landscape connectivity of the	index of connectivity summed across multiple sites in the study area	Landscape connectivity model used	Skagit Recovery Plan assumes that the smolt production increases when connectivity is

study area.		in Chinook Plan	improved.
Enhance valued nearshore habitats that provide rearing habitat and food for Chinook survival success by reducing sediment impacts to eelgrass, tidal flats, and food resources.	Develop a conceptual model to estimate if a projects has a high, medium or low potential for providing increased sediment storage, particularly for coarse sediments.	Conceptual model for sediment and flow dynamic	Sediment storage benefits that result in reduced negative impacts to existing habitats may be temporary in that the areas storing sediment will eventually reach equilibrium or capacity.
Maintain or improve existing diversity of tidal marsh habitat along the historical elevation gradient (i.e. mudflat to riverine tidal)	Diversity metric of habitat types or variance in elevation gradients (high, medium low)	Hydromodel and GIS analysis of DEM (digital elevation model) to categorize expected habitats based on inundation levels. Hood's model predicting vegetation communities	DEM are accurate for the analysis. Higher diversity of habitats buffers against climate change impacts and provides a greater likelihood of capturing the most valuable habitats for Chinook. If sea level rise and summer low flows result in marsh recession, than to maintain habitat diversity projects will need to be placed to allow habitat to shift in space.

TASK 1 – HDM GOAL

HDM GOAL: Using alternative analysis, develop a suite of projects that are well supported to achieve long-term viability of Chinook salmon tidal delta habitat and community flood risk reduction in a manner that protects and enhances agriculture and drainage.

Task 2 - OBJECTIVES

FLOOD

GENERAL OBJECTIVES	ASSUMPTIONS
Reduce flood damages and risks to life safety.	Individual projects will meet specific objectives.

SPECIFIC OBJECTIVES	INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
Reduce water surface elevation within study area	Flood stage relative to existing conditions	Model estimates for water surface elevation (WSE) USGS Gauge Readings	Reducing WSE reduces flood damages Can tie results back to MV gauge Sediment dynamics play a key role in transport capacity
Reduce risk of levee failure by constructing newly proposed levees with a uniform engineering design that reduces known flood risk and/or probable levee failure.	Liner Feet of replaced or relocated levee in known risk locations Weak spot addressed	GIS analysis. Areas that pose risk identified from research, institutional knowledge of weak spots, levee failure map, historic Corps levee repair documentation	Engineered levee design reduces failures as compared to existing conditions, addresses levee failure types e.g. Under Seepage, Riverside or Landside Static Slope Failure, Riverside or Landside Seismic Slope Failure, Riverside Rotational Failure due to Rapid Draw Down, Rotational Failure due to Extended High River Levels, Liquefaction, Through Seepage, Scour, Sequential Failure.
Reduce risk of unplanned levee overtopping	Linear feet of replaced or relocated levee/sea dike in potential overtopping locations	GIS analysis. Areas that pose risk identified from research, institutional knowledge of weak spots, LiDAR,levee failure map, historical Corps levee repair documentation	Engineered levee design reduces failures, as compared to existing conditions, addresses overtopping issues.
Reduce risk associated with scour locations	Removes a known scour site or sour sites predicted by model	GIS analysis with data from model and institutional knowledge of weak spots; GI Sediment reports; USGS Bathymetry; Corps/County cross sections; historic Corps levee repair documentation.	Majority of repairs are scour related Compare relative to existing conditions
Improve Agriculture Flood Drainage	Site includes a flood flow return site identified by CDD#22 & Skagit County	GIS analysis	Identified locations are the best possible locations for flood return flows.

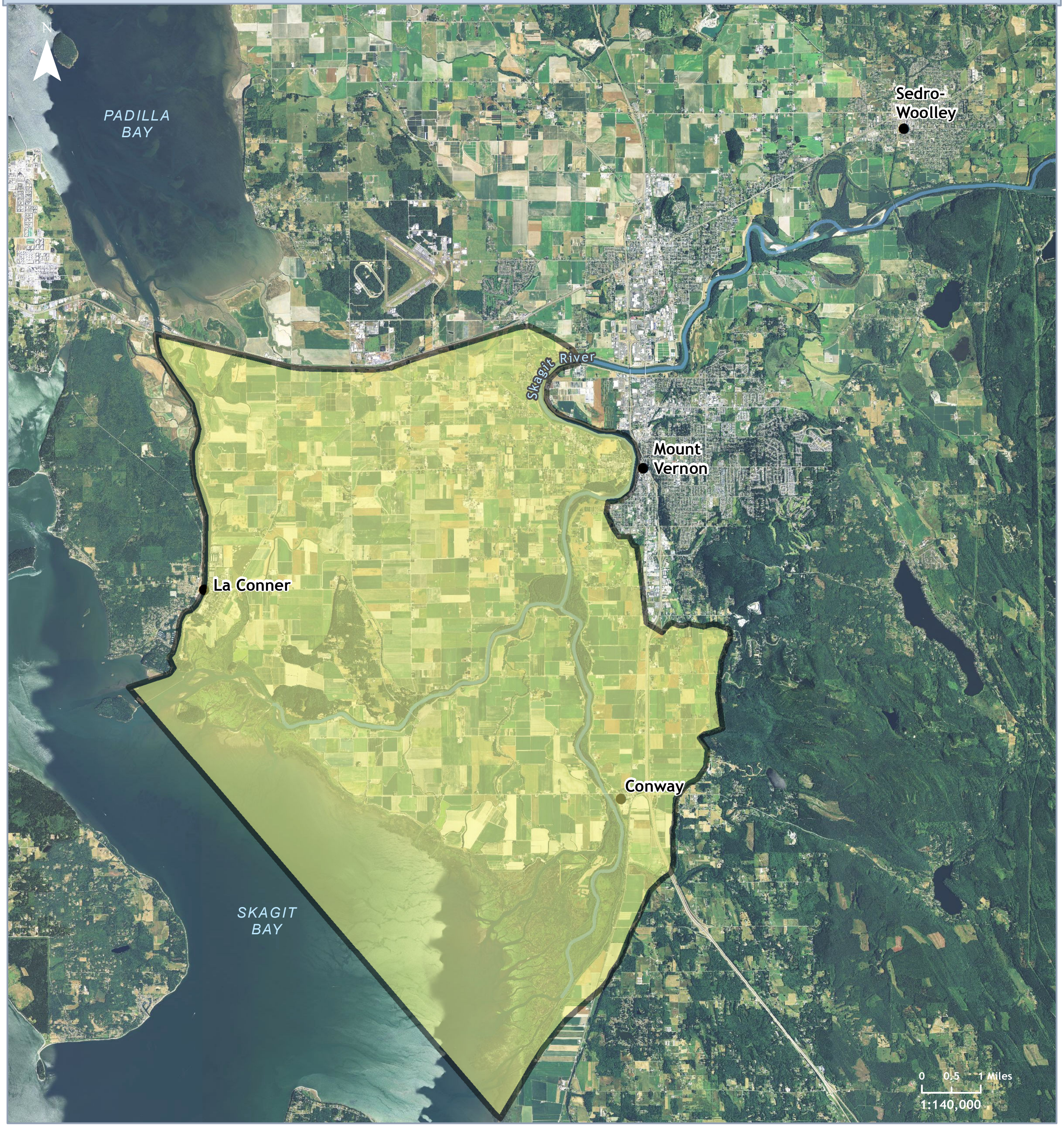
TASK 1 - HDM GOAL			
Using alternative analysis, develop a suite of projects that are well supported to achieve long-term viability of Chinook salmon tidal delta habitat and community flood risk reduction in a manner that protects and enhances agriculture and drainage.			
Task 2 - OBJECTIVES			
FARM			
GENERAL OBJECTIVE		**ASSUMPTIONS**	
Protect the short and long term viability of agriculture in the Skagit delta.		Flood and restoration projects will be designed at the site scale to protect existing agriculture, irrigation and drainage, and to prevent increased soil salinity.	
SPECIFIC OBJECTIVES	**INDICATORS**	**MEANS OF ESTIMATION**	**ASSUMPTIONS**
Minimize the conversion of farmland by maximizing Chinook smolt production per acre of farmland converted by flood and restoration projects.	1. Area of farmland converted by a concept flood or restoration project. 2. The number of Chinook smolts produced by a concept flood or restoration projects per acre of farmland converted by the project.	GIS, Skagit GI, Skagit Chinook Model. GIS, Skagit Chinook Model	The farmland area converted by a concept flood or restoration project can be estimated using GIS. The number of Chinook smolts produced by different concept flood and restoration projects can be estimated using the Skagit Chinook Model.
Support tidgate maintenance through the TFI Implementation Agreement.	Acres of a concept flood or restoration project that supports Chinook smolt production and TFI Implementation Agreement.	GIS, Skagit GI, Skagit Chinook Recovery Plan, Skagit Chinook Model, TFI Implementation Agreement	Acres of concept flood and restoration projects that produce Chinook smolts will result in estuary restoration credits that can be used by the Skagit delta districts participating in TFI Implementation Agreement for tidegate and floodgate maintenance.

			Some concept flood and restoration projects may produce Chinook smolt production and TFI Implementation Agreement without converting farmland.
Restore public land first.	Land ownership associated with concept flood and restoration projects.	GIS, Skagit GI, Skagit Chinook Recovery Plan, Skagit County iMap, Skagit County Parcel ID.	Concept flood and restoration projects on public land are a higher priority for the agriculture community than projects on private land.
Minimize Conversion of Protected Farmland Parcels.	Does the restoration footprint overlap with an existing farmland easement(s).	GIS analyses	Already preserved farmland should be avoided for uses that conflict with the purpose of the easement.

Skagit Delta Hydrodynamic Model Project

APPENDIX C
Maps and Project Descriptions

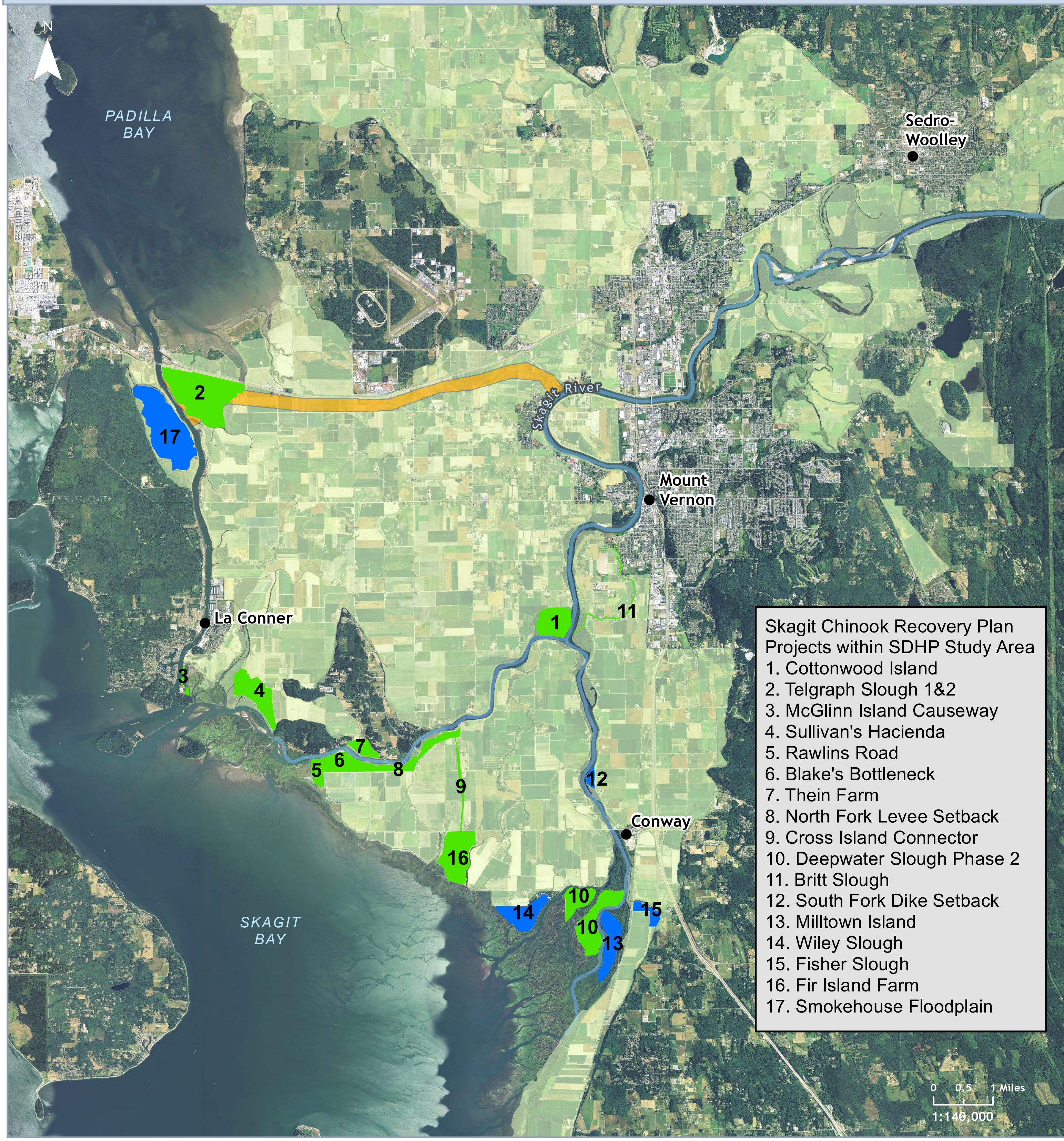
Skagit Delta Hydrodynamic Project Study Area



Skagit Delta Hydrodynamic Project Study Area
Project Study Area outline

Data Sources: Aerial Imagery (2013 NAIP), Project Study Area (NOAA)

Implemented and Proposed Salmon Recovery and Selected Flood Risk Reduction Projects



Land Zoned for Agriculture in Skagit County

Land Zoned for Agriculture

Potential Areas for Flood Protection Projects from Skagit General Investigation (GI)

Project areas associated with GI

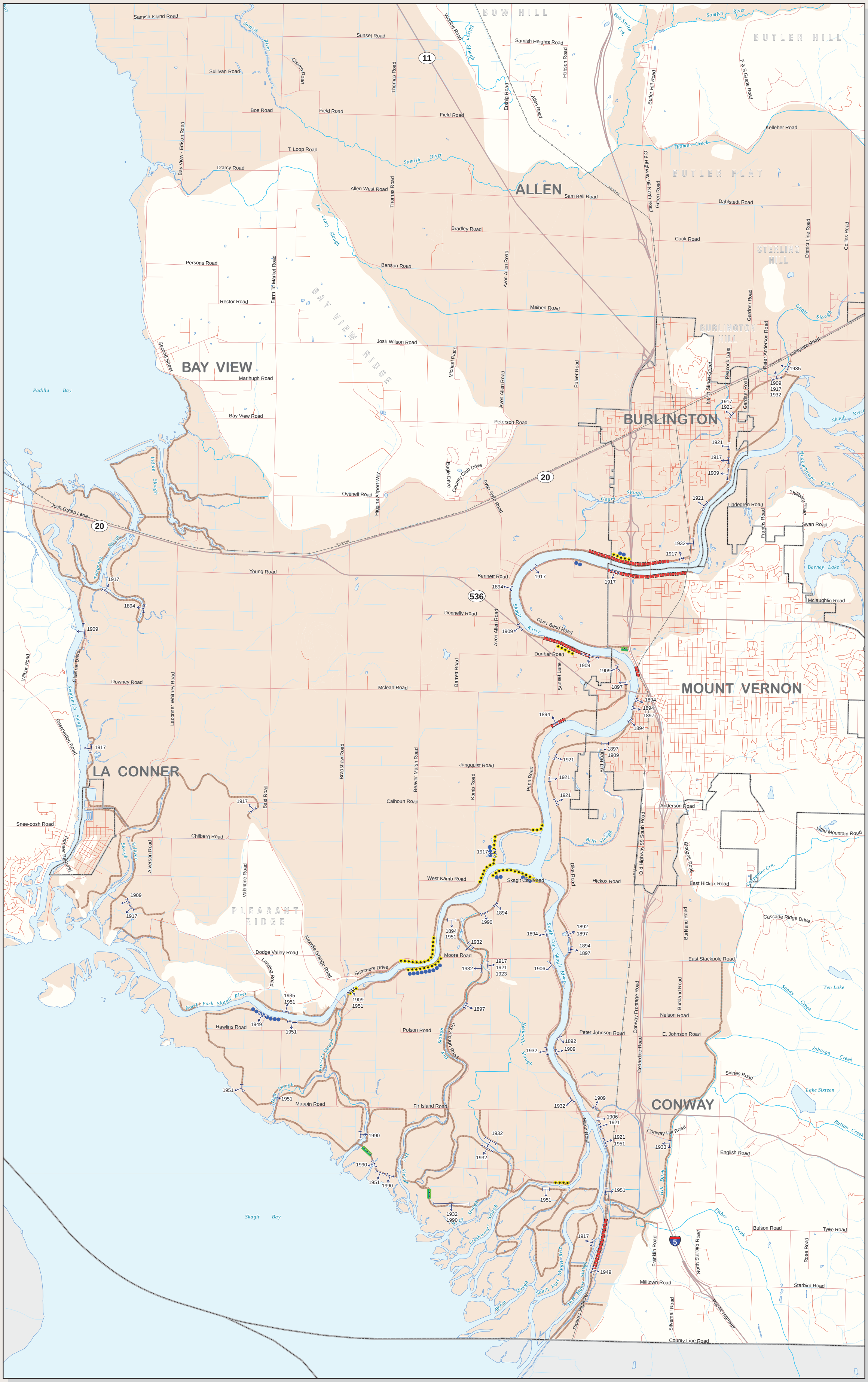
Potential Areas for Fish Restoration

Restoration Areas from the Chinook Recovery Plan as provided by WDFW

Restoration Areas identified by the Chinook Recovery Plan already completed or underway

Data Sources: Aerial Imagery (2011 NAIP), Chinook Recovery Areas (WDFW), Zoned Ag Lands (TNC), Skagit GI Alternatives (Skagit County)

Flood Event Levee Issue Map
Lower Skagit River Basin
Skagit County Washington



Legend

- Boils
- Overtopping
- Repeat Bank Damage Area
- Seepage
- Historic Dike Failure Location and Direction
- Historic Dike Locations
- FEMA Q3 Flood Plain
- Railroads
- Incorporated Areas

DATA SOURCE

Historic dike failures depict locations where known failures of dikes have occurred.
Data Source for dike failure location and year are from "Floods in the Skagit River Basin, Washington",
U.S. Geological Survey, Water Supply #1527, 1961.

Historic dike failures are shown and other failures will likely occur during future events less than a 100 year flood. These failures will result in inundation of flood plain areas.

Isolated (non flooded) areas will occur during the 100 year flood, but generally speaking, the entire flood plain shown will be inundated.

100 YEAR FLOOD

The large flood depicted on this map is basically the FEMA mapped 100 year flood. This flood would have approximately a 1% chance of occurring on any given year.

Some FEMA mapped areas within the 500 year flood have been included within the flood plain shown.

If such a flood were to occur, many hundreds of homes would be flooded, thousands of people may have to be evacuated, and numerous public facilities and businesses would be inundated.
In some neighborhoods flood waters would be deep and currents swift. Many roads would become impassable and extremely dangerous to use.

Under extreme conditions a flood greater than the 100 year flood can occur.

Q3 Data Source:

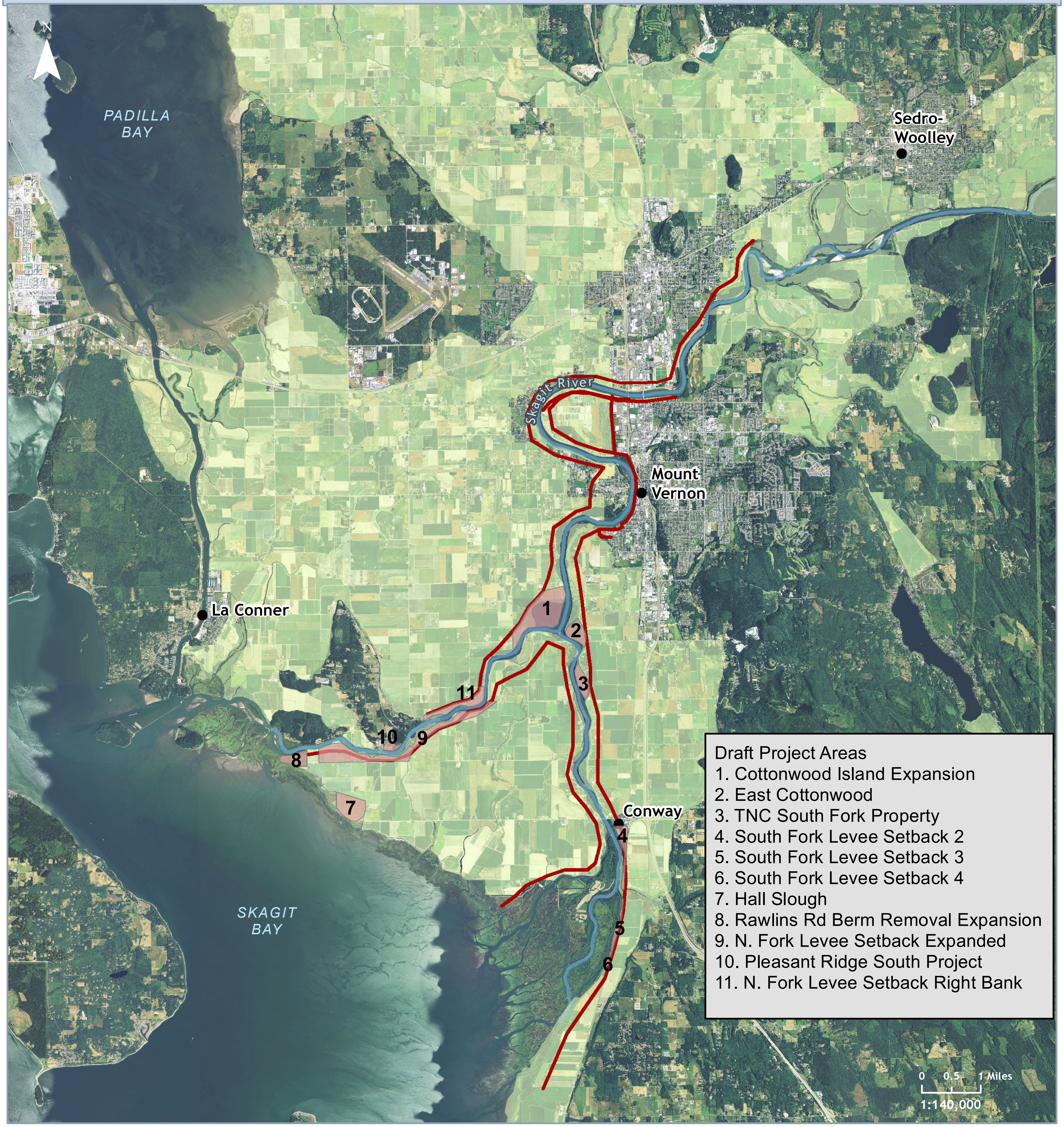
In its continuing efforts to perform hazards mitigation and to improve customer service by expanding the availability of flood risk data, the Federal Emergency Management Agency (FEMA) has released the Q3 Flood Data product. Designed to support FEMA's Response and Recovery activities and flood insurance policy marketing initiatives, Q3 Flood Data will be used in floodplain management, hazards analysis, and risk assessment activities. The product contains a subset of information derived from paper Flood Insurance Rate Maps (FIRMs). While the digital data were developed to support floodplain management activities, they do not replace the paper FIRMs

Note: Map dataset was developed in 1996 by the U.S. Army Corps of Engineers and Skagit County Officials. For further information contact Skagit County Public Works, Surface Water Management Division.

Map Produced by Skagit County GIS
July 2, 2013

0 0.5 1
Miles

New and Expanded Project Concepts



Land Zoned for Agriculture in Skagit County

Land Zoned for Agriculture

Potential Areas for Flood Protection Projects from Skagit General Investigation (GI)

Former levee setback alternatives from GI; not proposed as a project but shown for informational purposes

Potential Project Areas -DRAFT

Hypothetical project areas for salmon recovery and flood risk reduction (not to scale)

Data Sources: Aerial Imagery (2013 NAIP), Zoned Ag Lands (TNC), Skagit GI Alternatives (Skagit County), Fish/Flood Project Areas (NOAA)

Project Summaries

1. North Fork Dike Setback – Full

Project Type:	*Existing Chinook Plan Project*
Project Status:	*No progress*
Location:	*From former inlet of Dry Slough to western terminus of the levee system near Rawlins Road. Awaiting GIS file for exact location and expanse.*
Area:	*658 acres*
Ownership:	*Assumed Private*
Land use:	*Assumed Agriculture, Residential, Commercial*
Project Description:	*Refer to Skagit Chinook Recovery Plan page 191.*

2. North Fork Dike Setback – Phase 1

Project Type:	*Existing Chinook Plan Project*
Project Status:	*10% Feasibility Study Completed 2011(PSNERP)*
Location:	*The project area includes a corridor landward of existing dike along the left bank of the NF Skagit River extending from the west end of the river dike in the vicinity of Rawlins Road extending upriver to approximately the intersection of Moore Road and Polson Road.*
Area:	*247 acres*
Ownership:	*Private*
Land use:	*Agriculture, Residential, Commercial*
Project Description:	*The project area is landward (south) of the existing dike along the left bank of the NF Skagit River. The project area includes farmland, residences, outbuilding and a commercial campground/boat launch. The project concept relocates the existing river dike to the south. The project concept will expand the river flood plain, replace the existing dike with an engineered dike and may provide local flood relief. The project concept will restore tidally inundated scrub-shrub, forested wetland habitats, and channel habitat beneficial to Chinook recovery.*

3. Fir Island Cross Island Connector

Project Type:	*Existing Chinook Plan Project*
Project Status:	*No progress*
Location:	*Project includes a corridor through the central area of Fir Island extending from approximately the vicinity of the Moore Road and Polson Road intersection in southwest direction across the island to approximately the vicinity of WDFW's Fir Island Farm (Snow Goose Reserve).*
Area:	*472 acres*
Ownership:	*Private*
Land use:	*Agriculture, Residential*
Project Description:	*The project area is landward of the NF Skagit River dike and the Skagit Bay dike. The project area is predominantly farmland though could include residences and outbuildings. Project concept constructs a new*

distributary channel between the NF Skagit River and the central area of Fir Island along Skagit Bay. The new distributary channel is anticipated to improve the connectivity between the NF Skagit River and Skagit Bay increasing the sediment transported to and deposited in the central area of Fir Island along Skagit Bay. The new distributary channel is expected to provide localized flood relief in the NF Skagit River. The new distributary channel is expected to provide improve juvenile salmon access to the estuary habitats in the central area of Fir Island along Skagit Bay.

4. <u>Rawlins Road</u>

Project Type:	*Existing Chinook Plan Project*
Project Status:	*Feasibility Study Completed 2006*
Location:	*The project site is located along the left bank NF Skagit River and Skagit Bay in the vanity of the west end of Rawlins Road.*
Area:	*53 acres*
Ownership:	*Private and Washington Department of Fish and Wildlife*
Land use:	*Agriculture, Natural*
Site Description:	*The west side of the project site is on the bay side of the existing marine flood dike and is open to the tidal process of Skagit Bay. The west side of the project site is dominated by tidal marsh and tidal channel habitats typical of the Skagit Bay estuary. The only infrastructure on the west side of the project site includes two manmade ditches that were excavated for the purpose of constructing the marine dike and operating the Rawlins Road tidegate. The east side of the project site is farmland. There are no residents or out buildings at the east side of the project site. A number of restoration concepts have been considered for the site. The most aggressive concept considered constructs a new engineered marine dike along the east site boundary. The project concept is expected to establish a new distributary channel from the NF towards the Hall Slough. The project concept is anticipated to provide localized flood relief in the NF Skagit River. The project concept will restore tidal processes, tidal marsh and tidal channels to the farmland half of the site that would be beneficial to Chinook recovery.*

5. <u>Deepwater Slough Phase 2</u>

Project Type:	*Existing Chinook Plan Project*
Project Status:	*10% Feasibility Study Completed 2011(PSNERP)*
Location:	*The project site includes two adjacent islands located in the SF Skagit River delta. The west island is bounded by Freshwater Slough and Deepwater Slough. The east island is bounded by Deepwater Slough, Steamboat Slough and Tom Moore Slough. The project site is located due east of the boat ramp at WDFW Headquarters on Fir Island.*
Area:	*268 acres*
Ownership:	*Washington Department of Fish and Wildlife*

Land use: *Agriculture*

Project Description: *The project areas are surrounded by dikes. The only infrastructure at the project site is a steel bridge across Deepwater Slough connecting the two island units. The project concept will restore tidal and riverine process to the islands by removing the existing flood dikes and the bridge. The project is expected to expand the river flood plain and provide localized flood relief in the SF Skagit River. The project is expected to restore tidal marsh and channel habitats beneficial to Chinook recovery.*

6. <u>Thein Farm</u>

Project Type: *Existing Chinook Plan Project*

Project Status: *No progress*

Location: *The project site is located along the right bank of the Skagit River downstream of the Best Road Bridge in the vicinity of Landing Road.*

Area: *59 acres*

Ownership: *Private*

Land use: *Agriculture*

Project Description: *The project site is landward of the dike along the right bank of the NF Skagit River. The project site is farmland and there are no residences or outbuildings at the site. The project concept is to restore riverine and tidal process to the site by relocating the river dike to the north along the base of Pleasant Ridge and along Landing Road. The project will replace the existing river dike with an engineered dike and will expand the flood plain of the NF Skagit River. The project is expected to restore tidal marsh and channel habitats beneficial to Chinook salmon recovery.*

7. <u>Sullivan Hacienda</u>

Project Type: *Existing Chinook Plan Project*

Project Status: *No progress*

Location: *The project site is located along the east shoreline of Sullivan Slough, along the right bank of the NF Skagit River and south of Staffanson Lane.*

Area: *200 acres*

Ownership: *Private*

Land use: *Agriculture*

Project Description: *The project site is landward of the dike along the right bank of the NF Skagit River. The project site is farmland and there are no residences or outbuildings at the site. The project concept is to restore riverine and tidal process to the site by relocating the river dike to the north and east. The project will replace the existing river dike with an engineered dike and will expand the flood plain of the NF Skagit River. The project is expected to restore tidal marsh and channel habitats beneficial to Chinook salmon recovery.*

8. <u>Cottonwood Island</u>

Project Type: *Existing Chinook Plan Project*

Project Status: *Feasibility Study Completed 2007*

Location:	*Cottonwood Island is located along the right bank of the mainstem Skagit River and NF Skagit River northwest of the confluence of the NF and SF Skagit River.*
Area:	*7.4 acres*
Ownership:	*Washington Department of Fish and Wildlife*
Land use:	*Natural*
Project Description:	*The project site is on the river side of the existing flood dike and there are no residences or outbuilding. The project site is dominated by mature trees and shrubs. The project concept will restore riverine flow to a historic distributary channel. The project is expected to provide localized flood relief and restore riverine channel habitat beneficial to Chinook recovery.*

9. <u>Fir Island Farm</u>

Project Type:	*Existing Chinook Plan Project*
Project Status:	*Feasibility Study Completed 2011* *Final Design To Be Completed 2014*
Location:	*Project site is located on Fir Island south of Fir Island Road, west of Dry Slough and east of Brown Slough.*
Area:	*130 acres*
Ownership:	*Washington Department of Fish and Wildlife*
Land use:	*Agriculture, Snow Goose Reserve*
Project Description:	*The project site is located landward of the marine dikes along Skagit Bay. The site is farmland and managed as a Snow Goose Reserve. There are no residents or outbuildings located at the project site. The project will replace the existing overtopping marine dike with an engineered setback dike. The project will maintain the agriculture drainage in Brown Slough, Dry Slough, and No Name Slough through new tidegate and/or pump station infrastructure. The project will restore natural tidal processes, tidal marsh and tidal channel habitats beneficial to Chinook recovery.*

10. <u>Blakes Bottleneck</u>

Project Type:	*Existing Chinook Plan Project*
Project Status:	*No progress*
Location:	*Project site is located along the left bank of the NF Skagit River approximately 1 mile downstream of the Best Road NF Bridge and approximately .25 miles north of Rawlins Road.*
Area:	*18.5 acres*
Ownership:	*Private*
Land use:	*Commercial, Residential*
Project Description:	*The project site is located landward of the dike along the left bank of the NF Skagit River. Project site includes farmland, residences, a commercial trailer park-boat ramp and out building. It is a sub project of the larger NF Dike Setback project (#1) and North Fork Dike Setback Phase 1 (#2).*

The project concept is to relocate the existing flood dike landward to the south. The project is expected to expand the river floodplain, remove a perceived flow constriction in the NF Skagit River channel and replace the existing dike with an engineered dike. The project is expected to restore tidal marsh and channel habitats beneficial to Chinook recovery.

11. McGlinn Causeway

Project Type:	*Existing Chinook Plan Project*
Project Status:	*Feasibility Study Phase 1 Completed* *Feasibility Study Phase 2 Incomplete*
Location:	*The project site is located in the vicinity of the west and north shorelines of McGlinn Island at the south end of the Swinomish Channel.*
Area:	*0*
Ownership:	*Private, Tribal, Federal*
Land use:	*Natural, Commercial, Navigation*
Project Description:	*Project site includes a causeway between LaConner and McGlinn Island that was constructed with dredge spoils from the Swinomish Channel. It also includes a rock jetty that was constructed in 1938 between McGlinn Island and Goat Island to isolate the Swinomish Channel from the NF Skagit River. There is a commercial boat yard at the south end of the causeway. The project concept is to improve the hydraulic connectivity between the NF Skagit River and the Swinomish Channel through strategic modifications to the causeway and rock jetty. The project is expected to improve the migration of salmoids between the NF Skagit River and the Swinomish Channel. The project is expected to improve the habitat conditions in the Swinomish Channel and improve the accessibility of Padilla Bay habitats to NF Skagit salmoinds.*

12. Milltown Island

Project Type:	*Existing Chinook Plan Project*
Project Status:	*Ongoing construction*
Location:	*Milltown Island is located in the SF Skagit River south of Conway and west of Milltown. Milltown Island is located between Tom Moore Slough to the west and Steamboat Slough to the east.*
Area:	*212*
Ownership:	*Washington Department of Fish and Wildlife*
Land use:	*Natural, Recreation*
Project Description:	*The project site is surrounded by partially breached dikes. There are no residences or outbuildings at the project site. The project site primarily consists of abandoned farm fields dominated by reed canary grass, manmade drainage channels, riverine wetlands, and remnant dikes vegetated with mature shrubs and trees. The project concept is to restore channel habitat on the island by strategically breaching the abandoned dike. The project may provide local flood relief in the SF Skagit River.*

The project is expected to restore tidal-riverine wetlands, forests and channels that will be beneficial to Chinook recovery.

13. Telegraph Slough #1

Project Type:	*Existing Chinook Plan Project*
Project Status:	*10% Feasibility Study Completed 2011(PSNERP)*
Location:	*The project site is located along the east shoreline of the Swinomish Channel immediately south of the State Highway 20 Bridge over the Swinomish Channel.*
Area:	*220 acres*
Ownership:	*Private*
Land use:	*Agriculture, Residential.*
Project Description:	*The project site is located landward of the dikes along the east shoreline of the Swinomish Channel. The project site is farmland and includes residences and outbuildings. There may be significant waterline and gas line infrastructure at the site. The project will replace the existing dike along the Swinomish Channel with an engineered setback dike. The project will restore natural tidal processes, tidal marsh and tidal channel habitats beneficial to Chinook recovery.*

14. Telegraph Slough #2

Project Type:	*Existing Chinook Plan Project*
Project Status:	*10% Feasibility Study Completed 2011*
Location:	*Project site is located south of State Highway 20 and due east and adjacent to the Telegraph Slough #1 project site.*
Area:	*265 acres*
Ownership:	*Private*
Land use:	*Agriculture*
Project Description:	*The project site is located landward of the dikes along the east shoreline of the Swinomish Channel. The project site is farmland and includes residences and outbuildings. There may be significant waterline and gas line infrastructure at the site. The project will replace the existing dike along the Swinomish Channel with an engineered setback dike. The project will restore natural tidal processes, tidal marsh and tidal channel habitats beneficial to Chinook recovery. Project is contingent on Telegraph Slough Pahe 1 being implemented.*

15. Limited Swinomish Channel Bypass - Dry

Project Type:	*Skagit County Flood GI Project*
Project Status:	*New*
Location:	*The project is a corridor approximately parallel to State Highway 20 from approximately from RM 15.9 downstream of the City of Burlington to the*

Swinomish Channel south of the State Highway 20 Swinomish Channel Bridge.

Area: *885 acres (bypass channel)*
Ownership: *Private*
Land use: *Agriculture, Residential, Commercial*
Project Description: *The project consists of a 1000 foot wide bypass channel extending from down river of Burlington at RM 15.9 in a westerly direction parallel with State Highway 20 for 7.3 miles to the Swinomish Channel south of the State Highway 20 Swinomish Channel Bridge. The bypass corridor includes farmland, residences and commercial buildings. The corridor is expected to only bypass flood flows from the Skagit River and would not support a perennial flow. The bypass is expected to provide localized flood relief. The bypass is expected to have very limited value for Chinook recovery.*

16. <u>North Fork Dike Setback – Right Bank</u>

Project Type: *New*
Project Status: *New*
Location: *The project site includes an area along the right bank of the NF Skagit River along Summers-Beavermarsh Road from the east toe of Pleasant Ridge in an easterly direction to approximately .25 miles northeast of where Summers-Beavermarsh Road turns sharply north.*
Area: *50 acres*
Ownership: *Private*
Land use: *Agriculture, Agriculture Out Buildings, Single Family Residences, County Road*
Project Description: *The project area is landward of the dikes along the right bank of the NF Skagit River and is dominated by farmland, farm related out buildings, and single family residences. The project concept is to relocate the existing flood dike landward. The project is expected to expand the river flood plain and replace the existing at risk dike with an engineered flood dike. The project is expected to restore wetland, shrub, forest and channel habitats beneficial to Chinook recovery.*

17. <u>South Fork Dike Setback #2</u>

Project Type: *New*
Project Status: *New*
Location: *The project site is located along the left bank of the SF Skagit River. It is located immediately south of and abutting the pole yard in the Town of Conway. It is located between the river flood dike to the west and the BNSF rail lines to the east.*
Area: *50 acres*
Ownership: *Private*
Land use: *Agriculture and forestry*

Project Description: *The project site is located landward of the dikes along the left bank of the SF Skagit River. The site is triangular in shape with the narrow point of the triangle to the south. The north half of the site is dominated by mature trees and shrubs. The south half of the site is being used for agriculture purposes. There are no residences or out building on the site. The project concept is to expand the flood plain area of the river by relocating the existing flood dike to the east. The existing flood dike replaced with an engineered dike. The project is expected to restore wetland, shrub, forest and channel habitats beneficial to Chinook recovery.*

18. <u>South Fork Dike Setback #3</u>

Project Type: *New*
Project Status: *New*
Location: The s*ite is along the left bank of the SF Skagit River. It is located immediately south of and abutting the South Fork Dike Setback project #2 described above. It is located between the river flood dike to the west and the BNSF rail lines to the east.*
Area: *23.5*
Ownership: *Private*
Land use: *Natural*
Project Description: *The project site is located landward of the dikes along the left bank of the SF Skagit River.* T*he site is long and narrow. The site is dominated by wetlands, shrub and mature trees. There are no residences or out building on the site. The project concept is to expand the flood plain area of the river by relocating the existing flood dike to the east. The existing flood dike replaced with an engineered dike. The project is expected to restore wetland, shrub, forest and channel habitats beneficial to Chinook recovery.*

19. <u>South Fork Dike Setback #4</u>

Project Type: *New*
Project Status: *New*
Location: *The site is along the left bank of the SF Skagit River. It is located y south of the South Fork Dike Setback project #3 described above and south of the WDFW's Milltown boat ramp. It is located between the river flood dike to the west and the BNSF rail lines to the east.*
Area: *4.5 acres*
Ownership: *Private*
Land use: *Natural*
Project Description: *The project site is located landward of the dikes along the left bank of the SF Skagit River. The site is a small wetland site dominated by shrub and trees. There are no residences or out building on the site. The project concept is to expand the flood plain area of the river by relocating the existing flood dike to the east. The existing flood dike replaced with an*

engineered dike. The project is expected to restore wetland, shrub, forest and channel habitats beneficial to Chinook recovery.

20. <u>Cottonwood Island Expansion</u>

Project Type:	*Modified/Expanded Chinook Plan Project*
Project Status:	*New*
Location:	*Project site is approximately located in the area between the intersection of Calhoun Road with the Skagit River, the intersection of Kamb Road with the SF Skagit River and the intersection of Calhoun Road with Kamb Road in the vicinity of Cottonwood Island.*
Area:	*257 acres*
Ownership:	*Washington Department of Fish and Wildlife, Private*
Land use:	*Natural, agriculture, residential, industrial*
Project Description:	*The project site includes the Cottonwood Island (#7) and an area landward of the flood dikes around Cottonwood Island to the northeast and southwest. Cottonwood Island is dominated by mature shrubs and trees. The project area landward of the flood dikes is dominated by farmland, farm related out buildings, and single family residences. The project concept is to expand the Cottonwood Island project (#7) by relocating the existing flood dike landward. The project is expected to expand the river flood plain, restore shrub, forest, wetland and channel habitats beneficial to Chinook recovery and replace the existing at risk dike with an engineered flood dike.*

21. <u>East Cottonwood</u>

Project Type:	*New Project*
Project Status:	*Feasibility Study In Progress 2013/2014*
Location:	*The project site is located due east and adjacent to the SF-NF Skagit River confluence. It is bounded by the NF-SF Skagit River to the west and the flood dike that parallels Dike Road to the east. The south end of the site is approximately west of the intersection of Dike Road and East Hickox Road.*
Area:	*61 acres*
Ownership:	*Washington Department of Fish and Wildlife*
Land use:	*Natural*
Project Description:	*The site is dominated by mature shrub and tree species. No residents or out buildings are present. A gas pipeline is in the project vicinity. The project concept is to restore distributary and blind channel habitat beneficial to Chinook recovery.*

22. North Fork Dike Setback Expanded

Project Type:	*Modified/Expanded Chinook Plan Project*
Project Status:	*New*

Location: *The project expands the area of the NF Dike Setback Project Phase 1 (#2) by including the area along the left bank of the NF Skagit River between Moore Road and Polson Road.*
Area: *291 acres*
Ownership: *Private*
Land use: *Farming and Residential*
Project Description: *The project concept expands the NF Dike Setback Project #1 by extending the length of dike that is relocated to the south to include the dike reach between Moore Road and Polson Road. The project concept is expected to expand the river flood plain, restore shrub, forest, wetland and side channel habitats beneficial to Chinook recovery and replace the existing at risk dikes with an engineered flood dike.*

23. <u>Geyer Property</u>

Project Type: *New*
Project Status: *Feasibility Study Completed 2009*
Location: *Site is along the left bank of the SF Skagit River adjacent to Dike Road and immediately north of West Stackpole Road. The site is located between the SF Skagit River and the flood dike parallel to and west of Dike Road.*
Area: *56 acres*
Ownership: *The Nature Conservancy*
Land use: *Natural*
Project Description: *The project site is on the river side of the existing flood dike. The site is dominated by mature shrub and tree species. No residents or out buildings are present. The project concept is to restore distributary and/or blind channel habitats at the project site that are beneficial to Chinook recovery.*

24. <u>Hall Slough</u>

Project Type: *New*
Project Status: *New*
Location: *The project site is located on Fir Island northwest of the intersection of Fir Island Road and Maupin Road.*
Area: *110 acres*
Ownership: *Private*
Land use: *Agriculture*
Project Description: *The project site is active farm land. There are no residences or out buildings at the site. The project concept is to restore the tidal process of Skagit Bay to the site by relocating the existing flood dike to the north and east. The project is expected to restore tidal marsh and tidal channel habitats beneficial to Chinook recovery. The project could enhance the gravity drainage through the Halls Slough tidegates by allowing the drift*

log accumulation in front of the tidegate to be naturally displaced further north.

25. Pleasant Ridge South

Project Type: *New*
Project Status: *New*
Location: *The project site is located along the right bank of the NF Skagit River approximately .25 miles downstream of the Best Road bridge across the NF Skagit River*.
Area: *27 acres*
Ownership: *Private*
Land use: *Agriculture*
Project Description: *The project site is landward of the dike along the right bank of the NF Skagit River. The majority of the project site is surrounded to the east, north and west by an elevated ridge. The project site is farmland and there are no residences or outbuildings at the site. The project concept is to restore riverine and tidal process to the site by removing the river dike and constructing a new engineered dike along the toe of Pleasant Ridge where needed. The project will expand the flood plain of the NF Skagit River. The project is expected to restore tidal marsh and channel habitats beneficial to Chinook salmon recovery.*

26. <u>Rawlins Road Berm Removal</u>

Project Type: *New*
Project Status: *New*
Location: *Left bank NF Skagit River and west from the end of Rawlins Road.*
Area: *57 acres*
Ownership: *Washington Department of Fish and Wildlife*
Land use: *Natural, Recreation*
Project Description: *The project site is along the left bank of the NF Skagit River immediately downstream of the E-W NF Skagit River flood dike intersection with the N-S Fir Island marine flood dike. The project site is on the bay side of the existing N-W Fir Island marine dike. The project site is* dominated by native *tidal marsh and tidal channel habitats typical of the Skagit Bay estuary. There are also manmade channels at the project site associated with historic dike construction and drainage infrastructure. An elevated berm along the left bank of the NF Skagit River down river of the flood dikes is vegetated with mature shrubs and trees. The origin of the elevated berm is unknown and needs to be investigated. The project concept is to lower sections of this berm to promote the development of distributary channels from the NF Skagit River to the south that would be beneficial to Chinook recovery and potentially provide localized flood relief.*

Skagit Delta Hydrodynamic Model Project

APPENDIX D
Alternative Analysis

12/9/2013

SKAGIT DELTA HYDRODYNAMIC MODEL PROJECT - DRAFT ALTERNATIVE ANALYSIS

OBJECTIVES	INDICATORS	Project 1		Project 2		Project 3		Project 4		BASIS FOR NORMALIZED SCORES		Weighting of Indicators within an "F"
FISH												
Restore Sufficient Estuary Habitat to Produce 1.35 Million Smolts		Data	Score	Data	Score	Data	Score	Data	Score	Maximum	Minimum	**Points (weighted)**
1. Increase Area Subject to Natural Tidal and Riverine Processes.	Total project area with restored processes											14.29
2. Increase Area of Tidal and Riverine Channels Suitable To Chinook Rearing Fry.	Total number of acre-hours suitable habitat predicted											14.29
	Steady state predictions of channel area											14.29
3. Increase Chinook Smolt Production	Estimated new smolts produced annually											14.29
4. Increase the Landscape Connectivity	Index of connectivity summed across study area											14.29
5. Enhance Valued Nearshore Rearing Habitats By Reducing Sediment Impacts.	H,M,L potential for increased sediment storage											14.29
6. Maintain and/or Improve Diversity of Tidal Marsh Habitats.	Diveristy metric of habitat types across elevation gradient											14.29
Total Score												
Rank												**100**
FLOOD												
Reduce Flood Damages and Risks to Safety		Data	Score	Data	Score	Data	Score	Data	Score	Maximum	Minimum	**Points (weighted)**
1. Reduce Water Surface Elevation Within the Study Area.	Flood stage relative to existing conditions											20
2. Reduce Risk of Levee Failure By Constructing New Engineered Levees.	Linear feet of replaced or relocated levee in known risk locations											20
3. Reduce Risk of Unplanned Levee Overtopping.	Replaced or relocated levee/sea dike in potential overtopping locations											20
4. Reduce Risk Of Levee Failure Associated with Scour Locations.	Includes a known scour site or site predicted by model											20
5. Improve Agriculture Flood Drainage	Site includes a flood flow return site identified by CDD#22 & Skagit County											20
Total Score												
Rank												**100**
FARM												
Protect Short and Long Term Viability of Agriculture		Data	Score	Data	Score	Data	Score	Data	Score	Maximum	Minimum	**Points (weighted)**
1. Minimize Conversion of Farmland By Maximizing Smolts Per Acre Restored.	Acres of converted farmland											20
2. Minimize Conversion of Farmland By Maximizing Smolts Per Acre Restored.	Predicted smolts/acre of converted farmland - Fish3/Farm1											20
3. Support Tidegate Maintenance Through the TFI Implementation Agreement.	Restoration acres that support TFI credits											20
4. Restore Public Land First.	Landownership											20
5. Minimize Conversion of Protected Farmland Parcels.	Yes or No whether restoration footprint overlapes esiting farmland easement											20
Total Score												
Rank												**100**
MULTIPLE BENEFITS										Maximum	Minimum	
Multiple Benefit Total Score												
Multiple Benefit Total Score Rank												
Balance Between Benefits (F:F:F or standard deviation)												

Indicators highlighted in blue require additional modeling

Alternative Analysis - Summary Sheet Fish Rank

Project	Fish Rank	Fish Score		Flood Rank	Flood Score	Farm Rank	Farm Score	Total Rank	Total Score	Total stdv
BLAKES BOTTLENECK										
COTTONWOOD ISLAND										
COTTONWOOD ISLAND EXPANSION										
DEEPWATER SLOUGH 2										
DOYLE PROPERTY										
EAST COTTONWOOD										
FIR ISLAND CROSS ISLAND CONNECTOR										
FIR ISLAND FARM (DAVIS/DRY SLOUGH)										
GEYER PROPERTY										
HALL SLOUGH										
LIMITED SWINOMISH CHANNEL BYPASS - DRY										
MCGLINN CAUSEWAY										
MILLTOWN ISLAND										
NF DIKE SETBACK EXPANDED										
NF DIKE SETBACK RT BANK										
NORTH FORK DIKE SET BACK - full										
NORTH FORK DIKE SET BACK - Phase 1										
RAWLINS ROAD										
RAWLINS ROAD BERM REMOVAL										
SF LEVEE SETBACK #2										
SF LEVEE SETBACK #3										
SF LEVEE SETBACK #4										
SULLIVAN HACIENDA										
TELEGRAPH SLOUGH #1										
TELEGRAPH SLOUGH #2										
THEIN FARM										

Alternative Analysis - Summary Sheet Flood Rank

Project	Flood Rank	Flood Score		Fish Rank	Fish Score	Farm Rank	Farm Score	Total Rank	Total Score	Total stdv
BLAKES BOTTLENECK										
COTTONWOOD ISLAND										
COTTONWOOD ISLAND EXPANSION										
DEEPWATER SLOUGH 2										
DOYLE PROPERTY										
EAST COTTONWOOD										
FIR ISLAND CROSS ISLAND CONNECTOR										
FIR ISLAND FARM (DAVIS/DRY SLOUGH)										
GEYER PROPERTY										
HALL SLOUGH										
LIMITED SWINOMISH CHANNEL BYPASS - DRY										
MCGLINN CAUSEWAY										
MILLTOWN ISLAND										
NF DIKE SETBACK EXPANDED										
NF DIKE SETBACK RT BANK										
NORTH FORK DIKE SET BACK - full										
NORTH FORK DIKE SET BACK - Phase 1										
RAWLINS ROAD										
RAWLINS ROAD BERM REMOVAL										
SF LEVEE SETBACK #2										
SF LEVEE SETBACK #3										
SF LEVEE SETBACK #4										
SULLIVAN HACIENDA										
TELEGRAPH SLOUGH #1										
TELEGRAPH SLOUGH #2										
THEIN FARM										

Alternative Analysis - Summary Sheet Farm Rank

Project	Farm Rank	Farm Score		Fish Rank	Fish Score	Flood Rank	Flood Score	Total Rank	Total Score	Total stdv
BLAKES BOTTLENECK										
COTTONWOOD ISLAND										
COTTONWOOD ISLAND EXPANSION										
DEEPWATER SLOUGH 2										
DOYLE PROPERTY										
EAST COTTONWOOD										
FIR ISLAND CROSS ISLAND CONNECTOR										
FIR ISLAND FARM (DAVIS/DRY SLOUGH)										
GEYER PROPERTY										
HALL SLOUGH										
LIMITED SWINOMISH CHANNEL BYPASS - DRY										
MCGLINN CAUSEWAY										
MILLTOWN ISLAND										
NF DIKE SETBACK EXPANDED										
NF DIKE SETBACK RT BANK										
NORTH FORK DIKE SET BACK - full										
NORTH FORK DIKE SET BACK - Phase 1										
RAWLINS ROAD										
RAWLINS ROAD BERM REMOVAL										
SF LEVEE SETBACK #2										
SF LEVEE SETBACK #3										
SF LEVEE SETBACK #4										
SULLIVAN HACIENDA										
TELEGRAPH SLOUGH #1										
TELEGRAPH SLOUGH #2										
THEIN FARM										

Alternative Analysis - Summary Sheet Multiple Benefit Rank

Project	Total Rank	Total Score	Total stdv		Fish Rank	Fish Score	Flood Rank	Flood Score	Farm Rank	Farm Score
BLAKES BOTTLENECK										
COTTONWOOD ISLAND										
COTTONWOOD ISLAND EXPANSION										
DEEPWATER SLOUGH 2										
DOYLE PROPERTY										
EAST COTTONWOOD										
FIR ISLAND CROSS ISLAND CONNECTOR										
FIR ISLAND FARM (DAVIS/DRY SLOUGH)										
GEYER PROPERTY										
HALL SLOUGH										
LIMITED SWINOMISH CHANNEL BYPASS - DRY										
MCGLINN CAUSEWAY										
MILLTOWN ISLAND										
NF DIKE SETBACK EXPANDED										
NF DIKE SETBACK RT BANK										
NORTH FORK DIKE SET BACK - full										
NORTH FORK DIKE SET BACK - Phase 1										
RAWLINS ROAD										
RAWLINS ROAD BERM REMOVAL										
SF LEVEE SETBACK #2										
SF LEVEE SETBACK #3										
SF LEVEE SETBACK #4										
SULLIVAN HACIENDA										
TELEGRAPH SLOUGH #1										
TELEGRAPH SLOUGH #2										
THEIN FARM										

Skagit Delta Hydrodynamic Modeling and Alternative Analysis Methodology

The following method will be used for scoring the evaluation criteria, ranking the alternatives, and developing priority groups.

- Each interest category (Fish, Flood and Farm) has a total maximum score of 100 points.
- Total available points for any project alternative is 300 points (3 category x 100 points each).
- The evaluation criteria (i.e. the indicators) within each interest category are normalized such that the maximum total for any summation set of evaluation criteria is 100 points. If there are seven evaluation criteria assigned to an interest category, then each criterion can have a maximum point total of 14.25 points, which when added together would equal 100 points. If there are five evaluation criteria, then each would have a maximum of 20 points.
- Weighting of indicators within an interest category can occur by adjusting the number of points that the indicator contributes to total category score. For example if a category had five indicators, the first one could be assigned 40 points and the remaining four could all be worth 15 points. If weighting occurs the total potential points for that category must remain 100.
- Normalization of each criterion is performed as follows:
    - For maximize type scores – divide the evaluation criteria output (such as acres or additional smolts) by the maximum output in the category to normalize. Then multiply by 100 points divided by the number of criteria in the prioritization group.
    - For minimize type scores – divide the minimum criteria output total by the alternative criteria output. Then multiply by 100 points divided by the number of criteria in the prioritization group.
    - For the objective "Minimize Conversion of Farmland By Maximizing Smolts Per Acre Restored", if a project required no farmland to be converted for its implementation the maximum point value of 20 was given to the two evaluation criteria for this objective.
- Ranking is performed using the following approach.
    - A simple average rank score is calculated for each project based on 1) the total scores for an individual prioritization category and 2) total scores summed across the three interest categories (Multiple-Benefit Score). If two or more projects have the same score, an average rank was calculated.
    - A standard deviation is calculated for a project's total score (Multiple Benefit Score) in each interest category. The higher the standard deviation the larger the discrepancy between the scores for each category.

SHDM ALTERNATIVE ANALYSIS
EXPLANATION of INDICATORS and MEANS of ESTIMATION

FISH INDICATORS

1. **Total area with restored processes** – The total net gain of acres within the study area with restored tidal and/or riverine processes. Individual or large suites of projects have the potential to restore processes at the local scale (i.e. within the footprint of the project) as well as to impact the hydrologic connectivity of existing marsh lands due to changes in flow patterns. To calculate the total acres across the study area subject to natural tidal and riverine inundation, hydraulic modeling will be used to calculate the effect of a project(s) over the entire study area.
2. **Total number of acre-hours suitable habitat is predicted** – Juvenile salmon can only use channels that have a water depth ranging from 20 cm to 2 m with a velocity below 1.3ft/sec. Because the Skagit delta is a tidal system, the total acres of suitable channel habitat available for juveniles will fluctuate throughout the course of the two-week tidal period. This indicator incorporates the temporal component by calculating the total acre-hours of channel habitat available during a specific period of time. This indicator will require hydrodynamic modeling.
3. **Steady state predictions of channel area** – Consistent with the Chinook Recovery Plan 2005, Greg Hood's Island Marsh Model is used to predict the total channel area (acres) that will be created and sustained at a project site. This metric is measured within the footprint of a project and is the estimated acres of new channel habitat regardless of channel depth or velocity.
4. **Estimated new smolts produced annually** – The Skagit Chinook Model will be used to calculate the number of additional smolts produced for a project site. The model takes into account the project area, the area of channel habitat supported by the project and created in adjacent habitat due to the increased tidal prism, and the connectivity of the project area; all three factors influence the number of smolts restored habitat can support. If available these estimates will be compared to existing smolt density data to gauge the accuracy of the model's predictions.
5. **Index of connectivity summed across study area** – The function of any given habitat depends on its spatial position in the landscape and its relationship to and connection with other habitats. Similar habitats in different locations in the delta have been shown to support different densities of juvenile Chinook. Some projects have the potential to increase the connectivity of existing or proposed projects. The landscape connectivity model found in the Chinook Recovery Plan will be used to generate an index of connectivity that is summed across multiple sites in the study area.
6. **High, medium, low potential for increased sediment storage** – The potential for a project to increase sediment storage in the delta will be determined by developing a conceptual model of sediment transport processes in the study area. This conceptual model combined with GIS calculations will allow us to estimate the effect of a project(s) on the channel cross section, discharge velocity, and sediment transport capacity of the river. Project(s) will be categorized as having a high, medium or low potential to increase sediment storage.
7. **Diversity metric of habitat types across elevation gradient** – Maintaining or improving the existing diversity of habitats along the historical elevation gradient (i.e. mudflat to riverine tidal) has the potential to buffer against climate change impacts, such as sea level rise, and provides a greater likelihood of capturing the most valuable habitats for Chinook. It is currently unknown

as to whether Chinook display any habitat preferences across a tidal elevation gradient. Using Digital Elevation, we can predict if a restored area will create one type of habitat or will restore a variety of habitats, such a mudflat, low marsh and high marsh.

FLOOD INDICATORS

1. **Flood stage relative to existing conditions** – Hydraulic modeling of the delta will be used to determine if a project(s) reduce the surface elevation of the Skagit River during a predicted flood flow. Surface water elevation will be measured in the local area as opposed to at a specific river gauge.
2. **Linear feet of replaced or relocated levee in known risk locations** – GIS is used to calculate the linear feet of levee in known risk locations that are within the footprint of a project site by overlaying project sites and identified flood risk locations. Flood risk locations were mapped as a part of a stakeholder engagement process with the Diking Districts within the study area.
3. **Project includes a known site of scour or site predicted by model under existing conditions** – Hydraulic modeling of the delta will be used to identify scour sites and determine if these scour locations will be addressed by the project(s).
4. **Linear feet of replaced or relocated sea dike in potential overtopping locations** – GIS is used to calculate the linear feet of sea dike where potential overtopping occurs that is within the footprint of a project site. Overtopping locations were identified by CDD#22.
5. **Project site includes a flood flow return site identified by CDD#22** – GIS is used to determine if a flood flow return site identified by CDD#22 is within the footprint of a project site.

FARM INDICATORS

1. **Acres of converted farmland** – GIS is used to determine the area of a project site that is zoned by Skagit County as AG-NRL or OSRSI and has a history of farming. The objective for this indicator is to minimize conversion of farmland by maximizing smolts per acre.
2. **Predicted smolts/acre of converted farmland (Fish Indicator 4/Farm Indicator 1)** – The number of smolts produced for a project site (fish indicator #4) is divided by the acres of converted farmland (farm indicator 1) to calculate smolts produced per acre of converted farmland.
3. **Restored acres that support TFI credits** – Under TFI lands zoned for agriculture that are restored to natural riverine and tidal processes generate credits TFI credits. GIS is used to determine the area of a project site that is zoned for agriculture by the County. If the TFI Oversight Committee has allowed credits to be generated by specific cultivated lands not zoned for agriculture, a GIS analysis will be conducted to determine the potential credits generated.
4. **Landownership** – Higher priority is given for projects on public land verses private land. Skagit County zoning map will be used to determine whether a project site is publicly owned or privately owned.
5. **Does the project footprint overlap an existing farmland easement** – GIS will be used to overlay project sites and Skagit County and NRCS farmland protection easements to determine if any projects are on land preserved for farmland. Preference is to avoid land under preservation.

Skagit Delta Hydrodynamic Model Project

APPENDIX E
Modeling and Non-Modeling Scopes of Work

SKAGIT DELTA HYDRODYNAMIC MODELING PROJECT
MODELING SCOPE OF WORK

DRAFT

February 10, 2014

Revised: March 11, 2014

BACKGROUND INFORMATION ON SKAGIT DELTA HYDRODYNAMIC MODEL PROJECT

The Skagit Hydrodynamic Model Project is supported by and contributes to the Farms, Fish and Floods Initiative (3FI). 3FI aims to create and advance mutually beneficial strategies that support the long-term viability of agriculture and salmon while reducing the risks of destructive floods. 3FI is a landscape scale effort in the Skagit Delta where representatives from conservation and agricultural interests have agreed to a common agenda and established partnerships that can bring about breakthroughs in estuary restoration, flood risk reduction and farmland protection in a way that supports multiple community interests. By approaching the 3FI goals at a landscape scale, the 3FI members hope to work with a broad base of stakeholders and trustees to identify actions needed to achieve these goals. The goal for the Skagit Delta Hydrodynamic Model Project (SHDM Project), as identified by the SHDM Team is:

> Using alternative analysis, develop a suite of projects that are well supported to achieve long-term viability of Chinook salmon tidal delta habitat and community flood risk reduction in a manner that protects and enhances agriculture and drainage.

MODELING SKAGIT RIVER PROJECT ALTERNATIVES

PROPOSED RESTORATION PROJECTS AND PROJECT GROUPS

There are 26 potential projects in the 3FI area listed in the Table 1 and Figure 1. They are arranged into groups based on location and the type of project. They are either on the north or south fork, or on the bay front. They are mostly dike setbacks, or dike removals, that increase floodplain and wetland area, reduce river flood stage and result in the construction of new dikes built to a higher standard. The other major group is hydraulic projects that change the flow pattern by excavating new channels to distribute flow across the bay front. The approximate size of the project is listed in acres. It is important to note that the Full North Fork Dike Setback includes the area within projects 9 through 13. The North Fork Dike Setback Phase 1 Expanded includes the footprint of North Fork Dike Setback Phase 1. Similarly, Cottonwood Island Expansion includes the footprint of Cottonwood Island.

Groups	No.	Project	Fork	Type	Acres
Distributary	1	MCGLINN CAUSEWAY	NA	Hydraulic	9
	2	FIR ISLAND CROSS ISLAND CONNECTOR	NA	Hydraulic	472
	3	SWINOMISH CHANNEL BYPASS	NA	Hydraulic	???
Bayfront	4	HALL SLOUGH	NA	D Setback	110
	5	FIR ISLAND FARM (DAVIS/DRY SLOUGH)	NA	D Setback	126.6
	6	TELEGRAPH SLOUGH #1	NA	D Setback	222
	7	TELEGRAPH SLOUGH #2	NA	D Setback	265
NF Steback	8	NORTH FORK DIKE SET BACK - FULL	NF	D Setback	658
	9	NORTH FORK DIKE SET BACK - PHASE 1	NF	D Setback	247
	10	NORTH FORK DIKE SET BACK - PHASE 1 EXPANDED	NF	D Setback	291
	11	BLAKES BOTTLENECK	NF	Hydraulic	18.5
	12	RAWLINS ROAD	NF	D Setback	53
	13	RAWLINS ROAD BERM REMOVAL	NF	D Removal	57
	14	NF DIKE SETBACK - RIGHT BANK	NF	D Setback	74
	15	DOYLE PROPERTY	NF	D Setback	27
	16	THEIN FARM	NF	D Setback	59
	17	SULLIVAN HACIENDA	NF	D Setback	200
South Fork Island	18	MILLTOWN ISLAND	SF	D Removal	212
	19	DEEPWATER SLOUGH 2	SF	D Removal	268
South Fork Left Bank	20	SF LEVEE SETBACK #2	SF	D Setback	50
	21	SF LEVEE SETBACK #3	SF	D Setback	23.5
	22	SF LEVEE SETBACK #4	SF	D Setback	4.5
Forks	23	GEYER PROPERTY	SF	D Setback	56
	24	EAST COTTONWOOD	SF	D Setback	61
	25	COTTONWOOD ISLAND EXPANSION	NF	D Setback	257
	26	COTTONWOOD ISLAND	NF	Hydraulic	7.4

Table 1: list of restoration projects grouped by area and type. Acreage is approximate and subject to revision after Modeling Task 2, below.

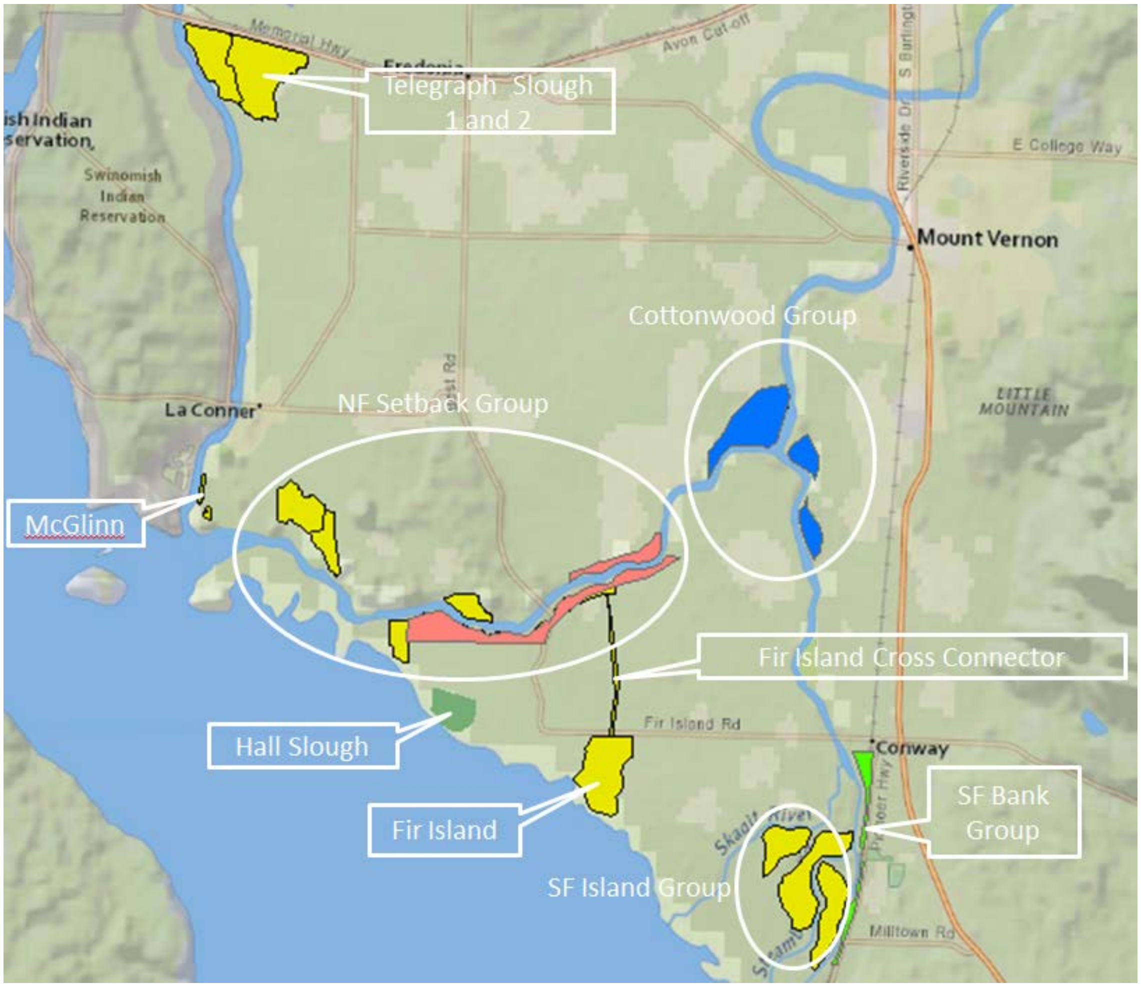


Figure 1: Map of restoration projects shown in groups (the Swinomish Channel Bypass project is not shown on this map).

The first group of projects, the **Distributary Group**, are located in different areas but use a common method to provide benefits – the construction of distributary channel. The effects vary considerably and will depend on the design of the channel and the way the benefits are calculated. The channels have minimal design data but it should be enough to model them. Steady or unsteady boundary conditions could be used depending on the type of benefits calculated – flood benefits may only require steady state conditions, whereas habitat benefits might need unsteady.

The **Bayfront Group** is all dike setback projects located away from the main river channels and would benefit fish travelling along the near shore. They could be simulated using simple tidal boundary conditions and are not anticipated to need to be modeled independently.

The **NF Setback Group** are dike setback projects on the lower part of the North Fork. Combined they restore over 2.5 square miles of former marsh area and could create a significant change in river hydraulics and sediment dynamics. They can be modeled as a group together, but may need to be separated depending on local conditions such as landowner willingness or limited benefits. The NF group has potential to significantly benefit fish and reduce flood stage. It may also store sediment, reduce delta progradation, and change NF/SF flow and sediment distribution. Modeling these projects to account for system-wide effects and long term changes will be complicated, but a simple approach for this planning stage is possible. Simply knowing the change in water surface elevation as a result of this restoration would answer many questions about performance.

The **SF Island Group** are a pair of island projects that in the middle of the distributary network of the South Fork with clear benefits to out-migrating juvenile Chinook, although with uncertain benefits for flood reduction. Modeling can be initially restricted to simple methods but will need to be more realistic as design progresses.

The **SF Left Bank Group** are small projects with limited restored floodplain area. Impacts from these project can be done through rating curves and are not anticipated to need modeling.

The **Forks Group** is located right around the forks but includes not only 3 setback projects but also a side channel. The side channel project is not likely to have a significant hydraulic effect and may be treated like a setback.

Indicators to be Modeled

A total of 15 objectives, which specific indicators, have been developed to evaluate the restoration alternatives and their benefits to fish, flood and farm. The data to assess these objectives come from various sources and only a portion will be evaluated using a hydrodynamic model.

FISH: Restore Sufficient Estuary Habitat to Produce 1.35 Million Smolts

1. Increase Area Subject to Natural Tidal and Riverine Processes within Study Area.
2. Increase Area of Tidal and Riverine Channels Suitable To Chinook Rearing Fry.
3. Increase Chinook Smolt Production
4. Increase the Landscape Connectivity.
5. Enhance Valued Nearshore Rearing Habitats By Reducing Sediment Impacts.
6. Maintain and/or Improve Diversity of Tidal Marsh Habitats.

FLOOD: Reduce Flood Damages and Risks to Safety

1. Reduce Water Surface Elevation Within the Study Area.
2. Reduce Risk of Levee Failure By Constructing New Engineered Levees.
3. Reduce Risk of Unplanned Levee Overtopping.
4. Reduce Risk of Levee Failure Associated with Scour Locations.
5. Improve Agricultural Flood Drainage

FARM: Protect Short and Long Term Viability of Agriculture

1. Minimize Conversion of Farmland By Maximizing Smolts Per Acre Restored.
2. Support Tidegate Maintenance Through the TFI Implementation Agreement.
3. Restore Public Land First.
4. Minimize Conversion of Protected Farmland Parcels.

Below are the specific objectives and their associated indicators that require hydrodynamic modeling to give quantifiable results:

1. **Increase Area Subject to Natural Tidal and Riverine Processes (Fish Objective 1).** The indicator for this is the change in net area subject to tidal inundation. Tidal wetlands have a high value for juvenile salmon and projects that increase wetland area have greater benefit. The area benefit can be determined by a frequency analysis of river stage and the area and elevation of the restored floodplain surface; floodplains that are regularly inundated due to tide and river discharge can be restored as functioning wetlands. The calculation considers the entire delta including changes in the balance of flow and sediment between the N and S forks that may affect existing habitat on the other fork.
2. **Increase Area of Tidal and Riverine Channels Suitable To Chinook Rearing Fry (Fish Objective 2).** The desired indicator for this is the total number of acre-hours suitable habitat area is inundated. Tidal channel area will be determined using a different model, supplied by others but using data from the hydrodynamic model.
3. **Reduce water surface elevation within the study area (Flood Objective 1).** The indicator is the change in local flood stage relative to existing conditions as a result of project activities. If a project results in a reduction in flood water surface elevation, adjacent dikes in the vicinity of the restoration can be evaluated for a lower risk for over-topping, seepage and boils. Reduced flood risk results in a benefit to landowners.
4. **Reduce Risk of Levee Failure Associated with Scour Locations (Flood Objective 4).** The indicator is that a predicted levee scour under exiting conditions is removed by project actions. Modeling would calculate shear stress and determine locations where this stress is highest. There may be other reasons why dikes are at risk for erosion (such as meander migration) and these would be identified. Predicted scour locations would then be correlated with potential restoration sites to increase the overall benefit of the projects that would reinforce weak dikes or relocate dikes built to a higher standard.

MODELING PROCESS TASKS

Modeling to evaluate the effects of the restoration projects on Skagit river hydrodynamics and habitat is broken into three phases plus deliverables. A flow chart is shown in the figure below. The first phase concerns the development of the model itself and includes Tasks 1-4. Phase 2 is the evaluation of the data from Phase 1 and includes additional model runs to refine the analysis, Tasks

5-7. Phase 3 is optional and is included only if climate change sensitivity is detected, Tasks 8-9. If climate change (sea level rise, increase in salinity, or increase in river flood discharge) is likely to affect one or more the indicators for project evaluation and performance, then Phase 3 work should be initiated.

PHASE 1

Task 1. Update existing model with recent river bathymetry and other new geometry and hydraulic data. Run this model to get baseline conditions.

Task 2. Develop a detailed description of restoration projects involving additional review of topography, Lidar, and aerial photos sufficient to render them accurately in the model.

Task 3. Put the geometry for all of the restoration projects into the model and run them collectively. If water surface elevation data is available (data supplied by an outside source), the model will be calibrated at selected discharges.

Task 4. Use the preliminary data from this model run to evaluate the overall effects of the restoration projects by comparing them to the existing conditions. This step determines whether there are any system-wide effects which are defined as:

a. Changes in the balance of flow between the north and south forks. The balance is assumed to be stage-dependent and several discharges must be examined to determine changes in performance.
b. Changes in the balance of sediment discharge between the north and south forks. Since the model does not directly measure sediment transport, surrogates must be established to evaluate it.
c. Relative changes in river salinity and the extent of upstream travel of the salt water wedge.
d. Pronounced effects on habitat in one fork or the other. This can be quantified by comparing the area and frequency of inundation in overbank areas under existing conditions as opposed to conditions with all of the restoration projects in place.

PHASE 2

Task 5. If there are no system-wide effects, examine local changes to understand the impacts of the projects and collect data for the alternatives analysis. To do this, first look for inter-project effects and remove larger project(s) that might mask the effects of smaller projects. It is assumed that the data output from this one or multiple runs would let us evaluate the indicators needed for the alternative analysis.

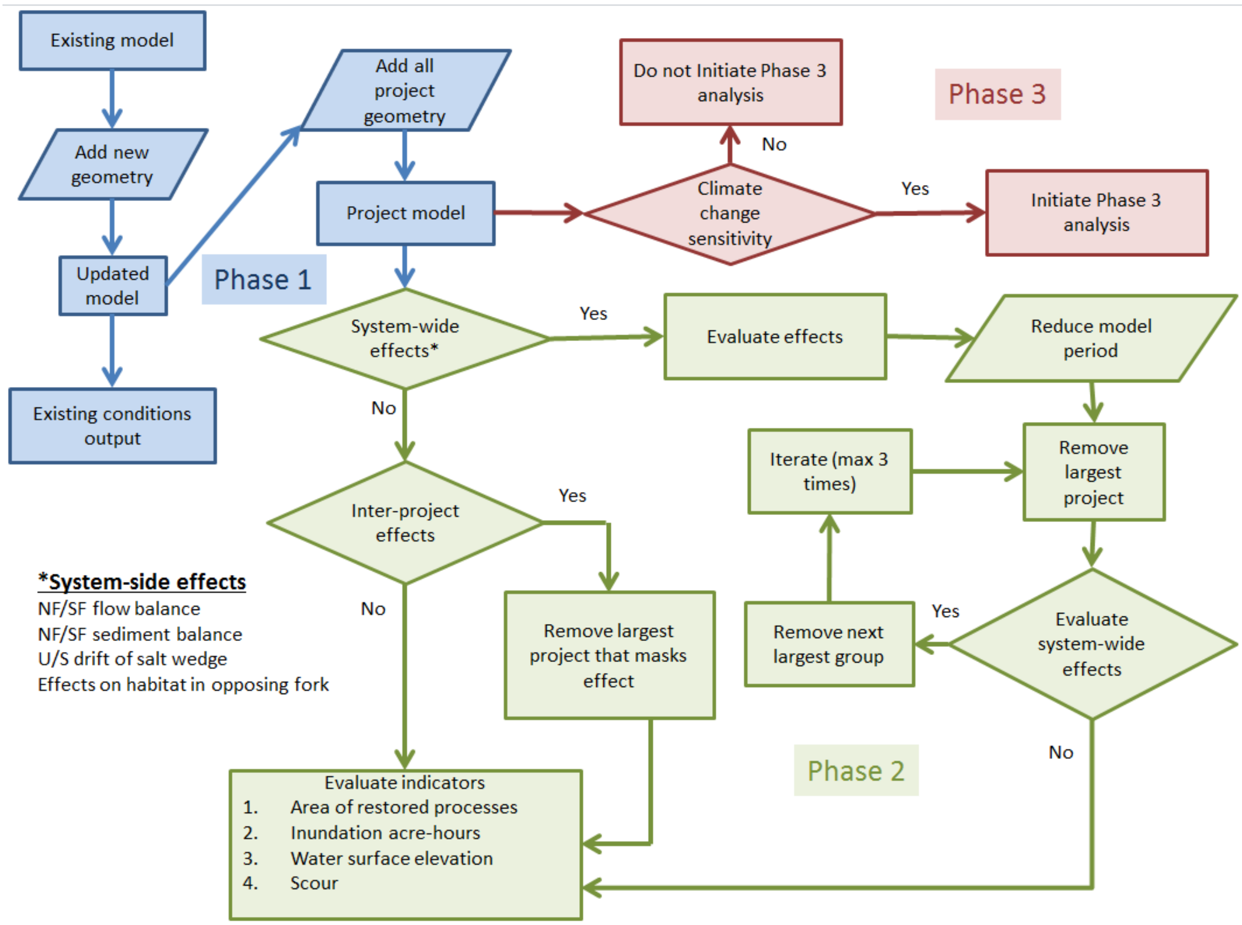
Task 6. If there are system-wide effects, reduce the model period to focus on when the effects are most critical and then remove the group (see description of groups above) that is most likely causing the effects. If the effects remain, remove the next likely group until the effects are no longer present.

Task 7. After the groups of influence are identified, remove the largest projects that are likely causing the effect iterative a maximum of 4 times until the projects that drive the effect of interest is identified. The result from these collective runs would then feed into the alternative analysis.

PHASE 3

Task 8. After this full analysis is complete, examine for climate change effects. These are conditions that could affect agricultural performance, flood risk or habitat. If there is a likelihood of deleterious effects, rerun the existing conditions using the middle estimate of sea level rise and three peak discharge estimates from climate change predations.

Task 9. Rerun the same climate change scenario in the model with the proposed projects running the same boundary conditions.



Deliverables

1. Coordination meetings
    a. Initial coordination meeting with SHDM Team
        i. Discuss modeling strategy
        ii. Discuss project descriptions

   b. Meeting with Modelling Committee after Task 4 to determine significance of system-wide effects and strategy to deal with effects.
   c. Present draft results after Task 9 to Modelling Committee.
   d. Presentation of final results to full 3FI committee.
2. Raw data without reports (the numbers indicate the task outlined above in Modeling Process Tasks from which the data is developed):

   Task 1: Data maps and tables of area and inundation frequency of tidally flooded areas under existing conditions.

   Task 1: Rating curve for discharge in the north and south forks.

   Task 1: Rating curves for water surface elevation, velocity and shear stress for critical locations in dike system (predefined by Modelling Committee).

   Task 2: In cooperation with Modeling Committee, a list of project descriptions and verified maps of project extent for setback projects. Agreed-upon cross sections, profiles and performance specifications for hydraulic projects (flow diversion).

   Task 4: Rating curves for discharge and sediment discharge in north and south forks at comparable location to Task 1. (See Collins, B., 1998. Preliminary assessment of historic conditions of the Skagit River in the Fir Island area, for sediment discharge rating)

   Implications for salmonid habitat restoration. Prepared for the Skagit System Cooperative.

   Task 4: Map of salinity under proposed conditions.

   Task 4: Data maps and tables of area and inundation frequency of tidally flooded areas under proposed conditions.

   Task 5: Preliminary results for the 4 objectives:

      1. Increase in area subject to natural tidal and riverine processes (using results from Tasks 1 and 4)
      2. Increase area of tidal and riverine channels suitable to chinook rearing fry (data requirements to be determined).
      3. Reduce water surface elevation within the study area (using results from Tasks 1 and 4)
      4. Reduce risk of levee failure associated with scour locations (using results from Tasks 1 and 4)

   Task 6: Preliminary results of model runs using the described elimination process.

   Task 7: Preliminary results of model runs using the described elimination process.

   Task 9: Preliminary results of climate change effects on restoration objectives examined in Task 5

3. Draft modeling report. The form of this report will be a Journal Publication Style product.
4. Final modeling report

SCHEDULE

Schedule to be negotiated as a part of final scope of work. Start date is tentatively January 2015 and duration is one year.

Table 1

Skagit Delta Hydrodynamic modeling Project

WDFW - SRFB Grant Application

Pacific Northwest National Laboratory - Subcontractor Cost Estimate

Task No.	Phase	Task Title	Cost
Task 1	Phase I	Update Model with New Bathymetry Data and Develop Baseline	$46,374
Task 2		Refinement of Model Grid for Incorporation of Selected Projects	$46,374
Task 3		Simulation with All Selected Projects Included	$30,580
Task 4		Assessment of Results with All Projects and Comparison to Baseline	$30,580
		Sub-total Phase 1	**$153,908**
Task 5	Phase II	Assessment of Inter-project Effects - Removal of selected larger projects	$25,626
Task 6		Assessment of Inter-project Effects - Removal of group of projects (3)	$18,188
Task 7		Identification of Most Effective Projects	$18,188
		Sub-total Phase II	**$62,002**
Task 8	Phase III	Assessment of Climate Change Effect - Baseline Condition	$28,712
Task 9		Assessment of Climate Change Effect - with Restoration Projects	$28,712
		Sub-total Phase III	**$57,424**
Task 10	Deliverables	Results, Data and Study Report (Journal Paper Style) for Phase I	$26,970
Task 11		Project Coordination, Meetings, and Presentations	$19,160
		Deliverables	**$46,130**
		Total	**$319,464**

SHDM Project - Chinook Related Non-Modeling Data Analysis
Scope of Work

The following is the scope of work to be completed by SRSC Research for the Skagit Hydrodynamic Model Project (SHDM). It contains these elements: 1) make predictions for eleven new SHDM project concepts and five existing restoration projects (currently not active but in the Skagit Chinook Plan), and develop a draft tool to estimate habitat formed in adjacent marshes as a result of restoration from an upstream project.

For the eleven SHDM project concepts (Top 11 rows of Table 1 below), SRSC is asked to:

1. Calculate landscape connectivity per the Skagit Recovery Plan method. Document calculations and fish pathways by map.
2. Identify if the project improves system-wide connectivity of the delta and what that increase is anticipated to be. For applicable projects, recalculate landscape connectivity to influenced channels and report results, including a map.
3. Calculate channel area based on the most appropriate method, including confidence intervals (since these now exist), and include (if applicable) estimates of habitat formed in adjacent marshes. Results (with CI) are for quantity, type, and arrangement of channel habitat including a discussion of our opinion on where within the CI a project would end up. Habitat formed in adjacent (downstream) marshes as a result of increase tidal energy created by the new project footprint. Results from applying the draft tool described above to applicable projects
4. Calculate the Chinook benefit according to Skagit Recovery Plan method using the point estimate for channel habitat and the associated confidence intervals.
5. If merited, compare Chinook benefit prediction to results from nearby monitoring sites and briefly discuss relevant factors. Only use fish monitoring data nearby to the site and not already included in the fish model.
6. Document results of calculations (bullets above) in a standardized report for each project.

SRSC's estimate for completing these the above tasks for all eleven SHDM project concepts per Table 1 is $11,590.

For the existing projects that have not been implemented (bottom 5 rows of Table 1 below) SRSC is asked to:

1. Calculating landscape connectivity per the Skagit Recovery Plan method is **<u>not</u>** needed because it has already been completed.
2. Identify if the project improves system-wide connectivity of the delta and what that increase is anticipated to be. For applicable projects, recalculate landscape connectivity to influenced channels and report results, including a map.
3. Calculate channel area based on the most appropriate method, including confidence intervals (since these now exist), and include (if applicable) estimates of habitat formed in adjacent marshes. Results (with CI) are for quantity, type, and arrangement of channel habitat including a discussion of our opinion on where within the CI a project would end up. Habitat formed in adjacent (downstream) marshes as a result of increase tidal energy created by the new project footprint. Results from applying the draft tool described above to applicable projects
4. Calculate the Chinook benefit according to Skagit Recovery Plan method using the point estimate for channel habitat and the associated confidence intervals.
5. If merited, compare Chinook benefit prediction to results from nearby monitoring sites and briefly discuss relevant factors. Only use fish monitoring data nearby to the site and not already included in the fish model.
6. Document results of calculations (bullets above) in a standardized report for each project

SRSC's estimate for completing these tasks for the remaining 5 projects per Table 1 is $5,268.

SRSC doesn't have an off-the-shelf tool for adjacent marsh estimates. SRSC brainstormed a method for estimating habitat formed in adjacent marshes as a result of new tidal energy created by a new project footprint. It would take 2 weeks of Greg's time ($7,200). The tool would be developed using habitat change results from Wiley and Deepwater.

The total cost of all three elements is $24,058.

Table 1. List of projects and the SOW elements needed. Not included are projects completed (Smokehouse Floodplain, Milltown Island, South Fork Dike Setback, Swinomish Ch. fill removal, Wiley Slough, Fisher Slough) or in design or feasibility stages (South Fork Setback Part 2, McGlinn Island, Fir Island Farm).

Project Name	Project Source/Status	Restoration Predictions					
		Landscape Connectivity		Habitat formed		Fish benefit	
		Project footprint	Delta System	Project footprint	Adjacent marshes	Juvenile Chinook salmon Carrying Capacity	Fish monitoring data available for discussion
1. Cottonwood Island Expansion	SHDM Concept	Yes	No	Yes	No	Yes	Yes Cottonwood backwater
2. East Cottonwood	SHDM Concept	Yes	No	Yes	No	Yes	Yes Cottonwood backwater
3. Geyer Property	SHDM Concept	Yes	No	Yes	No	Yes	No
4. South Fork Levee Setback 2	SHDM Concept	Yes	No	Yes	No	Yes	Yes Fisher Ref Blind
5. South Fork Levee Setback 3	SHDM Concept	Yes	No	Yes	No	Yes	Yes Milltown sites
6. South Fork Levee Setback 4	SHDM Concept	Yes	No	Yes	No	Yes	Yes Milltown sites
7. Hall Slough	SHDM Concept	Yes	No	Yes	Yes	Yes	Yes Brown Sl sites post model results
8. Rawlins Rd Berm Removal Expansion	SHDM Concept	Yes	No	Yes	Yes	Yes	Yes Fishtown Blind
9. N. Fork Levee Setback Expanded	SHDM Concept	Yes	No	Yes	No	Yes	Yes Grain of Sand post model results, NF #1
10. Schmidt Property	SHDM Concept	Yes	No	Yes	No	Yes	Yes NF #1
11. N. Fork Levee Setback Right Bank	SHDM Concept	Yes	No	Yes	No	Yes	Yes Grain of Sand post model results
11.4.6 Deepwater Slough-Phase 2	Chinook Plan Concept	Yes	Yes	Yes	Yes	Yes	Yes Deepwater sites
11.4.1 Blake's Bottleneck	Chinook Plan Concept	Yes	No	Yes	No	Yes	No
11.4.5 Sullivan's Hacienda	Chinook Plan Concept	Yes	No	Yes	No	Yes	No
11.3.3 Telegraph Phase 1	Chinook Plan Concept	Yes	No	Yes	No	Yes	Fornsby sites
11.4.2 Telegraph-Phase 2	Chinook Plan Concept	Yes	Yes	Yes	yes	Yes	Fornsby sites

	hrs	hrs	hrs			$ rate	$ rate	$ rate
Task for Eleven TFI projects	**Eric**	**Greg**	**Karen**	**total cost**		**Eric**	**Greg**	**Karen**
Calculated Connectivity per recovery plan methods			10	$480		100	90	48
Calculate system level change in connectivity	10		20	$1,960		100	90	48
Calculate channel area based on most appropriate method (including CI)		10		$900		100	90	48
Calculate habitat formed in adjacent marshes		10	10	$1,380		100	90	48
Calculate Chinook benefit according to recovery plan methods	10			$1,000		100	90	48
Document results of calculations in a standardized report stating methods	5	5	20	$1,910		100	90	48
Briefly discuss estimates if merited (e.g. exisiting fish data nearby)	30		20	$3,960		100	90	48
Total				**$11,590**		100	90	48
habitat outside the dikes		80		**$7,200**		100	90	48
						100	90	48

Per unit cost of the 5 remaining projects in Table 1 ($11590/11) **$5,268**

$24,058 Grand Total

Skagit Delta Hydrodynamic Model Project

APPENDIX F
Outreach Materials and Response to Comments

Background information on Skagit Delta Hydrodynamic Model Project

The Skagit Hydrodynamic Model Project, on which you were asked to provide input, is a project that is supported by and contributes to the Farms, Fish and Floods Initiative (3FI). 3FI aims to create and advance mutually beneficial strategies that support the long-term viability of agriculture and salmon while reducing the risks of destructive floods. 3FI is a landscape scale effort in the Skagit Delta where representatives from conservation and agricultural interests have agreed to a common agenda and established partnerships that can bring about breakthroughs in estuary restoration, flood risk reduction and farmland protection in a way that supports multiple community interests. By approaching the 3FI goals at a landscape scale, the 3FI members hope to work with a broad base of stakeholders and trustees to identify actions needed to achieve these goals. Enclosed is a fact sheet on 3FI, which details the 3FI goals, members and current projects, such as Skagit Delta Hydrodynamic Model Project.

The goal for the Skagit Delta Hydrodynamic Model Project (SDHP), as identified by the SDHP Team is:

Using alternative analysis, develop a suite of projects that are well supported to achieve long-term viability of Chinook salmon tidal delta habitat and community flood risk reduction in a manner that protects and enhances agriculture and drainage.

SDHP will help prioritize and garner public support for projects identified by The Skagit Watershed Chinook Recovery Plan and the Skagit Flood General Investigation downstream of the Mount Vernon by determining which projects or suite of projects provide multiple benefits, such as flood storage, salmon habitat and protection of agricultural lands. SDHP will also advance these identified restoration and flood control actions by understanding how these projects are likely to affect river hydrology and other processes individually and in the aggregate, and how individual or suites of projects may influence the success of other projects. The SDHP is also open to examining any new projects identified outside of the Chinook Recovery Plan and Flood GI that have the potential to provide salmon recovery, flood risk reduction and/or agricultural goals.

WDFW (Brian Williams) and NOAA (Polly Hicks) are co-managing the SDHP and have convened a diverse SDHP Team of scientists, modelers and key local stakeholders involved in salmon recovery, flood protection and agriculture that includes representatives from WDFW, NOAA, TNC, WWAA, DD#3, DD#17, CDD#22, Northwest National Lab, USGS, Seattle City Light, Skagit County, and the Skagit Conservation District. The SDHP Team is using an adapted version of the Logic Framework to guide our process (see attached). As a first step in the logic framework, the SDHP Team has identified our goal and specific measurable objectives (both qualitative and quantitative). The objectives represent the farm, fish and flood interests and have identified indicators, means of estimation and assumptions. Once the objectives are finalized they will serve as a basis for the alternative analysis that will be designed to prioritize individual or suites of projects based on their ability to contribute to multiple objectives. The objectives also serve as a basis for developing a scope of work for modeling efforts that will examine how individual or suites of projects influence the river hydrology and other processes. A draft map of the SDHP study area is attached for your information.

Outreach

At this time, we are sharing the SDHP Team's goal and draft objectives with targeted representatives from interested or affected communities to get additional input and ensure that our objectives represent the diverse interests of these communities. We would appreciate your review and feedback. **Comments need to be submitted by May 24, 2013.** Thank you for your assistance.

Skagit Delta Hydrodynamic Model Project
Overview of Work Products
January 2014

Background

The Skagit Delta Hydrodynamic Model Project (SDHP) is supported by and contributes to the mission and goals of the Farms, Fish and Floods Initiative. The SDHP Work Group includes a diverse mix of representatives from the farm, fish and flood communities with the goal of

> *"Using alternative analysis, develop a suite of projects that are well supported to achieve long-term viability of Chinook salmon tidal delta habitat and community flood risk reduction in a manner that protects and enhances agriculture and drainage."*

To achieve this goal the SDHP Work Group established a set of farm, fish and flood objectives with measurable indicators that were reviewed by the larger delta stakeholders in 2013. Since that time the Work Group identified a comprehensive list of projects to be considered, an alternative analysis tool to rate and rank individual and groups projects, and the framework for a hydrodynamic model to provide data necessary for the alternative analysis as well as understand land-scape scale impacts from implementing a large suite of projects. A summary of our work is provided below and the attached pdf file contains the referenced work products.

Projects Under Consideration

Within the study area (first map), the SDHP Work Group compiled restoration projects from the Chinook Recovery Plan and flood projects from the Skagit River Flood GI located within the study area (second map). The Recovery Plan project polygons were drawn by WDFW and we are working to ensure that they match the original polygons for these projects. The SDHP Work Group also identified 11 new levee setback and/or removal projects based on levee risk information compiled by the delta diking districts, information from a 2002 Corps Skagit River Flood Mitigation Study, and new projects undergoing feasibility (third map). Some projects are expansions of existing ones in order to increase the benefits.

The SDHP Working Group recognizes that not all projects will be necessary to achieve our stated goal. All projects will be included in the initial analysis and modeling in order to determine which have the greatest potential for multiple benefits.

Alternative Analysis Tool

The alternative analysis is an analytical tool designed to measure how individual projects or groups of projects contribute to salmon recovery and flood risk reduction while minimizing impacts to agriculture. The measurable indicators for each of the farm, fish and flood objectives were used as the basis for the alternative analysis (Alternative Analysis Table). As a tool, the alternative analysis is sufficiently robust to accommodate changes to the existing objectives and indicators, the addition of new objectives and indicators and the addition of new projects.

In the alternative analysis, each interest category (farms, fish and flood) are equally weighted, thus allowing us to understand how each project or group of projects contributes to each interest category as well as understand its multiple benefits across the interest categories. The alternative analysis allows individual indicators within an interest category to be weighted so that key indicators contribute more to an interest category's total score. Regardless of whether weighting is used, the total number of points for any interest category cannot exceed 100 points. Using the multiple benefit rankings for the individual or grouped projects in combination with how these projects contribute to the objectives of each interest category, the SDHP Team will identify priority multiple benefit projects (Alternative Analysis Methodology).

Four of the indicators require hydrodynamic modeling to calculate their scores. Though we are currently working to gather the data and calculate the scores for the non-modeling indicators it is important to note that without the modeling scores outputs from the alternative analysis should be considered very preliminary. To ensure consistency with the Chinook Recovery Plan, the SDHP Work Group is working to clarify project footprints where specific GIS files are not available and to obtain Chinook smolt production estimates for all projects.

Modeling Framework
In addition to modeling the four alternative analysis indicators, the modeling work will also allow the SDHP Work Group to identify potential landscape-level effects resulting from implementing a significant number of the projects. The landscape-level effects of interest include:

- Changes to the North Fork-South Fork distribution of water flow.
- Changes to the distribution of sediment.
- Changes to salinity mixing zone and location of the salt wedge.
- Changes to existing habitats.

A step wise process has been outlined to allow for efficient modeling of the projects which is described and illustrated in the Modeling Framework document.

Nest Steps
We will be working to secure funds to conduct the modeling work and finalize the data for the alternative analysis. Once these data is collected and input into the alternative analysis, the SDHP Team will prioritize individual and grouped projects using the alternative analysis tool. Based on this prioritization, we will use secured funds to conduct feasibility or project development work for one or two high priority projects.

Date: April 7, 2014

SKAGIT DELTA HYDRODYNAMIC MODEL PROJECT					
COMMENT TRACKING TABLE					
Project Managers	**NOAA Fisheries and Washington Department of Fish & Wildlife**				
No.	**Date**	**Party**	**Comment**	**Responder**	**Response**
GENERAL COMMENTS				**RESPONSE TO COMMENTS**	
1		SRSC	Move the north boundary of the study area to SR 20.	PLH	The SHDM Team thought that this was a good suggestion and adjusted the boundary accordingly.
2	2/12/2014	Lorna (Dike Dist Partnership Meeting)	Do not label this project and it's work as addressing Skagit flood reduction. The project study area is too small and only addresses flooding issues in the agricultural areas. It is important to address flood needs in these agriculutral areas as they are under-valued in the Corps GI.	PLH	It is accurate to state that our study area is limited to being focused on flood-risk reduction in the agricultural lands of the Skagit's lower delta and floodplain. We focused our work in this area of the landscape because it was not being addressed in the Skagit GI and was seen locally as an unmet need of importance. See page 4.
3	2/12/2014	Lorna (Dike Dist Partnership Meeting)	Northern boundary of study area (Hwy 20) is arbitrary. Recommend a hydrologically connected boundary than would extend up into Padilla Bay. This aligns better with TFI and the tidegates under consideration for permitting.	PLH	The current boundary was established because it incorporates the area where TFI credits can be generated and it aligns with the Skagit Chinook Recovery Plan target area for estuarine habitat restoration. We acknowledge that the area in which TFI credits are generated is not fully inclusive of the area where credits are expended for tidegate repairs.
4	2/12/2014	Lorna (Dike Dist Partnership Meeting)	Check on model being used, as an older model of the delta had tidal affects up to the Sedro-Wolley Bridge.	PLH	Noted. Baseline data for the model is going to be updated with current topography data in order to increase model accuracy.
5	2/12/2014	Lorna (Dike Dist Partnership Meeting)	Becareful that you are creating habitat as opposed to simply moving it around.	PLH	The SHDM Team is cognizant of the potential for habitat restoration actions to impact existing habitat. We are examining this through the modeling effort by looking at the net gain of habitat across the landscape and identifying which project(s) have the potential to negatively impact existing habitat. See Alternative Analysis Fish Objective 1 (Appendix D) and Hydrodynamic Model Scope of Work (Appendix E).
6	2/12/2014	Lorna (Dike Dist Partnership Meeting)	Drainage infrastructure is critical to the agricularal viability. Consider adding an objective or goal around the capacity for drainage.	PLH	The SHDM Team understands the critical role that drainage plays in maintaining viable agriculture in the delta. We will continue to explore whether a measurable drainage indicator can be identified. See page 2 of the report.
7	2/12/2014	Gary Jones (Dike Dist Partnership Meeting)	Consider wether there will be negative impacts from sediments in restored areas to exisiting gravity drainages.	PLH	The SHDM Team is examining landscape scale sediment processes at this time. See Fish Objective #5. Changes to drainage resulting from sedimentation issues will also be analyzed during the design phase of project development after project(s) have been prioritized for implementation.
8	1/7/2014	SRSC	We are disappointed to see the exclusion of the area referred to as “River Bend” in the analysis.	PLH	The specific project goal developed by the SHDM Team focussed on "Chinook salmon tidal delta habitat". Because the River Bend is outside the area that is tidally influenced, it was excluded from the study area.
9	1/7/2014	SRSC	The inclusion of only the “Avon Bypass” flood reduction alternative in the map labeled “Implemented and Proposed Salmon Recovery and Flood Risk reduction Projects” leaves us a bit confused. Why are no other alternatives being shown on this map? We are not aware of any final decisions by which the Avon Bypass has been selected as the preferred alternative under the GI study. Is this a choice that is being advanced by the 3FI group independent of the GI study?	PLH	We have corrected the map and its title to be clear that only Skagit Flood GI projects within the study area were included in our analysis. 3FI Oversight Team as well as the SHDM Team are not currently advancing a prefered GI alternative, but instead are only including in our analysis the GI alternatives that are within our study area and that are still being considered by the Skagit GI. At the beginning of this process the 3FI Oversight Team encouraged the County and the Corps to consider ecological benefits into their cost-benefit analysis. See page 3 of the report for more information on how the SHDM Project and the Skagit Flood GI compliment and differ from each other.
10	1/7/2014	SRSC	We also note that [Avon Bypass] is being included in the “distributary group” for restoration purposes. That suggests that at least some portions of the project footprint are being dedicated to habitat for fish. What assumptions will be applied as metrics get developed for this foot print? More specificity would be helpful.	PLH	The SHDM Project analyzes habitat restoration actions, flood-risk reduction actions, and multiple-benefit actions. The Avon Bypass is currently designed as a flood-risk reduction action. We are analyzing all of the projects through the Alternative Analysis and letting the data output help us identify multiple-benefit projects around which strong community support can be developed. In order for our decisions to be informed by data instead of assumptions while respecting the ideas from all the delta stakeholders, we are relying on the Alternative Analysis to help understand the strengths and weaknesses of each project.
11	1/7/2014	SRSC	Similarly, the figure labeled “New and Expanded Project Concepts” shows the levee setback alternative from the GI. Does this mean the 3FI project is looking at the potential of advancing both the levee setback and the Avon Bypass alternatives? The 3FI project might consider a different way to communicate the flood alternatives and how they are being analyzed.	PLH	The GI levee setback alternative was removed from consideration in that process because of the low cost-to-benefit ratio. However, the SHDM Project is interested in helping to meet the need for improve flood-risk reduction in the delta agricultural lands. The SHDM Team used the GI's levee setback project boundary and information on known weak sections of the existing levees to identify potential new or expanded project concepts. Please see page 4 of the report as well as the revised maps included in Appendix C for more information.

No.	Date	Party	Comment	Responder	Response
GENERAL COMMENTS				RESPONSE TO COMMENTS	
12	1/7/2014	SRSC	Finally, it is unclear to us how this effort will intersect with the GI, in that a draft DEIS is intended to be released this spring, with a selected preferred alternative. Please explain how the results of this study are intended to be used with the GI, which is intended to be completed in 2015.	PLH	Please see pages 3 and 4 of the report for how the SHDM Project and the Skagit GI differ and compliment each other.
13	1/7/2014	SRSC	Area subject to natural tidal and riverine processes. The first sentence states that "change in net area subject to tidal inundation" is the indicator. The last sentence states "… net benefit could be discarded" in the planning stage in order to simplify calculations. We take this to mean this metric will not be calculated at this time? Even if the net is not calculated what is being proposed at the site level?	PLH	Once funds for the modeling work are secured the net area will be calculated. In the mean time the SHDM Team examined specific site inundation potential using GIS as a surrogate in order to test the Alternative Analysis. The Scope of Work for the Hydrodynamic Modeling was revised to make this clear.
14	1/7/2014	SRSC	Is there an effort to make distinctions between different wetland habitat types and what they mean to fish? Or are all wetlands being treated equal?	PLH	For each project in Phase 2 the following work will be completed by SRSC Research for the SHDM Project to estimate fish benefit from different actions. 1. Calculate landscape connectivity per the Skagit Recovery Plan method. Document calculations and fish pathways by map. 2. Identify if the project improves system-wide connectivity of the delta and what that increase is anticipated to be. For applicable projects, recalculate landscape connectivity to influenced channels and report results, including a map. 3. Calculate channel area based on the most appropriate method, including confidence intervals (since these now exist), and include (if applicable) estimates of habitat formed in adjacent marshes. Results (with CI) are for quantity, type, and arrangement of channel habitat including a discussion of our opinion on where within the CI a project would end up. Habitat formed in adjacent (downstream) marshes as a result of increase tidal energy created by the new project footprint. Results from applying the draft tool described above to applicable projects. 4. Calculate the Chinook benefit according to Skagit Recovery Plan method using the point estimate for channel habitat and the associated confidence intervals. 5. If merited, compare Chinook benefit prediction to results from nearby monitoring sites and briefly discuss relevant factors. Only use fish monitoring data nearby to the site and not already included in the fish model. 6. Document results of calculations (bullets above) in a standardized report for each project. Additionally, WDFW/ESRP and NOAA Restoration Center are supporting research being conducted by SRSC, NWFSC, and USGS regarding how different types of estuary habitat contribute to juvenile Chinook growth rate and thus vary in how valuable they are for fish. This work will not be compelted in time for the modeling process, but the Alternative Analysis is structured to allow additional information and new indicators to be added at later points in time.
15	1/7/2014	SRSC	How will tidal and riverine influences get parsed out in the modelling effort? We also note this indicator appears to be referred to as "Total project area with restored processes" in the indicator table. Is this correct? If so, we would argue that area of tidal inundation is not in itself an adequate measure of restored processes.		Please see the Scope of Work for modeling provided in Appendix E. The Team is using hydrology and sediment storage as indicators for restored processes. While this is not a comprehensive analysis of how all processes will function each site, at the scale of this investigation (i.e. delta wide) they are appropriate indicators. Because the Alternative Analysis is structured to allow new indicators or projects to be added, we welcome specific ideas about indictors that help parse out project benefits at the scale of this analysis.
16	1/7/2014	SRSC	Increase in area of tidal and riverine channel suitable to chinook rearing fry. Similar questions arise regarding this objective in that not all channels are created equal in their role and function relative to chinook rearing. It is not clear from the documents provided just how distinctions will be made between different types of habitat and their predominant influences. These variables will influence the productivity of individual habitats for chinook.	PLH	See response to comment 14 for how channel area will be translated to Chinook benefit using the existing Chinook model. Additionally, in Appendix D the Explanation of Indicators and Means of Estimation document details how the indicator "acre-hours suitable habitat predicted" helps to parse out differences between channels. For this indicator channels that hold water for longer and therefore provide more suitable habitat over the temporal scale are given greater weight than channels that drain completely or do not retain enough water for juvenile use.
17	1/7/2014	SRSC	SRSC is concerned that some of the polygons under consideration as elements taken from the Chinook Recovery Plan are inconstant with the footprints presented in The Plan. Telegraph 1 & 2, Sullivan's Hacienda in particular catch our eye, as does the footprint associated with Smokehouse Floodplain. Why are these footprints being reconfigured through the 3FI effort? We could not locate a rational in the documents provided.	PLH	The SHDM Team is also concerned about these inconsistencies and would like to have the original GIS polygons for all of the Chinook Recovery Plan projects to ensure consistency. We are working with SRSC to obtain these files. Please see page 3 of the report.

No.	Date	Party	Comment	Responder	Response
GENERAL COMMENTS				RESPONSE TO COMMENTS	
18	1/7/2014	SRSC	Also, we would note that Cottonwood Island polygon being shown was not included in the Recovery Plan, however, the smolt calculation was based off a larger footprint of nearly 170 acres (note: there is an error here in the Plan as Acres to Hectares conversion was not applied) , which would require some level of levee reconfiguration. The same is true of the Britt Slough footprint which would require some alterations to the levee network. In the calculation for the Britt Slough restoration action the area labeled "East Cottonwood" in the expanded project concepts was included (Note: The area calculation of 56.8 hectares is correct and in the proper units).	PLH	As noted on page 3 of the report, we are using the current polygons of projects that have had additional feasibility and design work completed. The Chinook smolt benefit will be calculated based on the revised footprints. A revised Chinook smolt benefit was already calculated for Cottonwood and is available through Habitat Work Schedule.
19	1/7/2014	SRSC	SRSC applauds the progress of the 3FI in securing buy-in for a more complete dike set back effort along the North Fork. We are confident this will provide considerable benefit to both fish and flood control efforts. However, we are aware of several farm land preservation easements within this designated corridor. These could prove to be barriers to implementation. How are the 3FI partners addressing this potential roadblock in the dialog amongst the various stakeholders and the projects goals of preserving farmlands?	PLH	As noted in the Alternative Analysis and related documents (Appendix D), an objective of the SHDM Team is to avoid or minimize impacts to farmland that is currently protected by a agriculture easement. As a result, a project that includes an existing agricultural easement will score lower than projects that do not include an agriculture easement.
20	1/7/2014	SRSC	We are equally encouraged to see the inclusion of what is labelled the "Cottonwood Island Expansion". This too could be an exciting project with benefits to fish and floods. SRSC has gone on record on numerous occasions stating that recent investigations of restoration on and around Cottonwood Island should include a significant effort at levee setback so that natural riverine processes can be reestablished. In fact, the purposeful exclusion of the footprint image for this project from the Recovery Plan was largely due to broader concerns that inclusion of a large footprint could negatively affect the selection of a preferred alternative through a previously funded feasibility effort being conducted by SWC at the time. Unfortunately, most of the feasibility work conducted to date has failed to fully examine the possibilities of such an effort. With several attempts at designing this project landing on highly engineered alternatives that work within the confines of the existing levee footprint. We are excited to see buy in from the project partners on the more aggressive restoration effort at this location. Seeing that such a fresh look at this highly studied area could renew the effort to set back the levee system, SRSC would like for the Skagit Forks Project funded in 2013 to be re-scoped so that it might include such an aggressive footprint.	PLH	Noted and support for these efforts is appreciated.
21	1/7/2014	SRSC	In regard to the project labeled "Geyer property" SRSC is again on record regarding our concerns of working within the confines of the existing levee footprint. If our assumptions are correct this property is under the ownership of TNC and was purchased using SRFB funding for habitat protection. Cursory analysis of the area suggests the site has very little potential for long term increases in habitat area as it is presently configured. Near term engineered actions could provide relatively small increases in habitat area for fish, but these features would like be subject to sediment deposition over time. This raises the question of how indicator metrics will be adjusted for sustainability over time if proposed restoration actions rely on engineered approaches, confined footprints, or are at risk from sea-level rise? How will site stability and trajectory be accounted for in the modeling effort?	PLH	Currently we have identified a modeling phase to examine how project(s) function over time given potential future climate change impacts. Project site analyses that evaluates how specific engineering techniques will function over time, including the longevity of the implemented techniques, is beyond the scope of the SHDM landscape scale analysis.
22	1/7/2014	SRSC	The concern we have regarding the Geyer property is amplified at sites identified as South Fork Levee Setback 1,2 & 3 along with the Rawlings Rd berm removal expansion. All of these strike us as being highly marginalized actions that are being "squeezed" into very tight and confined boundaries. Pioneer Hwy being the primary impediment to the East on the South Form Projects and the existing Fir Island levee system being the impediment to meaningful work at Rawling's Rd. At least, as there are presented here we have little confidence they will result in meaningful results. Moreover, their inclusion could skew model results if adjustments are not included for site trajectory over time.	PLH	We are analyzing all of the projects through the Alternative Analysis and letting the data output help us identify multiple-benefit projects around which strong community support can be developed. In order for our decisions to be informed by data instead of assumptions while respecting the ideas from all the delta stakeholders, we are relying on the Alternative Analysis to help understand the strengths and weaknesses of each project.

Appendix B: Restoration Project Concepts

Skagit Delta Hydrodynamic Modeling Project: Project Summaries 2016

A product of the Skagit Hydrodynamic Model Project Team

Funded by NOAA Restoration Center and
Washington State Recreation and Conservation Office/Salmon Funding Recovery Board

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Significant contributions by:
Skagit Hydrodynamic Model Project Team members
Individual project sponsors

Background information

The Farms, Fish and Flood Initiative (3FI) aims to create and advance mutually beneficial strategies that support the long-term viability of agriculture and salmon while reducing the risks of destructive floods. 3FI is a landscape scale effort in the Skagit Delta where representatives from conservation and agricultural interests have agreed to a common agenda and established partnerships that can bring about breakthroughs in estuary restoration, flood risk reduction and farmland protection in a way that supports multiple community interests.

The Skagit Delta Hydrodynamic Model Project is supported by and contributes to 3FI. The goal for the Skagit Delta Hydrodynamic Model Project (SHDM Project), as identified by the 3FI/SHDM Team is:

Using alternative analysis, develop a suite of projects that are well supported to achieve long-term viability of Chinook salmon tidal delta habitat and community flood risk reduction in a manner that protects and enhances agriculture and drainage.

The SHDM Project is moving into Phase 2, which includes analyzing the remaining Chinook Recovery Plan restoration projects in the estuary as well as newly developed restoration project ideas to determine which have the potential for providing multiple-benefits (fish, farm and flood). The analyses to be completed include hydrodynamic modeling, GIS analysis and estimation of potential Chinook salmon benefits through the use of two mathematical models developed by the Skagit Rivers System Cooperative (SRSC). This document provides a summary of each project.

Project Ideas

There are 22 potential projects in the SHDM project study area (Figures 1-2). The projects are mostly dike setbacks, or dike removals, that have the potential to increase floodplain and wetland area, reduce river flood stage and result in the construction of new dikes built to a higher standard. Another major group is hydraulic projects that change the flow pattern by excavating new channels to distribute flow across the bay front. The final project category is the backwater channel group, where an existing channel within the dikes is altered to increase backwater flow and fish use.

A majority of the projects were first identified and described in the Skagit River Chinook Recovery Plan (CRP)[1], which laid out a pathway to help recover threatened Chinook salmon in the Skagit Watershed. The original shape files for these projects were obtained from SRSC for this effort. Where more than one shape file existed we followed the recommendations of SRSC for the correct shape file to use. Some of the CRP projects have been further refined or developed through other planning processes such as the Puget Sound Nearshore Estuary Restoration Project (PSNERP)[2] or through individual project sponsor actions as noted in the project summaries. Additional project ideas or expansions of existing CRP project footprints were also pulled from the Skagit River Flood General Investigation[3] process and developed by the SHDM Project Team. In order to increase the potential for multiple benefit projects, the SHDM Project Team reviewed areas of known weaknesses in the existing dike system, as identified

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[1] Skagit River Systems Cooperative and Washington Department of Fish and Wildlife. 2005. Skagit Chinook Recovery Plan. - www.skagitcoop.org/documents/SkagitChinookPlan13.pdf

[2] PSNERP is a US Corps of Engineers General Investigation with WDFW as the local sponsor with the goal of evaluating significant ecosystem degradation in the Puget Sound Basin and then recommending a series of actions to help address these problems. - www.pugetsoundnearshore.org/

[3] www.skagitcounty.net/Departments/PublicWorksSalmonRestoration/main.htm

by diking districts, and CRP project footprints to determine if there were any new concepts or alternative CRP project footprints that could address flood risk reduction needs. The source(s) of each project is listed in the project summary.

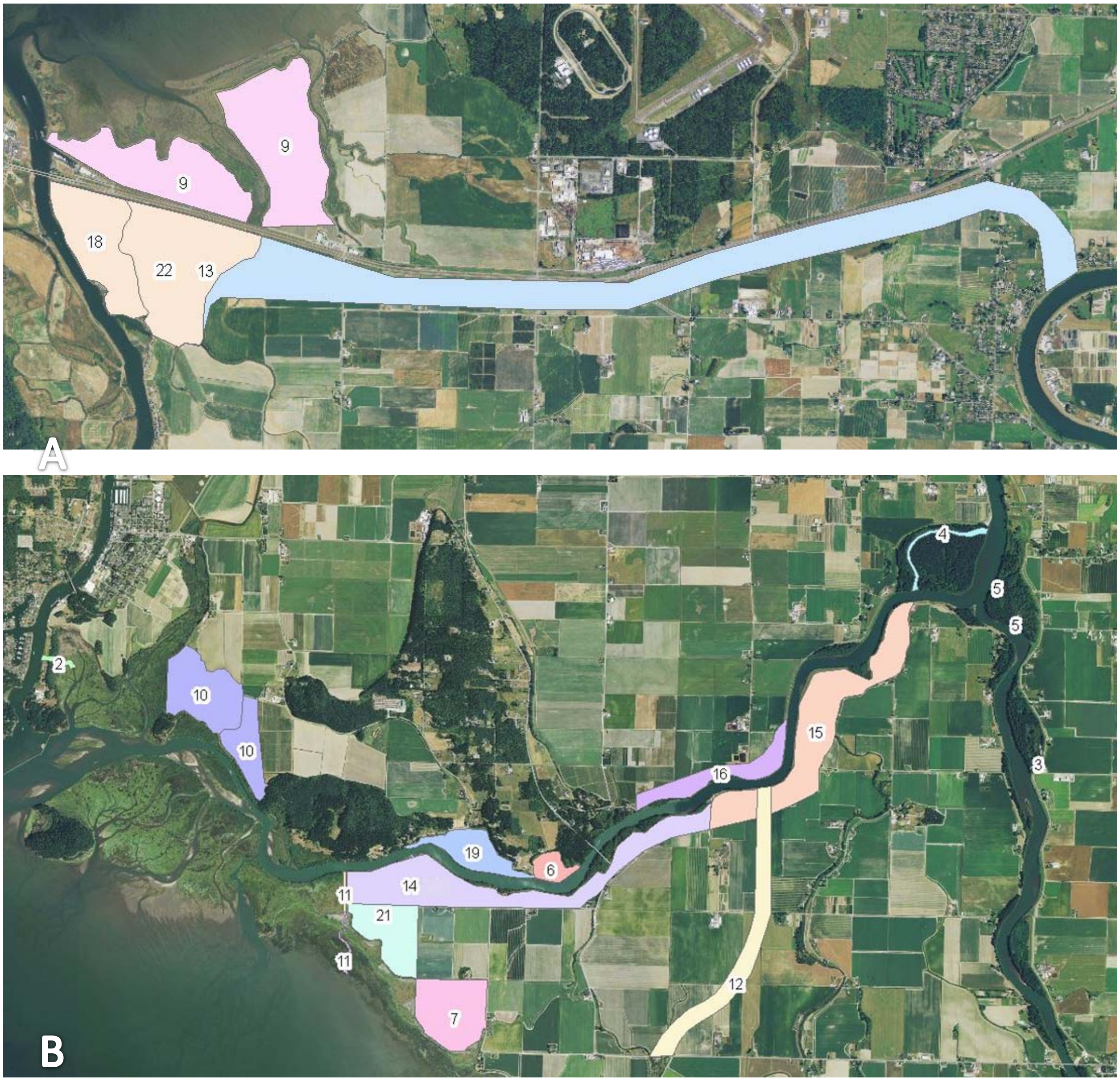


Figure 1. Projects included in the Skagit Delta Hydrodynamic Model Project. Figure 1 A includes the projects located in the northern portion of the study area and Figure 1 B includes those from the south western portion of the study area. The numbers labeling each project polygon are associated with Table 1.

To be included in the study, a project had to be fully or at least partially located within the study area. Some projects foot prints extended out of the study area; to prevent projects from being arbitrarily truncated the entire project footprint is included in the analysis. At a minimum, a project had to have the potential to benefit to at least one of the three interests, although the subsequent analysis and project ranking will help identify and prioritize those that provide benefits to multiple interests. Finally a project had to have enough information available to be able to be modeled.

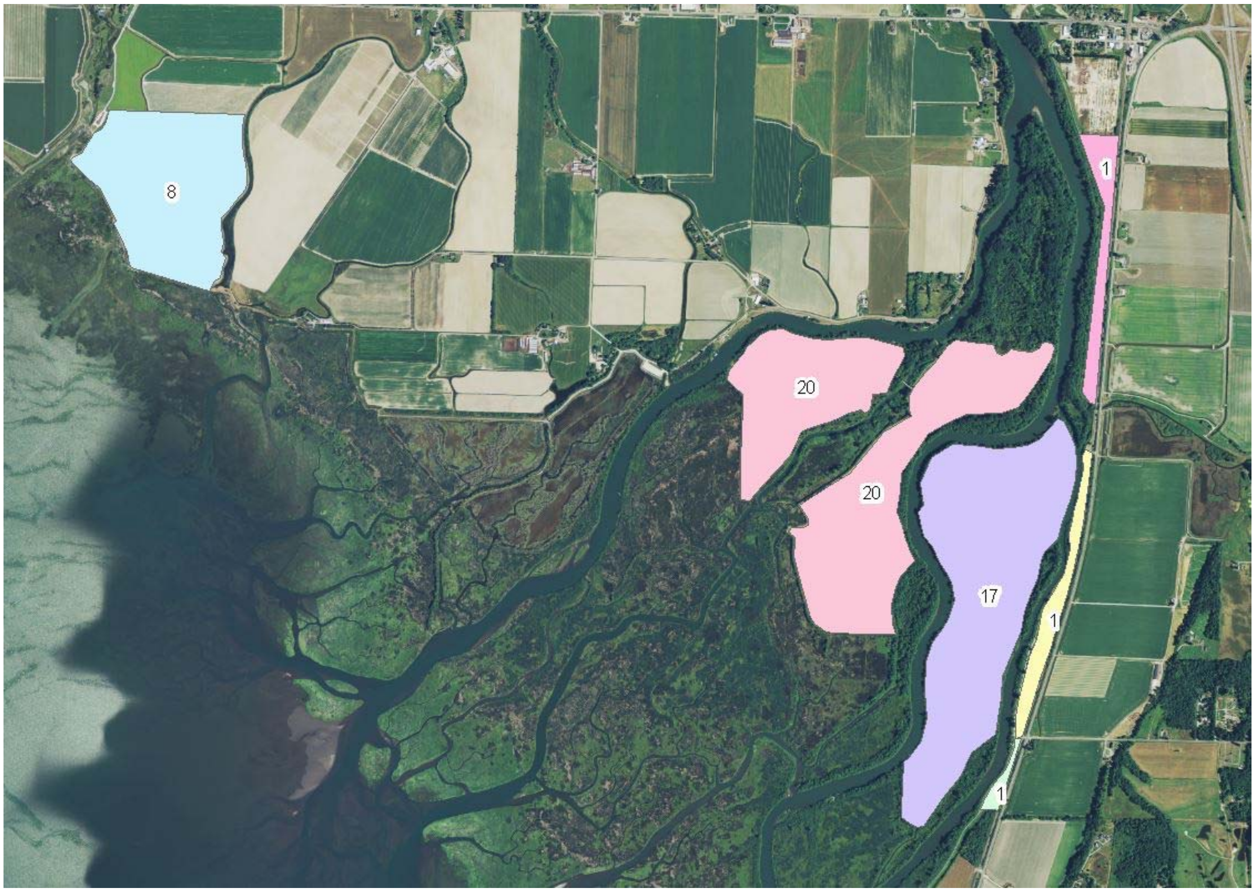


Figure 2. Projects included in the Skagit Delta Hydrodynamic Model Project that are located within the south eastern portion of the study area. The numbers labeling each project polygon are associated with Table 1.

Table 1 lists the projects to be modeled as well as the hydrodynamic model run in which the project will be simulated. For each project, the type of project and approximate size in acres is provided. The projects are numbered based on their associated model run. Projects were grouped into seven different runs to enable one to determine the effects of an individual project without it being masked by larger effects of another project. While McGlinn Island is a major hydraulic project, it is not anticipated to mask the effects of the other projects included in the small project run and therefore is being modeled in run 1 with the small projects. For the project summaries that follow, the projects are listed in alphabetical order. Please refer to the scope of work for the hydrodynamic modeling for more information on the full list of all of the model scenarios to be run.

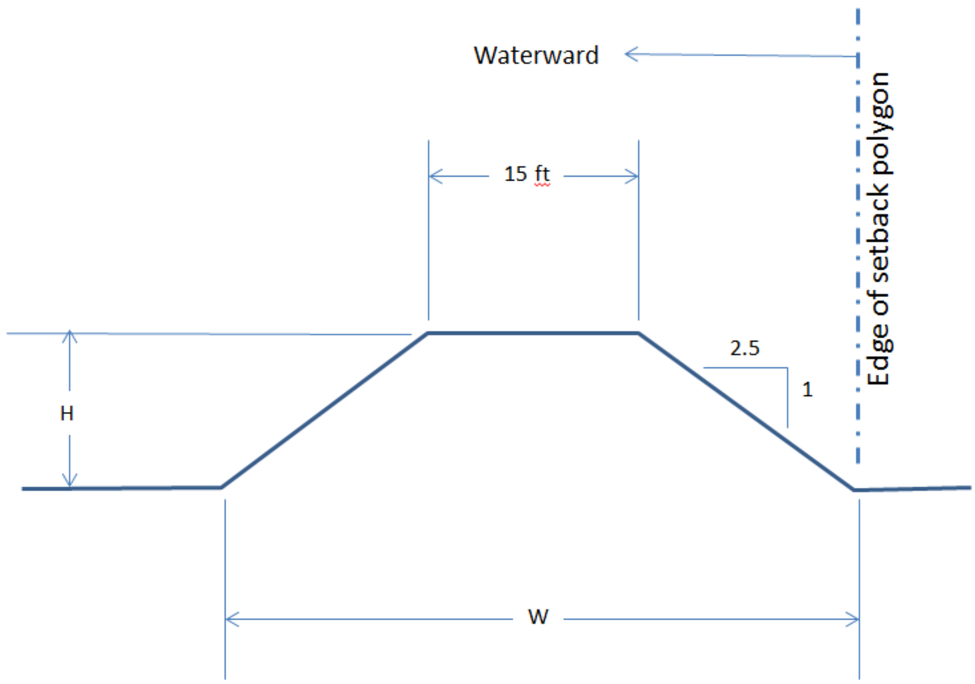
Table 1. Projects to be included in the SHDM. Projects are grouped into separate modeling runs to allow for the identification of project-level impacts.

HDM Model Run	Project No.	Project Name	Project Type	Areas
	Task 3: Small Projects			
R1	1	SF Levee Setback 2, 3, 4	Dike Setback	57
	2	McGlinn Causeway	Hydraulic	7
	3	TNC South Fork	Backwater Channel	1
	4	Cottonwood Island	Hydraulic	15
	5	East Cottonwood	Backwater Channel	2
	6	Pleasant Ridge South	Dike Setback	30
	7	Hall Slough	Dike Setback	134
	8	Fir Island Farm	Dike Setback	140
	9	Telegraph Slough Full	Dike Setback/Hydraulic	1048
	10	Sullivan Hacienda	Dike Setback	205
	11	Rawlins Road Distributary Channel	Hydraulic	8
	Task 4: Major Hydraulic Projects			
R2	12	Fir Island Cross Island Connector	Hydraulic	150
R3	13	Avon-Swinomish Bypass	Hydraulic	1293
	Task 5: Major Setback Projects			
R4	14	NF Left Bank Levee Setback C	Dike Setback	275
R5	15	NF Left Bank Levee Setback A	Dike Setback	553
	Task 6: Moderate Setback Projects			
R6	16	NF Right Bank Levee Setback	Dike Setback	86
	17	Milltown Island	Dike Breach	222
	18	Telegraph Slough 1	Dike Setback	185
	19	Thein Farm	Levee Setback	78
R7	20	Deepwater Slough Phase 2	Dike Removal	268
	21	Rawlins Road	Dike Setback	192
	22	Telegraph Slough 1&2	Dike Setback	495

General Project Assumptions

Dike Setback Projects

It is assumed that the dike structure would be located to the waterward side of the edge of the setback polygon and that the height of the setback dike would be similar to the existing dike at the same location. The width of the setback dike, toe to toe, (W) would be dependent on the height above the adjacent floodplain (H). Figure 3 shows a typical dike cross section and the approximate toe width.



H	W
8	55
9	60
10	65
11	70
12	75
13	80
14	85
15	90
16	95
17	100
18	105

Figure 3. Cross section of typical setback dike with table of toe width as a function of dike height.

Maintaining Agricultural Drainage

All projects must maintain the existing agriculture drainage for adjacent and upstream agricultural lands. Design elements required to ensure that agricultural drainage is maintained will be identified and developed at the project feasibility and/or design stages for prioritized projects because design elements may differ based on the specific drainage system dynamics and needs of the agricultural lands. For example in the Fisher Slough Project (completed in 2011), to protect drainage of adjacent agricultural lands, the project incorporated tile drains on the landward side of the new dike as well as pilings at the toe of the dike to prevent groundwater seepage. For the Fir Island Farm Project (currently in design), an expanded storage pond, additional drainage tidegates and a new pump station were all incorporated to ensure that agricultural drainage will be maintained after the project is complete and in the future given sea level rise predictions.

Avon-Swinomish Channel Bypass (Project #13)

Key Project Elements	
Project Origin	Skagit River Flood GI
Project Status	Study proposed but not completed[4]
Project Location	Mainstem of Skagit River out to Swinomish Channel
Project Type	Hydraulic
Approximate Project Area	1293 acres

Project Narrative:
The project consists of a 1,000 foot wide bypass channel extending from the Skagit River at RM 15.9 in a westerly direction parallel with State Highway 20 for 7.3 miles to the Swinomish Channel south of the State Highway 20 Swinomish Channel Bridge. The corridor is expected to bypass flood flows from the Skagit River and would include a low flow channel for continuous flow to allow fish use. The bypass would decrease salinity in the Swinomish channel and provide fish access and sediment delivery to Padilla Bay.

Figure 4 shows an artist's conception of the bypass channel. The general layout is shown in the above Project Map. Figure 5 through Figure 11 are cross sections of the proposed bypass channel provided in the study plan. The project would impact agricultural lands, including parcels with agricultural easements, associated agricultural outbuildings, residences and commercial buildings as well as roads and associated infrastructure. The project overlaps with the entire footprint of Telegraph Slough 1 and Telegraph Slough 1&2 (projects #18, 22) and part of Telegraph Slough Full (project #9).

[4] Study Plan to Evaluate the Potential Effects of the Skagit River Flood Hazard Mitigation Project on the Waters and Ecology of Skagit and Padilla Bays, Battelle Marine Sciences Laboratory, Sequim, Washington. Feb 6, 2011.

Figure 4. Artist's conception of the Avon/Swinomish bypass channel, looking west.

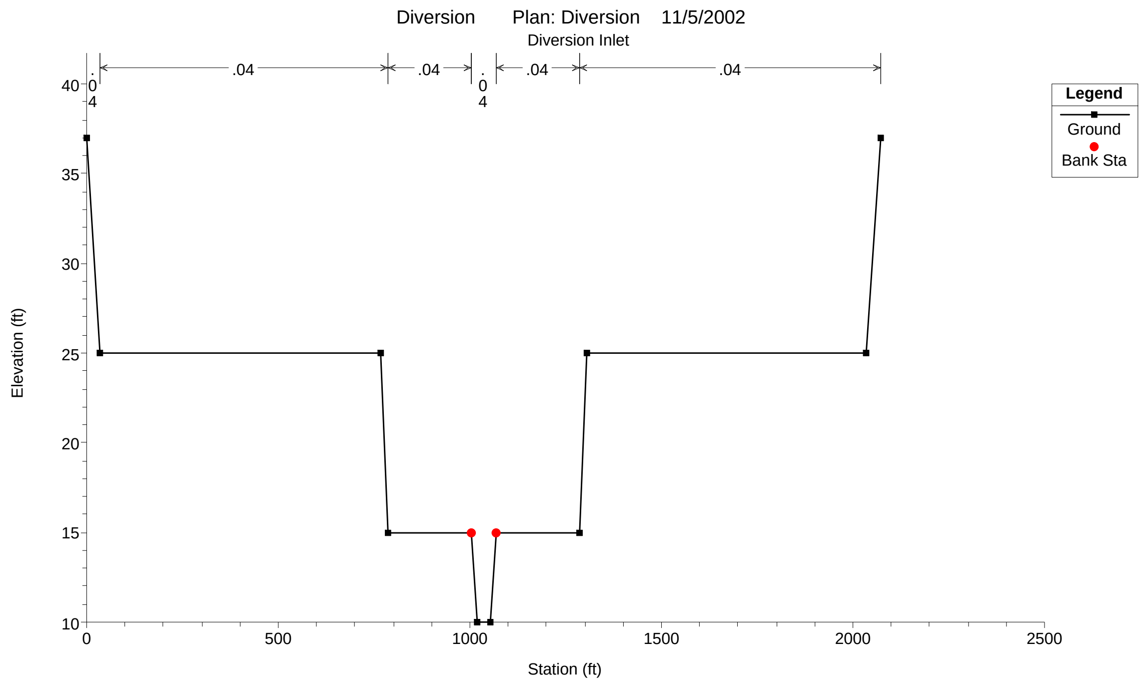


Figure 5: First Cross Section in Diversion after Inlet 35 foot Low Flow Channel Invert at 10 feet NGVD29 500 feet at elevation of 15 feet NGVD 29 Rest of 2000 feet at 25 feet NGVD 29.

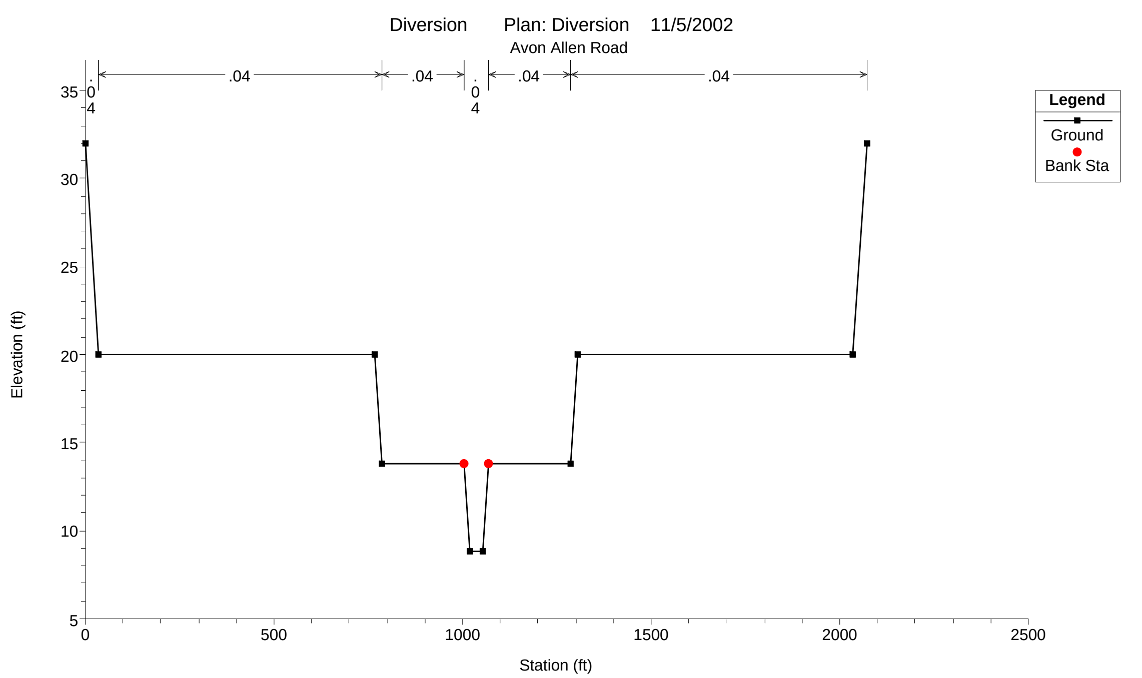


Figure 6: Avon Allen Road 35 foot Low Flow Channel Invert at 8.8 feet NGVD 29 500 feet at elevation of 13.8 feet NGVD 29 Rest of 2000 feet at 20 feet NGVD 29

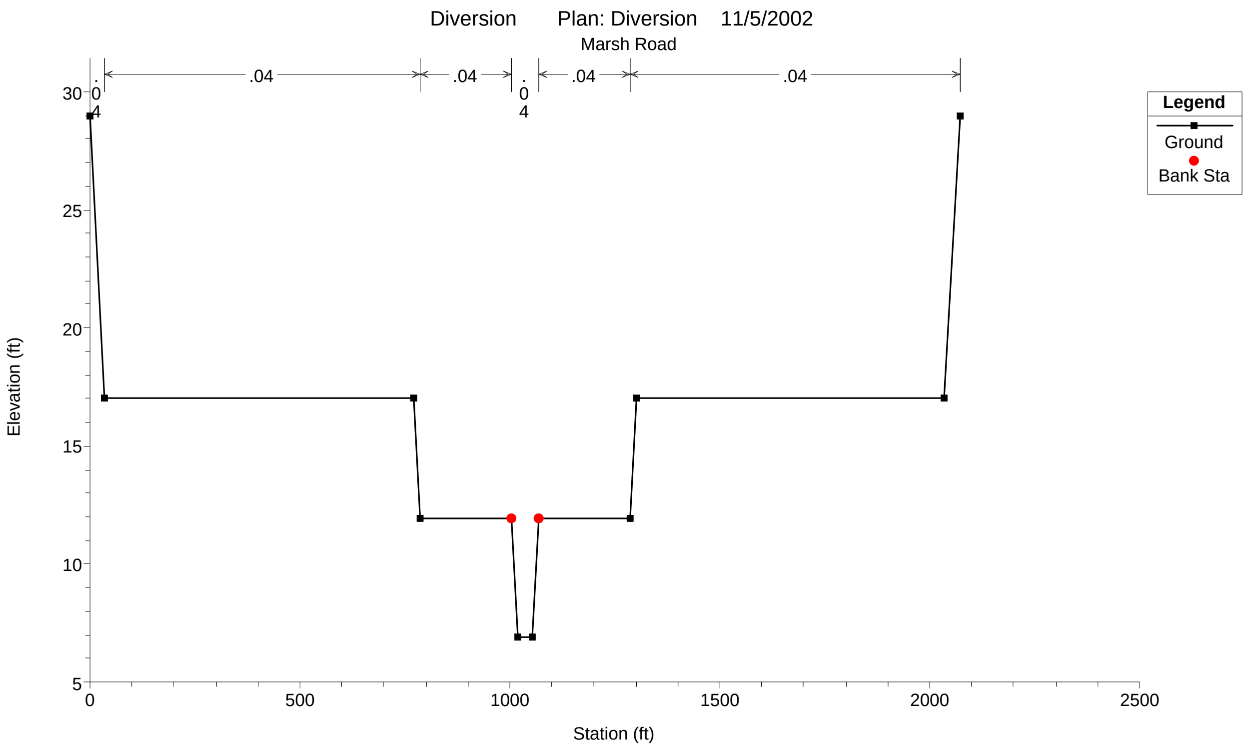


Figure 7: Marsh Road 35 foot Low Flow Channel Invert at 6.9 feet NGVD 29 500 feet at elevation of 11.9 feet NGVD 29 Rest of 2000 feet at 17 feet NGVD 29

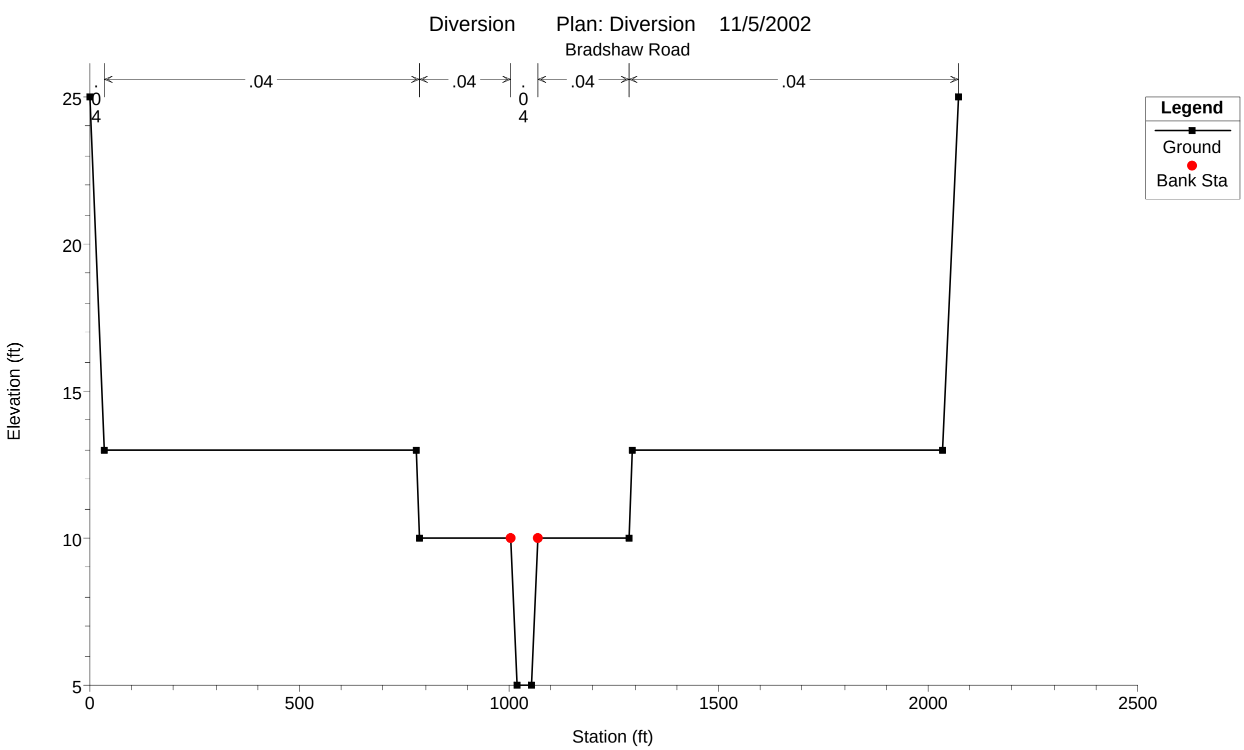


Figure 8: Bradshaw Road 35 foot Low Flow Channel Invert at 5 feet NGVD 29 500 feet at elevation of 10 feet NGVD 29 Rest of 2000 feet at 13 feet NGVD 29

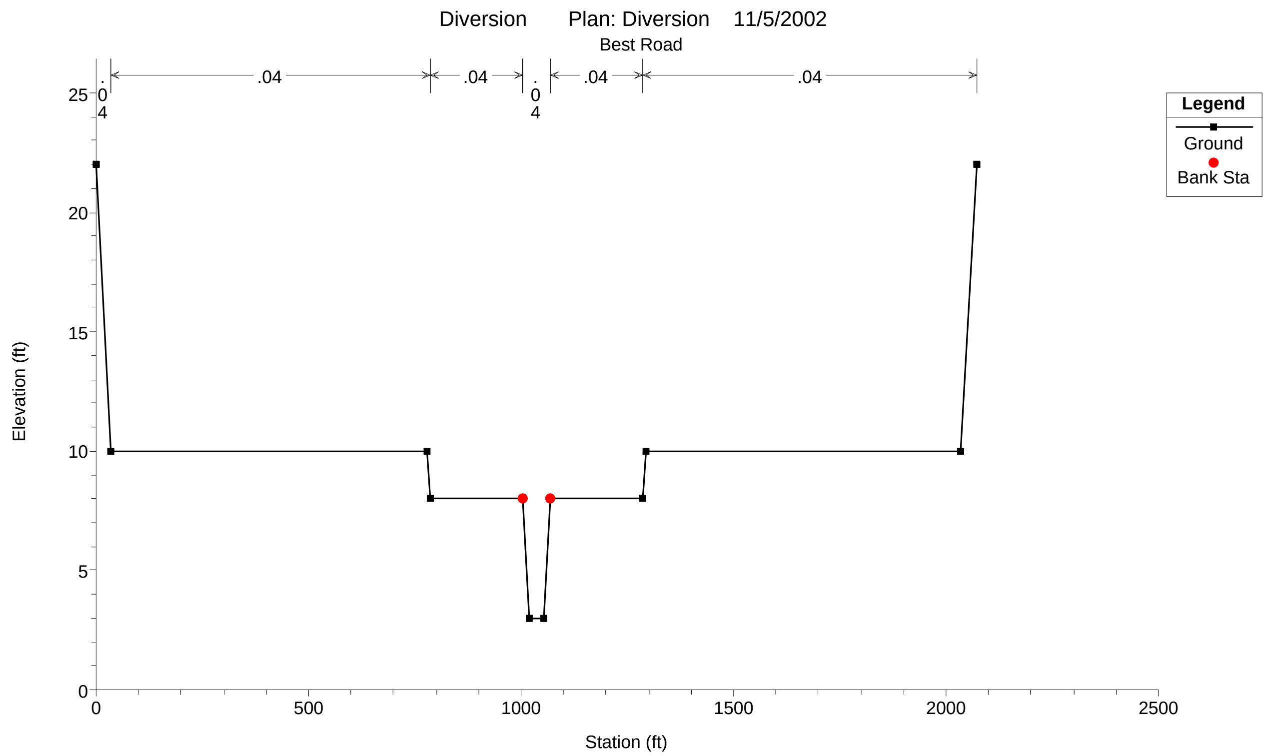


Figure 9: Best Road 35 foot Low Flow Channel Invert at 3 feet NGVD 29 500 feet at elevation of 8 feet NGVD 29 Rest of 2000 feet at 10 feet NGVD 29

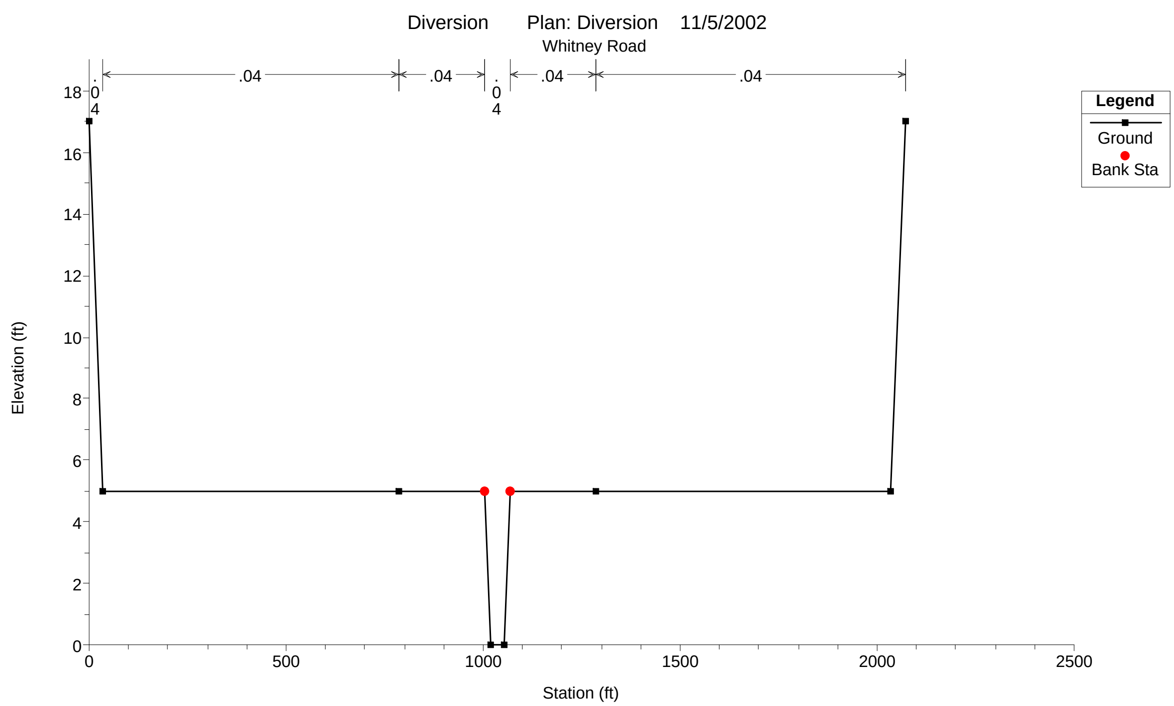


Figure 10: Whitney Road 35 foot Low Flow Channel Invert at 0 feet NGVD 29 Rest of 2000 feet at 5 feet NGVD 29

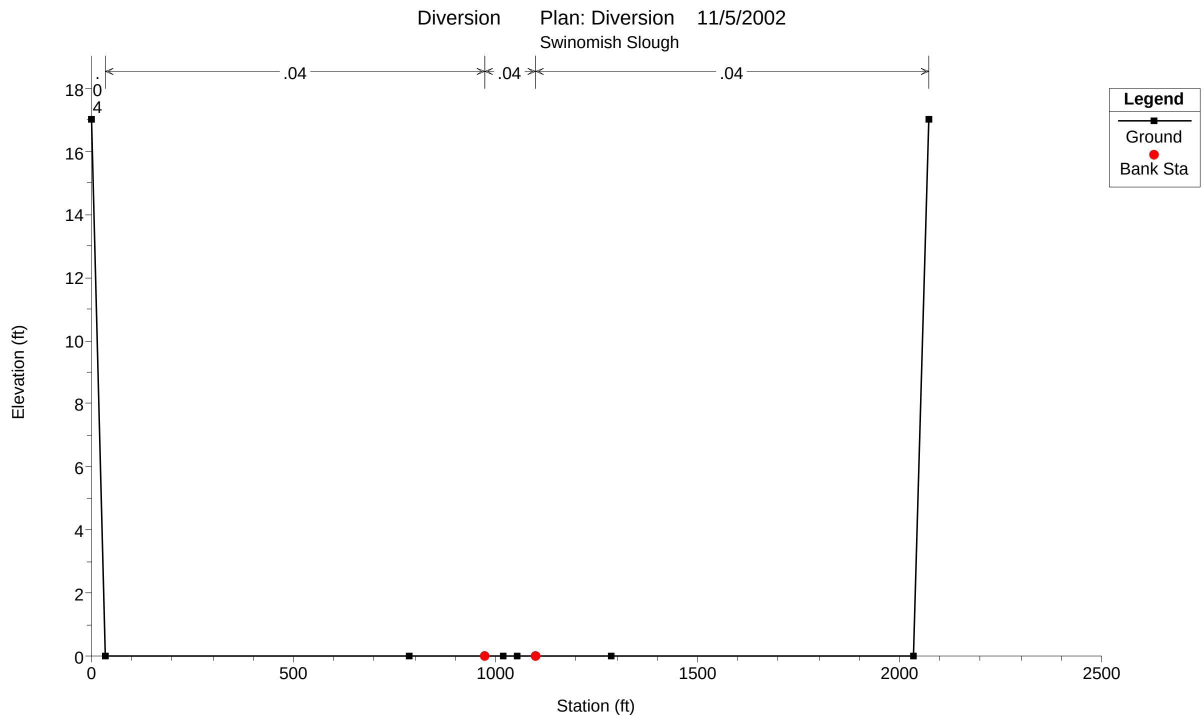


Figure 11: Outlet to Swinomish Slough 2000 feet at 0 feet NGVD 29

Cottonwood Island (Project #4)

Key Project Elements	
Project Origin	Chinook Recovery Plan; and SCD Design Plan Sets[5]
Project Status	Preliminary plans complete 2011
Project Location	Above the N & S Forks
Project Type	Hydraulic
Approximate Project Area	15 acres

Project Narrative:

The project was originally proposed in the CRP as a dike setback and fill removal project. As the project was further investigated and designed, the levee setback was removed and the project was refocused on opening up the channel for fish use.[6] The current project design developed by the Skagit Conservation District (SCD) is proposes to restore hydraulic connectivity to the channel while minimizing

[5] Cottonwood Island Slough Habitat Restoration Project. Plan set dated 7/28/2011. Skagit Conservation District, Tom Slocum, design engineer. (File name: *Final Prelim Design Drawings May 2011.pdf)*.

[6] Cottonwood Island Restoration and Feasibility Study – Hydrodynamic and Sediment Transport Analysis. Batelle – Pacific Northwest Division, prepared for Skagit Watershed Council. October, 2007.

the accumulation of sediment. The project site is on the river side of the existing flood dike and there are no residences or outbuildings onsite. The site is dominated by mature trees and shrubs. The project concept would restore riverine flow to a historic side channel thus providing salmon habitat benefits.

SCD plans enlarge an existing side channel. The invert gently slopes at 0.0002 ft/ft from an elevation of 8.8 ft NAVD88 at the upstream junction with the Skagit River to 7.8 ft at the downstream end, Figure 12 and Figure 13. The cross section is trapezoidal with a toe width of about 33 ft and a top width of 75 ft, the slides sloping at approximately 3:1 (Figure 14).

SCD plans have a control structure at the inlet to limit flow into the side channel during flood season. The intent is to prevent the sediment-laden flood waters from depositing sediment in the channel and filling it up over time. This control structure will not be modeled as part of this study because sediment transport is not modeled. The project will be modeled as an open channel.

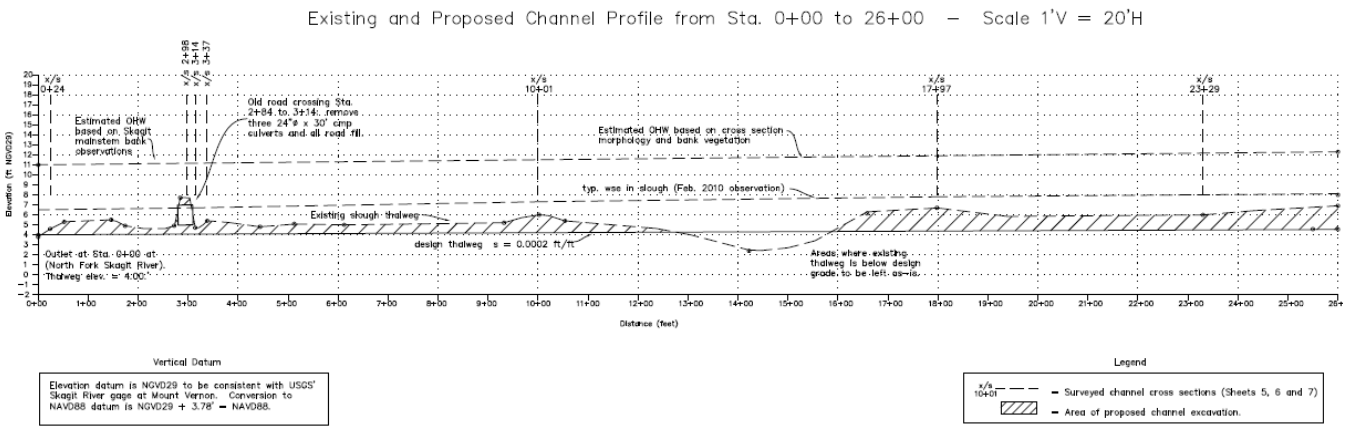


Figure 12: Profile of the Cottonwood Island side channel project - downstream end. (Higher resolution images, or AutoCAD drawings available).

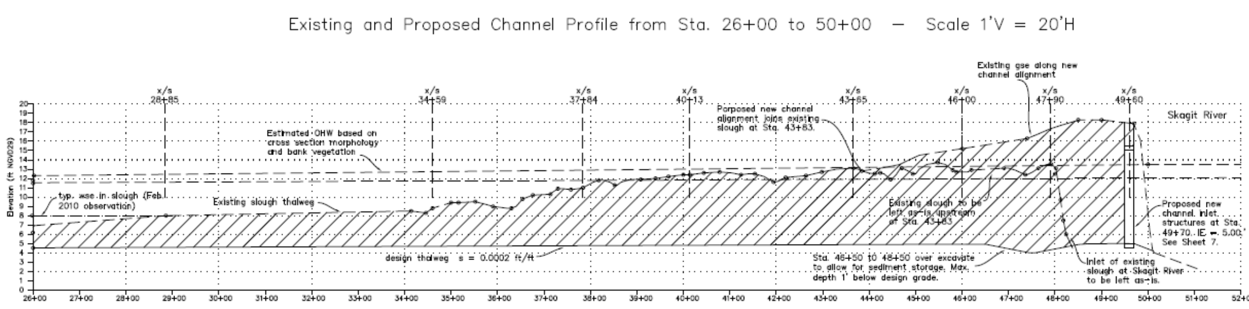


Figure 13: Profile of the Cottonwood Island side channel project - upstream end. (Higher resolution images, or AutoCAD drawings available).

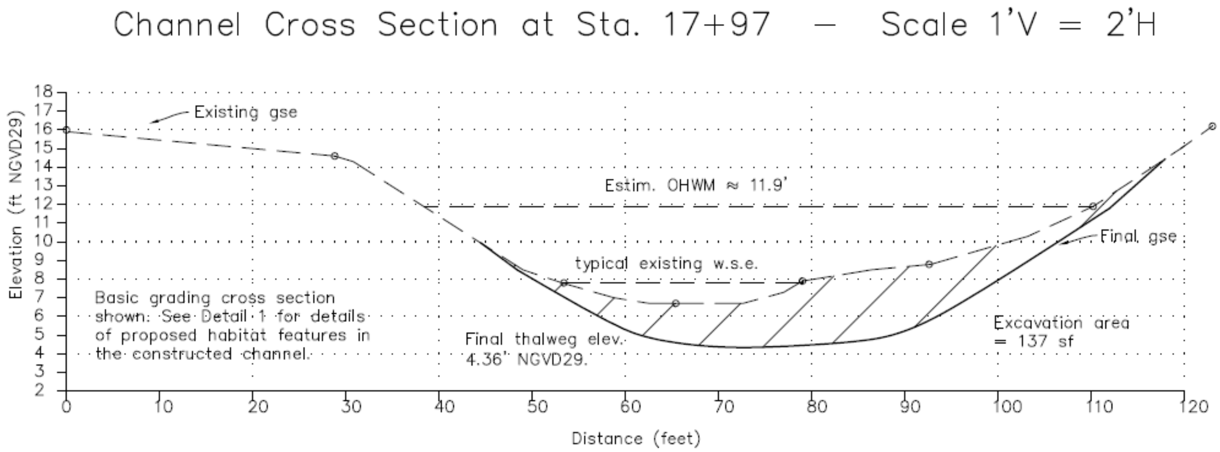
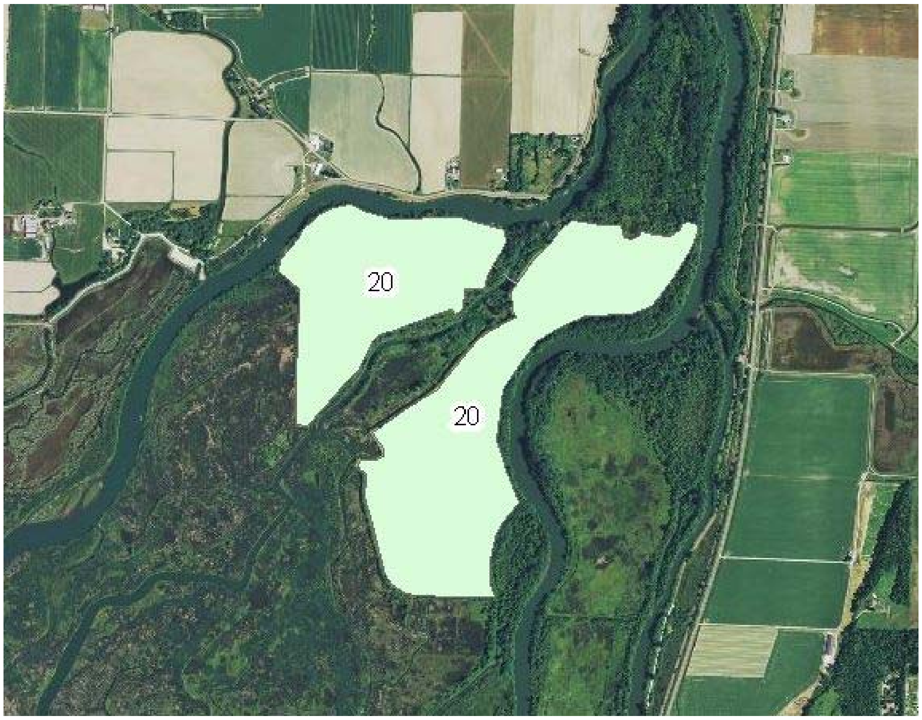


Figure 14: Typical cross section for the Cottonwood Island side channel. (Higher resolution images, or AutoCAD drawings available).

Deepwater Slough Phase 2 (Project # 20)



Key Project Elements	
Project Origin	Chinook Recovery Plan; and PSNERP
Project Status	10% Feasibility Completed 2011
Project Location	South Fork
Project Type	Dike Breach
Approximate Project Area	268 acres

Project Narrative:
Deepwater Phase 2 spans two islands located near the mouth of the South Fork (SF) of the Skagit River. A conceptual design for Deepwater Slough Phase 2 was prepared for the PSNERP study (PSNERP 2012)[7], Figure 15 and 16. This analysis will evaluate the full restoration project proposed in the PSNERP study. The project would lower portions of the perimeter dike, lower the internal cross dike, and create a series of dike breaches to connect distributary and blind channels to existing sloughs. It would also include excavation of blind tidal channel networks within each island although these details will not be added to the HDM model. The project would result in unrestricted tidal freshwater flows, restore tidal wetlands and create rearing habitat for juvenile salmon such as Chinook. Under the Skagit Tidegate and Fish Initiative (TFI), this project will also generate credits to help maintain critical agricultural

[7] Puget Sound Nearshore Ecosystem Restoration Project. 2012. Strategic Restoration Conceptual Engineering — Design Report. Published by Washington Department of Fish and Wildlife, Olympia, Washington, and U.S. Army Corps of Engineers, Seattle, Washington.
http://www.pugetsoundnearshore.org/technical_papers/cdr/Design_Rpt_final.pdf

infrastructure. The site is currently managed by WDFW for agricultural purposes and hunting access. There are no buildings or structures on the site.

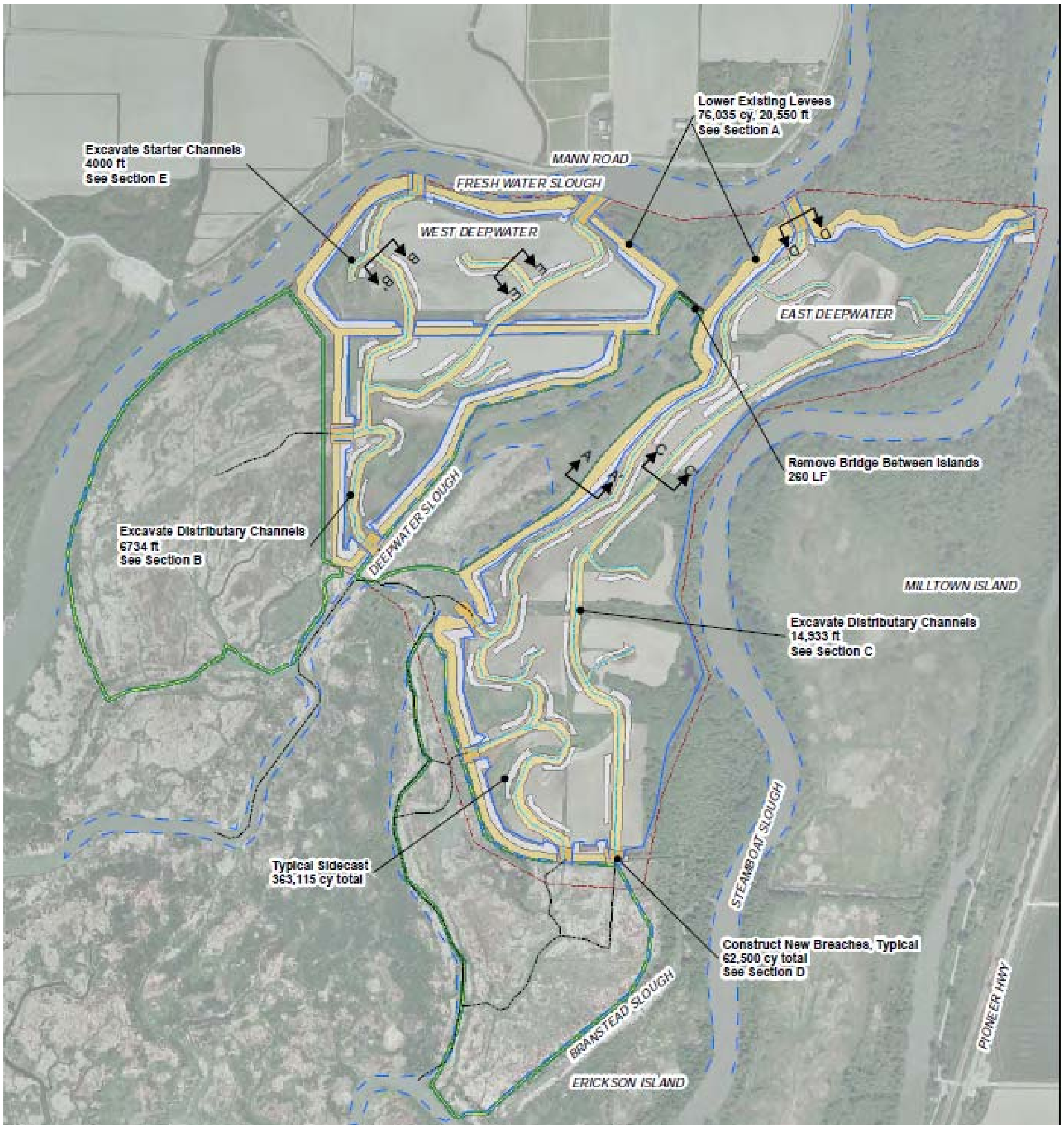


Figure 15: Plan view of the full restoration of Deepwater Slough. (PSNERP, 2012).

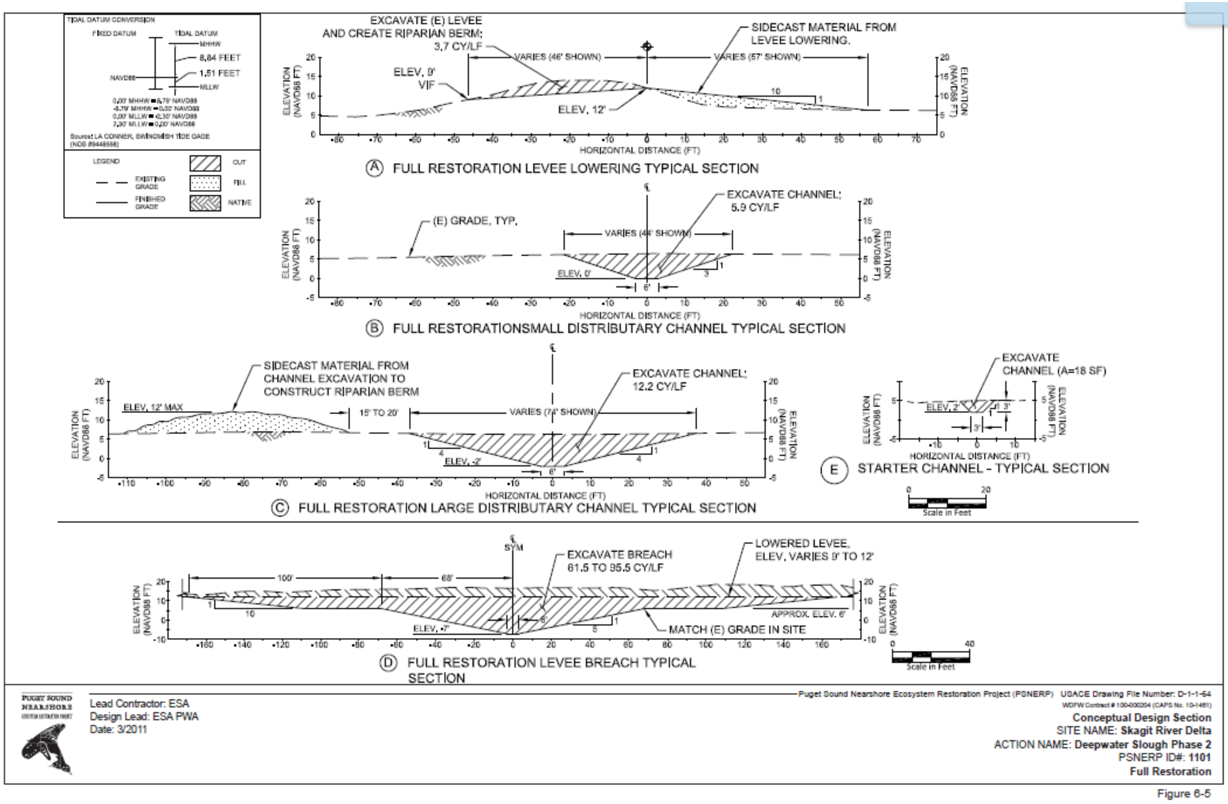
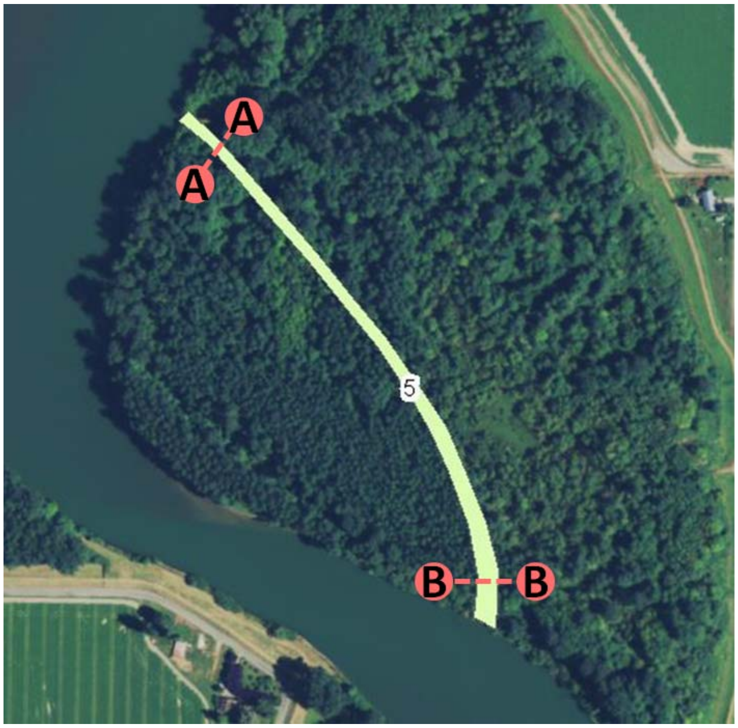


Figure 16: Cross sections of dike breaches and tidal channels. (PSNERP, 2012)

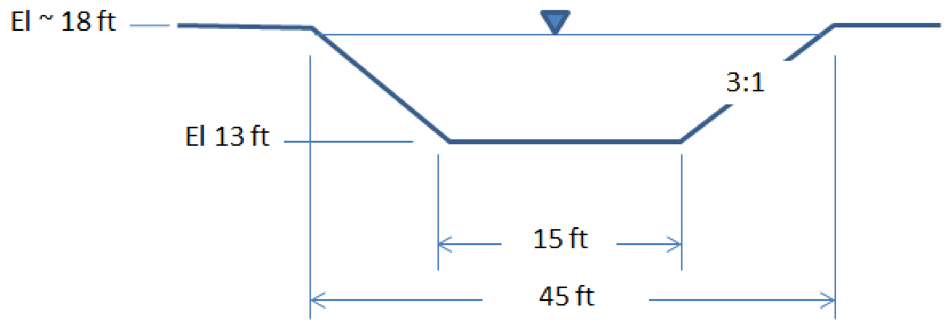
East Cottonwood (Project #5)



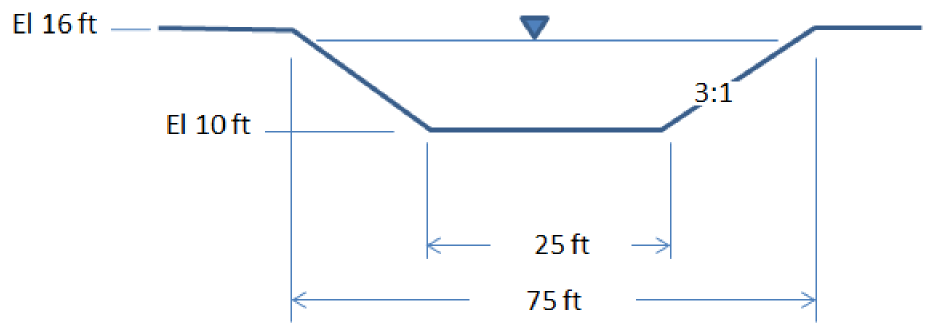
Key Project Elements	
Project Origin	New project – WDFW
Project Status	In development (Feb, 2015)
Project Location	At the N & S Skagit Forks
Project Type	Backwater Channel
Approximate Project Area	2 acres

Project Narrative:
The site is on the riverward side of the existing flood dike and is dominated by mature shrub and tree species. No residences or outbuildings are present. An 8-inch gravity sewer line crosses the proposed channel path, but the elevation of the pipe is unknown at this time. It is assumed that the sewer line is deep enough to clear the channel invert. The project concept is to restore side channel habitat beneficial to Chinook salmon.

The Figure above shows the plan view of the East Cottonwood site, including the proposed connected side channel and cross section locations. The channel would be approximately 1900 feet long with a slope of about 0.1%. Cross sections for the proposed channel are shown in Figure 17. The downstream invert elevation would allow the channel to be inundated at the majority of river stages and particularly during the spring outmigration. Positive drainage would be maintained to prevent stranding.



Section AA (NTS)



Section BB (NTS)

Figure 17. Cross sections of the proposed backwater channel in the East Cottonwood project. AA is at the upstream of the proposed channel near the connection to the Skagit River and BB is at the downstream end near the proposed outlet to the South Fork.

Fir Island Cross Island Connector (Project #12)

Key Project Elements	
Project Origin	Chinook Recovery Plan; Habitat Restoration Pathways for Fir Island, WA[8]; and Skagit River Flood Risk Management Study Hydraulic Effectiveness of Measures[9]
Project Status	No progress
Project Location	North Fork to Bayfront
Project Type	Hydraulic
Approximate Project Area	150 acres

Project Narrative:
The Cross Island Connector project would construct a new distributary channel between the NF Skagit River and the central area of Fir Island along Skagit Bay. The project was originally conceptualized in the CRP and has had subsequent evaluations on its potential placement as well as flood risk reduction relief benefits (see footnotes). The version to be modeled draws from the results of these previous analyses. The project footprint generally follows the topographic low points in Fir Island and would include new levees along the entire length of the channel. The new distributary channel is anticipated to improve the connectivity between the NF Skagit River and Skagit Bay and increase the volume of sediment transported to and deposited in the central area of Fir Island along Skagit Bay, and the distribution of fresh water. The new distributary channel is expected to provide improved juvenile salmon access to the estuary habitats in the central area of Fir Island along Skagit Bay. It is also is expected to provide localized flood relief in the NF Skagit River and would provide TFI credits to the agricultural community. The project area is predominantly farmland and may include residences and outbuildings depending on its footprint should it advance beyond basic analyses. The figure above illustrates the approximate geometry of the new channel.

The PWA Restoration Pathways document does not give a definitive alignment for this channel, but the NHC Skagit Flood study does. We propose to use this alignment for modeling purposes. At this stage of analysis its exact location is not critical and the location can be adjusted should the project advance as a priority. If there is support for this project, the location will need to be taken into consideration at a later stage of feasibility and design. To date there has been landowner opposition to this project due to the significant increase in new dikes to the system as well as concerns about the potential for increased regulatory burdens on adjacent farmland. The sinuosity is assumed to be contained within the roughly linear dikes.

The PWA Restoration Pathways recommends some channel characteristics shown in Table 2. The channel must be contained within newly constructed dikes to prevent flooding of the adjacent farmland during floods and high tide. The proposed typical cross section is shown in Figure 18. This cross section

8 An Assessment of Potential Habitat Restoration Pathways for Fir Island, WA, Phillip Williams and Ass., prepared for Skagit Watershed Council, Feb 29, 2004.

9 Skagit River Flood Risk Management Study Hydraulic Effectiveness of Measures, Northwest Hydraulic Consultants, prepared for Skagit County, Jan 12, 2012.

is based off of the channel dimension assumptions detailed in Table 2: from *Table 3-1* in Restoration Pathways. Elevations converted from NGVD to NAVD88 datum.

Table 2: from *Table 3-1* in Restoration Pathways. Elevations converted from NGVD to NAVD88 datum.

Parameter	**Pathway 4**
Bankfull Width (ft)	175
Bankfull Depth (ft)	8.5
Bankfull Discharge [a] (cfs)	6,400
Bankfull Water Surface Elevation (ft, NAVD88)	+11.54
Thalweg Elevation at North Fork (ft, NAVD88)	+3.04
Sinuosity	1.2
Stream Length (ft)	15,000
Equilibrium Slope for Fluvial Portion	0.00036
Fluvial Portion Length (ft)	6,600

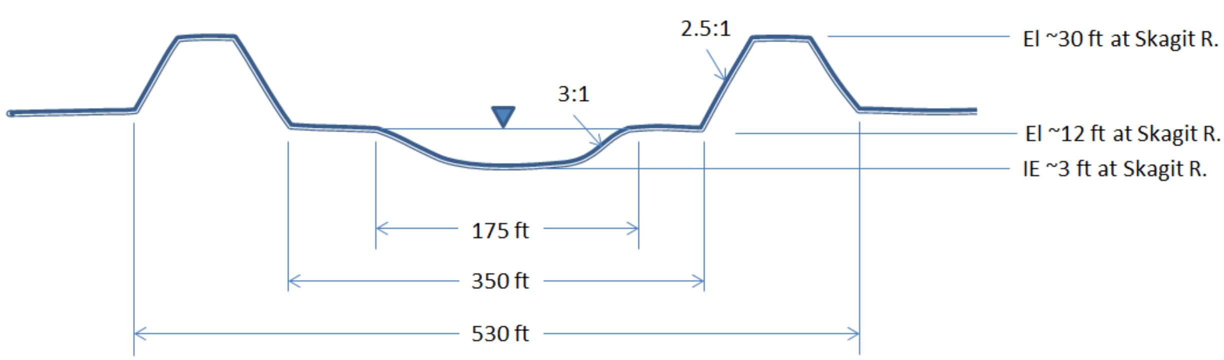


Figure 18: Conceptual cross section of Cross Island Connector at the intersection with the NF Skagit River, with approximate elevations and dimensions. Drawing not to scale.

Fir Island Farm (Project #8)

Key Project Elements	
Project Origin	Chinook Recovery Plan
Project Status	Construction planned 2015-2016
Project Location	Bayfront
Project Type	Dike setback
Approximate Project Area	140 acres

Project Narrative:

The project site is located on Fir Island along Skagit Bay at the WDFW Snow Goose Reserve. The project will replace the existing overtopping marine dike with an engineered setback dike. The project footprint is consistent with the proposed 2015 final design. The project will maintain the agriculture drainage in Brown Slough, Dry Slough, and No Name Slough through new tidegate and pump station infrastructure. The project will restore natural tidal processes, tidal marsh and tidal channel habitats beneficial to Chinook recovery. The project has and will generate TFI credits to help maintain critical agriculture infrastructure. The site is currently farmland owned and managed by WDFW. There are no residences or outbuildings located at the project site.

Hall Slough (Project #7)

Key Project Elements	
Project Origin	Skagit River Flood Control Project: Environmental Restoration & Mitigation Planning[10]; House Bill 1418 Report[11]; SHDM Team
Project Status	No progress
Project Location	Bayfront
Project Type	Dike Setback
Approximate Project Area	134 acres

[10] Skagit River Flood Control Project: Environmental Restoration and Mitigation Planning Evaluation Area Studies. 2002. Tetra Tech, Inc prepared for U.S. Army Corps of Engineers.

[11] Analysis of the Restoration Potential of Former Tidelands in the Skagit Delta. 2004. G. Hood, Skagit River Systems Cooperative. *In* House Bill 1418 Report: Tidegates and Intertidal Salmon Habitat in the Skagit Basin. 2005. C. J. Smith and E. Murray, Washington State Conservation Commission.

Project Narrative:
The project concept is to restore the tidal processes of Skagit Bay to the site by replacing the existing marine dike with an engineered setback dike. The new setback dike would be located to the north and east of the existing dike. The project would restore tidal marsh and tidal channel habitats beneficial to Chinook recovery. The project could improve the gravity drainage for adjacent agricultural lands by allowing the drift log accumulation in front of the existing Hall Slough tidegates to be naturally deposited further north. The project would generate TFI credits to help maintain critical agriculture infrastructure. The project site is active farm land without residences or out buildings. The land is currently under an agricultural easement that does not prevent future restoration actions should the landowner be willing.

McGlinn Causeway (Project #2)

Key Project Elements	
Project Origin	Chinook Recovery Plan; and PSNERP
Project Status	Phase 1 Feasibility Complete
Project Location	North Fork and Swinomish Channel
Project Type	Hydraulic
Approximate Project Area	7 acres

Project Narrative:

The project concept is to improve the hydraulic connectivity between the NF Skagit River and the Swinomish Channel through the jetty and causeway which separate the two water bodies. The project is expected to improve the migration of salmoids between the NF Skagit River and the Swinomish Channel. The project is also expected to improve the habitat conditions in the Swinomish Channel and improve the accessibility of Padilla Bay habitats to NF Skagit salmonids. The primary source for the design is from the PSNERP Conceptual Engineering report, Chapter 19 McGlinn Island Causeway (PSNERP, 2012) and the Habitat Restoration Feasibility Phase 1: Establishing the Viability of Hydraulic

Connectivity between Skagit & Padilla Bays, by the Skagit River System Cooperative and Battelle[12]. Drawings for the jetty lowering are from Northwest Hydraulic Consultants. No agricultural lands or residences are within the project footprint.

This project is composed of two elements: the first is a breach in the causeway between La Conner and McGlinn Island that was constructed with dredge spoils from the Swinomish Channel; the second is lowering a portion of the jetty between the NF Skagit and the southern end of the Swinomish Slough.

Figure 19 and 20 show the plan and cross section of the proposed causeway breach. The proposed breach would be a zero gradient trapezoidal channel with a toe width of 134 ft and 2:1 side slopes. The elevation of the bed would be 1 ft NAVD88, which is approximately -0.5 ft in MLLW datum. This means that the channel would be tidally inundated for the majority of the time. Since the bottom of the channel would not be armored, it would scour to any depth that shear stress and sediment transport determined.

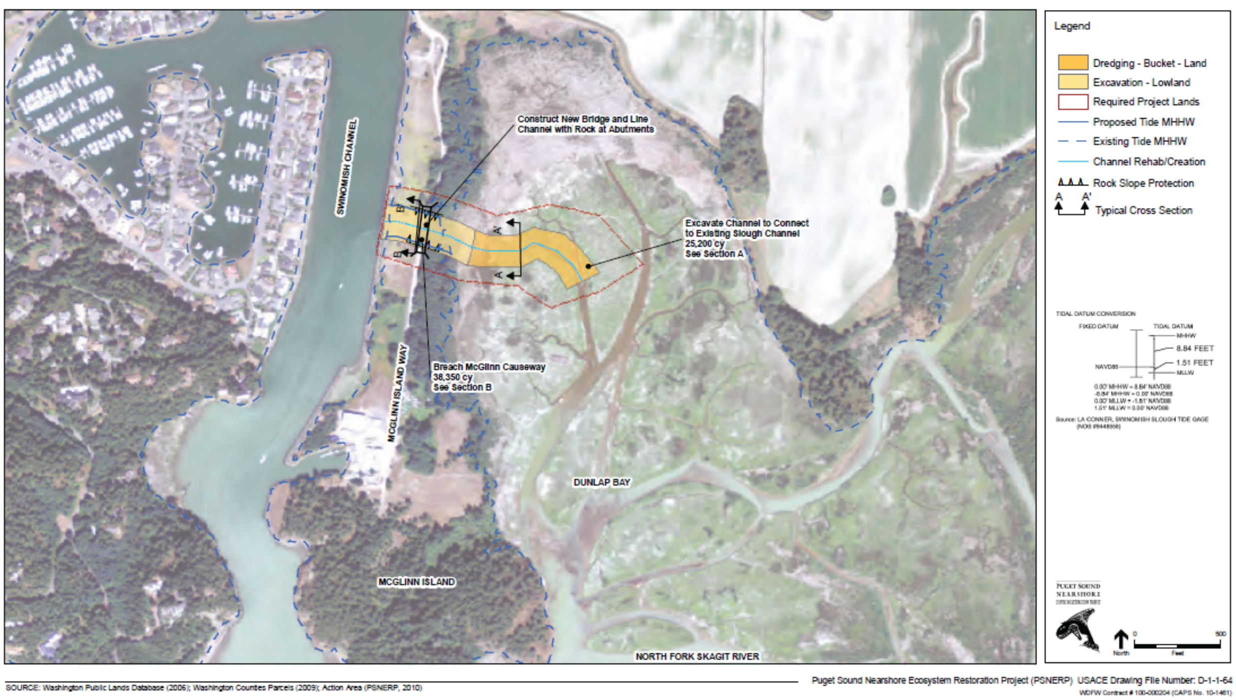


Figure 19. Plan view of the causeway breach with new bridge and a dredged channel connecting Dunlap Bay with the Swinomish Channel. (PSNERP, 2012)

12 SRSC, Battelle PNNL, USGS. 2008. McGlinn Island Causeway & Jetty Habitat Restoration Feasibility Phase 1: Establishing the viability of hydraulic connectivity between Skagit and Padilla Bays. Skagit River System Cooperative, La Connor, WA

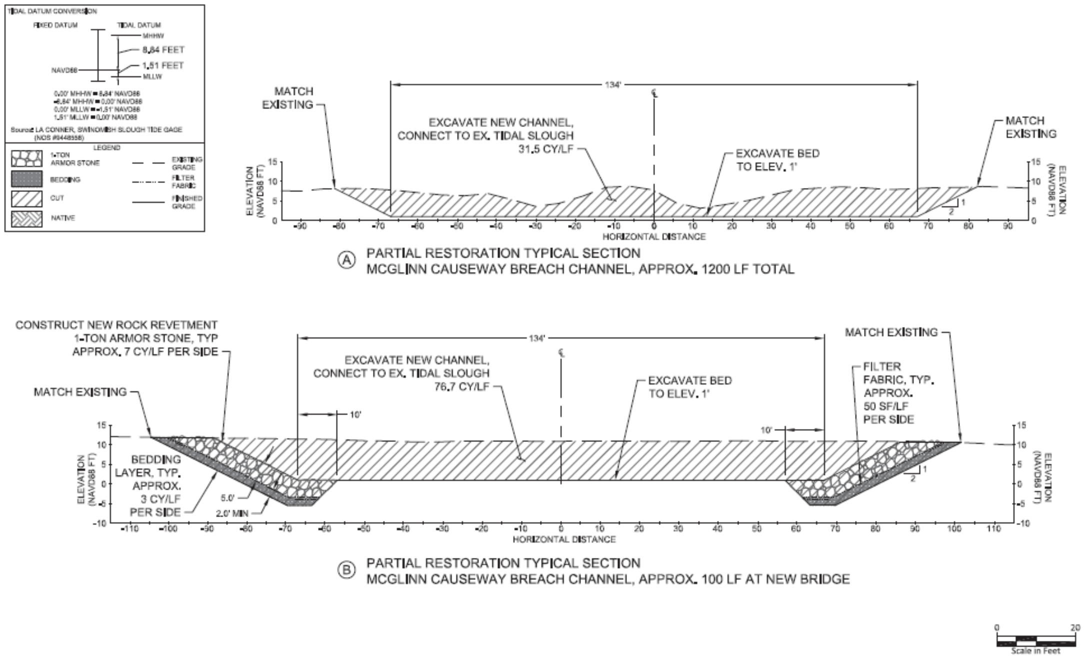


Figure 20. Cross sections for the connecting channel and bridge for the McGlinn Causeway project.

Figure 21 and Figure 22. show the plan and cross sections for lowering of the jetty. The lowered section is approximately 500 ft long at an elevation of 4.4 ft NAVD88. For modeling purposes, the exact configuration of the lower section is not important. This design also includes fishway-like stepped pool structure at the fish hole. This detail is not necessary for the model.

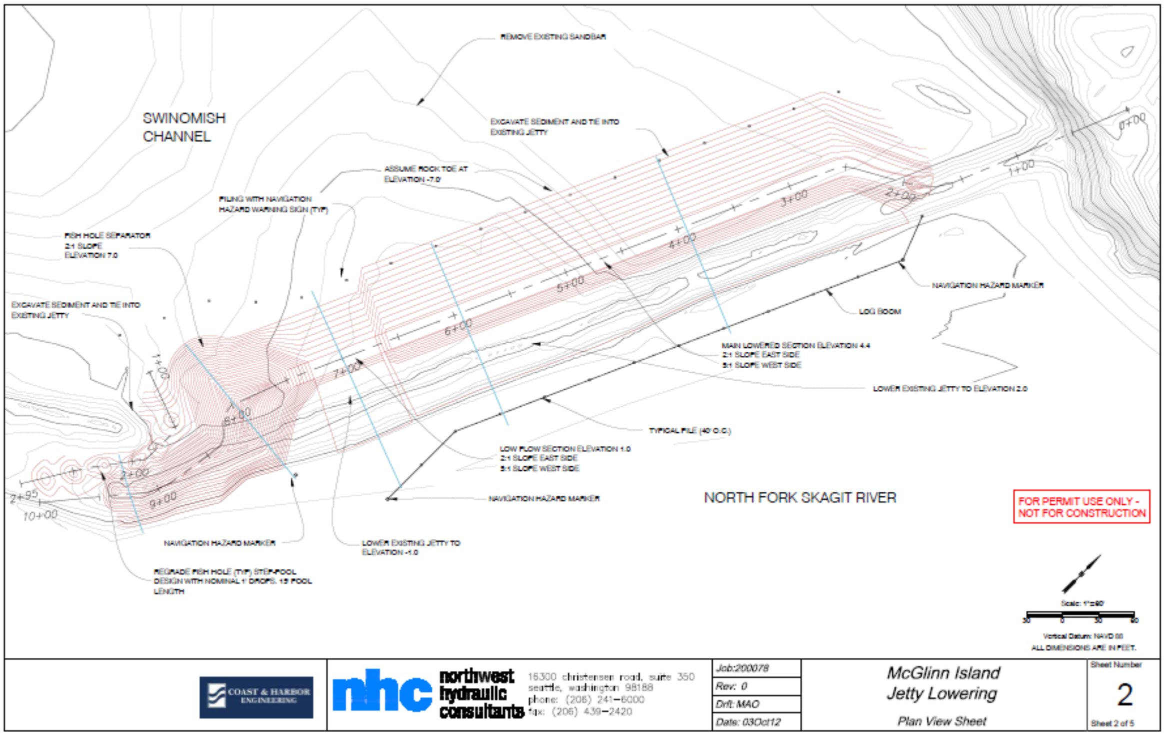


Figure 21. Plan view of jetty lowering.

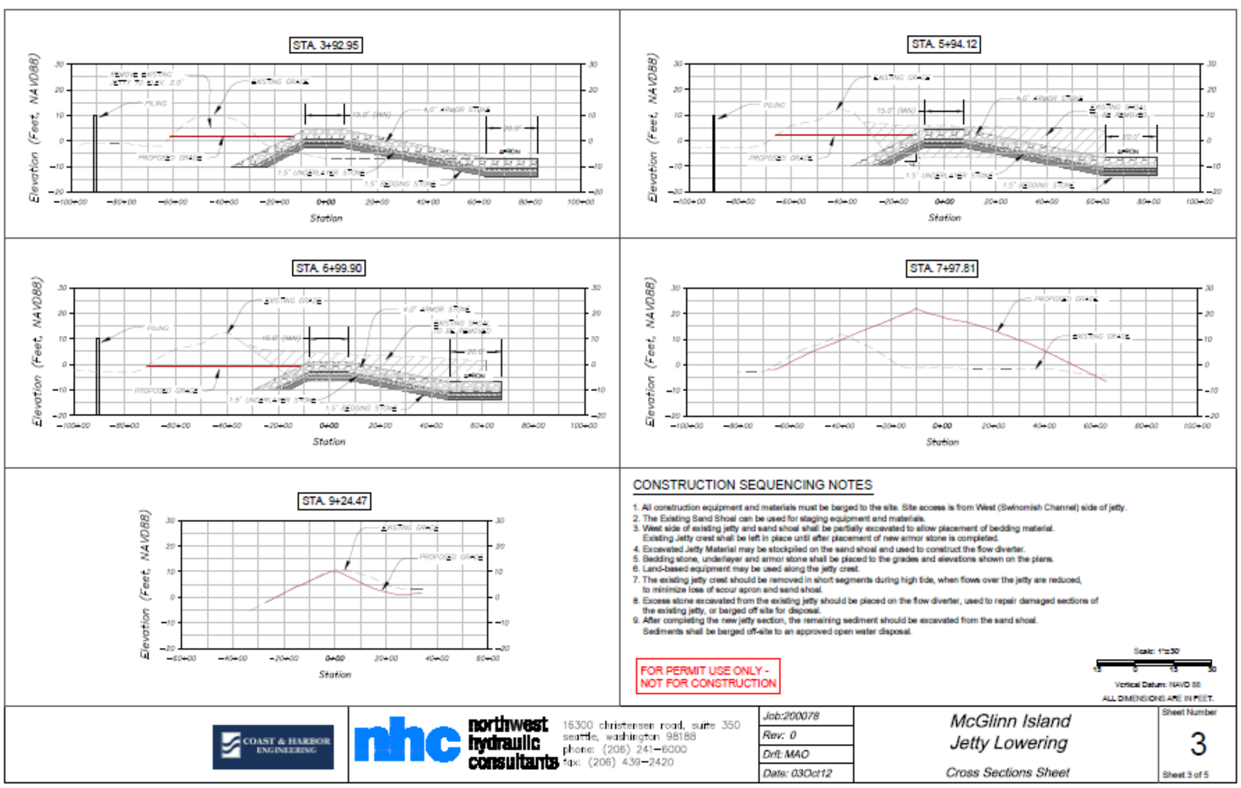


Figure 22. Cross section of jetty lowering.

Milltown Island (Project # 17)

Key Project Elements	
Project Origin	Chinook Recovery Plan; and PSNERP
Project Status	Ongoing construction
Project Location	South Fork
Project Type	Levee Breach
Approximate Project Area	222 acres

Project Narrative:
Milltown Island is located at the mouth of the SF Skagit River and is surrounded by partially breached abandoned levees. The project site primarily consists of abandoned farm fields, manmade drainage channels, and wetlands. Portions of the abandoned levees were breached in 1999 by the US Navy in cooperation with the Army Corps of Engineers, SRSC and WDFW (SRSC 2009). In 2006 and 2007, SRSC removed additional portions of the historic levee, constructed tidal channels, and planted native vegetation (SRSC 2009).

The proposed project concept was originally identified in the CRP and was further developed by PSNERP. The proposed project would restore additional tidal channel habitat on the island by removing the remaining dikes along the perimeter of the island. Final design of this project will also evaluate breaching the existing perimeter dike in at least 14 locations to preserve existing riparian vegetation and increase the number of tidal channel inlets to a number consistent with natural marsh drainage patters. The project may have the potential to also provide local flood relief in the SF Skagit River. The project is expected to restore tidal-riverine wetlands, forests and channels that would be beneficial to Chinook recovery. There are no residences on the project site, but there is an outbuilding. The site is no longer used for agricultural production.

North Fork Left Bank Levee Setback A, B, and C (Project #14 &15)

Key Project Elements	
Project Origin	Chinook Recovery Plan; PSNERP
Project Status	No progress on the full project design. See description below.
Project Location	North Fork (NF)
Project Type	Dike setback
Approximate Project Area	
Setback A (Project #15)	553
Setback B (not shown)	
Setback C (Project #14)	275

Project Narrative:
This dike setback project is primarily derived from the Skagit Chinook Recovery Plan. Modifications to the CRP project footprint have been made to facilitate modeling and to create smaller stand-alone projects should the entire footprint not be a prioritized project. The CRP project footprints (phase 1 and phase 2) are included in the footprints proposed for this HDM effort. There are three sections to the NF Left Bank Levee Setback Project proposed for the SHDM Project alternative analysis. Only two of these will be directly incorporated into the hydrodynamic modeling; the third will be calculated based off of the results from modeling the other two projects.

The first, Setback A, begins just downstream of the forks at the inlet of Dry Slough and continues to the marine dike at the end of Rawlins Road. As a result Setback A (#15) includes the foot print of Setback C

(#14) shown in the above image. The width of the setback would be approximately 1,000 ft, but varies along the length. The elevation of the setback dike would be similar to the existing dike and the side slopes are assumed to be 2.5:1 (see General Project Assumptions). This is the full North Fork Dike Setback project listed in the CRP as well as an expansion to include the northern portion of Rawlins Road Setback project so that the footprint extends west to the marine dike at the end of Rawlins Road. This added area would complete the setback project by providing route for overbank flood water to reach the bay over the marsh to the west and south. This would effectively increase the cross sectional area at the mouth of the river and would remove the constriction created by making the Rawlins Rd setback project an independent activity.

The upstream extent of North Fork Left Bank Levee Setback B begins where Moore Road runs east to west across Fir Island and encompasses the remaining downstream portions of Setback A. This North Fork Left Bank Levee Setback B will not be modelled on its own. The characteristics and values for Setback B can be calculated as a percentage of Setback C.

Setback C is the smallest of the footprints with an upstream extent of Polson Road extending down to the marine dike. The PSNERP version of this project as well as Phase 1 from the CRP are fully contained within this footprint with the exception of the PSNERP proposed work on the opposite bank at Thein Farm. PSNERP projects benefits can be deduced as a portion of this project along with those from Thein Farm, but the PSNERP project footprint is not directly included in this modeling work. Additionally, Skagit County has a grant to conduct feasibility and preliminary design for 22 acre levee setback just upstream of the North Fork Bridge on the left bank of the river. This smaller project is also fully contained within the footprint of Setback C.

All of the setback alternatives have the potential to provide localized flood benefits as they contain levees that were identified by the local diking districts as having known seepage or boils, with Setback A and B having the largest amount of levees with known weaknesses when compared to Setback C. Each setback alternative is expected to restore riverine and tidal marsh habitats beneficial to Chinook salmon. All of the setback alternatives would impact existing farmland, associated farming structures, residences as well as a marina and RV park. All versions of the setback would generate TFI credits to help maintain critical agriculture infrastructure. Setbacks A and B would impact preserved farmland parcels.

All three setback alternatives include the footings of the current NF Bridge. Skagit County has developed some initial plans to eventually replace the NF Bridge[13]. If the hydraulics of the bridge opening are modeled, then the new bridge layout should be used. The exact design and location of the bridge have not been determined, but we can assume for now that it is approximately in the same location and has a pier location similar to what is shown in Figure 23.

[13] Skagit County Public Works Department North Fork Skagit River Bridge Type Size & Location Study. Feb 24, 2014, Shearer Design, LLC.

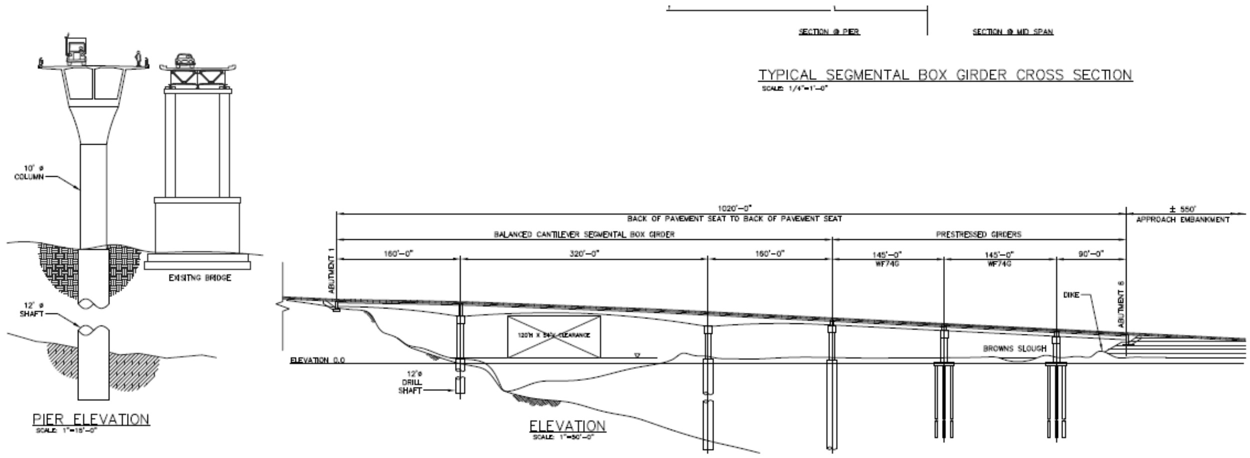
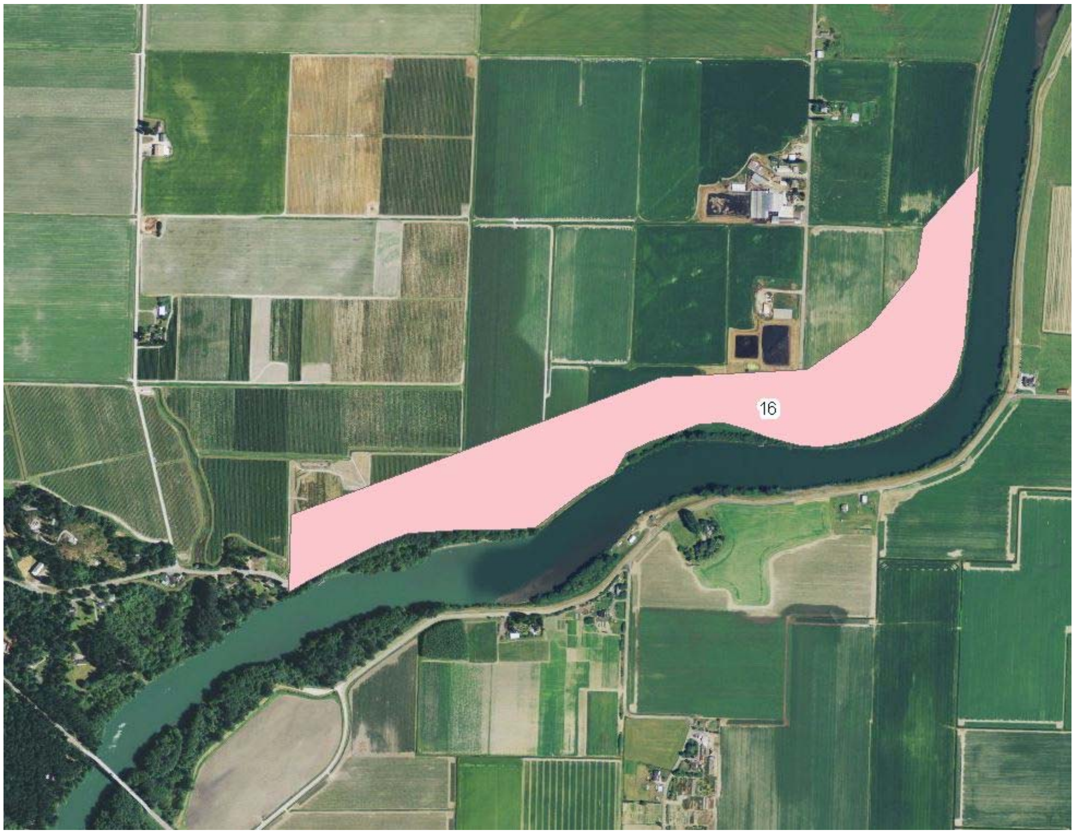


Figure 23: Cross section of proposed NF Skagit Bridge. (Higher resolution drawing is available, if necessary.)

North Fork Right Bank Levee Setback (Project # 16)



Key Project Elements	
Project Origin	New - Identified by SHDM Team
Project Status	New
Project Location	North Fork
Project Type	Dike Setback
Approximate Project Area	86 acres

Project Narrative:
The project area is located along the right bank of the NF Skagit River. The project concept is to relocate the existing flood dike approximately one channel width landward of its current location. The project is expected to expand the river flood plain and replace the existing dike with an engineered flood dike. This section of dike was one of several areas identified as having known seepage problems by the local diking districts; therefore, it is anticipated that replacing the dike with a new engineered structure and setting it away from the river will provide increased flood risk reduction to the local area. The project is expected to restore wetland, shrub, forest, and channel habitats beneficial to Chinook recovery. The project would generate TFI credits to help maintain critical agriculture infrastructure. The area is dominated by farmland, farm related buildings, and residences.

Pleasant Ridge South (Project #6)

Key Project Elements	
Project Origin	New – Identified by SHDM Team
Project Status	New
Project Location	North Fork
Project Type	Dike Setback
Approximate Project Area	30 acres

Project Narrative:
The project site is landward of the existing NF Skagit River levee along the right bank of the NF Skagit River. The majority of the project site is surrounded to the east, north and west by an elevated ridge. The project concept would restore riverine and tidal process to the site by removing the existing river levee and constructing a new engineered levee along the toe of Pleasant Ridge as needed to protect adjacent private property. The project would expand the floodplain of the NF Skagit River. The project is expected to restore tidal marsh and channel habitats beneficial to Chinook salmon. The project would generate TFI credits to help maintain critical agriculture infrastructure. The project site is farmland and there are no residences or outbuildings at the site.

Rawlins Road (Project # 21)

Key Project Elements	
Project Origin	Chinook Recovery Plan
Project Status	Feasibility Complete 2006[14]
Project Location	North Fork
Project Type	Dike Setback
Approximate Project Area	192 acres

Project Narrative:
This project was originally proposed in the CRP as part of a suite of projects that would setback NF Skagit River levees and could have mutual benefits if implemented together; the larger project was called Blake's Bottleneck. A feasibility study of the Rawlins Road Project was completed by Battelle in 2006 for SWC. The 2006 Batelle study used a smaller footprint than what was included in the CRP for Blake's Bottleneck. For this study we are including the full footprint that was included in the larger Blake's Bottleneck project. Should the project rank well, but a smaller footprint desired, the benefits determined from the model can be scaled down to that footprint. The larger project footprint includes agricultural lands, residences and outbuildings.

[14] Hydrologic and Hydrodynamic Modeling of Skagit River Estuary - Rawlins Road Restoration Feasibility Study. Battelle – Pacific Northwest Division, prepared for Skagit Watershed Council. October, 2006.

The project would restore riverine and tidal process to the site by replace the existing dike with an engineered dike located approximately 2700 feet east of the existing marine dike. The project would also remove a portion of the NF Skagit River levee. The project is expected to restore tidal marsh and channel habitats beneficial to Chinook salmon recovery. It also has the potential to have significant changes to the hydrodynamic behavior of the lower NF Skagit River and delta (Battelle 2006). The project would maintain the agriculture drainage through improved/new tidegate and drainage infrastructure. The project would generate TFI credits to help maintain critical agriculture infrastructure.

Rawlins Road Distributary Channel (Project #11)

Key Project Elements	
Project Origin	Rawlins Road Restoration Feasibility Study (Battelle, 2006)
Project Status	Feasibility
Project Location	North Fork to Bayfront
Project Type	Hydraulic
Approximate Project Area	8 acres

Project Narrative:

The project site is on the bay side of the existing Fir Island marine dike near where it intersects the NF Skagit River. The project site is dominated by native tidal marsh and tidal channel habitats typical of the Skagit Bay estuary. There are also manmade channels at the project site associated with historic dike construction and drainage infrastructure, but no outbuildings. Along the northern edge of the site, adjacent to the NF of the Skagit, there is a natural river levee vegetated with trees and shrubs. The project concept is to create a channel waterward of the marine dike as shown in Figure 24 to create a pathway for juvenile chinook, sediment and fresh water directly to the Bayfront, and to potentially provide localized flood relief. The channel would have a 40 m toe with a 10:1 slope on the westerly edge. The length of channel proposed in the CRP is 1500 ft and would connect to a tidal channel that heads off in a southwesterly direction. The channel to be modeled extends further south to terminate in the Bayfront without relying on existing channels to resize (see above project map).

The efficacy of this project was called into question by the feasibility study as it only provided a minor improvement in Bayfront salinity gradient, but in light of the new major distributary 3000 feet to the west, the distribution of fresh water to the Bayfront is much improved and an additional, and more direct, route for fish to this habitat may be advantageous.

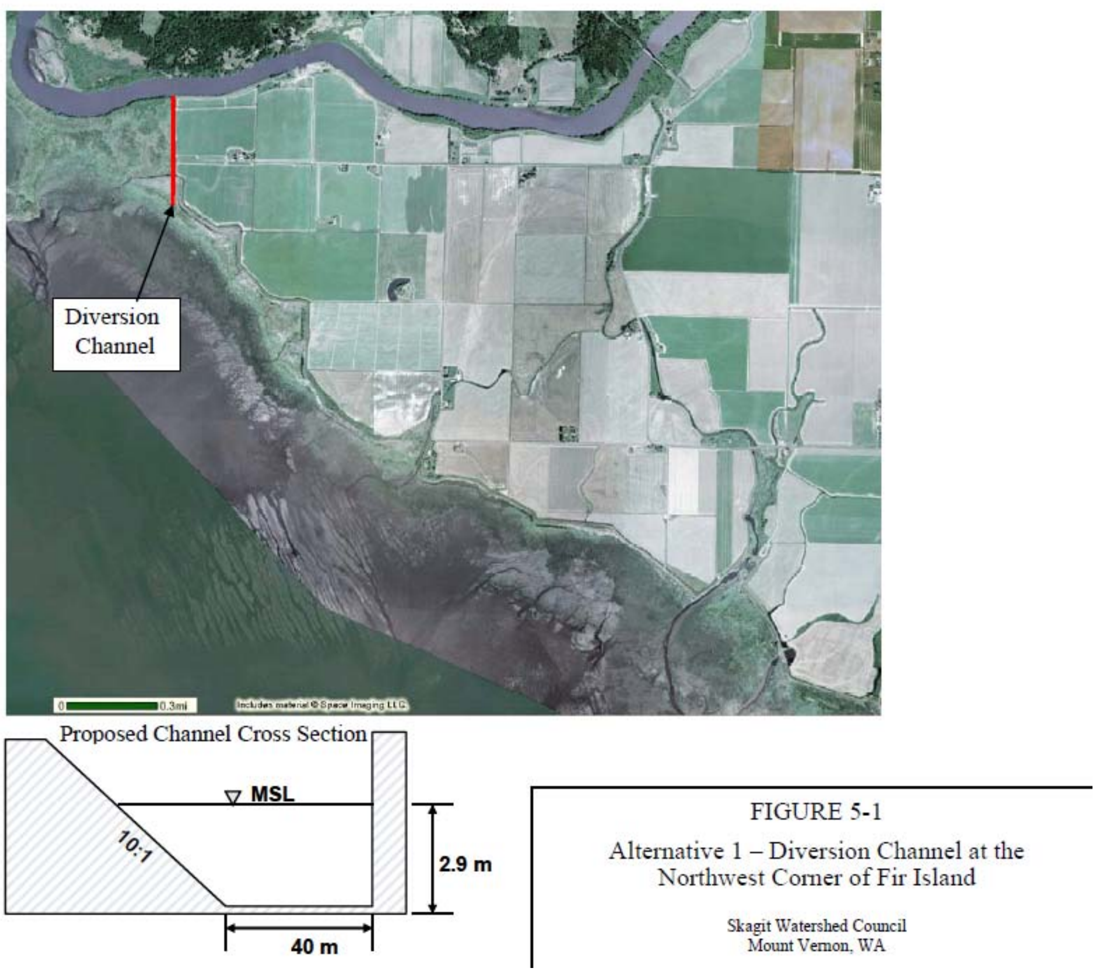


Figure 24. Proposed channel location and cross section from Batelle 2006 report.

South Fork Levee Setback 2, 3, 4 (Project #1)

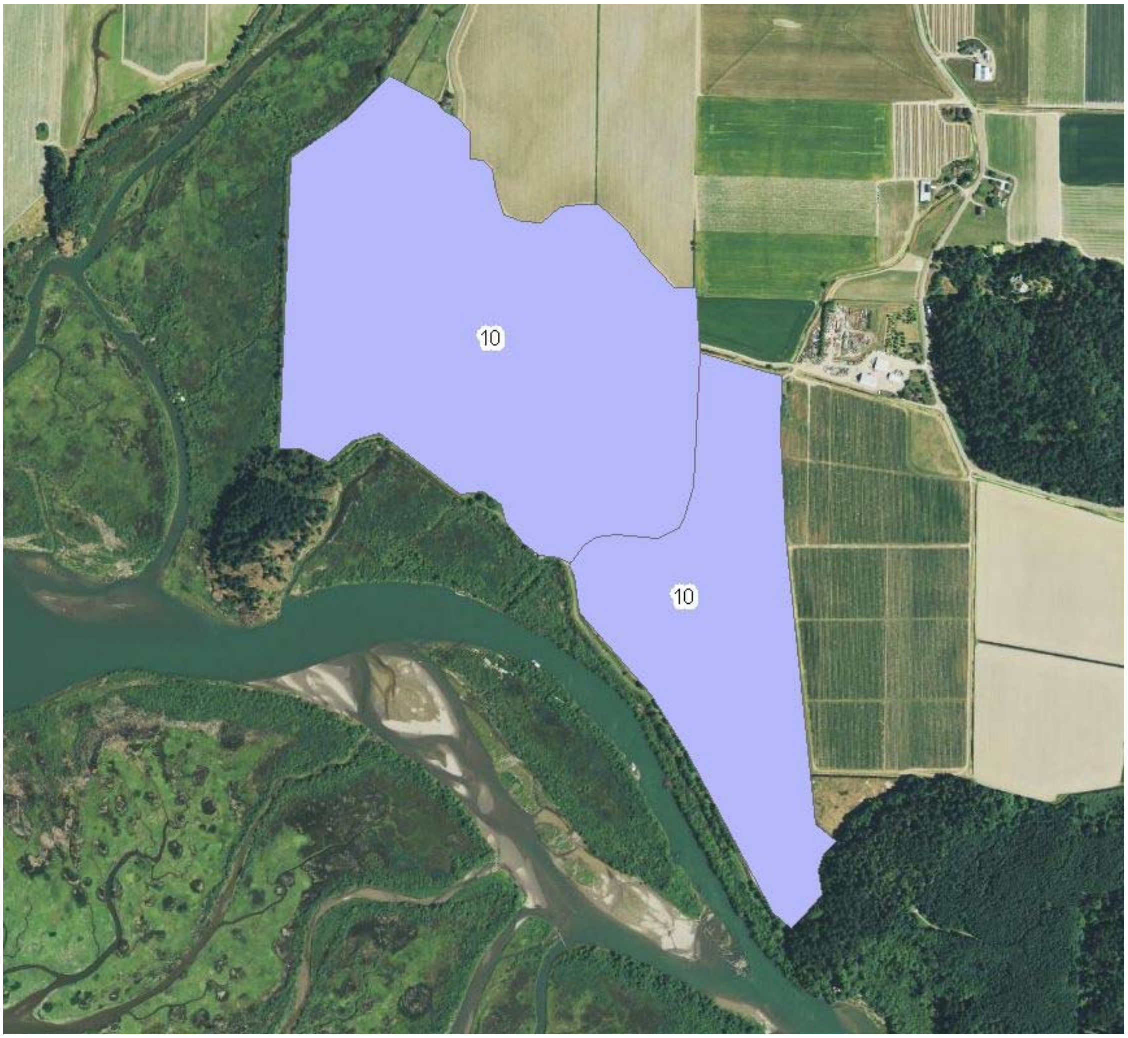
Key Project Elements	
Project Origin	New – Identified by SHDM Team
Project Status	New
Project Location	South Fork
Project Type	Dike Setback
Approximate Project Area	57

Project Narrative:

The project site is comprised of three separate levee setbacks to the west of Pioneer Highway south of Conway extending to Milltown. The northern setback (#2) starts just south of the pole yard in Conway and extends down to the north bank of Fisher Slough. This section would impact a small parcel of agricultural land while the remaining habitat is dominated by trees and shrubs over a remnant slough. This area of land is adjacent to the South Fork of the Skagit to the west and the BNSF Railroad to the east. The middle setback (#3) northern edge starts just below the south bank of Fisher Slough where it feeds into Tom Moore Slough and continues south to Milltown Road. The southern setback (#4) is located just south of Milltown Road. Both Setback 3 and 4 are bordered by Tom Moore Slough to the west and the BNSF Railroad line to the east and are comprised of forested or shrub dominated wetlands.

The project concept is to provide additional connected riparian habitat and potential backwater areas by setting the levee back to the railroad line on all three portions. This would improve flood infrastructure by relocating it away from the South Fork or Slough at locations where there has been repeated bank damage from floods.

Sullivan Hacienda (Project # 10)



Key Project Elements	
Project Origin	Chinook Recovery Plan
Project Status	No progress
Project Location	North Fork
Project Type	Dike Setback
Approximate Project Area	205 acres

Project Narrative:
The project site is landward of the dike along the right bank of the NF Skagit River near the mouth. The project footprint is consistent with the footprint shown in the CRP and is approximately equal to the dike location prior to 1956. The project would replace the existing marine dike with an engineered setback dike. The project would restore natural riverine and tidal processes, tidal marsh and tidal and blind channel habitats beneficial to Chinook recovery. The project site is farmland and there are no residences or outbuildings at the site. The project would maintain the agriculture drainage through improved/new tidegate and drainage infrastructure and would generate TFI credits.

Telegraph Slough 1 (Project # 18)

Key Project Elements	
Project Origin	Chinook Recovery Plan
Project Status	No Progress
Project Location	Swinomish Channel
Project Type	Dike setback
Approximate Project Area	185 acres

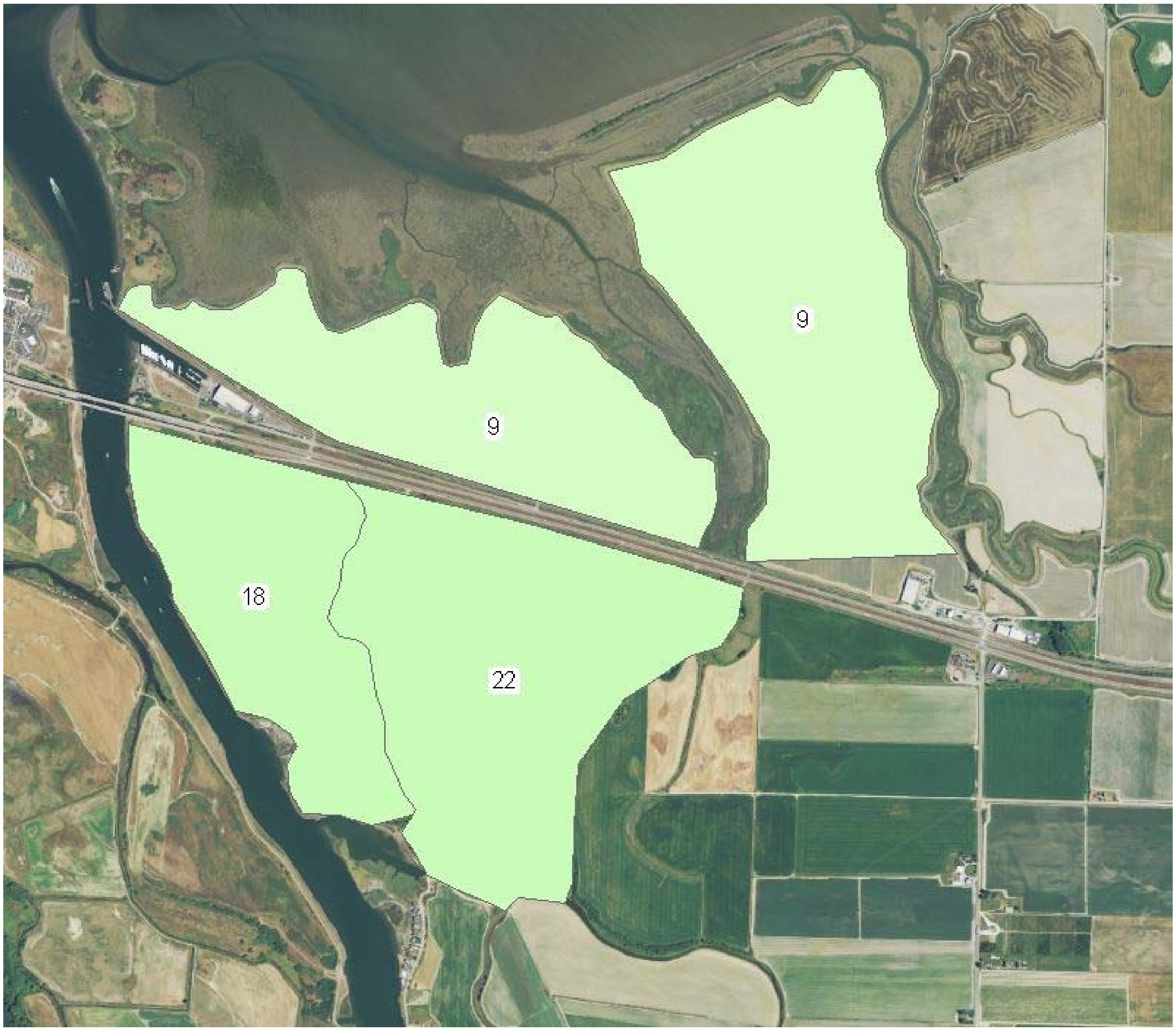
Project Narrative:
The Telegraph Slough 1 (TS1) project is located on the east bank of the Swinomish Channel. This project was proposed in the CRP and the project footprint is consistent with that plan. TS 1 would setback the existing levee with engineered dikes and restore approximately 185 acres of marsh to natural riverine and tidal processes, tidal marsh, and tidal and blind channel habitats beneficial to Chinook recovery. The project site is farmland and there are no residences or outbuildings at the site. The project would maintain the agriculture drainage through improved/new tidegate and drainage infrastructure. The project would generate TFI credits to help maintain critical agriculture infrastructure.

Telegraph Slough 1&2 (Project #22)

Key Project Elements	
Project Origin	Chinook Recovery Plan
Project Status	No Progress
Project Location	Swinomish Channel
Project Type	Dike setback
Approximate Project Area	495 acres (including Phase 1 footprint)

Project Narrative:
This project is also located along the east bank of the Swinomish Channel and includes the area identified in TS 1 plus additional area to the east. The Telegraph Slough 1&2 (TS1&2) project was also proposed in the CRP and the project footprint is consistent with that plan. TS 1&2 would restore an additional 310 acres of marsh by further setting back the dike and relocating the existing tidegates. TS 1&2 would also restore connectivity to Padilla Bay through the historic Telegraph slough corridor by constructing new bridges under SR20 and the Railroad. The CRP does not include specific detail on the bridge; therefore, we have incorporated the bridge design from the PSNERP for Telegraph Slough Full (Project #9), which is detailed below. The project footprint includes farmland with a residence and associate outbuilding, HWY 20 and associated drainage infrastructure. The project would generate TFI credits to help maintain critical agriculture infrastructure.

Telegraph Slough Full (Project #9)



Key Project Elements	
Project Origin	Chinook Recovery Plan; PSNERP
Project Status	10% Feasibility Study Completed 2011
Project Location	Swinomish Channel
Project Type	Dike setback
Approximate Project Area	1048 acres (including TS 1 & 2)

Project Narrative:
The full telegraph slough restoration project has been modified from the original proposals in the CRP and PSNERP 10% Feasibility study to include an additional area located north of SR20 and east of Telegraph Slough (the Telegraph Peninsula)as proposed by the Skagit Watershed Council. It is assumed

that the Telegraph Peninsula project action would function better for salmon if the connectivity of the area is increased by the larger Telegraph Slough project proposed by PSNERP.

The proposed full Telegraph Slough project would remove most of the existing dikes along Telegraph Slough, Padilla Bay, and the Swinomish Channel (east). A new engineered setback dike would be constructed along the southern portion of the Telegraph Peninsula and along the east and south sides of Telegraph Slough, and south of SR 20. The project would restore tidal hydrology to nearly all of the action area. The project is comprised of agricultural land with associated structures as well as residences and existing slough habitat. The project would generate TFI credits to help maintain critical agriculture infrastructure.

During the feasibility study PSNERP summarized the following specific design elements. SR 20 would be raised to a minimum elevation of 17 feet NAVD 88. The project would include 2 new 10-ft diameter culverts to improve hydraulic connectivity of smaller tidal drainages and would include two new bridges: one on SR20 and one at the BNRR rail crossing of Telegraph slough. Both bridges would be approximately 680 feet long, with six spans that are each approximately 113 feet long. The SR20 bridge would have a deck elevation of 23.5 ft. NAVD88 (EHW + 3.0 ft), based on a structure depth of 6 ft 6 inches and the Railroad bridge would have a deck elevation of 21.2 ft (EHW + 3.0 ft) based on a structure depth of 4 ft 2 inches (PSNERP 2012).

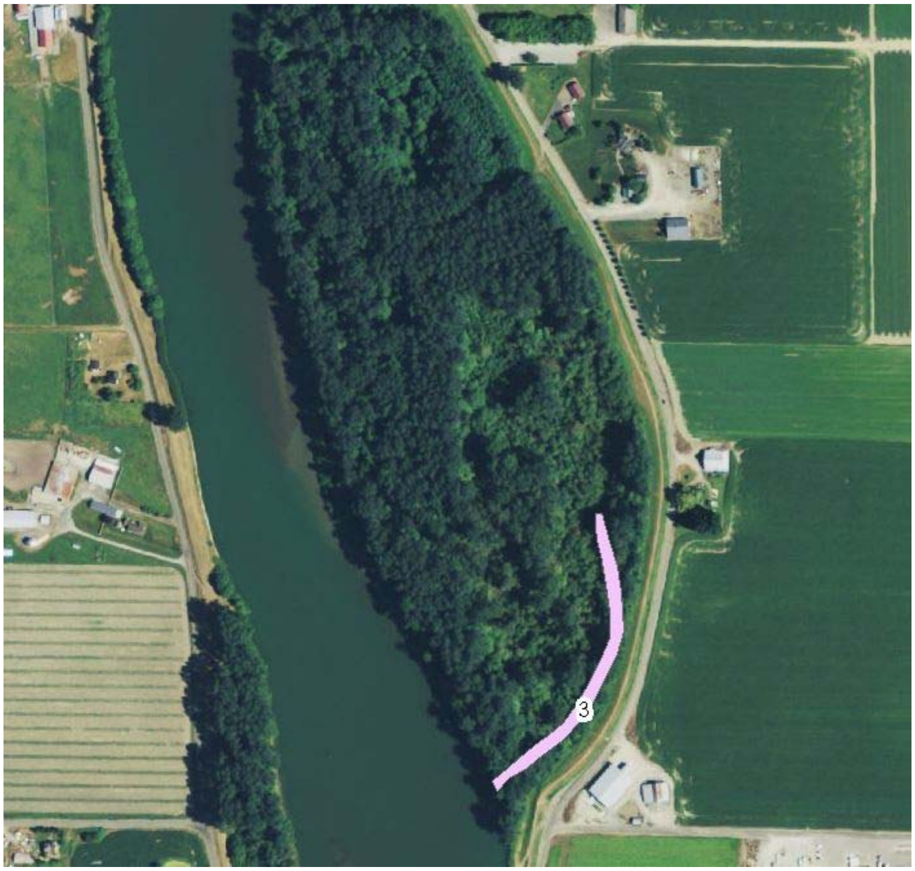
Thein Farm (Project # 19)

Key Project Elements	
Project Origin	Chinook Recovery Plan; and PSNERP
Project Status	No progress
Porject Location	North Fork
Project Type	Dike Setback
Approximate Project Area	78 acres

Project Narrative:

The Thein Farm project is located on the right bank of the NF Skagit River near the mouth. This project was originally proposed in the CRP as part of a suite of projects, known as Blake's Bottleneck, that setback NF Skagit River levees on both sides of the river and could have mutual benefits if implemented together. This is also a part of the PSNERP North Fork Dike Setback Project. The proposed project boundary to be modeled is consistent with the project in the CRP and would restore riverine and tidal process to the site by replacing the existing river levee with an engineered levee located to the north along the base of Pleasant Ridge and along Landing Road. The project would remove the existing levee and build a setback levee, which would expand the floodplain of the NF Skagit River. The project is expected to restore tidal marsh and channel habitats beneficial to Chinook salmon recovery. The project would generate TFI credits to help maintain critical agriculture infrastructure. The project site is farmland and there are no residences or outbuildings at the site.

TNC South Fork Property (Project #3)



Key Project Elements	
Project Origin	Inter-Fluve technical memo[15]
Project Status	Feasibility Complete 2009
Project Location	South Fork
Project Type	Backwater Channel
Approximate Project Area	1 acre

Project Narrative:
The project was originally developed by Inter-fluve for The Nature Conservancy. It is a backwater channel located on the riverward side of the existing flood dike. The site is dominated by mature shrub and tree species. No residences or outbuildings are present. The project concept is to improve the connectivity of blind channel habitats at the project site that are beneficial to Chinook recovery.

The design consists of enlarging the small side channel the currently exists to create a broad 790 foot long backwater channel. The invert of the proposed channel is at zero gradient, elevation 9.3 feet (it is assumed the vertical datum is NAVD88, but this is not specified on the plans) with a narrow outlet into the Skagit River to reduce the deposition of sediments and dewatering of existing wetland habitat (Figure 25). Above the narrow outlet, the channel toe width is approx. 5 ft with 4:1 side slopes (Figure

[15] Skagit River Side Channel Feasibility, 6/24/2009, Inter-fluve Technical Memorandum, prepared for The Nature Conservancy.

26). Inter-fluve estimated that this backwater project would only last on the order of decades without regular small-scale maintenance to dredge out the sediment that are likely to be deposited on site from the Skagit River flows.

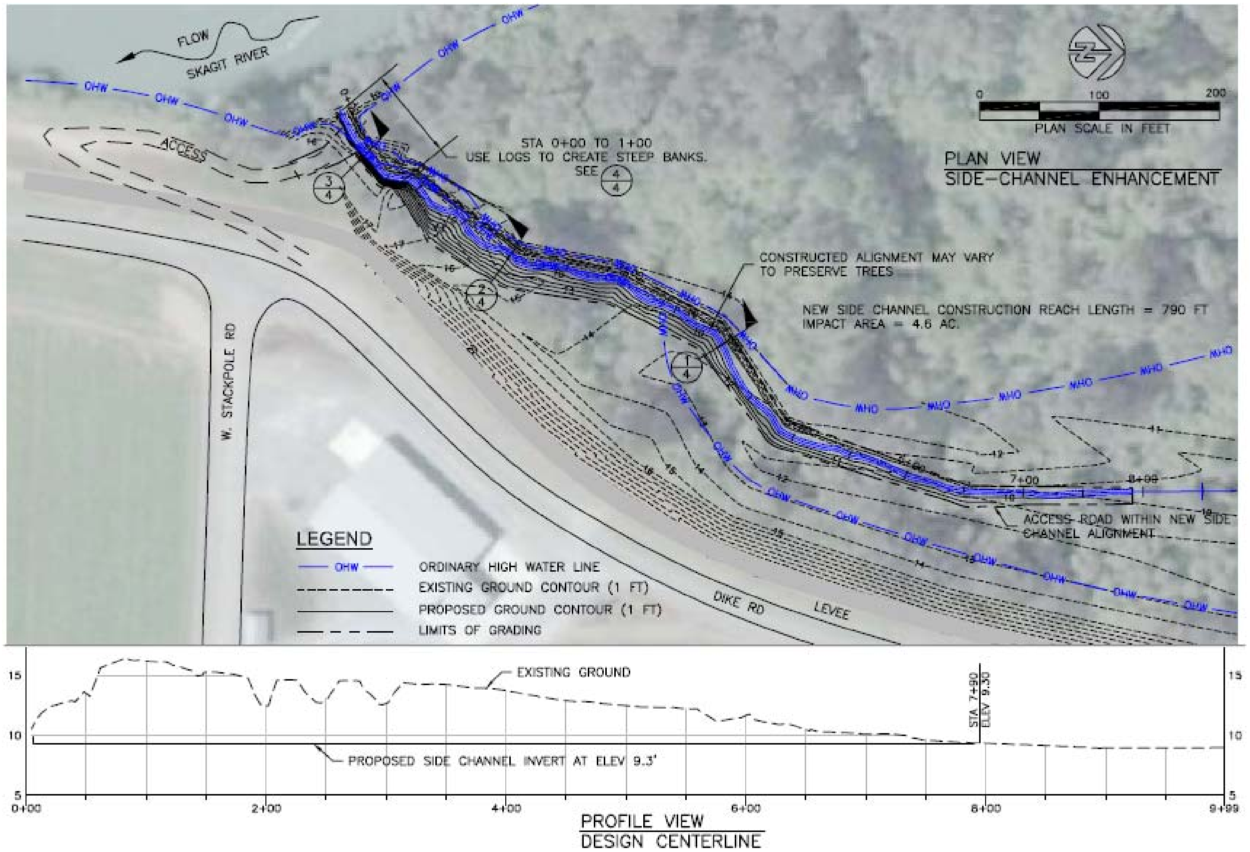


Figure 25. Plan and Profile of the proposed backwater channel for the TNC site. Vert Datum assumed to be NAVD88. (Inter-fluve, 2009)

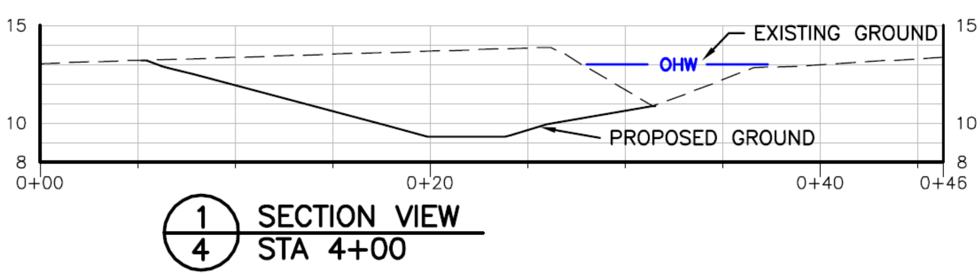


Figure 26. Channel cross section assumed to be typical throughout the length of the side channel. (Inter-fluve, 2009)

Appendix C: Battelle Report

PNNL-26867

Prepared for The Nature Conservancy

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Hydrodynamic Model Development and Application for Restoration Alternatives Assessment – Skagit Delta Hydrodynamic Modeling Project (SHDM)

Final Report

Jonathan Whiting
Taiping Wang
Tarang Khangaonkar

September 2017

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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PNNL-26867

Hydrodynamic Model Development and Application for Restoration Alternatives Assessment – Skagit Delta Hydrodynamic Modeling Project (SHDM)

Draft Report

JM Whiting
T Wang
TP Khangaonkar

September 2017

Prepared for
The Nature Conservancy
through MSOF Agreement No 66266
under contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Seattle, Washington 98109

Executive Summary

The Farm, Fish, and Flood Initiative (3FI) aims to create and advance mutually beneficial strategies that support the long-term viability of agriculture and salmon while reducing the risk of destructive floods. The Skagit Hydrodynamic Model Project (SHDM Project), which contributes to and is supported by 3FI, is a landscape-scale alternatives analysis design to help identify multiple-interest projects. The Nature Conservancy (TNC), The National Oceanic and Atmospheric Administration (NOAA), and the Washington Department of Fish and Wildlife (WDFW) are the project leads working with a larger SHDM team that comprised of representatives from conservation, agriculture, and flood risk reduction interests. The SHDM team has identified goals that further three interests, thereby creating a suite of objectives for providing juvenile chinook habitat, reducing flood risk and reducing impacts to agriculture. Performing an advanced assessment of planned restoration projects can determine which projects have the potential to provide benefits to all parties while minimizing impacts. Projects were assessed with hydrodynamic modeling, geographic information system (GIS) analysis, and estimation of potential Chinook salmon benefits through two mathematical models developed by the Skagit Rivers System Cooperative (SRSC). This report covers the development and application of the hydrodynamic model component of this analysis.

The SHDM team identified 23 potential projects within the Skagit River delta region. Three types of potential projects were assessed: (1) dike setbacks or removals that allow for tidal inundation and the construction of new dikes built to a higher standard, (2) hydraulic projects that change the flow pattern by excavating new channels to distribute flow across the landscape, and (3) backwater channels where an existing channel within existing dikes is altered to increase backwater flow. Most of these project concepts were identified and described in the Skagit River Chinook Recovery Plan (CRP), and many include further refinements from planning processes such as the Puget Sound Nearshore Estuary Restoration Project (PSNERP) and individual project sponsor actions. Additional project concepts were pulled from the Skagit River Flood General Investigation or developed by the SHDM team.

For this assessment, researchers at the Pacific Northwest National Laboratory (PNNL) developed a three-dimensional hydrodynamic model of the Skagit River delta region based on a prior version of the model developed at PNNL. The model is based on the Finite Volume Community Ocean Model (FVCOM), which solves the three-dimensional momentum, continuity, temperature, salinity, and density equations in an integral form by computing fluxes between non-overlapping, horizontal, and triangular control volumes. The new unstructured grid is the highest resolution yet produced by the PNNL modeling group for the Skagit River delta; it consists of 131,471 elements that vary in size from 400 meters (1,312 feet) to less than 10 meters (33 feet). Bathymetry was updated with recent Lidar and boat-based surveys available from sources including the U.S. Geological Survey (USGS) and the U.S. Army Corps of Engineers (USACE). Skagit River flow was determined by a USGS gauge near Mount Vernon and the flow distribution between North and South Forks of the river were calibrated with five short-term stage gauges maintained by WDFW. The model was forced with tides and resulting outputs were validated against the WDFW and SRSC monitoring stations. Simulations were conducted over a 7-month period from November 2014 through May 2015, which coincided with the WDFW and SRSC stream gauge deployment and encompassed several 2-year floods and a majority of the fish outmigration period.

A total of 7 model simulations were planned to assess 22 of the 23 potential projects in the Skagit River delta. Projects were grouped so that the effects of each project would be isolated and quantifiable. This allowed small projects to be grouped, while some very large projects were simulated as stand-alone cases. Each simulation generated a set of deliverables including inundation area calculations, cumulative frequency plots for water surface elevation, distribution of water depths across the project site, stage-

discharge curves, and GIS plots for depth of inundation, change in water surface elevation, change in bed shear stress, and change in salinity.

Following this initial assessment, the SHDM Team identified a group of selected projects for a simulation to assess cumulative impacts. Cumulative effects are an important and often overlooked element in restoration planning, as restored area can alter the tidal prism or hydraulics in a way that changes the viability of other projects. Avon-Swinomish Bypass and NF Left Bank Levee Setback A were excluded because they had significantly high levels of impact when compared to other projects.

Two more simulations were then conducted to assess the response of restoration projects to future climate change. The modeled future conditions included 0.57 m (1.87 ft) of sea level rise and a 2080 Skagit River hydrograph corresponding to the moderate emissions scenario (A1B-IPCC). This addresses questions about the longevity of restoration projects.

The hydrodynamic analysis was a progressive application addressing landscape-wide interactions and the resiliency of projects under future conditions. Results objectively inform the potential of individual projects to provide multiple benefits while minimizing potential impacts. In the future, sub-models can be nested within the larger model to inform engineering design by detailing how hydraulics are expected to change. Ranking of potential projects and judging the viability of each project will be reserved for separate publications by TNC, NOAA, and WDFW. This report seeks to exclusively explain methods and results.

Acronyms

3FI	Farm, Fish and Flood Initiative
CRP	Skagit Chinook Recovery Plan
DEM	Digital Elevation Model
EHW	Extremely High Water
FVCOM	Finite Volume Community Ocean Model
GIS	geographic information system
LIDAR	Light Detection and Ranging
MLLW	Mean Lower Low Water
NAVD 88	North American Vertical Datum of 1988
NF	North Fork
NOAA	National Oceanic and Atmospheric Administration
PNNL	Pacific Northwest National Laboratory
PSLC	Puget Sound Lidar Consortium
PSNERP	Puget Sound Nearshore Ecosystem Restoration Project
PST	Pacific Standard Time
SHDM	Skagit Hydrodynamic Model
SCD	Skagit Conservation District
SF	South Fork
SRSC	Skagit River System Cooperative
TFI	Skagit Delta Tidegate and Fish Initiative
TNC	The Nature Conservancy
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WDFW	Washington Department of Fish and Wildlife
WSE	Water Surface elevation

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1.0 Introduction

The Skagit Hydrodynamic Model Project (SHDM Project) was initiated by the Farm, Fish, and Flood Initiative (3FI) to conduct a landscape-scale alternative analysis in the Skagit River delta region. The SHDM Team is led by The Nature Conservancy (TNC), the National Oceanic and Atmospheric Administration (NOAA), and the Washington Department of Fish and Wildlife (WDFW). Researchers at the Pacific Northwest National Laboratory (PNNL) developed a three-dimensional hydrodynamic model to assess the hydrodynamic response from 22 potential projects proposed in the lower portion of the Skagit Watershed. Model results were fed into a larger analysis conducted by the SHDM Team where projects were ranked based on their potential to contribute to salmon recovery and local flood risk reduction while minimizing impacts to agriculture. This report seeks to exclusively explain methods and results from the modeling work.

1.1 Background

There is much interest in and motivation to restore historic tidal marsh habitat through nearshore restoration actions such as dike setbacks, hydraulic alterations, and the formation of new backwater channels. These projects strive to restore estuarine hydrologic and hydrodynamic functions in the tidal marshlands and tideflats with the help of shoreline modifications and reconstruction, thereby facilitating the return of natural processes (Raposa and Roman 2001; Warren et al. 2002). These processes include tidal inundation and flushing, supply of sediment and nutrients, and salinity and temperature conditions that result in greater biodiversity and a healthy ecosystem. Lack of quantitative information about the effects of proposed land use modifications on coastal hydrodynamic and hydrologic processes has been noted to be the primary cause for the sluggish pace in the implementation of nearshore restoration projects (Khangaonkar and Yang 2011). The complexity of evaluating alternatives is further increased when multiple restoration activities within a single estuary, river mouth, or along a length of shoreline result in cumulative impacts. Site-specific limitations, such as availability of freshwater, hinder achievement of restoration goals including recovery of tidal exchange, supply of sediment and nutrients, and establishment of fish migration pathways (Hood 2004; Tanner et al. 2002). Despite best intentions, efforts to restore nearshore habitats can result in poor outcomes if water circulation and transport are not properly addressed. Land use constraints can lead to selection of suboptimal restoration alternatives that may result in undesirable consequences, such as flooding, deterioration of water quality, and erosion, which require immediate remedies and costly repairs. Quantitative models designed for application to the nearshore environment can minimize uncertainty about restoration goals, such as the recovery of tidal exchange, supply of sediment and nutrients, and establishment of fish migration pathways. A high-resolution circulation and transport model of the Skagit River estuary has been developed to assist with nearshore habitat restoration design and analysis, and to answer the question, “Can we achieve beneficial restoration outcomes at small scale, as well as estuary-wide?” (Khangaonkar and Yang 2011).

Puget Sound is a complex system of estuaries, basins, deltas, and habitats occupying over 4,000 km of shoreline. Home to large populations of birds, marine mammals, and fish, this area supports an enormous industry for fishermen, hunters, nature enthusiasts, and more. However, Puget Sound has undergone significant physical changes over the last 150 years of settlement and development. Residents have built barriers and armoring along the shore to cordon off farmland and protect settlements from flooding. Compared to historical conditions across Puget Sound, total shoreline length has decreased by 15%, and embayment shore forms have declined nearly 46%, while in the 16 largest river deltas, there is 56% less tidal wetlands and 27% less shoreline length (Fresh et al. 2011). The historic estimated loss of delta channel edge and blind channel habitats preferred by juvenile Chinook salmon for rearing is 87% since the 1860’s (SRSC and WSFW 2005). These changes have contributed to the significant wildlife population declines including the loss of the largest runs of Pacific salmon in the lower 48 states. Specifically, Chinook salmon stocks originating from the Skagit River have declined from 40,000-50,000 in 1935 to a few hundreds or thousands in the 1990s (SRSC and WDFW 2005). Many salmon species are now listed under the Federal Endangered Species Act. River deltas play an important role in supporting wildlife populations. Juvenile salmon must spend time in estuaries where freshwater and saltwater mix to allow physiological changes to occur (Simenstad et al. 1982). This change, known as smoltification, allows them to survive in the saltwater environment (Langdon 1985). The presence of dikes has reduced connectivity between the river channels and intertidal marsh habitats historically used by out-migrating salmon (Diefenderfer et al. 2012). Because of the lack of availability of this refuge and without the required transition period, smolts become less active and more susceptible to predation, which decreases populations. The Skagit Chinook Recovery Plan cites the lack of estuary habitat as being the most critical limiting factor in Chinook salmon population levels (SRSC and WDFW 2005).

Of particular interest is the potential impact on risk associated with flooding. Over a century since the initial dike construction, the perimeter dikes in many Puget Sound estuaries are in a state of disrepair. High tides combined with flood flows or storm events have resulted in breached dikes on multiple occasions, requiring expensive repairs of the dikes and associated tide gates for drainage of interior farmlands. In the future, sea level rise is likely to exacerbate flood risk. Studies in the Skagit floodplain show that the 100-year peak high water will be exceeded essentially every year by the 2050s, and that a 57% increase in inundation area is expected by the 2040s because of combined sea level rise and projected changes in river flow (Hamman et al. 2016). Restorative action such as dike setbacks have the potential to reduce flooding risk by increasing the floodplain and wetland area that can act as a buffer against sea level rise and storm surge (Arkema et al. 2013). New dikes may also be built to a higher standard to withstand projected climate change (Yang et al. 2014). As flooding events become more common and property damage accumulates, there are many incentives for improving infrastructure for managing floods. However, it is also possible to increase flood risk because inundation may occur in areas that were previously protected from exposure to flood flows; hence, the need for hydrodynamic assessment, including conditions representative of storm conditions with high river flows and tides.

The Skagit region is also recognized as one of the most important agricultural valleys in Puget Sound. Each year the Skagit Valley grows over 80 different crops on 93,000 acres, producing 4 million pounds of raspberries, 1500 acres of flower bulbs, 300 million pounds of potatoes, and 1400 acres of broccoli (WST and WSDA 2010). This amounts to a significant portion of all fresh produce in Washington. Skagit Valley farmers also produce a significant amount of seed, providing 8% of the world’s spinach seed, 25% of the world’s cabbage seed, and 50% of the world’s beet seed (SPF 2016). This amounts to an industry that generated $272 million in 2012 within Skagit County (USDA 2012). Furthermore, Skagit farmland supports a large and diverse concentration of wintering raptors and waterfowl, while supporting many shorebirds during migration. Farmland across the Puget Sound region has experienced the squeeze of urban growth and has seen a 60% loss in farmland since 1950 (Canty et al. 2012). In recent years, habitat restoration efforts have also claimed some farmland area. Farming advocates are continually striving to protect their land against these external pressures.

In the midst of three distinct interest groups, many suggest addressing these agendas collectively (Beck 2014; Sáez 2015; Shepard et al. 2011; TNC 2013). The Farm, Fish, and Flood Initiative (3FI) aims to create and advance mutually beneficial strategies that support the long-term viability of agriculture and salmon while reducing the risk of destructive floods. Performing an advanced, large-scale assessment of planned restoration projects across the Skagit River delta region can identify which projects have the potential for providing benefits to all parties. The SHDM Project, led by TNC, NOAA, and WDFW, which contributes to and is supported by 3FI, is conducting such an analysis using quantifiable outputs from a hydrodynamic model. The goal of the SHDM Project is to “*develop a suite of projects that are* *well supported to achieve long-term viability of Chinook salmon tidal delta habitat and community flood risk reduction in a manner that protects and enhances agriculture and drainage*."

This report describes hydrodynamic modeling assessment conducted by researchers at PNNL in support of the overall assessment.

1.2 Study Area

The Skagit River is approximately 150 miles long and drains an area of 1.7 million acres from the Cascade Mountain Range to the northern end of Puget Sound. Skagit River passes through the City of Mount Vernon just before diverging into the North Fork (NF) and the South Fork (SF), which bound nearly 9,900 acres of farmland known as Fir Island occupied by 195 families. Both forks feed into Skagit Bay, which is bounded by Whidbey Island to the East, Fidalgo Island to the north, and Camano Island to the south. The SF diverges into several sloughs, the largest of which are Freshwater Slough to the east and Deepwater Slough to the west. Meanwhile on the NF, a new avulsion has formed and continues to develop, highlighting the need for recent topography maps. At this point, a significant fraction of NF flow exits through the avulsion, while there is evidence of sediment buildup and aggradation along the historic NF channel. This may also affect the viability of projects along the historic channel. Figure 1.1 shows a map of the region along with restoration project areas identified in blue color.

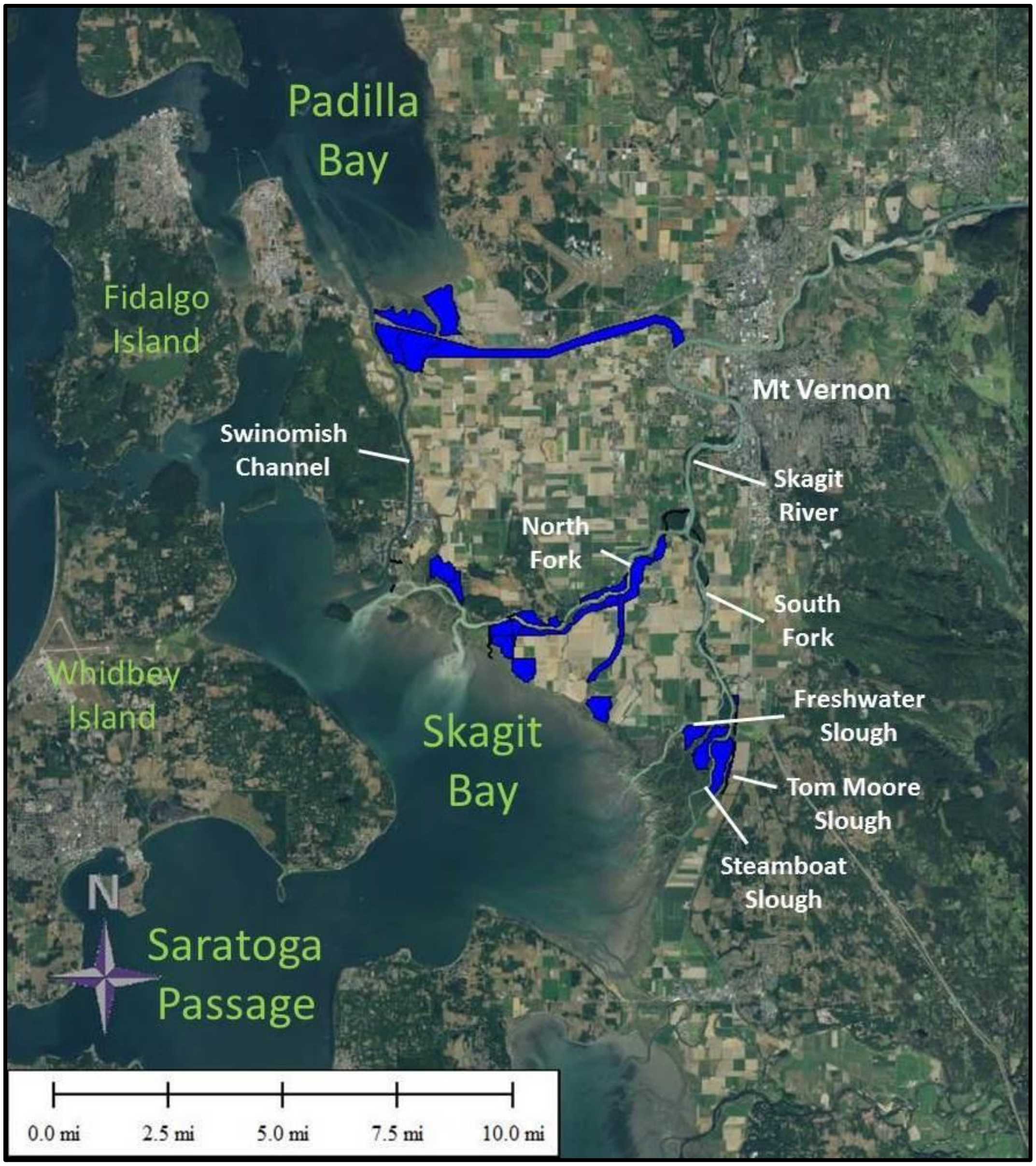

Figure 1.1. Map of the Skagit Bay region. Restoration areas are highlighted in blue.

The hydrodynamics of the region especially near the mouth of NF are complex. The Swinomish Channel, which connects Skagit Bay to the south and Padilla Bay to the north, is maintained by U.S. Army Corps of Engineers (USACE) as a navigation channel, is dredged periodically, and sees a significant amount of boat traffic. It serves as one of the three connecting waterways from Skagit Bay to the Puget Sound. River training jetties divert NF flow and associated sediment away from Swinomish Channel. A settler named Samuel Calhoun built the first dikes within the Skagit flats in 1863, initiating an influx of settlers who confined the river with dikes to control flooding and claim the fertile delta soil as farmland. The constructed dikes have undergone many improvements and repairs over the years, but flooding events in recent years have revealed that long-term improvements may be necessary to combat climate change and sea level rise. The Skagit River delta region is currently covered with farms, many in areas that were historically tidal marshes and mud flats.

1.3 Study Objectives and Approach

The SHDM Team identified 23 potential restoration projects within the study area, 22 of which were modeled directly by PNNL. The projects fall under three categories: (1) dike setbacks or removals that allow the construction of new dikes built to a higher standard, (2) hydraulic projects that change the flow pattern by excavating new channels to distribute flow across the bay front, and (3) backwater channels where an existing channel within dikes is altered to increase backwater flow. Most of the projects were identified and described in the Skagit River Chinook Recovery Plan (CRP) (SRSC and WDFW 2005). Additional projects were pulled from the Skagit River Flood General Investigation (USACE 2014) or developed by the SHDM Team. At a minimum for inclusion in the assessment, each project had to have the potential to benefit at least one of the three interests—farming, enhanced fishing, and flood prevention.

The primary objective was to assess each proposed project according to its potential benefits for providing juvenile chinook habitat, reducing flood risk and reducing impacts to agriculture.

This was accomplished by updating a prior version of the Skagit Bay model developed model by PNNL with new bathymetry, increased grid resolution, and recent inputs. Model bathymetry was updated with data from very recent Lidar and boat-based surveys available from sources including the U.S. Geological Survey (USGS) and USACE. The model was forced with tides at the four open boundaries and river flow from a USGS stream gauge near Mount Vernon and a NOAA meteorological station near Skagit Regional Airport. The model was validated using five temporary stream gauges deployed by the WDFW within the lower Skagit River delta and seven temporary intertidal stream gauges deployed by the SRSC within the intertidal area of the Skagit River. More details on these datasets are provided below in the Model Setup Section 2.1.

The model was used to simulate a 7-month period from November 2, 2014 through May 29, 2015 that coincided with the WDFW stream gauge deployment, while also encompassing two 2-year floods and a majority of the fish outmigration period. Potential projects were grouped so that the effects of each project would be isolated and quantifiable, allowing small projects to be grouped, while some very large projects were evaluated as stand-alone. Table 1.1.details the project grouping used for each simulation. Each simulation generated a set of deliverables including inundation area calculations, cumulative frequency plots for water surface elevation, distribution of water depths across the project site, stage-discharge curves, and geographic information system (GIS) plots for depth of inundation, change in water surface elevation, change in bed shear stress, and change in salinity. Some of these deliverables fed directly into the larger assessment of these restoration projects, while others fed into additional assessments performed by other members of the SHDM Team.

Table 1.1. List of proposed restoration projects grouped by simulation. Additional simulations were run on selected projects for cumulative effects as well as climate change analysis.

Model Simulation	Project	Project Name	Project Type	Approximate Area (acres)
Small Projects				
	1	SF Levee Setbacks 2, 3, 4	Dike Setback	55
	2	McGlinn Causeway	Hydraulic	5.8
	3	TNC South Fork	Backwater Channel	1.2
	4	Cottonwood Island	Hydraulic	14
	5	East Cottonwood	Backwater Channel	3
Simulation 1	6	Pleasant Ridge South	Dike Setback	28
	7	Hall Slough	Dike Setback	135
	8	Fir Island Farm	Dike Setback	138
	9	Telegraph Slough Full	Dike Setback/Hydraulic	538
	10	Sullivan Hacienda	Dike Setback	207
	11	Rawlins Road Distributary Channel	Hydraulic	5
Major Hydraulic Projects				
Simulation 2	12	Fir Island Cross Island Connector	Hydraulic	151
Simulation 3	13	Avon-Swinomish Bypass	Hydraulic	1297
Major Setback Projects				
Simulation 4	14	NF Left Bank Levee Setback C	Dike Setback	279
Simulation 5	15	NF Left Bank Levee Setback A	Dike Setback	284
Moderate Influence Projects Group #1				
	16	NF Right Bank Levee Setback	Dike Setback	86
	17	Milltown Island	Dike Breach	212
Simulation 6	18	Telegraph Slough 1	Dike Setback	188
	19	Thein Farm	Levee Setback	75
Moderate Influence Projects Group #2				
	20	Deepwater Slough Phase 2	Dike Removal	265
Simulation 7	21	Rawlins Road	Dike Setback	192
	22	Telegraph Slough 1&2	Dike Setback	305

2.0 Hydrodynamic Model Setup and Validation

In this section, the refinement and validation of a three-dimensional (3D) hydrodynamic model for the Skagit River estuary are presented. PNNL previously built a numerous hydrodynamic models of the Puget Sound, including several models applied to Skagit Bay at different spatial scales. Therefore, this modeling effort was built off an existing model of the region. The model was constructed using the Finite Volume Community Ocean Model (FVCOM) developed by the University of Massachusetts (Chen et al. 2003). FVCOM solves the 3D momentum, continuity, temperature, salinity, and density equations in an integral form by computing fluxes between non-overlapping, horizontal, and triangular control volumes. This finite volume approach combines the advantages of finite-element methods for flexibility in handling complex shorelines and the superior ability of finite difference methods for simple discrete structures and computation efficiency. A sigma-stretched coordinate system was used in the vertical plane to better represent the irregular bathymetry. Unstructured triangular cells were used in the lateral plane. The model employs the Mellor Yamada level 2.5 turbulent closure scheme for vertical mixing and the Smagorinsky scheme for horizontal mixing (Mellor and Yamada 1982; Smagorinsky 1963).

During this effort, the model grid was refined, the bathymetry was updated, and the model was both calibrated and validated with different sources to ensure that the results are accurate.

2.1 Model Setup

Data required for the hydrodynamic model setup and validation include shoreline geometry, bathymetry, tides, currents, river flow, salinity, temperature, and meteorological information. The shoreline geometry and bathymetry are used for construction of model grid consisting of triangular elements and nodes over which FVCOM solves the equations of continuity and momentum. Incoming tides from the domain boundaries, river inflows, and meteorological inputs are used to force the model to simulate tidal transport and circulation. The model simulates oceanographic physical properties such as water surface elevation, currents, and salinity profiles. Simulations were conducted over a 7-month period from November 2014 through May 2015 that coincided with the WDFW stream gauge deployment; this period included several 2-year floods and a majority of the fish outmigration. Additional simulations using design flows and typical 2-week neap-spring tidal forcing were also used to generate results.

Model setup information including previously developed and updated inputs is presented in the subsections below.

2.1.1 Model Grid

The unstructured finite volume grid for this study covers Skagit Bay, Saratoga Passage, and the southern portion of Padilla Bay. Also included are the Skagit River starting at Mount Vernon and the Swinomish Channel. Grid resolution in the river channels themselves were highly refined to ensure that flow dynamics at project sites were accurately reproduced. Restoration project areas were also finely gridded to represent the geometry of the dikes, topography, and bathymetry. Gridding these project areas up front (pre-restoration condition) allows convenient and consistent simulation of conditions with and without dike modification. Dike elevations at the dike nodes were set grade elevations to simulate the dike removal condition allowing water to inundate the previously dry regions.

The new unstructured grid is the highest resolution yet produced by the PNNL modeling group for the Skagit River delta; it consists of over 131,471 elements that vary in size from 400 m (1,312 ft) at the open boundaries to less than 10 m (33 ft) around important features such as jetties, dikes, levees, and narrow channels to resolve their complex geometry. This was a significant improvement on the 19,576 elements in the previous model. Using an unstructured grid allows the resolution to gradually increase toward nearshore regions and areas of interest, which is necessary when dealing with the complex shoreline geometry in the region. Figure 2.1 shows the extent of the model grid. The model grid was constructed in such a way that the grid lines were oriented along channels, dikes, jetties, and roads.

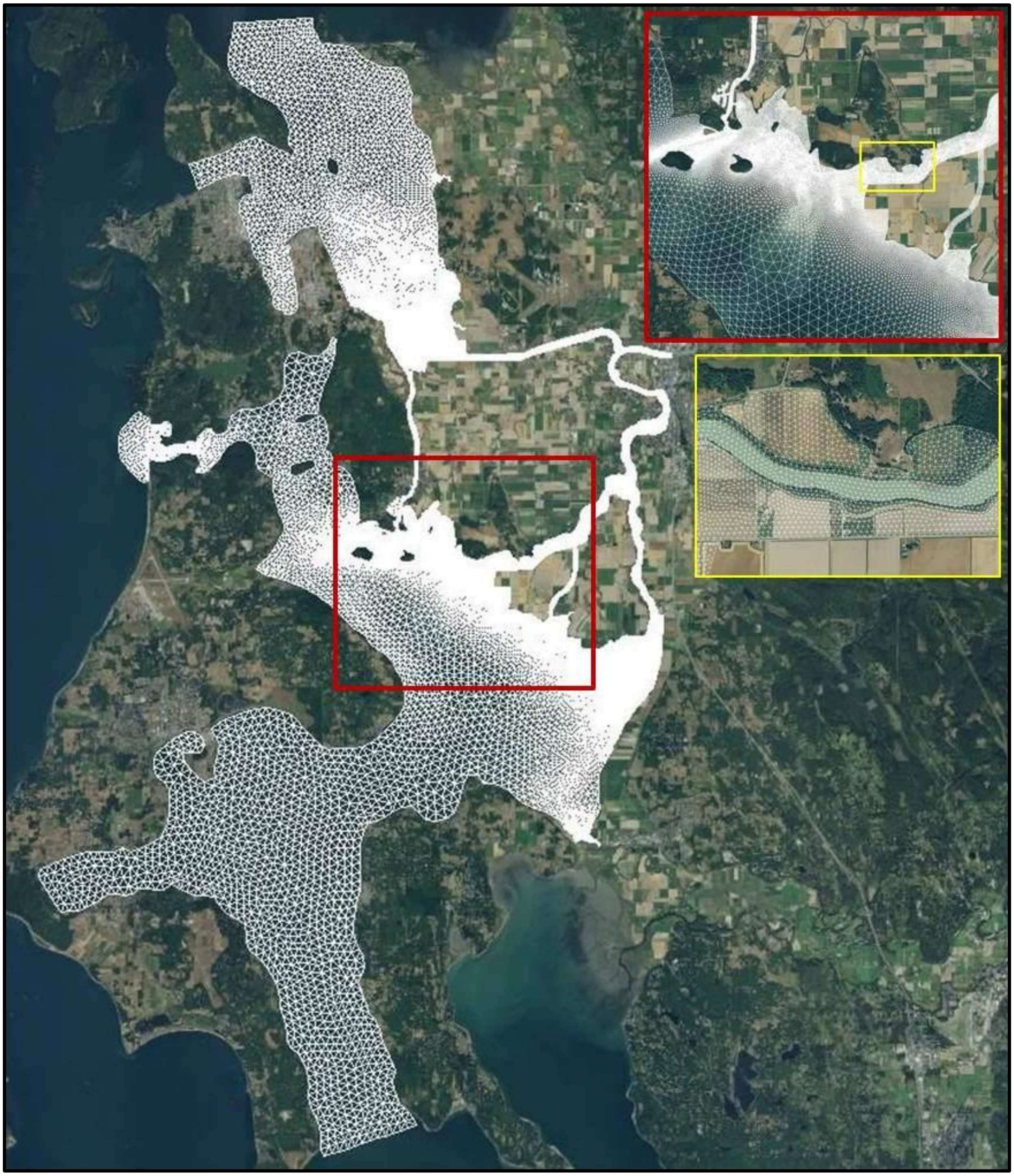

Figure 2.1. Model Grid for the Skagit River estuary.

2.1.2 Model Bathymetry

Model bathymetry required a substantial update to reflect recent system changes since the previous Skagit model developed by PNNL in 2008. The intertidal region is dynamic and frequently changes, despite constraints imposed by dikes. One example was the formation of the avulsion along NF within the last several years, which continues to grow as the historic NF channel begins to show signs of sediment aggradation (Hood 2010). To address these system changes, the bathymetry was updated to the most recent data available. Additionally, PNNL referenced the most recent aerial images from Google® and Bing® to approximate the avulsion channel geometry that was not timely captured by any of the available bathymetry datasets.

A bathymetry data set was provided by the USGS, who were tasked with the creation of a continuous elevation raster with 3 m horizontal resolution from all the most recent data sources available, seen in Figure 2.2. However, it was noticed that at several locations the continuous elevation raster differed from other data sources and imagery. The most notable example was the South Jetty near the Swinomish Channel, which was altogether missing in the continuous elevation raster. Additionally, bathymetry along the Swinomish Channel appeared constant (i.e. was essentially water surface elevation in the channel) and didn't reflect realistic bathymetry. Therefore, PNNL further supplemented and adjusted this raster with available boat surveys and Lidar data where spot checks revealed inconsistent data. Available boat surveys included: (1) a USACE R2 Sonic Multibeam survey of the Swinomish Channel with a 140° swath at 400 kHz with a 1.5° × 1.5° individual beam collected on June 24th 2014, (2) a USACE boat survey of the Skagit River intertidal region collected on 15–17 July 2014, and (3) a USGS boat survey of the Skagit River past Mount Vernon collected on 11–15 September 2012. The extent of the boat surveys can be seen in Figure 2.3. Further refinements were made using a continuous elevation raster with 3 m horizontal resolution compiled by USGS for the purposes of this modeling effort (Grossman, in preparation). However, the raster did not extend far enough north to detail Padilla Bay, so a 2006 USGS Lidar survey using Leica ALS-50 and Optech 2050 instruments to a horizontal accuracy of 1 m and vertical accuracy of 18.5 cm was used, obtained from the Puget Sound Lidar Consortium (PSLC). It should be noted that most bathymetry and topography were updated to recent surveys that were less than 1 year old, allowing most features to be accurately captured.

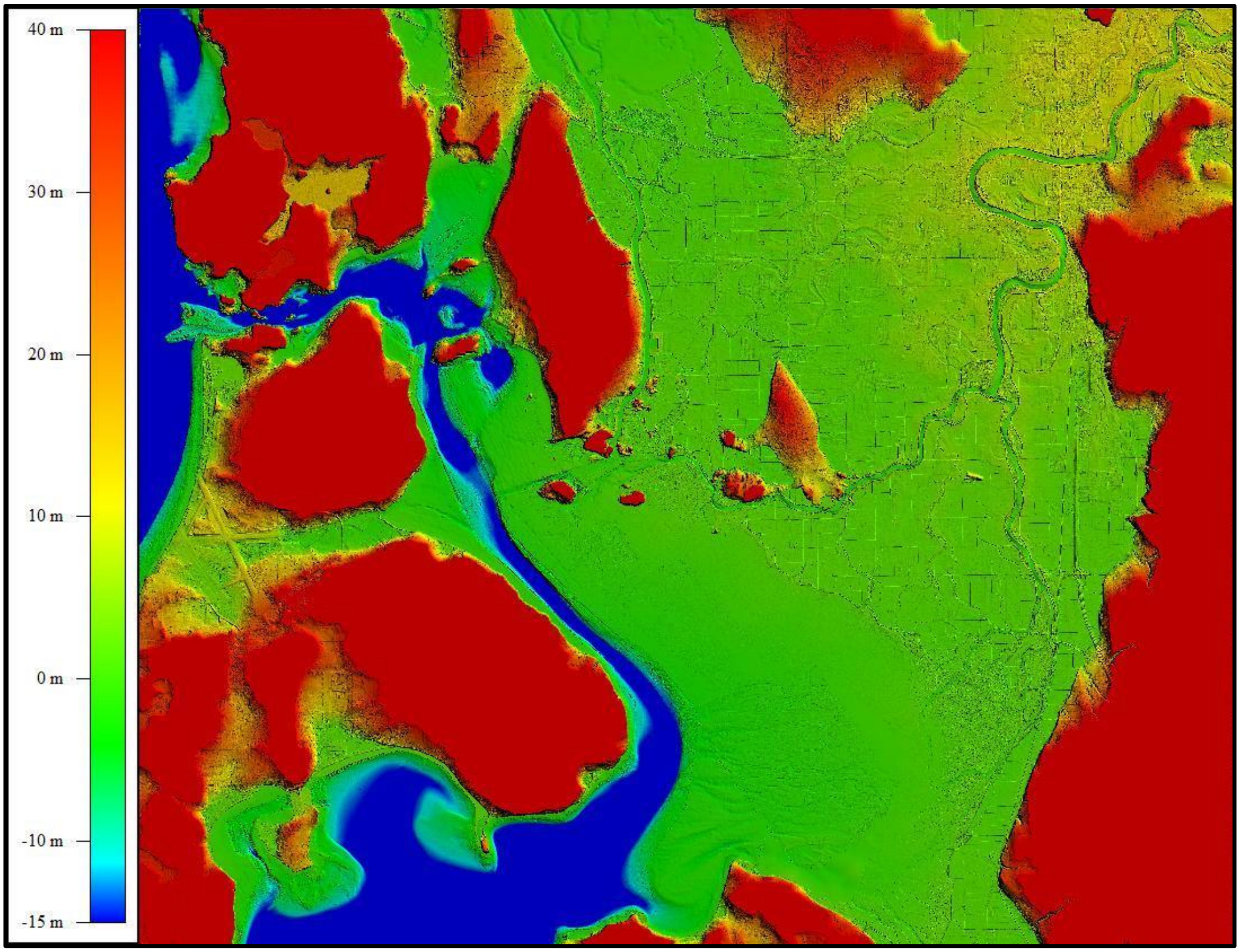

Figure 2.2. Lidar topography and bathymetry in the continuous elevation raster provided by the USGS based on a 2014 data set.

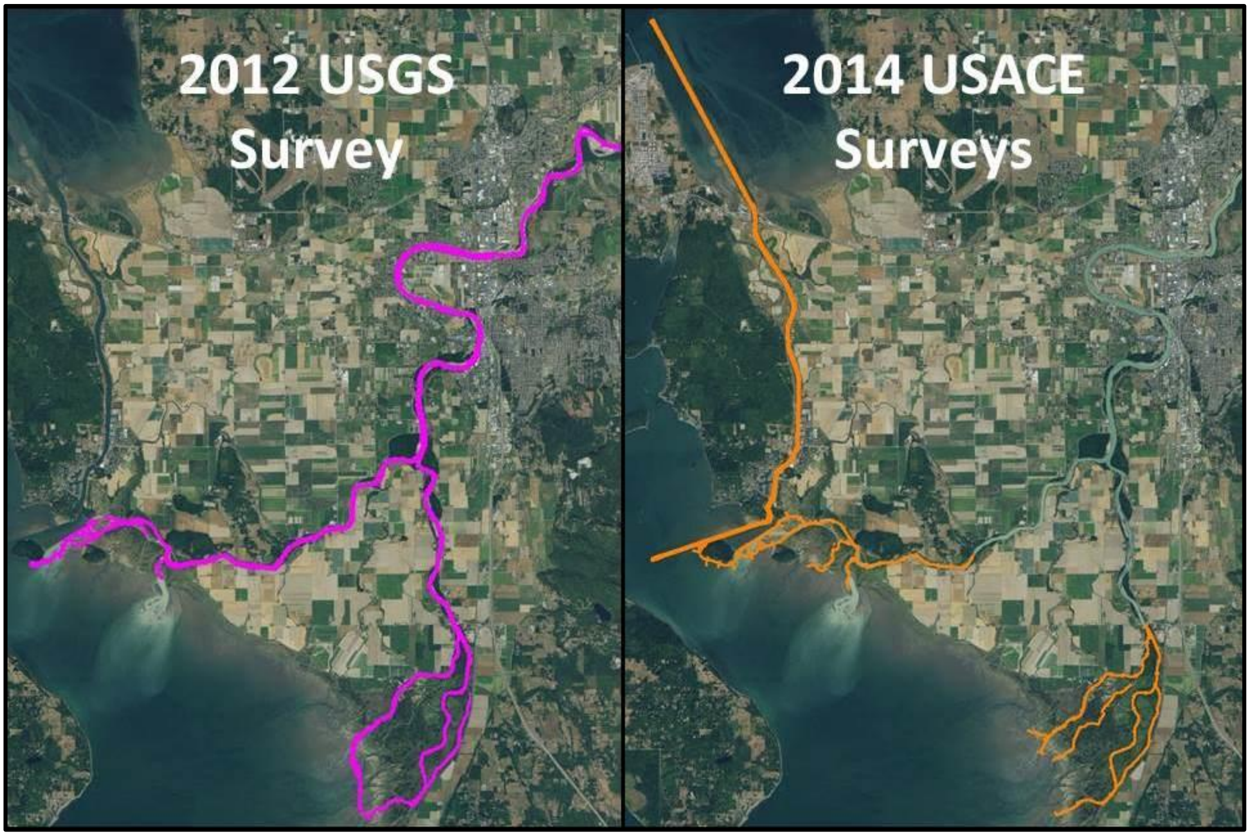

Figure 2.3. Supplemental bathymetry data available from various USGS and USACE boat surveys from years 2012 and 2014.

2.1.3 Model Boundary Conditions

Model boundary conditions were based on monitoring data corresponding to the selected simulation period of November 2014 through May 2015. At the river boundary, Skagit River flow was obtained from a USGS gauge at Mount Vernon. At the tidal open boundaries, WSE values were specified with harmonic tidal predictions obtained from XTide (Flater, 1996). Model outputs were validated against seven temporary intertidal stream gauges maintained by the SRSC and five gauges maintained by the WDFW. Monthly monitoring data from five stations maintained by the Washington Department of Ecology (Ecology) were used to specify salinity boundary conditions. Figure 2.4 shows the location of all available data sources.

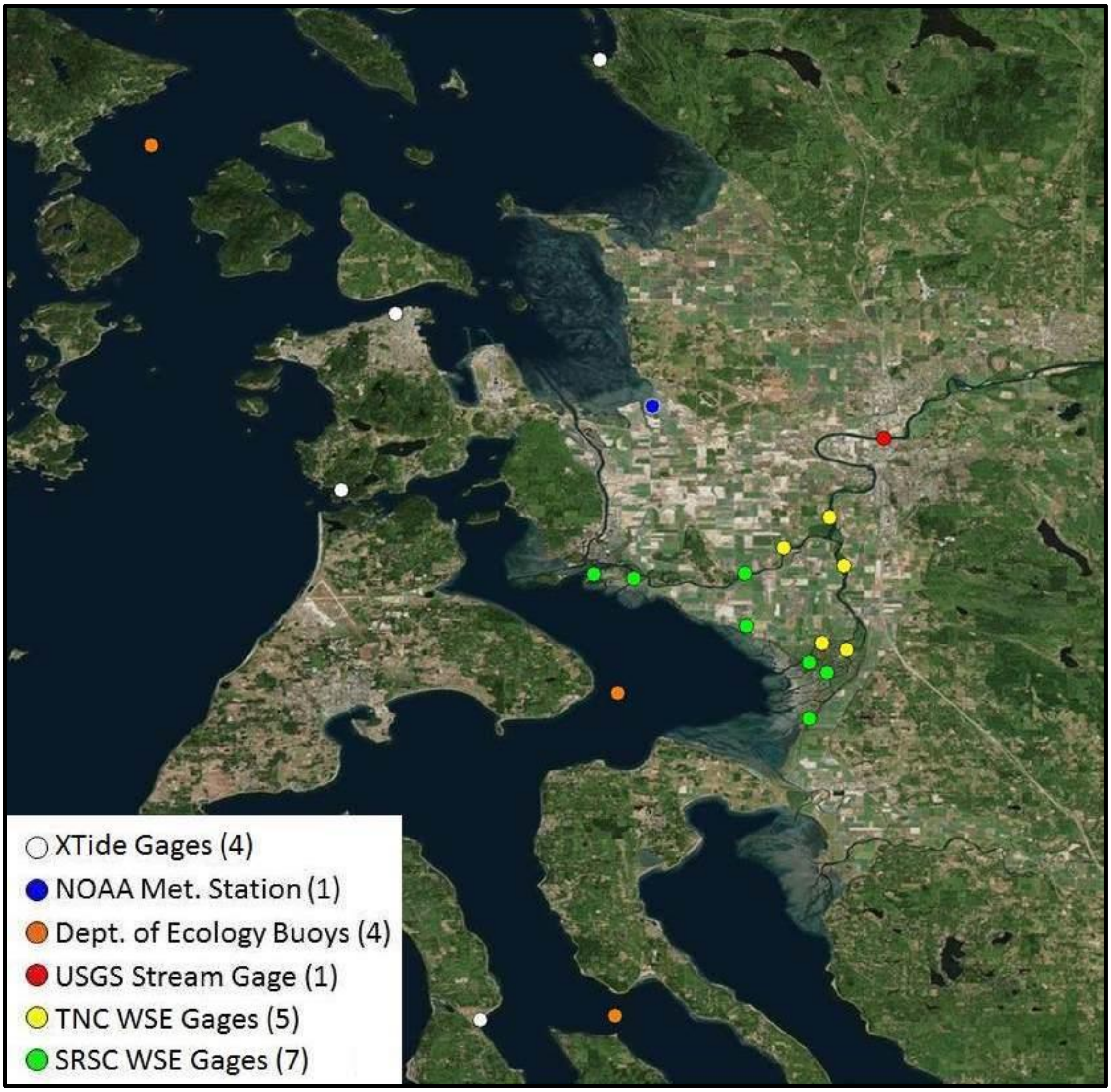

Figure 2.4. Overview of all gauges, buoys, and stations across the Skagit region where data were used for calibration or validation.

2.1.3.1 River Flows

Skagit River flow was determined by USGS stream gauge 12200500 near Mount Vernon. The time series of the flow during the simulation period can be seen in Figure 2.5.

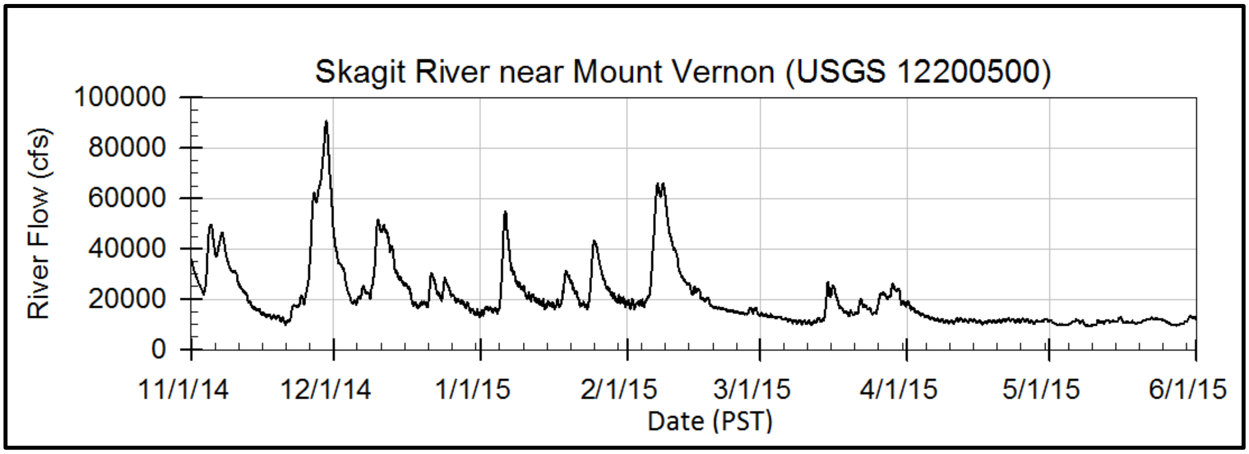

Figure 2.5. Time series of stream flow provided by USGS gauge 12200500 near Mount Vernon.

2.1.3.2 Tides

Model open-boundary conditions were tidally driven based on water surface elevations predicted using the XTide program derived from NOAA algorithms. Tidal elevations were specified at the following four open boundaries: (1) middle of Bellingham Bay – Chuckanut Bay station, (2) Guemez Channel – Anacortes station, (3) Deception Pass – Bowman Bay station, and (4) Saratoga Passage – Greenbank station. Figure 2.6 shows predicted tidal elevations at the Chuckanut, Anacortes, Bowman Bay, and Greenbank stations for the period from November 2014 through May 2015. Tidal elevations at all stations are very similar, except for subtle differences in the tidal phase and range. The tidal range is lowest at Bowman Bay and greatest at Greenbank, corresponding to incoming Pacific Ocean tides, which amplify with propagation into Puget Sound and up Whidbey Basin through Saratoga Passage to reach the Skagit Bay study area. While it may be difficult to see at this scale, the tidal patterns show spring-neap tidal signatures and large diurnal inequalities at all four stations.

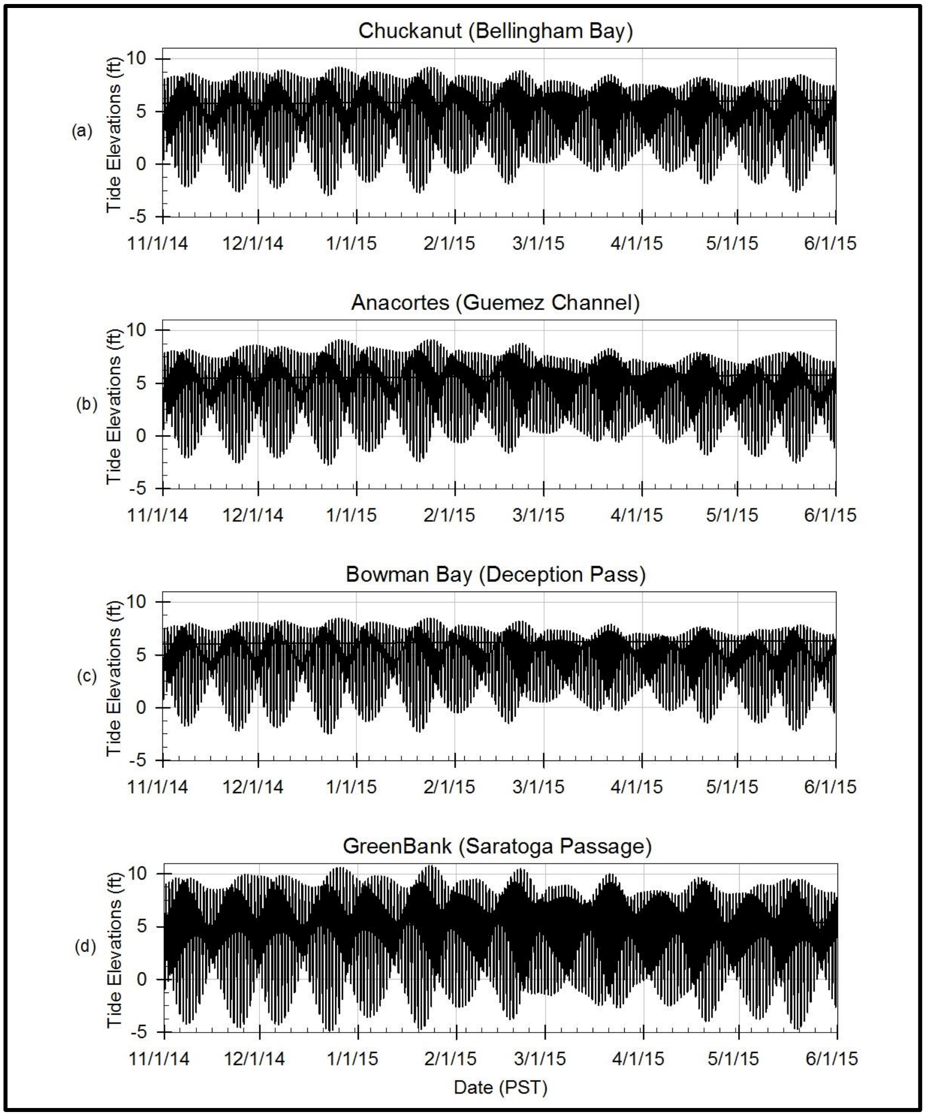

Figure 2.6. Predicted tidal elevations at the Chuckanut, Anacortes, Bowman Bay, and Greenbank stations. Elevations are with reference to North American Vertical Datum of 1988 (NAVD88) datum.

2.1.3.3 Salinity Profiles

The initialization of salinity values at each node proved challenging because of the variety of initial conditions across such a large and detailed domain. One potential solution is to include a long spin-up period where the system "normalizes" over time, however extremely long computational times prohibited this option. Instead, attempts were made to initialize the domain with reasonably accurate salinity distributions so that a long spin-up would not be necessary.

During the first two-week run, Fir Island Bay front region was initialized to average salinity based on available monitoring data from the Fir Island Farm project provided by WDFW, and the areas in Skagit Bay that were inundated during a low tide were initialized to 30 ppt, while all remaining floodplain and river channel nodes were initialized to 0 ppt. This run was conducted by including all restoration projects (except the Avon-Swinomish Bypass Project), thus allowing the full system to respond to both tidal and river mixing and to establish reasonable salinity distribution in the system more quickly. The final salinity values at each node were then used to initialize salinity for the full suite of simulations, with salinity values inside the project sites reset to the salinity values in adjacent river channels and bay waters. When calculating the change in salinity values between the restored scenarios and the baseline condition, 0 ppt salinity was used for the baseline condition to reflect the net change from areas that were never inundated during baseline.

2.1.3.4 Wind

Wind data are required to correctly simulate motion induced by wind stress at the water surface. Wind data were obtained from the NOAA meteorological station near Skagit Regional Airport, which is near the study area. The average wind speed during the period of interest was about 2.94 m/s. The dominant wind direction was toward the south. Wind stress was applied uniformly to the entire model domain.

2.2 Model Validation Results

Model validation is a standard procedure by which performance of the predictive tool is re-confirmed through comparison with data. Validation was performed using a data set independent of the one used for calibration, or by spot-checking the data set at different times.

2.2.1 Water Surface Elevation Model Validation

For this assessment, model validation focused on matching the water surface elevations at the 5 short-term water surface elevation (WSE) gauges maintained by the WDFW collected between November 5th 2014 and May 27th 2015. The WDFW deployed these WSE gauges specifically for the purpose of calibrating this model. One of the WDFW gauges was placed along the main stem of the Skagit River, just before the split between NF and SF so that data collected were consistent with the USGS stream gauge just upstream. The second and third WDFW gauges were placed just over a mile downstream of the bifurcation, on both the NF and SF. It should be noted that the NF gauge was at a difficult location to access; it has several gaps in collection and collection ended on April 6th 2015 because the gauge was washed out. The fourth and fifth WDFW gauges were placed about a mile and a-half downstream of a bifurcation between Steamboat Slough and Freshwater Slough. Another major channel breaks off from Steamboat Slough before the WDFW gauge, but calculating the differences at each bifurcation allows the flow of that channel to be predicted as well. Once the predicted WSE matched observed data, it was possible to compute associated river flows. During the time of collection, the model showed that the NF received 51.3% of Skagit River flow and the SF received the remaining 48.7%. Farther down the SF, a bifurcation sends 50% of the remaining flow down Freshwater Slough, while the remaining flow is then split 30% down Freshwater Slough and 20% down Tom Moore Slough. The average flow for November 2014 through May 2015 is 20,649 cfs according to the USGS stream gauge.

Each WDFW gauge was used to calibrate the model by adjusting the flow distribution. Small adjustments were made to the model grid and elevation values so that the model best matched observed WSE at each gauge. Calibration results are deemed acceptable when the relative error was less than 10%, consistent with other Salish Sea model applications (Khangaonkar et al. 2017). The model has relative errors for the Main Stem, NF, SF, Steamboat Slough, and Freshwater Slough of 0.96%, 6.09%, 3.46%, 7.65%, and 1.45%, respectively. A map identifying each gauge location is provided in Figure 2.7. A time series for each station is presented in Figure 2.8.

In addition to error statistics over the period of deployment, spot checks were conducted during high flow and low flow events. Figure 2.9 shows five times that were selected during extreme river flow values: lows flows on November 20 and December 31 and flood peaks on November 29, December 10, and January 6. Table 2.1 shows the error statistics for each of these selected times, and close model alignment with the stream gauges even during flow extremes.

Figure 2.7. Map showing the location of WSE gauges maintained by WDFW and used for model calibration.

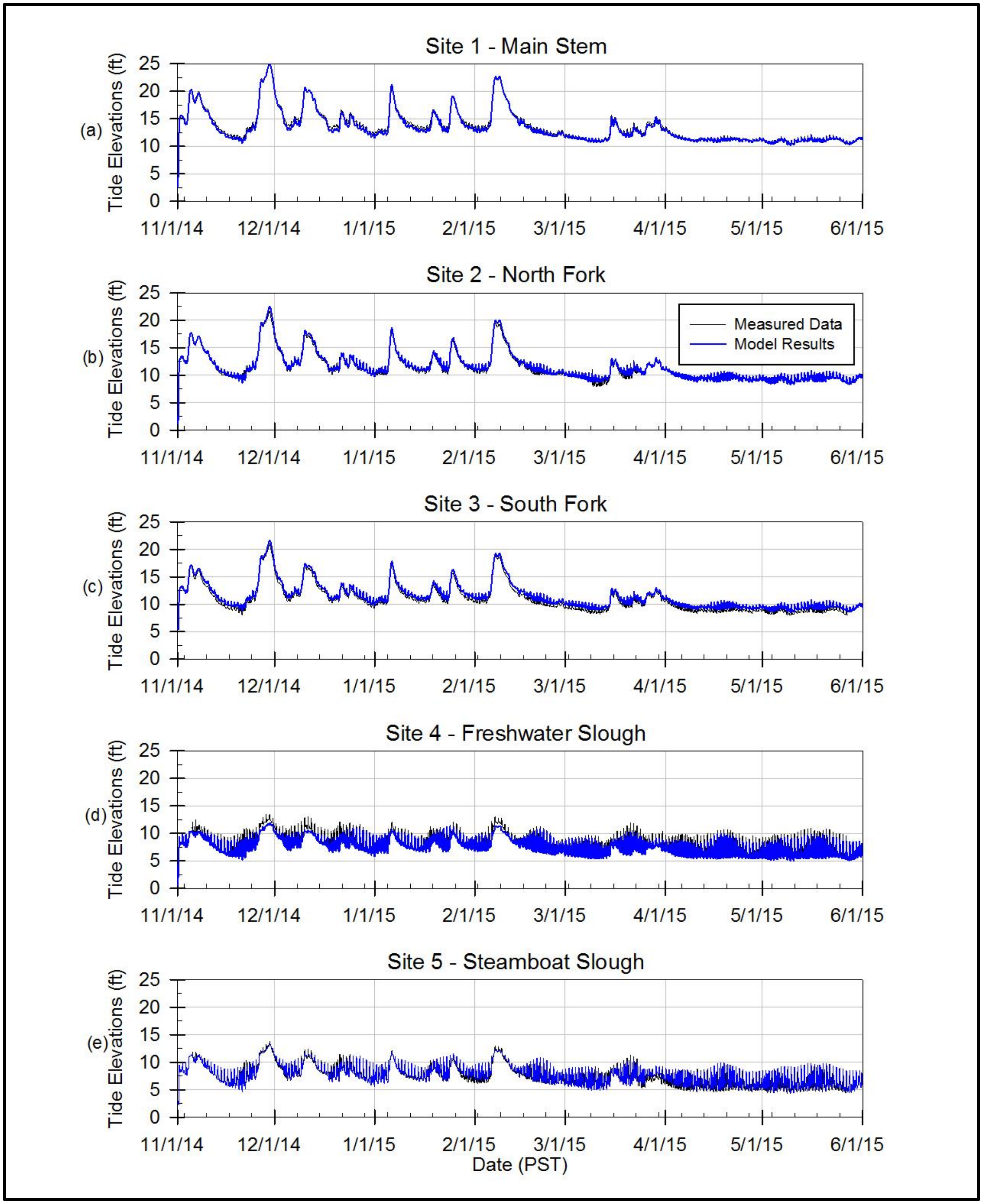

Figure 2.8. Calibration time series graphs at each of the five WDFW gauges. Elevations are with reference to NAVD88 datum.

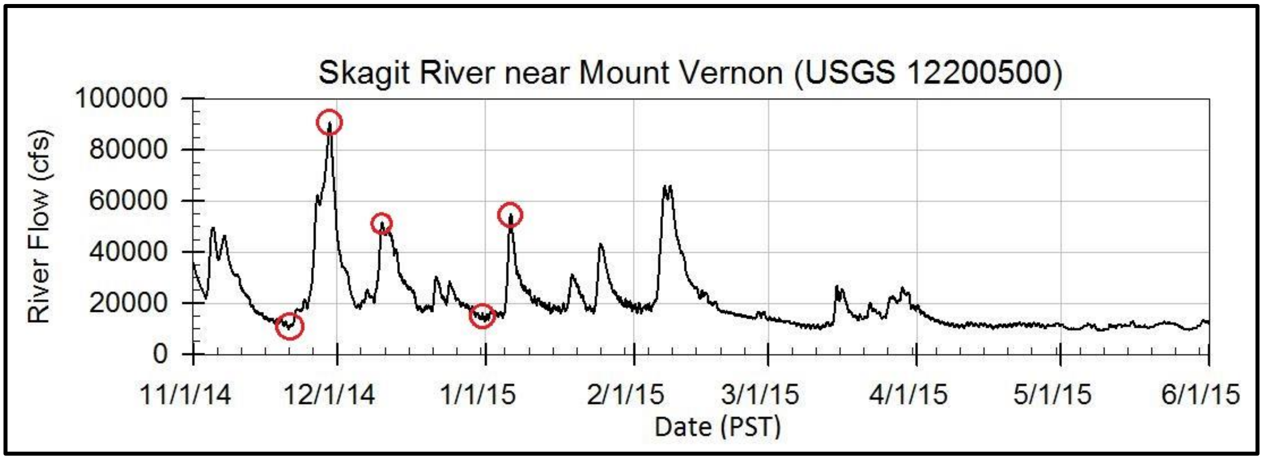

Figure 2.9. Extreme flow values where validation occurred on a time series of stream flow provided by USGS gauge 12200500 near Mount Vernon.

Additional validation was possible because SRSC had also collected data at seven temporary intertidal stream gauges as part of their regular monitoring efforts (E. Beamer, personal communication). Measurements were provided by SRSC and compared to model results to validate the intertidal region; each collection spanned a shorter period of 1–2 months. A map identifying each level logger location is provided in Figure 2.10. A time series for each station can be seen in Figure 2.11, comparing model results to observations. A detailed model calibration involving iterative refinement and adjustment of the model grid at these sites was beyond the scope. As a result, the site specific intertidal channels which control the water surface elevation were represented as broad channels, smoother and wider than actual channels which likely have smaller cross section and lower conveyance capacity. This is noticeable in Figure 2.11 where the sites drain out faster in the model than observed data which show evidence of channels retaining water. High relative errors reflect site specific model resolution limitations in the intertidal regions but do not affect model performance away from the intertidal sites.

Table 2.1. Water surface elevation errors at selected extreme flow values. Elevations are with reference to NAVD88 datum. There are several NA values because the Site 2 gauge washed out in mid-December.

Selected Times (PST)	Site 1 - Mainstem WSE (ft)		Site 2 - North Fork WSE (ft)		Site 3 - South Fork WSE (ft)		Site 4 - Freshwater Slough WSE (ft)		Site 5 - Steamboat Slough WSE (ft)	
	Gage	Model	Gage	Model	Gage	Model	Gage	Model	Gage	Model
11/20/2014 23:15	10.8100	10.7077	10.0394	8.7612	8.0830	9.0098	5.8451	5.4114	5.3717	5.1027
	Δ 0.10		Δ 1.28		Δ -0.93		Δ 0.43		Δ 0.27	
11/29/2014 12:45	25.1181	24.9642	21.5994	22.4957	20.9180	21.5984	13.2169	11.5768	13.6991	13.2411
	Δ 0.15		Δ -0.90		Δ -0.68		Δ 1.64		Δ 0.46	
12/10/2014 9:00	20.9729	20.5305	17.8442	17.9288	17.0741	17.2300	12.8980	10.5791	12.2759	11.8553
	Δ 0.14		Δ -0.08		Δ -0.16		Δ 2.32		Δ 0.69	
12/31/2014 21:00	11.8999	11.5568	NA	9.8537	9.2900	9.8599	6.2949	6.0883	6.1181	5.9705
	Δ 0.34		NA		Δ -0.57		Δ 0.21		Δ 0.15	
1/6/2015 6:15	21.2661	21.0843	NA	18.3904	17.4970	17.6814	11.9610	10.5384	11.9131	11.5856
	Δ 0.18		NA		Δ -0.18		Δ 1.42		Δ 0.33	

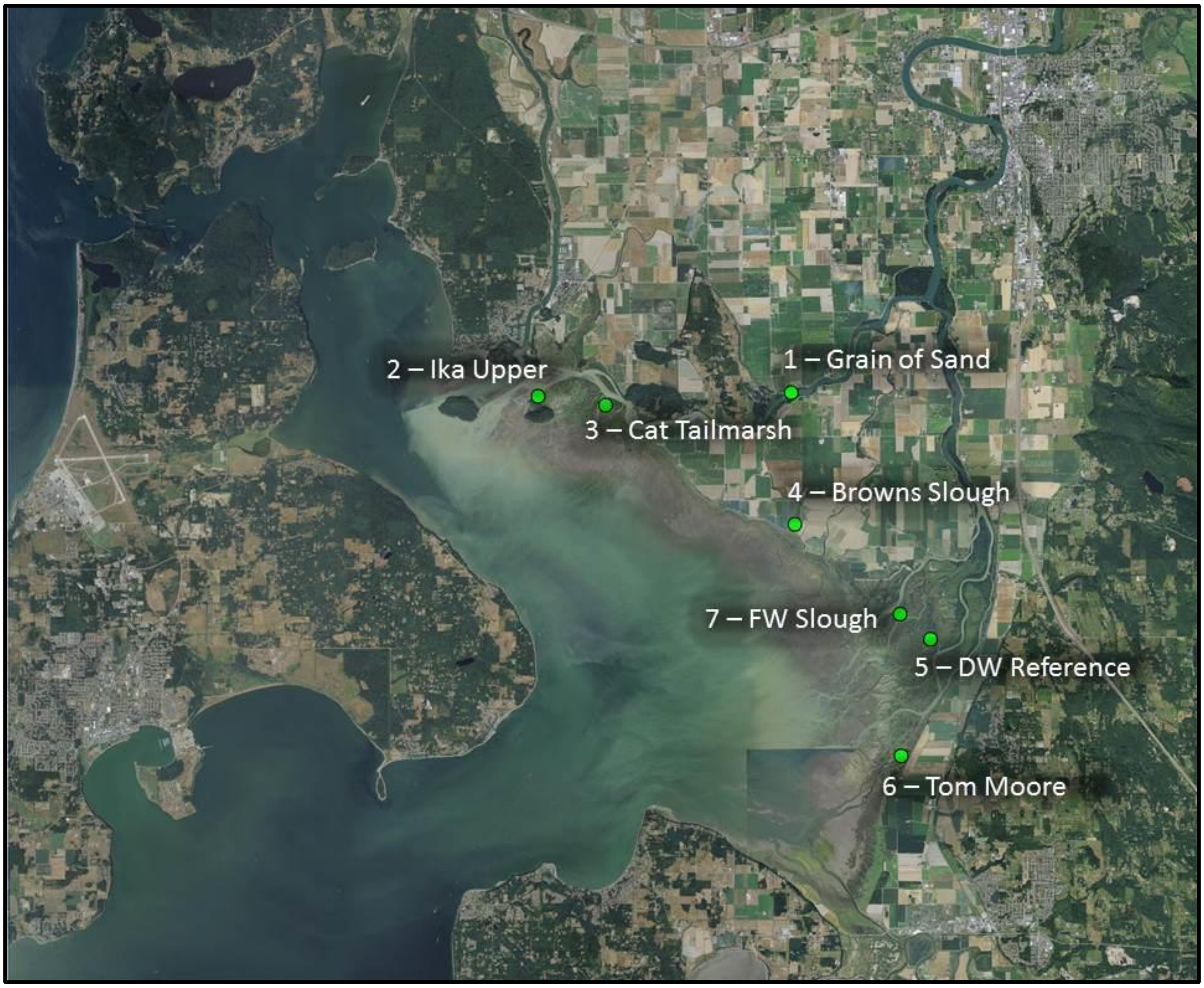

Figure 2.10. Map showing the locations of level logger gauges maintained by SRSC and used for model validation.

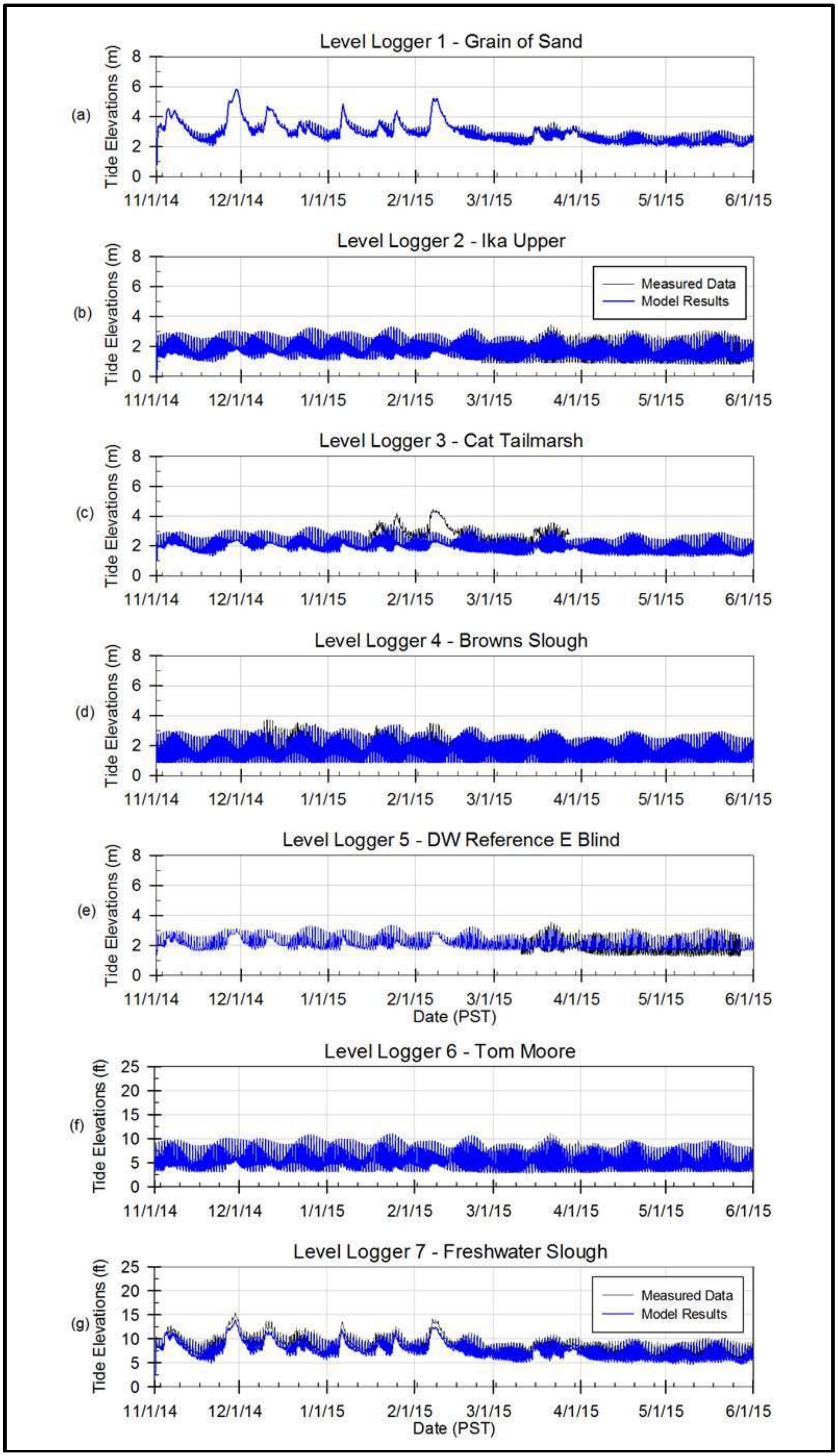

Figure 2.11. Validation time series graphs at each of the seven intertidal SRSC gauges. Elevations are with reference to NAVD88 datum.

3.0 Design of Simulations for Alternative Analysis Restoration Project Concepts

Seven simulations were conducted (plus baseline), grouping restoration sites in a best effort to isolate the effects of each individual proposed project. An additional three simulations were also conducted to examine cumulative effects as well as climate change effects with and without projects. To maintain the consistency among all the model scenarios and to improve the accuracy in calculating relative changes in key metrics such as water elevation and salinity, a single model grid was generated in the horizontal plane by incorporating all the important features (e.g. dikes, levees, floodplain channels, restoration project boundaries described in Barnard et al. 2016) of the model domain and was used for all the model scenarios. For each simulation, the grid elevation was updated with corresponding topo-bathymetric changes from the baseline condition caused by the restoration sites. For instance, the elevation of a grid node representing the dikes/levees will be changed to the new value reflecting the natural slope or any value specified in Barnard et al. (2016). Each simulation produced a set of deliverables that were chosen to inform the alternative analysis. Each simulation represents a suite of runs that were used to generate deliverables, including a real-time run and several design runs.

Each simulation included a real-time run and several design runs. The real-time run lasted for a 7-month period from November 2, 2014 through May 29, 2015 that coincided with the WDFW stream gauge deployment, while also encompassing two 2-year floods and a majority of the fish outmigration period. In order to effectively differentiate the impact of tidal and riverine forcing and address specific metrics, design runs were conducted for a 2-week period using designed open boundary tides and river flows that are constructed from historical datasets. Founded upon the validated model grid, the control provided by the design runs allowed for better comparisons between the baseline and with project simulations.

3.1 Current Conditions

Model setup procedures were geared towards emulating conditions from 2014-2015 to match the existing observed system. Results provide input to the immediate effects of proposed restoration activities under current conditions. The model was calibrated and forced by boundary conditions as described in the model setup section (2.1). The first eight simulations (plus baseline) used these conditions. The current conditions design runs can be seen in Figure 3.1.

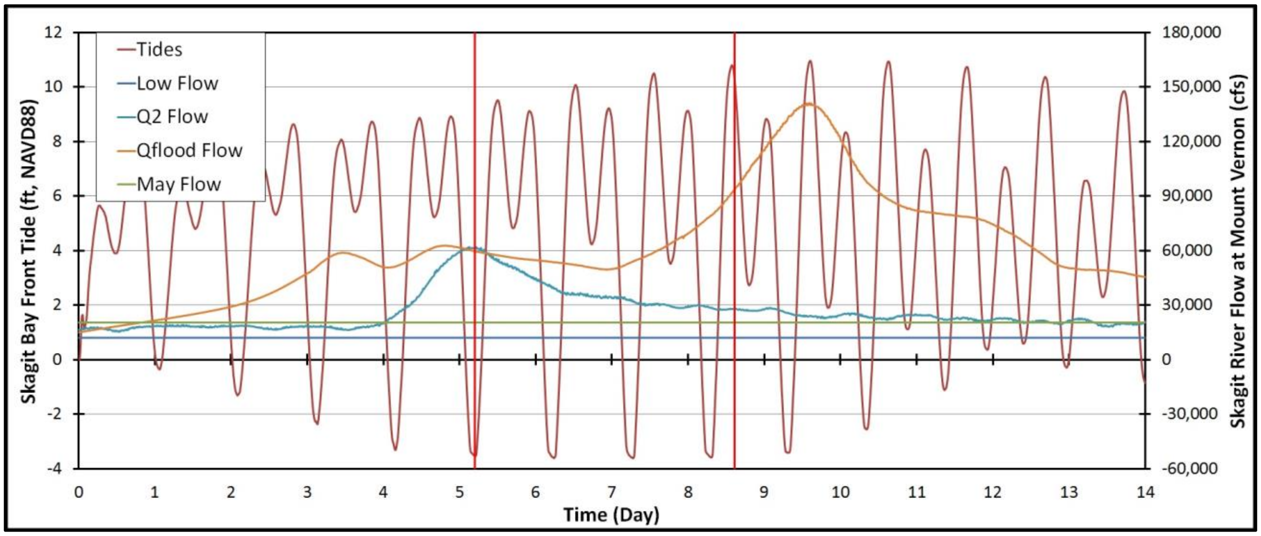

Figure 3.1. Current river hydrograph and tide conditions corresponding to the 2-week design runs. The first vertical red line corresponds to the low spring tide conditions, while the second red vertical line corresponds to the flood condition.

The following runs were used to generate deliverables:

1. **Real-time run:** The historic hydrograph and tide charts for a 7-month time period from November 2, 2014 through May 29, 2015 were used for the long-term run. Results from this run were used to generate the cumulative frequency plots (Appendix 6.0A.1, 0, 0, 0, 0, 0, 6.0G.3, 0, 0, 6.0J.5, 6.0K.5) and the plots comparing change in stage and discharge between with- and without-project conditions (Appendix 6.0B.9, 6.0C.9, 6.0D.8, 6.0E.9, 6.0F.9, 6.0G.9, 6.0H.9, 6.0I.7).

2. **Low flow and high spring tide run:** The low flow represents a constant river discharge rate of 12,000 cfs. The high spring tide oscillates to a maximum elevation of 10.8 ft (NAVD88). These conditions were used to isolate tidal influence and generate area calculations (Appendix 6.0B.1, 0, 1, 6.0C.2, 6.0D.1, 6.0D.2, 6.0E.1, 0, 6.0F.1, 6.0F.2, 6.0H.1, 0, 6.0I.1, 0), depth plots (Appendix 6.0A.2), shear stress plots (Appendix 6.0A.4, 6.0B.7, 6.0C.7, 6.0D.7, 6.0E.7, 6.0F.7, 6.0G.7, 6.0H.7), and salinity plots (Appendix 6.0A.5, 6.0B.8, 6.0C.8, 6.0E.8, 6.0F.8, 6.0G.8, 6.0H.8, 6.0I.6).

3. **Q2 flow and low spring tide:** The Q2 flow was derived from the flood on January 6, 2015, but scaled to a peak flow of 62,000 cfs to represent a 2-year flood. The low spring tide oscillates to a minimum elevation of -3.3 ft (NAVD88). These conditions were used to isolate riverine influence and generate area calculations (Appendix 6.0B.1, 0, 1, 6.0C.2, 6.0D.1, 6.0D.2, 6.0E.1, 0, 6.0F.1, 6.0F.2, 6.0H.1, 0, 6.0I.1, 0), WSE plots (Appendix 6.0A.3, 6.0B.6, 6.0C.6, 6.0D.6, 6.0E.6, 6.0F.6, 6.0G.6, 6.0H.6, 6.0I.5), depth plots (Appendix 6.0A.2), shear stress plots (Appendix 6.0A.4, 6.0B.7, 6.0C.7, 6.0D.7, 6.0E.7, 6.0F.7, 6.0G.7, 6.0H.7), and salinity plots (Appendix 6.0A.5, 6.0B.8, 6.0C.8, 6.0E.8, 6.0F.8, 6.0G.8, 6.0H.8, 6.0I.6).

4. **QFlood flow and high tide:** The QFlood flow was derived from the 1995 flood condition, which was the largest in recent memory. The river overtopped upstream, but remained within the dikes

downstream from the breach. In an effort to not over load the system, a sensitivity test was run to determine the highest tide matched with the hydrograph where the levees did not overtop. This resembled the best available bank-full conditions. The sensitivity test yielded a time when the hydrograph was at 93,200 cfs and the high tide oscillated to an elevation of 10.4 ft (NAVD88). These conditions were used to explore flood risk and generate WSE plots (Appendix 6.0A.3, 6.0B.6, 6.0C.6, 6.0D.6, 6.0E.6, 6.0F.6, 6.0G.6, 6.0H.6, 6.0I.5).

5. **Mean May flow and high spring tide:** The mean May flow represents a constant river discharge rate of 20,400 cfs, an average that was determined from the real-time hydrograph. The high spring tide oscillates to a maximum elevation of 10.8 ft (NAVD88). These conditions were used to assess fish habitat and generate depth plots (Appendix 6.0B.4, 6.0C.4, 6.0D.4, 6.0E.4, 6.0F.4, 6.0G.4, 6.0H.4, 6.0I.4) and depth histograms (Appendix 6.0B.5, 6.0C.5, 6.0D.5, 6.0E.5, 6.0F.5, 6.0G.5, 6.0H.5, 6.0I.4).

3.2 Future Conditions

The last two simulations were intended to assess the response of proposed restoration projects and the Skagit River delta to future climate conditions. The goal was to test the long-term viability of projects and determine their effectiveness under future conditions. The Q2 river hydrograph (Figure 3.2) is based on climate change projections for the Year 2080 from Lee et al. (2016), which assessed five different climate models under the A1B-IPCC emission scenario. The relative sea level rise (SLR) between Year 2015 and Year 2080 was calculated as 0.57 m (1.87 ft), following Khangaonkar et al. (2016), taken as the upper bound of the predicted SLR rate from the A1B scenario by an NRC Report (2012) (Figure 3.3). This value aligns with SLR projections for the Pacific coast from the gridded data presented in Pardaens et al. (2010) for the A1B scenario relative to year 2000, which also includes the range of mean SLR predictions varying from the low emissions B1 scenario to the high emissions scenario A1F1.

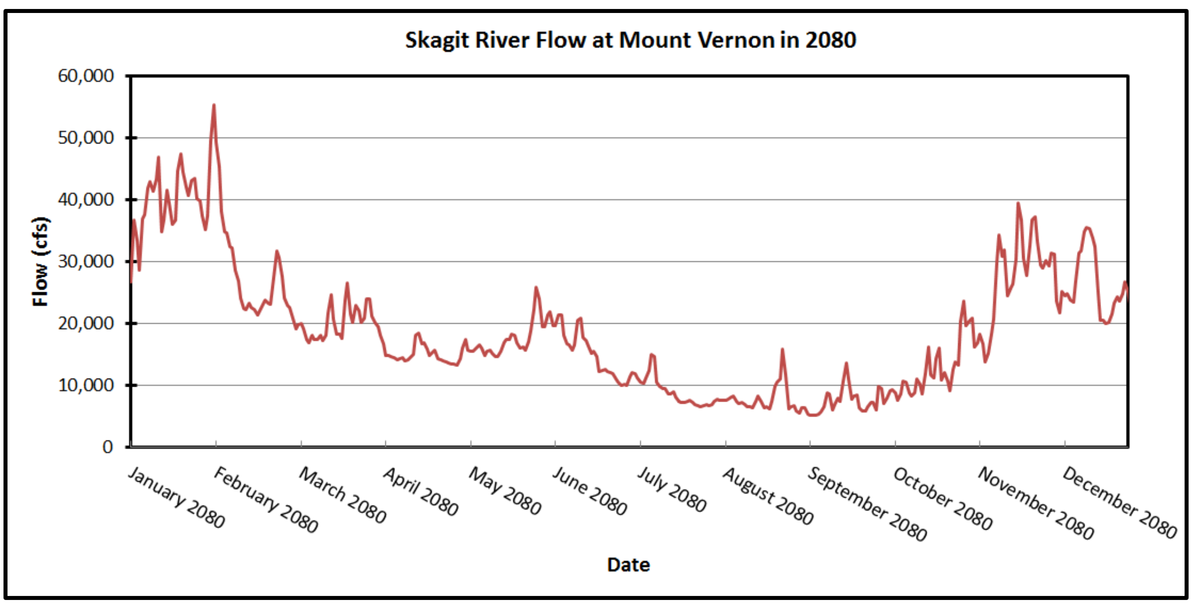

Figure 3.2. Future daily hydrograph used for the March to June 2080 simulation.

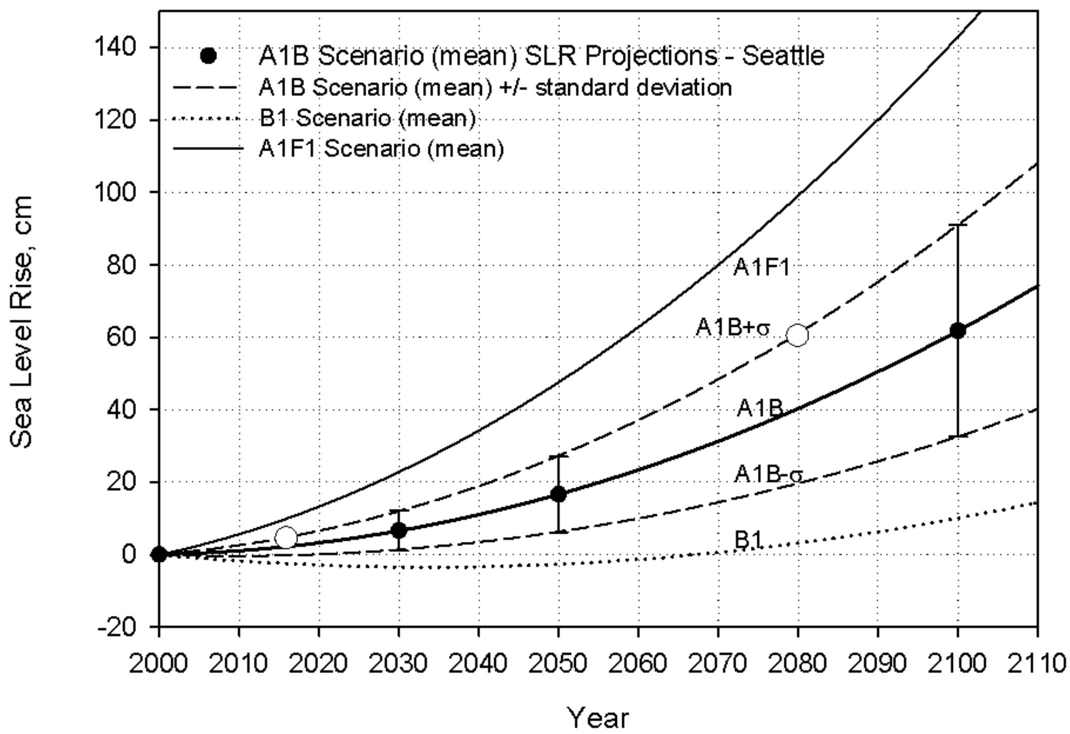

Figure 3.3. Projected SLR for Salish Sea (Seattle, WA) region of the Pacific Northwest for A1B, B1 and A1F1 scenarios (Source: NRC 2012). The upper and lower bounds of the model emissions scenario A1B are shown with a dashed line (modified from Khangaonkar et al. 2016).

The last two simulations used these conditions. The future conditions design runs can be seen in **Figure 3.4**.

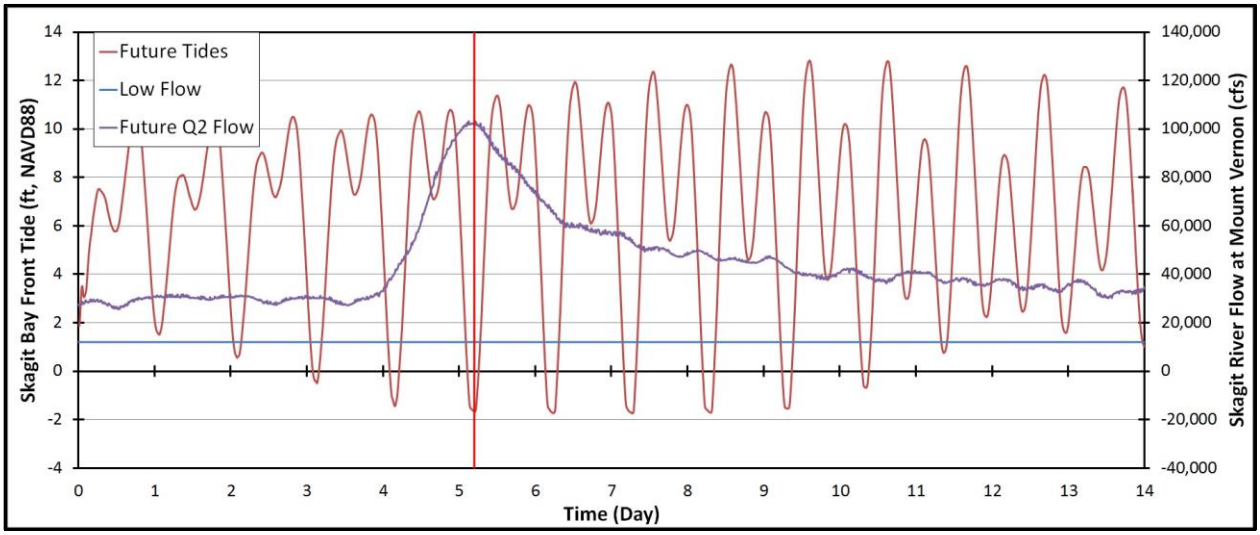

Figure 3.4. Future river hydrograph and tide conditions corresponding to the 2-week design runs. The vertical red line corresponds to the low spring tide condition.

The following runs were used to generate deliverables:

1. **Future real-time run:** The predicted future hydrograph and tide charts for the entire Year 2080 were used for the long-term run. Results from this run were used to generate the cumulative frequency plots (Appendix J.5, K.5).

2. **Future low flow and future high spring tide:** The future low flow represents a constant river discharge rate of 12,000 cfs, comparable to the low flow used with current conditions. The future high spring tide oscillates to a maximum elevation of 12.67 ft (NAVD88), representing a 0.57 m (1.87 ft) rise in sea level. These conditions were used to isolate tidal influence under future conditions and generate WSE plots (6.0J.1, 6.0J.2, 6.0J.3, 6.0J.4, 6.0K.1, 6.0K.2, 6.0K.3, 6.0K.4).

3. **Future Q2 flow and future low spring tide:** The future Q2 flow represents a hydrograph of a 2-year flood with a peak flow of 103,237 cfs. Hydrograph values were generated by Lee et al. (2016) for the Skagit River under the A1B emission scenario using five different models simulating current flood operations. The low spring tide oscillates to a minimum elevation of -1.43 ft (NAVD88), representing a 0.57 m (1.87 ft) rise in sea level. These conditions were used to isolate riverine influence and generate WSE plots (6.0J.1, 6.0J.2, 6.0J.3, 6.0J.4, 6.0K.1, 6.0K.2, 6.0K.3, 6.0K.4).

3.3 Simulation 1: Small Projects

Eleven proposed projects (Table 1.1.) were grouped together for this simulation, as seen in Figure 3.5. They were selected because of the relatively small area of influence or geographical isolation of each project. These grouped projects were either Bayfront projects, too small to have a significant effect, or isolated. Simulation 1 included SF Levee Setbacks, McGlinn Causeway, TNC South Fork, Cottonwood Island, East Cottonwood, Pleasant Ridge South, Hall Slough, Fir Island Farm, Telegraph Slough Full, Sullivan Hacienda, and Rawlins Distributary.

Figure 3.5. A map of project areas in the Small Projects simulation.

3.3.1 South Fork Levee Setbacks 2, 3, and 4

SF Levee Setback 2, 3, and 4 (Figure 3.6) comprises three separate levee setbacks in the SF to the west of Pioneer Highway and the BNSF Railroad and to the east of Tom Moore Slough. The existing levee would be removed and a new setback levee constructed against the railroad line.

The 55-acre dike setback project was identified by the SHDM Team for this project. More details on the project can be found in Barnard et al. (2016).

Figure 3.6. Outline of the South Fork Levee Setbacks 2, 3, and 4 dike setback project.

3.3.2 McGlinn Causeway

McGlinn Causeway (Figure 3.7) improves the hydraulic connectivity between the NF Skagit River and the Swinomish Channel through the jetty and causeway which separate the two water bodies. This project is composed of two elements: first, a breach in the causeway between La Conner and McGlinn Island that was constructed with dredge spoils from the Swinomish Channel; and second, lowering a portion of the jetty to mean sea level between the NF Skagit River and the southern end of the Swinomish Slough.

The 5.8-acre hydraulic project was identified in the Chinook Recovery Plan (SRSC and WDFW 2005) and PSNERP (2012). More details on the project can be found in Barnard et al. (2016).

Figure 3.7. Outline of the McGlinn Causeway hydraulic project.

3.3.3 TNC South Fork

TNC South Fork (Figure 3.8) involves the addition of a backwater channel located on the river side of the existing flood dike, enlarging an existing small side channel.

The 1.2-acre backwater channel project was identified in the Inter-Fluve Technical Memo (Inter-Fluve 2012). More details on the project can be found in Barnard et al. (2016).

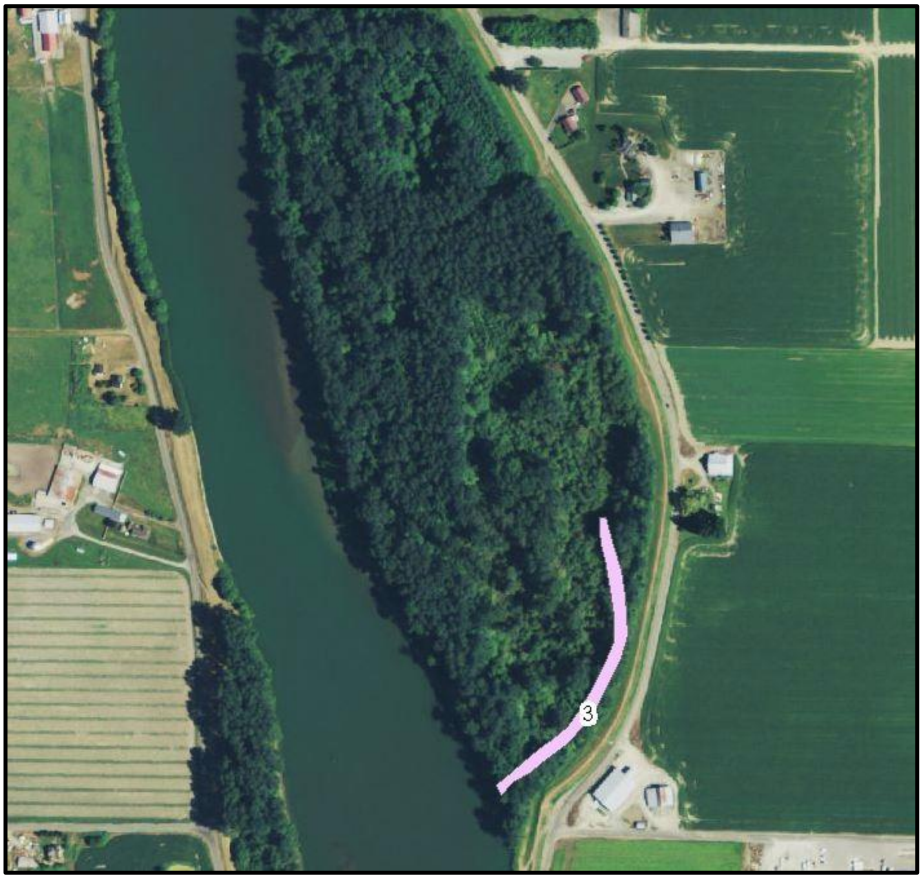

Figure 3.8. Outline of the TNC South Fork backwater channel project.

3.3.4 Cottonwood Island

Cottonwood Island (Figure 3.9) proposes to enlarge an existing side channel near the bifurcation between NF and SF, restoring hydraulic connectivity while minimizing the accumulation of sediment. Plans include a control structure, but it was not included in the model.

The 7.4-acre hydraulic project was originally proposed in the Chinook Recovery Plan (SRSC and WDFW 2005) and further detailed in the Skagit Conservation District (SCD) Design Plan Set (NHC 2012). More details on the project can be found in Barnard et al. (2016).

Figure 3.9. Outline of the Cottonwood Island hydraulic project.

3.3.5 East Cottonwood

East Cottonwood (Figure 3.10) proposes to restore a side channel near the bifurcation between NF and SF.

WDFW and SCD are currently working on a feasibility and design analysis for this 3-acre backwater channel project. More details on the project can be found in Barnard et al. (2016).

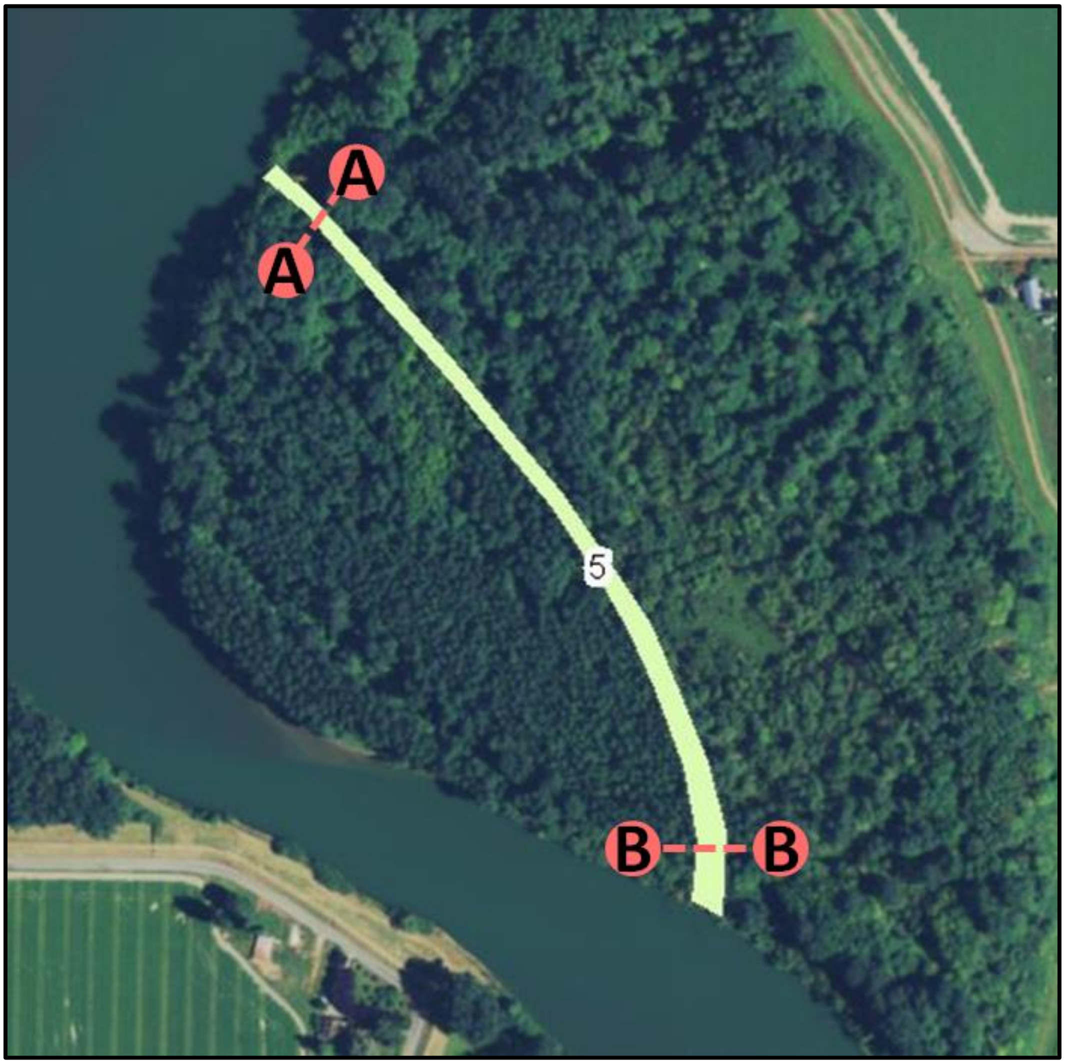

Figure 3.10. Outline of the East Cottonwood backwater channel project.

3.3.6 Pleasant Ridge South

Pleasant Ridge South (Figure 3.11) is landward of the existing NF Skagit River levee along the right bank of the NF Skagit River. The project concept is to restore riverine and tidal process to the site by removing the existing river levee and constructing a new engineered levee along the toe of Pleasant Ridge, as needed, to protect adjacent private property.

The 27-acre dike setback project was identified by the SHDM Team for this project. More details on the project can be found in Barnard et al. (2016).

Figure 3.11. Outline of the Pleasant Ridge South dike setback project.

3.3.7 Hall Slough

Hall Slough (Figure 3.12) proposes to restore the tidal processes of Skagit Bay to the site by replacing the existing marine dike with an engineered setback dike. The new setback dike would be located to the north and east of the existing dike.

The 110-acre dike setback project was identified in the Skagit River Flood Control Project (USACE 2002) and the House Bill 1418 Report (Washington State Conservation Commission 2004). More details on the project can be found in Barnard et al. (2016).

Figure 3.12. Outline of the Hall Slough dike setback project.

3.3.8 Fir Island Farm

Fir Island Farm (Figure 3.13) is located on Fir Island along Skagit Bay at the WDFW Snow Goose Reserve. The project was constructed during the time between when the SHDM project was initiated and the writing of this report. It replaced the existing overtopping marine dike with an engineered setback dike.

The 131-acre dike setback project was identified in the Chinook Recovery Plan (SRSC and WDFW 2005). More details on the project can be found in Barnard et al. (2016).

Figure 3.13. Outline of the Fir Island Farm dike setback project.

3.3.9 Telegraph Slough Full

Telegraph Slough Full (Figure 3.14) proposes to remove most of the existing dikes along Telegraph Slough, Padilla Bay, and the Swinomish Channel (east). A new engineered setback dike would be constructed along the southern portion of the Telegraph Peninsula and along the east and south sides of Telegraph Slough, and south of State Route 20 (SR20). The project would restore tidal hydrology to nearly all of the action area. The project would also restore connectivity to Padilla Bay through the historic Telegraph Slough corridor by constructing new bridges under SR20 and the railroad. It should also be noted that no modifications were made to the linear diked bar just north of the telegraph peninsula.

The 538-acre dike setback project was modified from the original proposals in the Chinook Recovery Plan (SRSC and WDFW 2005) and PSNERP (2012) to include an area located north of SR20 and east of Telegraph Slough (the Telegraph Peninsula). More details on the project can be found in Barnard et al. (2016).

Figure 3.14. Outline of the Telegraph Slough Full dike setback project.

3.3.10 Sullivan Hacienda

Sullivan Hacienda (Figure 3.15) is landward of the dike along the right bank of the NF Skagit River near the mouth. The project footprint is approximately equal to the dike location prior to 1956. The project would replace the existing marine dike with an engineered setback dike.

The 200-acre dike setback project was identified in the Chinook Recovery Plan (SRSC and WDFW 2005). More details on the project can be found in Barnard et al. (2016).

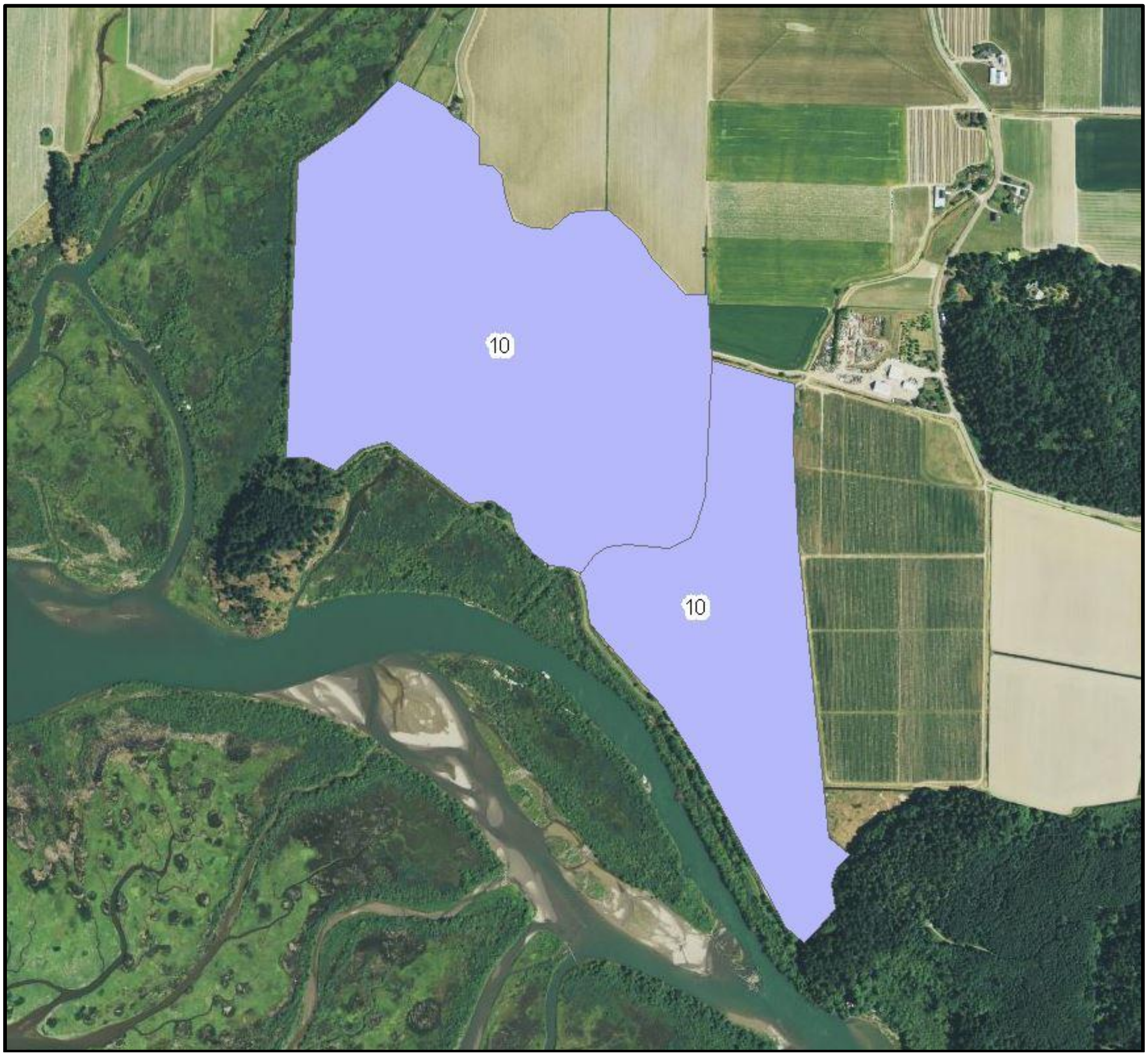

Figure 3.15. Outline of the Sullivan Hacienda dike setback project.

3.3.11 Rawlins Road Distributary Channel

Rawlins Road Distributary Channel (Figure 3.16) is on the bay side of the existing Fir Island marine dike near where it intersects the NF Skagit River. Along the northern edge of the site, adjacent to the NF Skagit River, there is a natural river levee vegetated with trees and shrubs. The project concept is to create a channel seaward of the marine dike to create a pathway for juvenile Chinook, sediment, and freshwater directly to the Bayfront, and to potentially provide localized flood relief. The channel to be modeled extends farther south to terminate in the Bayfront without relying on existing channels for resizing.

The 5-acre hydraulic project was identified in the Rawlins Road Restoration Feasibility Study (Battelle 2006). More details on the project can be found in Barnard et al. (2016).

Figure 3.16. Outline of the Rawlins Distributary hydraulic project.

3.4 Simulations 2 & 3: Major Hydraulic Projects

Each of the two major hydraulic projects shown in Figure 3.17 was run independently because these projects were believed to have the potential for system-wide effects. Simulation 2 was the Fir Island Cross Island Connector and Simulation 3 was the Avon-Swinomish Bypass.

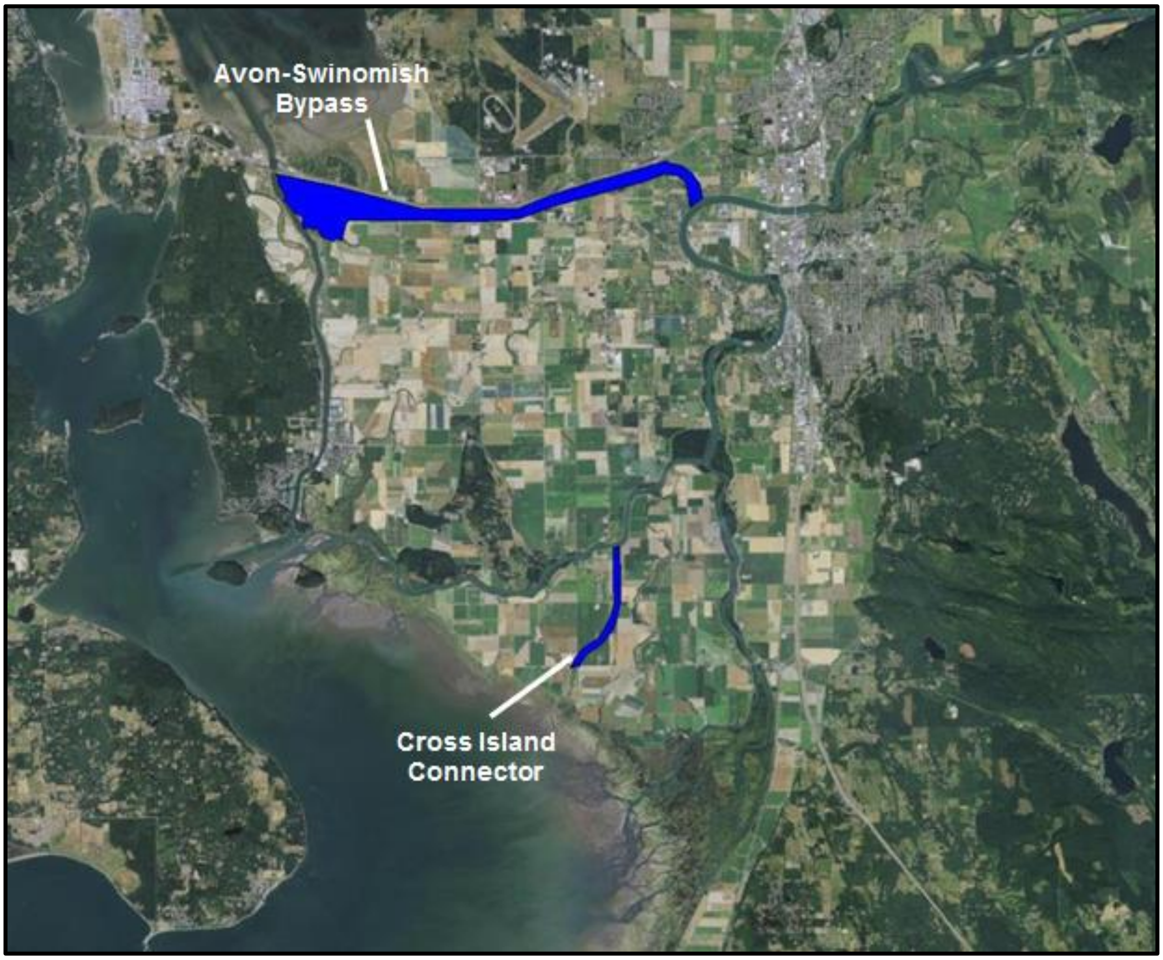

Figure 3.17. A map of both project areas in the Major Hydraulic Project simulations.

3.4.1 Cross Island Connector

Cross Island Connector (Figure 3.18) would construct a new distributary channel between the NF Skagit River and the central area of Fir Island along Skagit Bay. The project footprint generally follows the topographic low points in Fir Island and would include new levees along the entire length of the channel. The new distributary channel is expected to improve the connectivity between the NF Skagit River and Skagit Bay and increase the volume of sediment transported to and deposited in the central area of Fir Island along Skagit Bay, and the distribution of freshwater. The flows through this new channel were not prescribed, but are determined based on channel geometry.

The 472-acre hydraulic project draws from plans originally identified in the Chinook Recovery Plan (SRSC and WDFW 2005), though additional project details are provided in the Habitat Restoration Pathways for Fir Island (PWA and SSC 2004) and the Skagit River Flood Risk Management Study (NHC 2012). More details on the project can be found in Barnard et al. (2016).

Figure 3.18. Outline for the Cross Island Connector hydraulic project

3.4.2 Avon-Swinomish Bypass

Avon-Swinomish Bypass (Figure 3.19) consists of a 1000 ft wide bypass channel extending from the Skagit River at river mile (RM) 15.9 in a westerly direction parallel with SR20 for 7.3 miles to the Swinomish Channel south of the SR20 Swinomish Channel Bridge. The corridor is expected to bypass flood flows from the Skagit River and would include a low-flow channel for continuous flow to allow fish use. The bypass would decrease salinity in the Swinomish Channel and provide fish access and sediment delivery to Padilla Bay. The flows through this new channel were not prescribed, but are determined based on channel geometry.

The 885-acre hydraulic project was identified in the Skagit River Flood General Investigation (USACE 2014). More details on the project can be found in Barnard et al. (2016).

Figure 3.19. Outline of the Avon-Swinomish Bypass hydraulic project.

3.5 Simulations 4 & 5: Major Setback Projects

Each of the two major setback projects shown in Figure 3.20 were simulated independently because these projects were believed to have the potential for system-wide effects. Simulation 4 was the NF Levee Setback C and Simulation 5 was the NF Levee Setback A. NF Levee Setback B was omitted from the hydrodynamic modeling because it was the intermediate between Setbacks A and C.

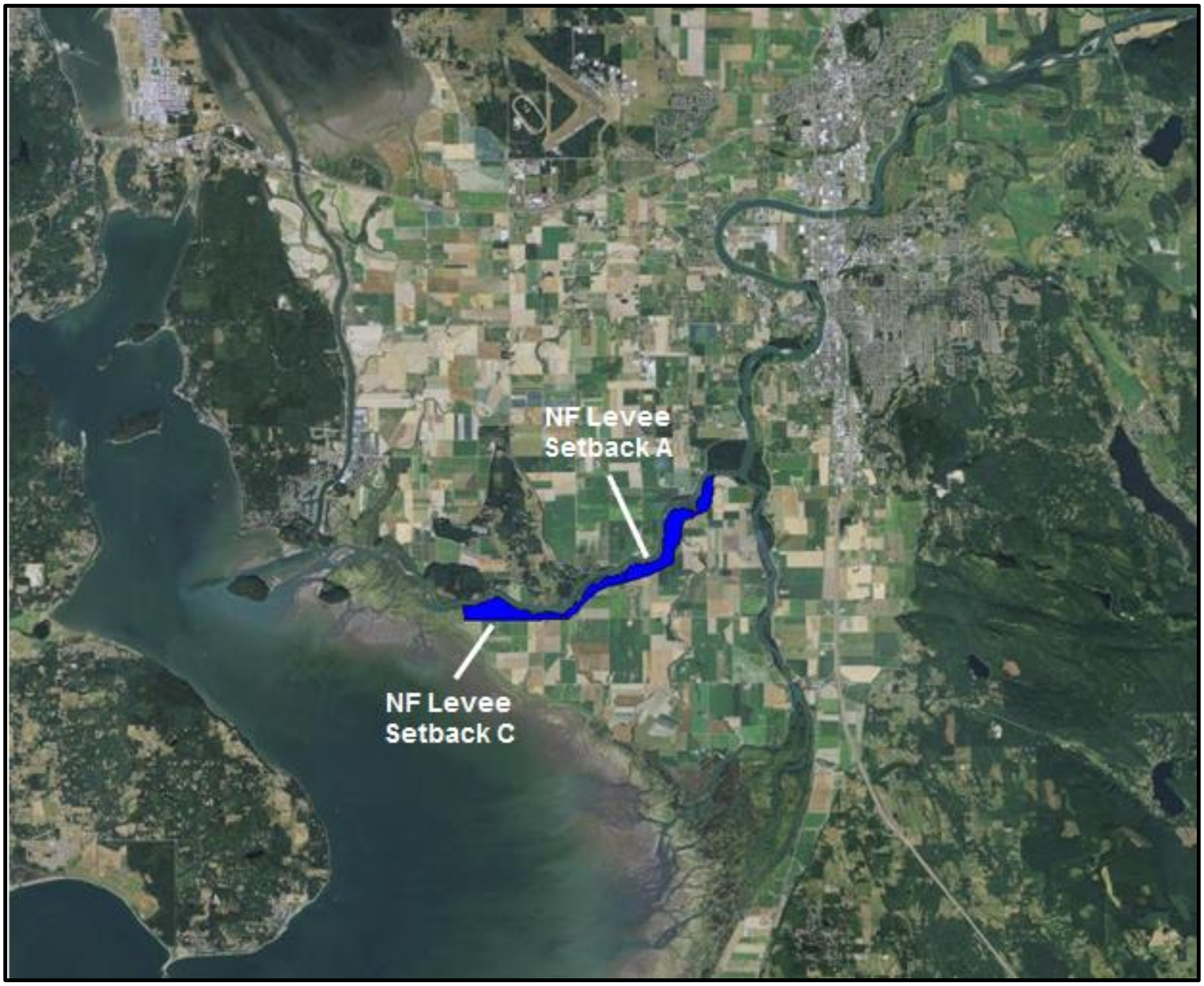

Figure 3.20. A map of both project areas in the Major Setback Project simulations (Setback A encompasses the area of Setback C).

3.5.1 North Fork Left Bank Levee Setback A and C

The NF Levee Setback projects (Figure 3.21) include three project footprints, but only two of these were directly incorporated into the hydrodynamic modeling; the third (Setback B) was assessed based on the results from modeling the other two projects, calculated as a percentage of Setback C.

The first, Setback A, begins just downstream of the forks at the inlet of Dry Slough and continues to the marine dike at the end of Rawlins Road. The upstream extent of North Fork Left Bank Levee Setback B begins where Moore Road runs east to west across Fir Island and encompasses the remaining downstream portions of Setback A. Setback C is the smallest of the footprints; it includes an upstream extent of Polson Road extending down to the marine dike. All three setback alternatives include the footings of the current NF Bridge, though it should be noted that Skagit County has developed initial plans to eventually replace the bridge (Shearer Design LLC 2014).

Setback A is a 563-acre setback project; Setback C is a 279-acre project. Both were primarily derived from the Skagit Chinook Recovery Plan (SRSC and WDFW 2005), while a variation of Setback C was also proposed in PSNERP (2012). More details on the project can be found in Barnard et al. (2016).

Figure 3.21. Outlines for the NF Left Bank Levee Setbacks A and C projects. Setback A includes the area of Setback C. Setback B was not modeled.

3.6 Simulations 6 & 7: Moderate Influence Projects

The remaining six projects (Table 1.1.) were large enough to have local effects (single fork or immediate vicinity), but unlikely to have system-wide effects. Additionally, Telegraph Slough projects were isolated on the Swinomish Channel and were not likely to affect the hydrology or hydraulics of the NF and SF Skagit River. This means that projects are less likely to affect each other because the spatial zone of influence does not overlap and can be modeled together. Simulation 6 included NF Right Bank Levee Setback, Milltown Island, Telegraph Slough 1, and Thein Farm (Figure 3.22). Simulation 7 included Deepwater Slough Phase 2, Rawlins Road, and Telegraph Slough 1 & 2 (Figure 3.23).

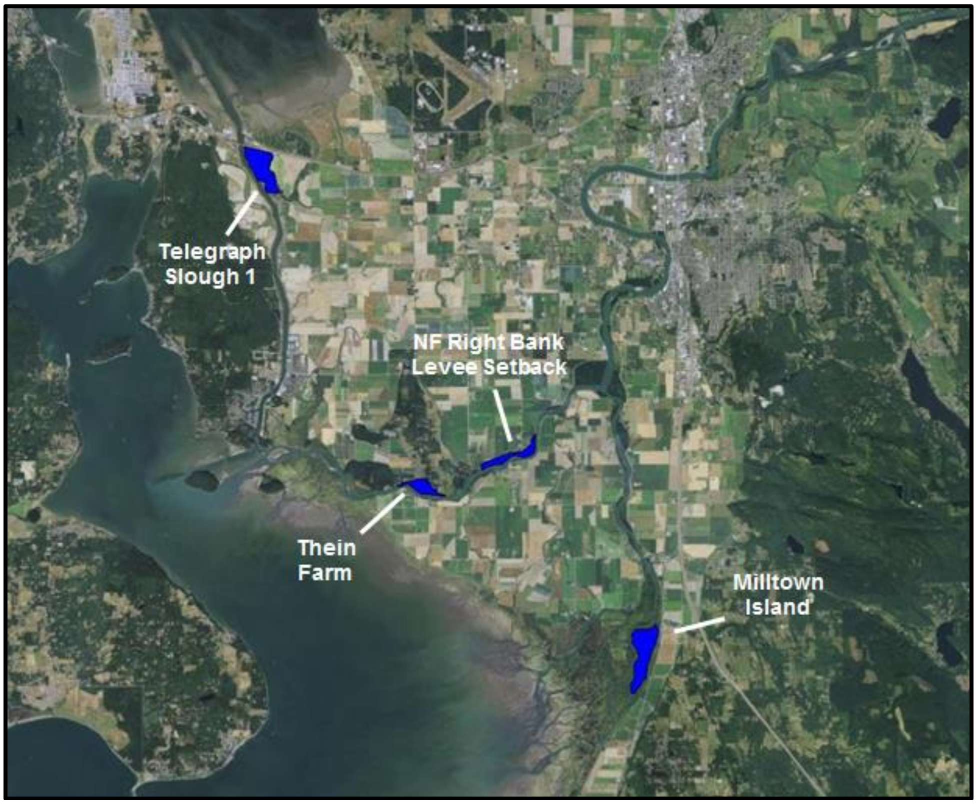

Figure 3.22. A map of project areas in Simulation 6 for Moderate Influence Projects.

Figure 3.23. A map of project areas in Simulation 7 for Moderate Influence Projects.

3.6.1 North Fork Right Bank Levee Setback

North Fork Right Bank Levee Setback (Figure 3.24) proposes to relocate the existing right bank flood dike approximately one channel width landward from its current location. The project is expected to expand the river flood plain and replace the existing dike with an engineered flood dike. This section of dike was one of several areas the local diking districts identified as having known seepage problems; therefore, replacing the dike with a new engineered structure and setting it away from the river is anticipated to provide reduced flood risk to the local area.

The 50-acre hydraulic project was identified by the SHDM Team. More details on the project can be found in Barnard et al. (2016).

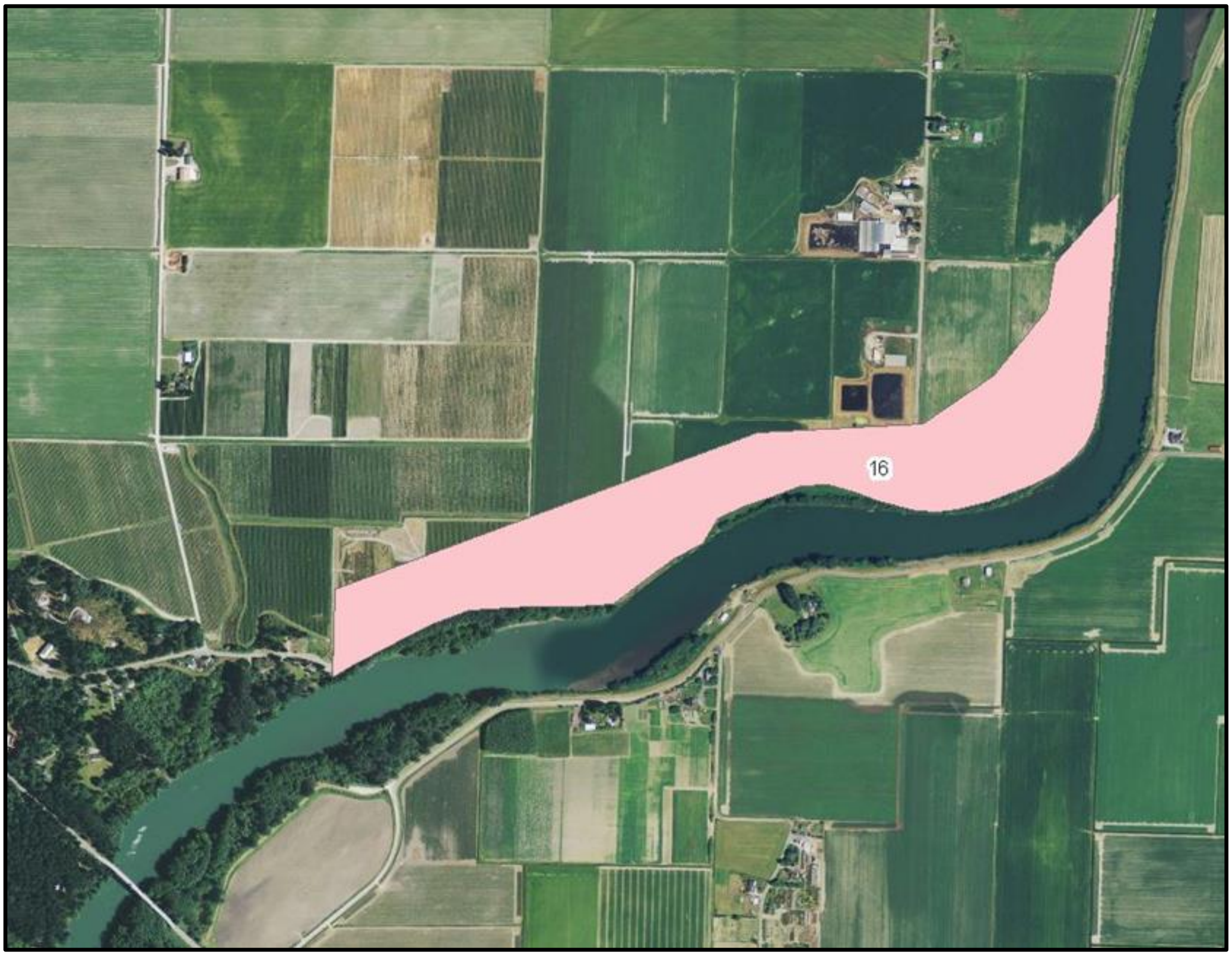

Figure 3.24. Outline of the North Fork Right Bank Levee Setback project.

3.6.2 Milltown Island

Milltown Island (Figure 3.25) is located at the mouth of the SF Skagit River and is surrounded by partially breached abandoned levees, breached in 1999 by the U.S. Navy in cooperation with the USACE, SRSC, and WDFW (SRSC 2006). In 2006 and 2007, the SRSC removed additional portions of the historic levee, constructed tidal channels, and planted native vegetation (SRSC 2006). The proposed project would restore additional tidal channel habitat on the island by removing the remaining dikes along the perimeter of the island.

The 212-acre levee breach project was identified in the Chinook Recovery Plan (SRSC and WDFW 2005) and PSNERP (2012). More details on the project can be found in Barnard et al. (2016).

Figure 3.25. Outline of the Milltown Island levee breach project.

3.6.3 Telegraph Slough 1

Telegraph Slough 1 (TS1) (Figure 3.26) is located on the east bank of the Swinomish Channel. Plans would set back the existing levee with engineered dikes and restore habitat to natural riverine and tidal processes.

The 220-acre dike setback project was identified in the Chinook Recovery Plan (SRSC and WDFW 2005). More details on the project can be found in Barnard et al. (2016).

Figure 3.26. Outline of the Telegraph Slough 1 dike setback project.

3.6.4 Thein Farm

Thein Farm (Figure 3.27) is located on the right bank of the NF Skagit River near the mouth and would restore riverine and tidal process to the site by replacing the existing river levee with an engineered levee located to the north along the base of Pleasant Ridge and along Landing Road. The project would remove the existing levee and build a setback levee, which would expand the floodplain of the NF Skagit River.

The 59-acre dike setback project was identified in the Chinook Recovery Plan (SRSC and WDFW 2005) as part of a suite of projects, known as Blake's Bottleneck, that set back NF Skagit River levees on both sides of the river and could have mutual benefits if implemented together. More details on the project can be found in Barnard et al. (2016).

Figure 3.27. Outline of the Thein Farm dike setback project.

3.6.5 Deepwater Slough Phase 2

Deepwater Phase 2 (Figure 3.28) spans two islands located near the mouth of the SF Skagit River. The project would lower portions of the perimeter dike, lower the internal cross dike, and create a series of dike breaches to connect distributary and blind channels to existing sloughs. It would also include excavation of blind tidal channel networks within each island, but these details were not added to the SHDM model. The project would result in unrestricted tidal freshwater flows, restore tidal wetlands, and create rearing habitat for juvenile salmon such as Chinook.

The 268-acre dike breach project was originally identified in the Chinook Recovery Plan (SRSC and WDFW 2005) and the conceptual design provided by PSNERP (2012). More details on the project can be found in Barnard et al. (2016).

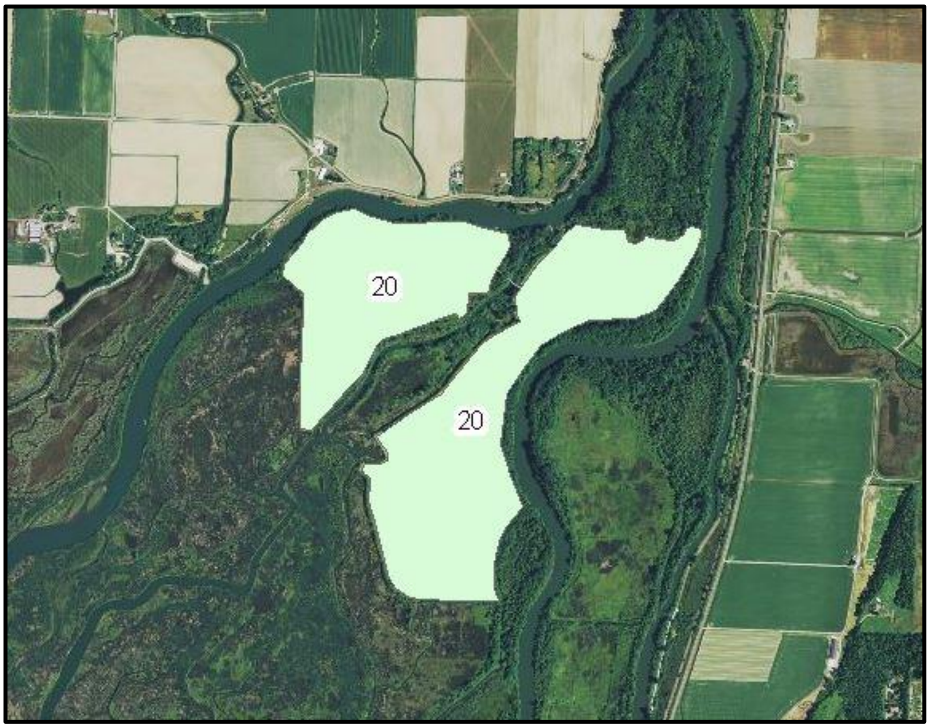

Figure 3.28. Outline of the Deepwater Slough Phase 2 dike breach project.

3.6.6 Rawlins Road

Rawlins Road (Figure 3.29) would restore riverine and tidal processes to the site by replacing the existing dike with an engineered dike located approximately 2700 ft east of the existing marine dike. The project would also remove a portion of the NF Skagit River levee. The project is expected to restore tidal marsh and channel habitats beneficial to Chinook salmon recovery. It also has the potential to significantly change the hydrodynamic behavior of the lower NF Skagit River and delta. The project would maintain the agriculture drainage through improved/new tidegate and drainage infrastructure.

The 192-acre dike setback project was originally identified in the Chinook Recovery Plan (SRSC and WDFW 2005), while a feasibility study of the Rawlins Road Project was completed by Battelle in 2006 for the Skagit Watershed Council (Battelle 2006). More details on the project can be found in Barnard et al. (2016).

Figure 3.29. Outline of the Rawlins Road dike setback project.

3.6.7 Telegraph Slough 1 & 2

Telegraph Slough 1 & 2 (TS1&2) (Figure 3.30) is also located along the east bank of the Swinomish Channel and includes the area identified in TS1 plus additional area to the east. TS1&2 would restore additional marsh by further setting back the dike and relocating the existing tidegates. TS1&2 would also restore connectivity to Padilla Bay through the historic Telegraph Slough corridor by constructing new bridges under SR20 and the railroad.

The 467-acre dike setback project was identified in the Chinook Recovery Plan (SRSC and WDFW 2005), though details for the SR20 bridge were taken from PSNERP (2012) for Telegraph Slough Full. More details on the project can be found in Barnard et al. (2016).

Figure 3.30. Outline of the Telegraph Slough 1 & 2 dike setback project.

3.7 Simulation 8: Selected Projects

After Simulations 1–7 were completed, the SHDM Team reviewed and analyzed the results while engaging project stakeholders for feedback. The goal after the initial assessment was to select a subset of projects deemed most feasible. These projects were simulated together in Simulation 8 to assess how they would interact with one another in tandem. The selected projects included all except the Avon-Swinomish Bypass and the NF Left Bank Levee Setback A, which had significantly higher levels of impact when compared to other projects (Figure 3.31).

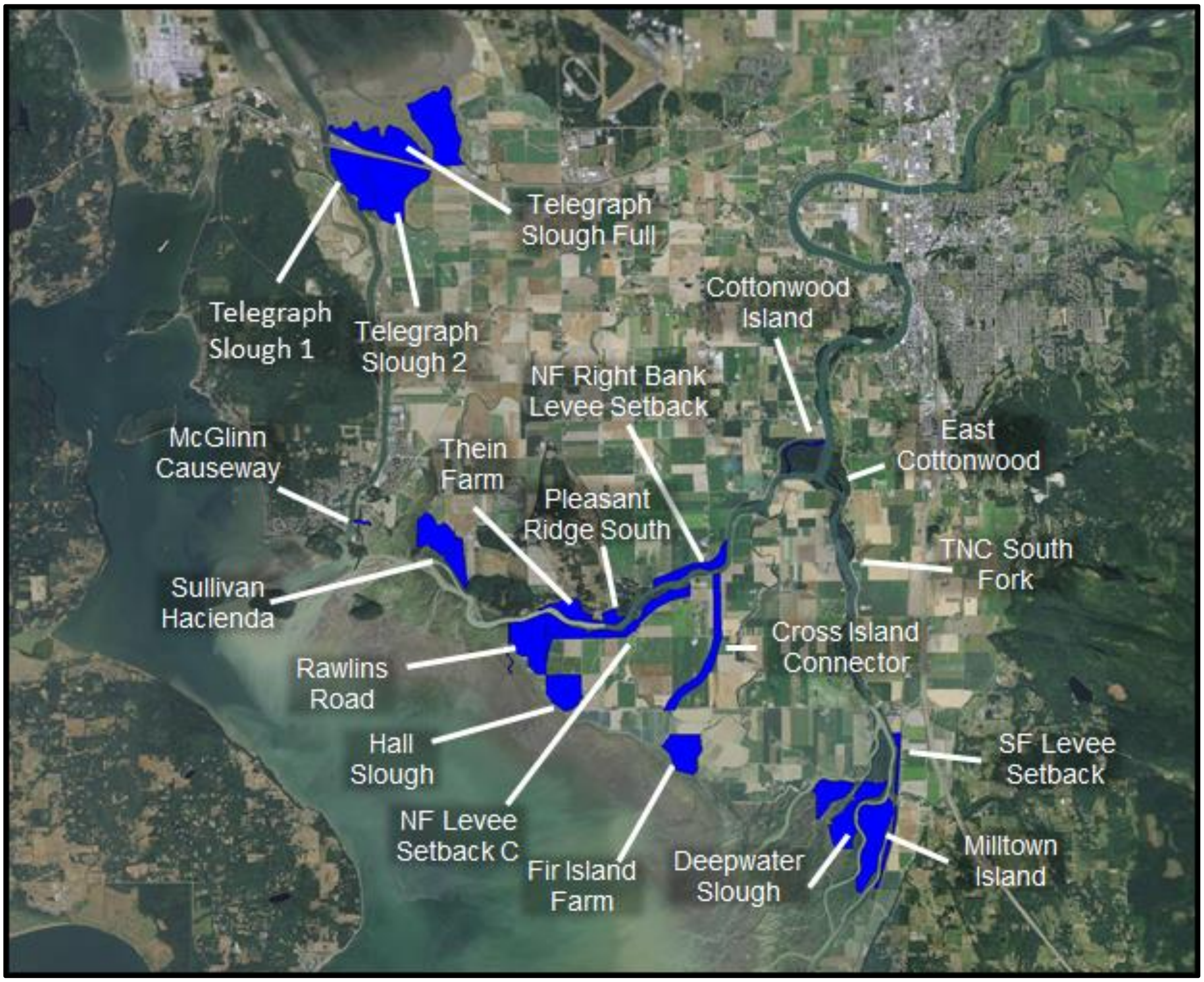

Figure 3.31. A map of project areas in Selected Projects simulation.

3.8 Simulation 9 & 10: Climate Change

The last two simulations were intended to assess the response of proposed restoration projects and the Skagit River delta to future climate conditions. The conditions that were modeled are described in Section 3.2. Simulation 9 included future conditions with no projects and is known as the Climate Change Baseline. Simulation 10 included future conditions with the same selected projects from Simulation 8.

4.0 Results

This section summarizes the results of simulations conducted for the high-level multi-criteria assessment of 22 out of 23 proposed restoration projects in the Skagit River estuary. A validated Baseline Simulation was compared against each of the restoration simulations. Projects were grouped into separate simulations as described in Section 3.0. This allowed the effects of each project to be isolated and quantified, which allowed small projects to be grouped, while providing independent simulations for some very large projects. This report simply presents the model results without detailed evaluation or interpretation of the findings and refrains from making any judgments about the viability of any projects. Results from this modeling effort are feeding into a larger analysis conducted by the SHDM Team in which projects will be assessed for their benefits to providing juvenile chinook habitat, reducing flood risk and reducing impacts to agriculture. This larger analysis performed by the SHDM Team will comment on the viability of each proposed project.

Deliverables from this current study are in the form of area of inundation calculations, cumulative frequency plots for WSE, maps showing the depths of inundation, histograms for water depths within project sites, maps showing the changes in WSE, maps showing the changes in bed shear stress, maps showing the changes in salinity, and plots showing the changes in stage and flow.

A comprehensive compilation of all deliverables for all simulations is included in the following Appendix sections. As each deliverable is introduced in the appendices, caveats related to the model results are explained. Additionally, individual images provide explanations where deemed necessary.

- Appendix A: Simulation 0: Baseline Deliverables
- Appendix B: Simulation 1: Small Projects Deliverables
- Appendix C: Simulation 2: Fir Island Cross Island Connector Deliverables
- Appendix D: Simulation 3: Avon-Swinomish Bypass Deliverables
- Appendix E: Simulation 4: North Fork Left Bank Levee Setback C Deliverables
- Appendix F: Simulation 5: North Fork Left Bank Levee Setback A Deliverables
- Appendix G: Simulation 6: Moderate Setback Projects Deliverables
- Appendix H: Simulation 7: Moderate Setback Projects Deliverables
- Appendix I: Simulation 8: Selected Projects Deliverables
- Appendix J: Simulation 9: Baseline Climate Change Deliverables
- Appendix K: Simulation 10: Climate Change with Selected Projects Deliverables.

4.1 Model Limitations and Interpretation of Model Deliverables

All models have errors and limitations that arise from a combination of simplification of complex hydrodynamic processes in the mathematical formulation, errors in the discretization, solution scheme, lack of adequate site-specific data, temporal and spatial resolution in model inputs and forcing parameters. Understanding model limitations is essential to ensure that application results are not misused or applied beyond their intended performance design and the deliverables presented are correctly interpreted.

The following is a list of notable model limitations and model interpretation guidelines, which are later repeated in the appropriate appendices.

- When calculating the area subject to tidal and riverine processes (Deliverables 1 & 2), the accuracy is limited by the spatial resolution of the triangular grid, which varies throughout the model domain. For any wetted node included in the project boundary polygon, its associated computational area was counted toward the total inundated area (this area consists of part of all neighboring cells, determined by geometry). This means that potential projects that are narrow, such as Cottonwood Island (Section 3.3.4), show a larger measured area when compared to the actual project footprint. Therefore, some project areas may be more accurately measured using GIS tools.
- Depth of inundation (Deliverable 4) is plotted so that a node is considered “wet” when the calculated water depth exceeds the minimum wetting and drying criteria of 10 cm (0.3281 ft). The model does not include evaporation or seepage of water into the ground, so low tide conditions may show small polygons along the Bayfront where small pooling does not dissipate after higher tides. These may be ignored as insignificant artifacts.
- Depth histograms (Deliverable 5) are also limited by model grid resolution, similar to the previous area calculations.
- Bed shear stress (Deliverable 7) is largely dependent on the bottom drag coefficient selected for the model. These results did not consider variation from different bed features, especially the vegetation type, in the restored marsh site other than assuming a constant, uniform bottom roughness (Z0) of 0.001 m and a minimum bottom drag coefficient (Cd) of 0.0025. The actual drag coefficient for each grid element during model simulation is dynamically calculated based on drag law formulation by assuming a logarithmic velocity profile for the bottom layer (Chen et al. 2003).
- Salinity (Deliverable 8) represents the averaged bottom 10% of water depth with low flow and a high spring tide, so this represents the maximum salt intrusion upstream. The model only shows salinity for “wet” cells where the calculated water depth exceeds a wetting and drying criteria of 30 cm (0.9843 ft), so depths less than this are not shown. (For salinity computations, a larger depth was needed to represent dry nodes for computational stability. For all other variables, a 10 cm criterion was used to define the cutoff for dry nodes).
- The WSE and flow curves (Deliverable 9) represent a comparison between the baseline and restored conditions every 15 minutes throughout the 7-month simulation. The calculations occur at the location of the WDFW gauges and represent changes in flow between different branches of the river delta. When the curve moves off-center, it represents a change in the system. Non-linear results are sometimes seen in Freshwater Slough and Steamboat Slough because they are located in the complex intertidal region.

5.0 Conclusions

This report describes a progressive application of model results to provide quantitative information for an objective assessment of proposed projects. Habitat restoration projects are commonly pushed forward without understanding the landscape-wide effects or changes to the project over time (Simenstad and Cordell 2000; Simenstad et al. 2005). The hydrodynamic model allowed the assessment of interactions between different restoration actions and their cumulative effects, while also assessing the impact of restoration projects in estimated 2080 future conditions. Model results can also assist engineering design by providing detailed results about how the hydraulics of the system can be expected to change. This analysis was conducted at a very high level, but sub-models can be created to assess individual projects in greater detail, using outputs from the landscape-wide model for boundary conditions.

At this point, the primary goal for the SHDM Project is to feed results into an additional alternative analysis in which each individual project will be assessed for restoration objectives and from which indicators will be created to promote long-term viability of Chinook salmon tidal delta habitat and community flood risk reduction in a manner that projects and enhances agriculture and drainage. Each project was assessed for the following objectives and indicators to evaluate potential benefits and impacts (Friebel et al., in preparation):

- **Increase the area subject to natural tidal and riverine processes in the study area** (Fish)
- **Minimize impacts to existing habitats subject to tidal and riverine processes** (Fish)
- **Increase the area of tidal and riverine channels suitable for Chinook rearing fry in the study area** (Fish)
- **Increase Chinook smolt production** (Fish)
- **Increase landscape connectivity of the study area** (Fish)
- **Maintain or improve existing diversity of tidal marsh habitat along the historical elevation gradient** (Fish)
- **Minimize conversion of agricultural land** (Farm)
- **Maximize the number of smolts per acre of converted agricultural land** (Farm)
- **Support tidegate maintenance through TFI Implementation Agreement** (Farm)
- **Prioritize Public Lands** (Farm)
- **Avoid conversion of farmland preservation easements** (Farm)
- **Reduce water surface elevation within the study area** (Flood)
- **Reduce risk of levee failure by constructing new engineered levees** (Flood)
- **Avoid creation of new dike infrastructure where none existed previously** (Flood)
- **Improve agriculture flood drainage** (Flood)

Details about the ranking of potential projects and judging of the viability of each project will be available from separate publications by TNC, NOAA, and WDFW. This report helps to understand the model results, but intentionally refrains from making any judgments about specific projects.

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Appendix A

Simulation 0: Baseline Deliverables

Appendix A

Simulation 0: Baseline Deliverables

The following list of deliverables is associated with Simulation 0. These deliverables were created by the SHDM Team to address specific objectives for the alternative analysis (Friebel et al., in preparation).

1. At each of the five gauge locations, cumulative frequency of water surface elevation (WSE) for the entire 7-month run. An Excel file of the data associated with the plot data was also provided.

2. Contour maps showing water depth for baseline (Simulation 0) during (1) low flow and high spring tide for overbank areas subject to tidal processes and (2) two year flood (Q2) flow and low spring tide for areas subject to riverine processes. High-resolution, georeferenced maps were also provided (not shown).

3. Contour maps showing WSE for baseline (Simulation 0) during (1) Q2 flow and low spring tide and (2) a flood condition and high tide. High-resolution, georeferenced maps were also provided, including (3) low flow and high spring tide (not shown).

4. Contour maps showing bed shear stress for baseline (Simulation 0) during (1) low flow and the peak shear stress during a full tidal cycle and (2) Q2 flow and low spring tide. High-resolution, georeferenced maps were also provided (not shown).

5. A contour map showing salinity for baseline (Simulation 0) during (1) low flow and high spring tide. High-resolution, georeferenced map was also provided (not shown).

A.1 Baseline Deliverable 1

Deliverable 1 is a set of cumulative frequency plots showing WSE at each of the five gauge locations used to calibrate the model. These are from the entire Baseline Simulation (Simulation 0), representing November 2, 2014 – June 16, 2015. All WSE values are relative to the NAVD88 datum. The plots can be seen in Figure A.1 through Figure A.5.

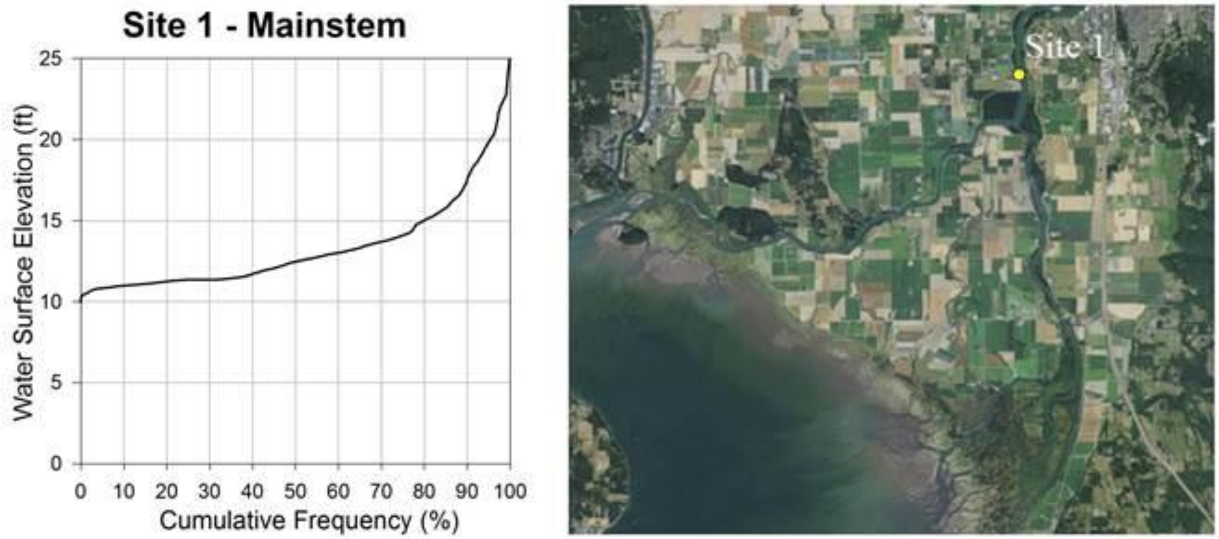


Figure A.1. Cumulative frequency plot and corresponding map for Site 1 (Mainstem) during the Baseline Simulation. The gauge location is designated by the yellow dot on the map.

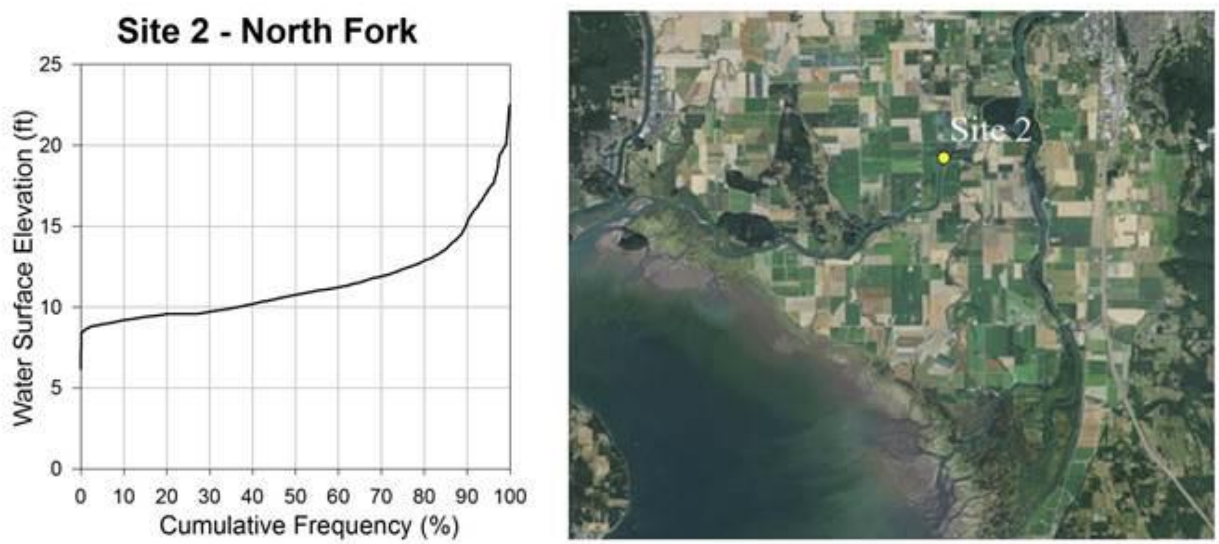


Figure A.2. Cumulative frequency plot and corresponding map for Site 2 (North Fork) during the Baseline Simulation. The gauge location is designated by the yellow dot on the map.

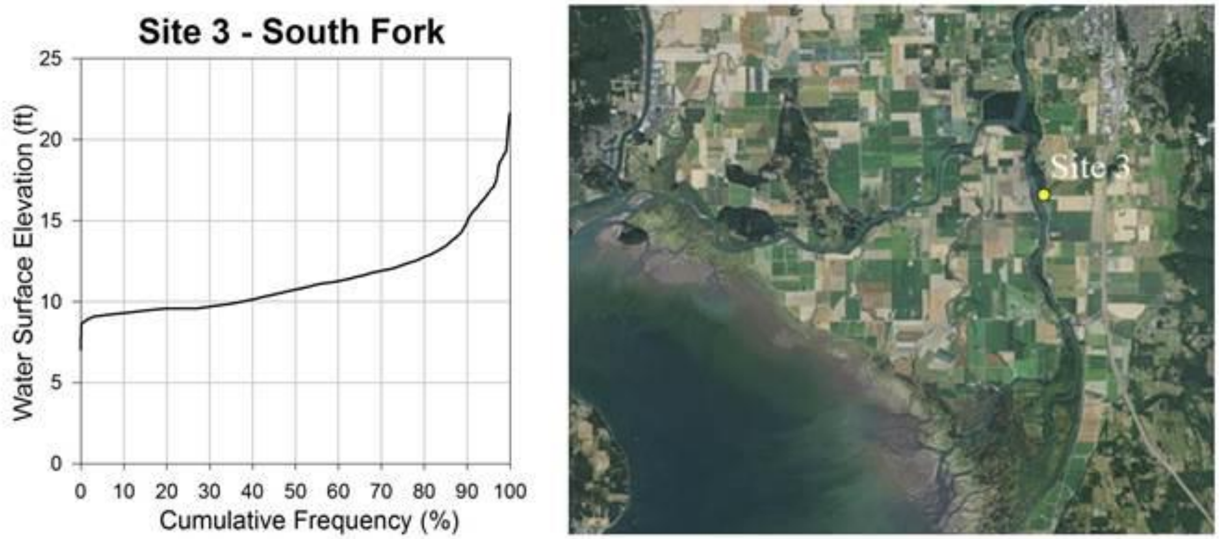


Figure A.3. Cumulative frequency plot and corresponding map for Site 3 (South Fork) during the Baseline Simulation. The gauge location is designated by the yellow dot on the map.

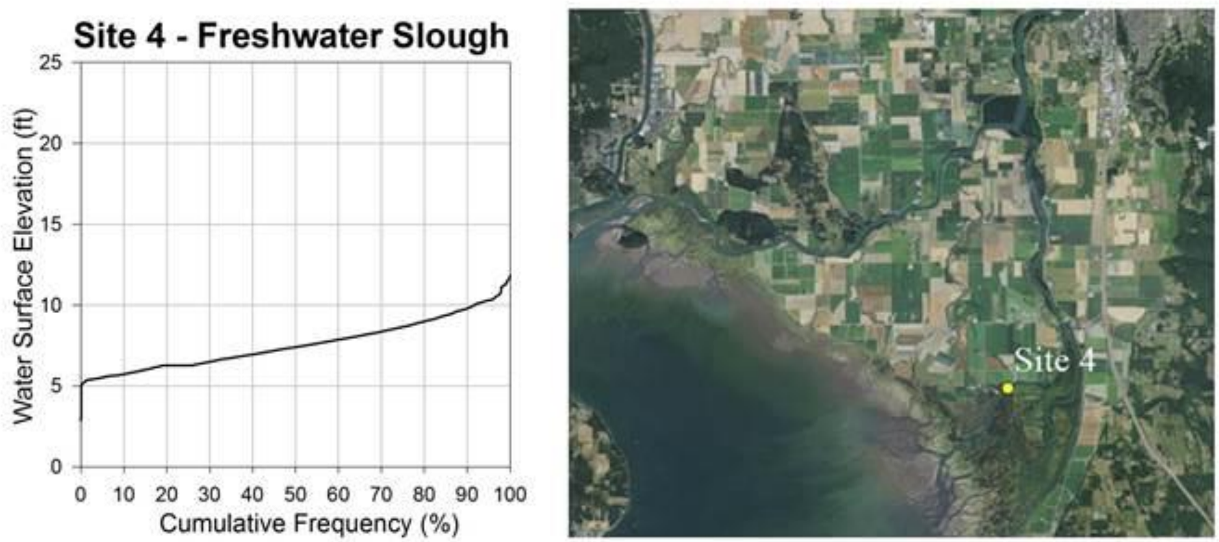


Figure A.4. Cumulative frequency plot and corresponding map for Site 4 (Freshwater Slough) during the Baseline Simulation. The gauge location is designated by the yellow dot on the map.

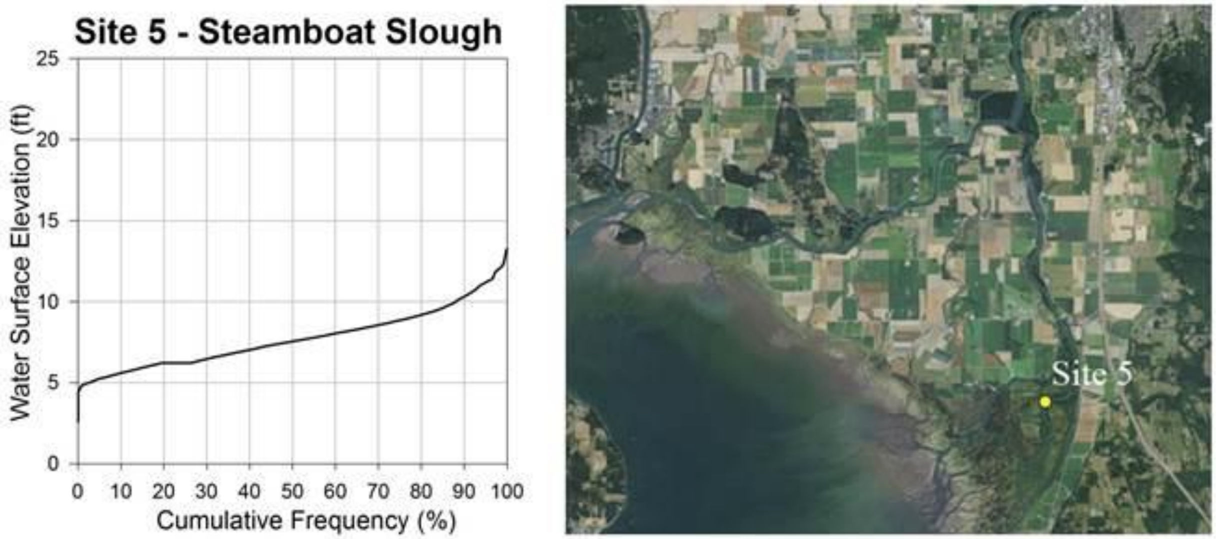


Figure A.5. Cumulative frequency plot and corresponding map for Site 5 (Steamboat Slough) during the Baseline Simulation. The gauge location is designated by the yellow dot on the map.

A.2 Baseline Deliverable 2

Deliverable 2 is a set of contour maps showing the depth of inundation during the Baseline Simulation (Simulation 0). Two conditions were plotted: (1) a high spring tide (10.8 ft) and low flow (12,000 cfs) and (2) a low spring tide (-3.3 ft) and a Q2 flow (62,000 cfs). All depth values are relative to model bathymetry, which uses linear interpolation to the resolution of the grid. The small polygons seen in some Bayfront maps are artifacts of a previous high tide caused by small pooling that does not dissipate because the model does not calculate evaporation or seepage of water into the ground. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the Skagit Hydrodynamic Model (SHDM) Team. The maps can be seen in Figure A.6 and Figure A.7.

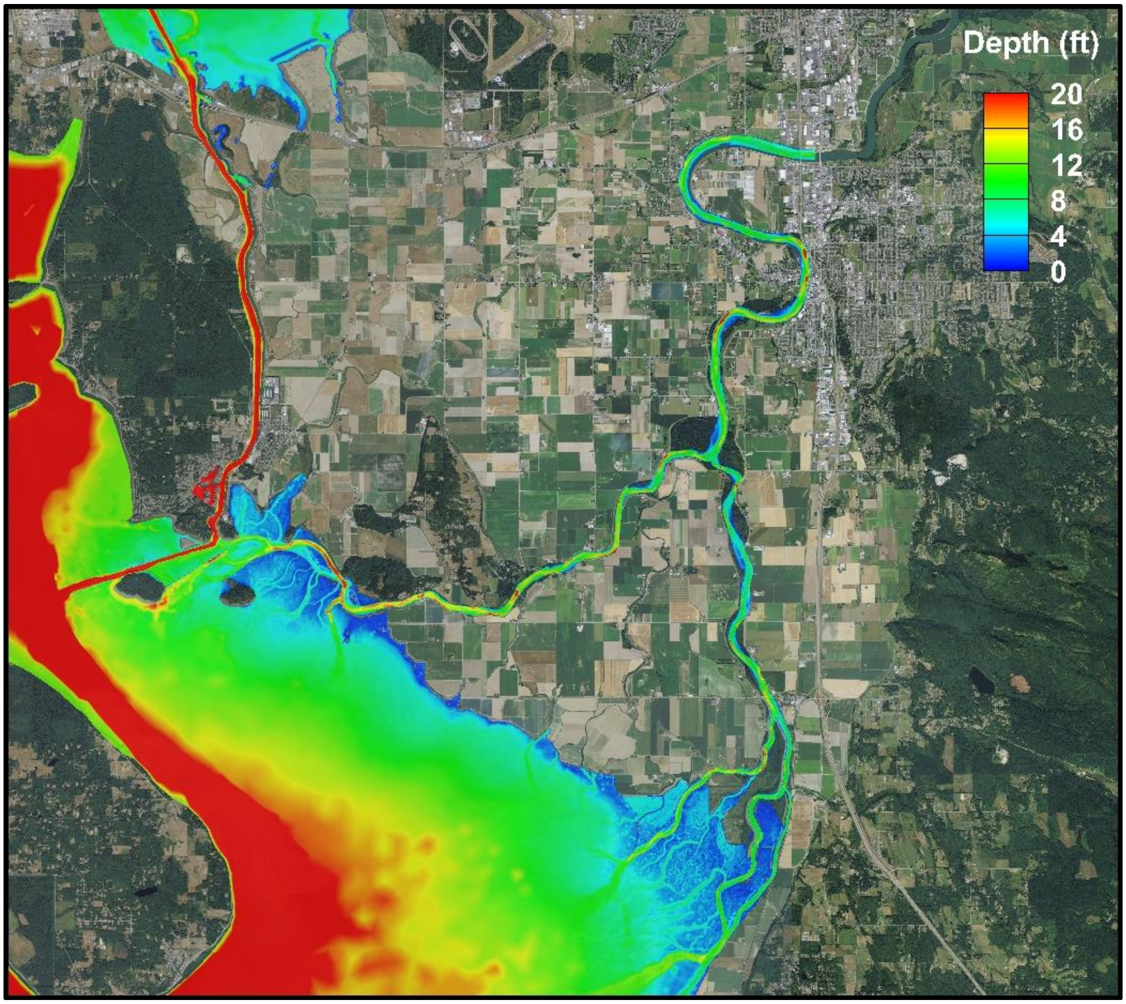


Figure A.6. Contour map of the depth for the full domain during the Baseline Simulation with low flow and high spring tide.

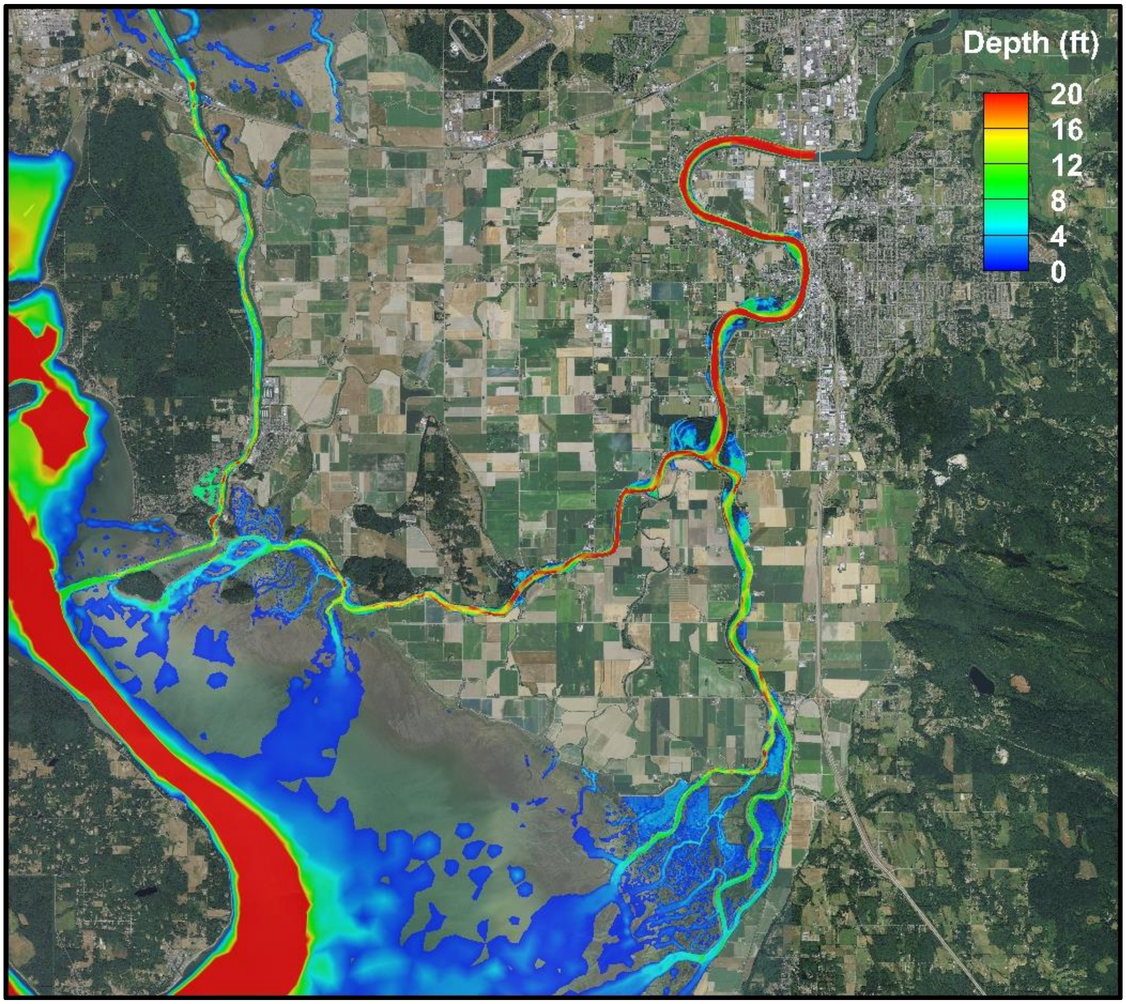


Figure A.7. Contour map of the depth for the full domain during the Baseline Simulation with Q2 flow and low spring tide.

A.3 Baseline Deliverable 3

Deliverable 3 is a set of contour maps showing WSE during the Baseline Simulation (Simulation 0). Two conditions were plotted: (1) a low spring tide (-3.3 ft) and Q2 flow (62,000 cfs) and (2) a high spring tide (10.8 ft) and a flood condition (93,200 cfs). All WSE values are relative to the NAVD88 datum. Areas that are not inundated are blanked out. The small polygons seen in some Bayfront maps are artifacts of a previous high tide caused by small pooling that does not dissipate because the model does not calculate evaporation or seepage of water into the ground. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure A.8 and Figure A.9.

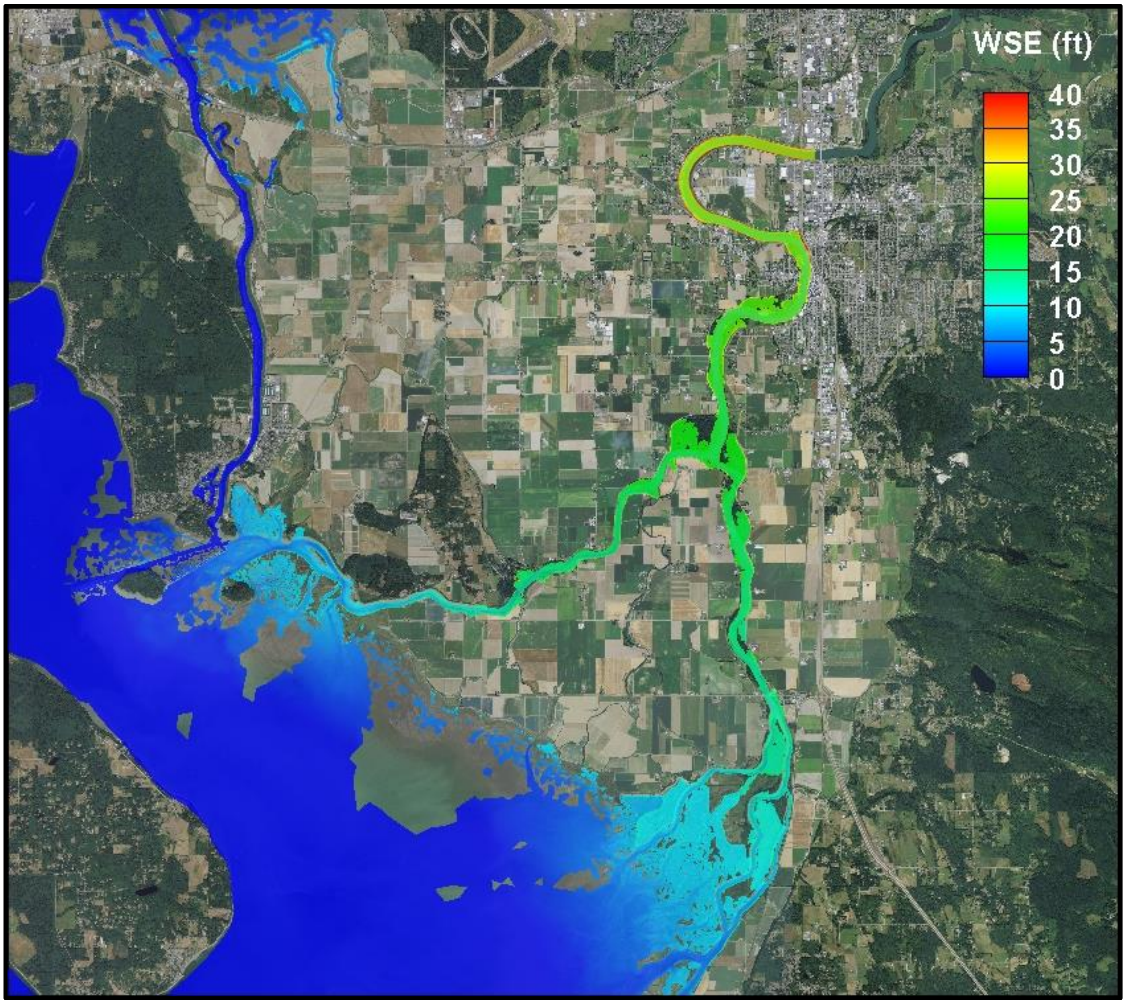


Figure A.8. Contour map of water surface elevation for the full domain during the Baseline Simulation with Q2 flow and low spring tide.

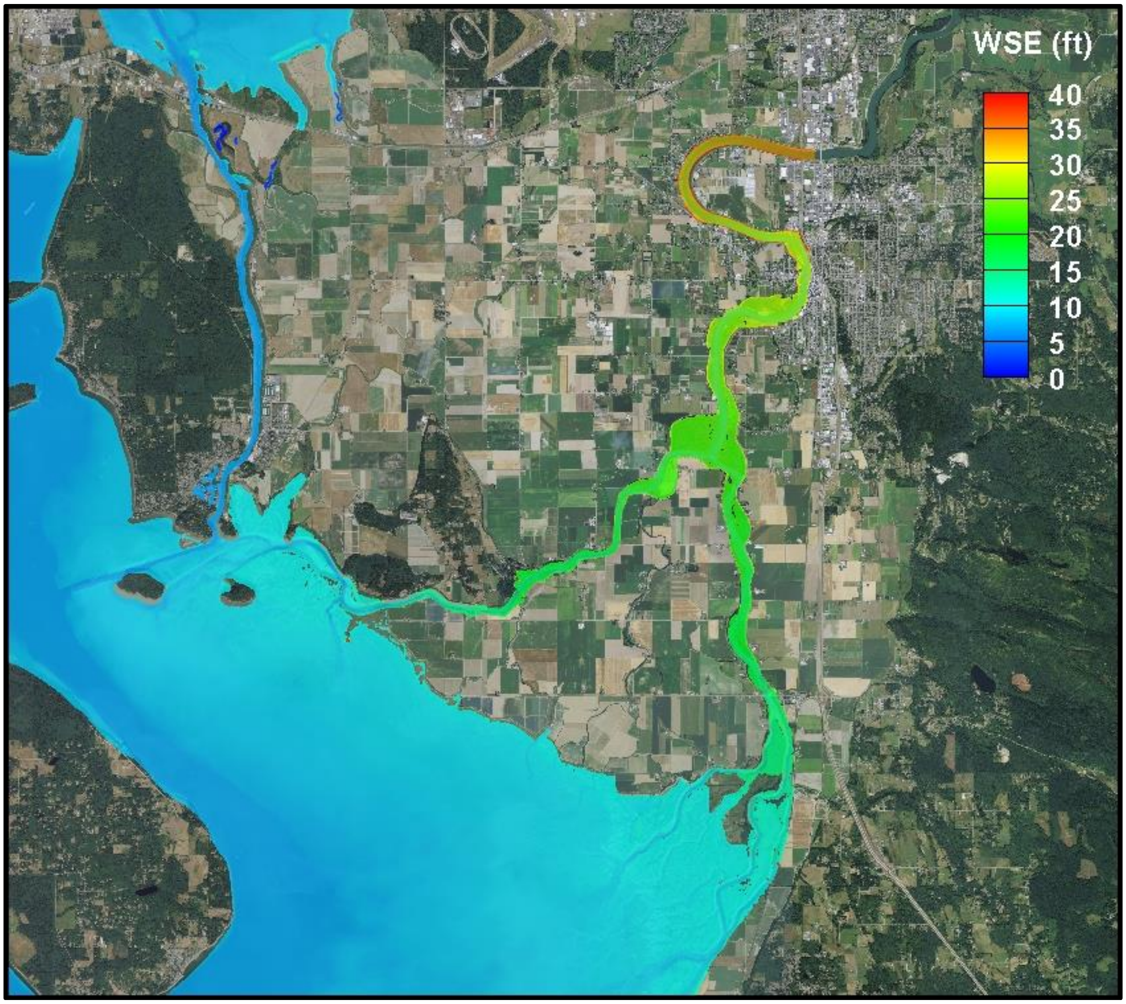


Figure A.9. Contour map of water surface elevation for the full domain during the Baseline Simulation with flood flow and high spring tide.

A.4 Baseline Deliverable 4

Deliverable 4 is a set of contour maps showing bed shear stress during the Baseline Simulation (Simulation 0). Two conditions were plotted: (1) a full spring tidal cycle during a low flow (12,000 cfs) when the peak shear across the map was recorded and (2) a low spring tide (-3.3 ft) and Q2 flow (62,000 cfs). The small polygons seen in some Bayfront maps are artifacts of a previous high tide caused by small pooling that does not dissipate because the model does not calculate evaporation or seepage of water into the ground. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure A.10 and Figure A.11.

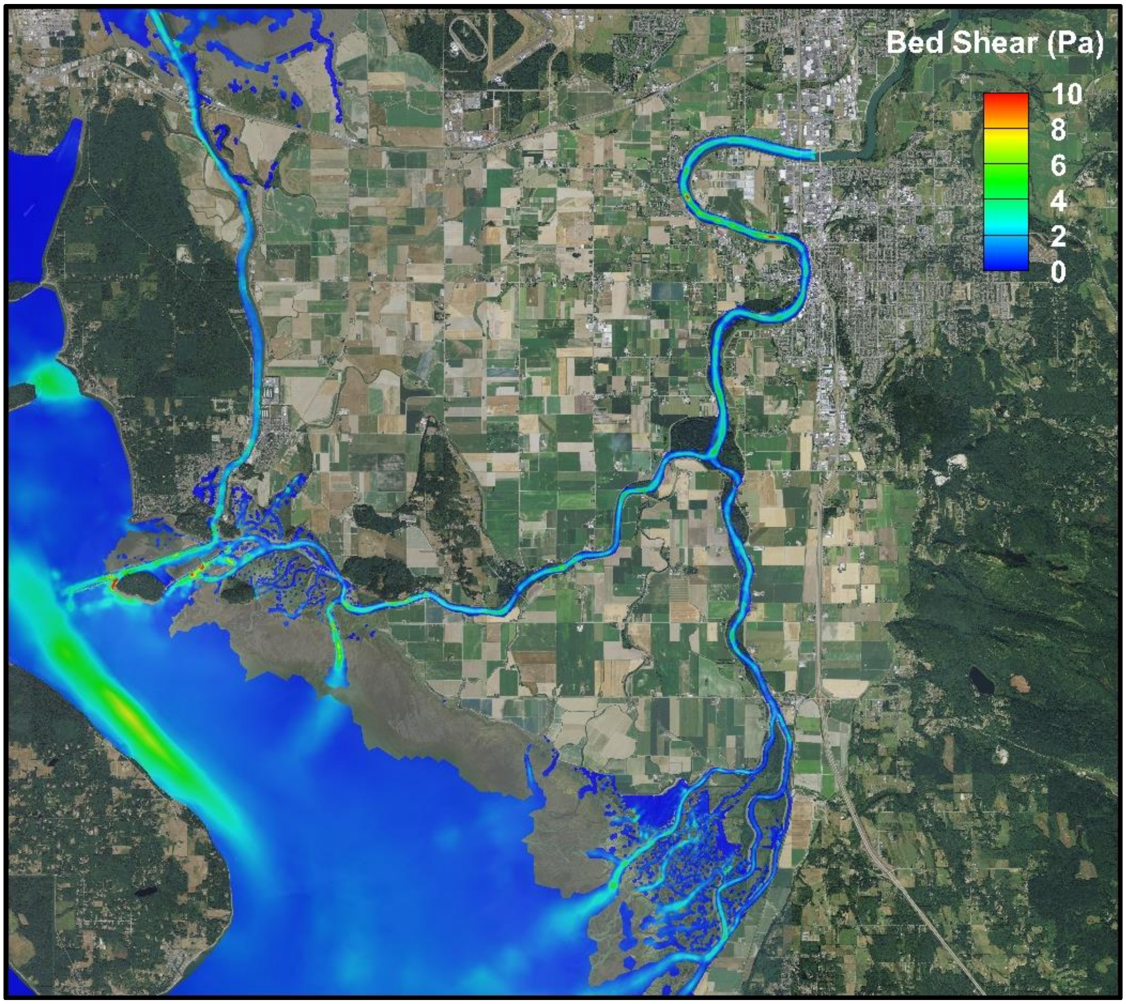


Figure A.10. Contour map of peak shear stress for the full domain during the Baseline Simulation with low flow across the full tidal cycle.

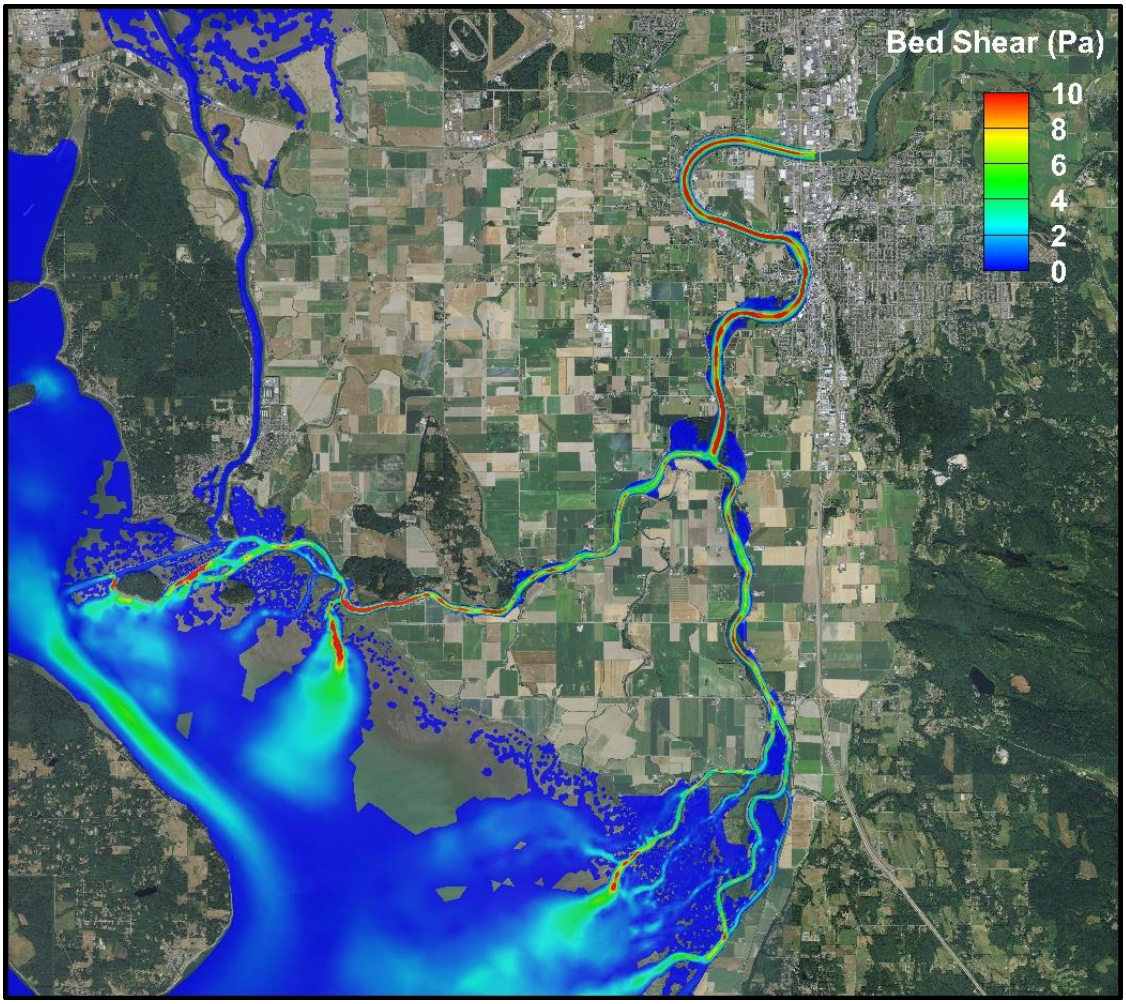


Figure A.11. Contour map of shear stress for the full domain during the Baseline Simulation with Q2 flow and low spring tide.

A.5 Baseline Deliverable 5

Deliverable 5 is a contour map showing salinity levels during the Baseline Simulation (Simulation 0). The plotted condition was a low flow (12,000 cfs) and high spring tide (10.8 ft). High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The map can be seen in Figure A.12.

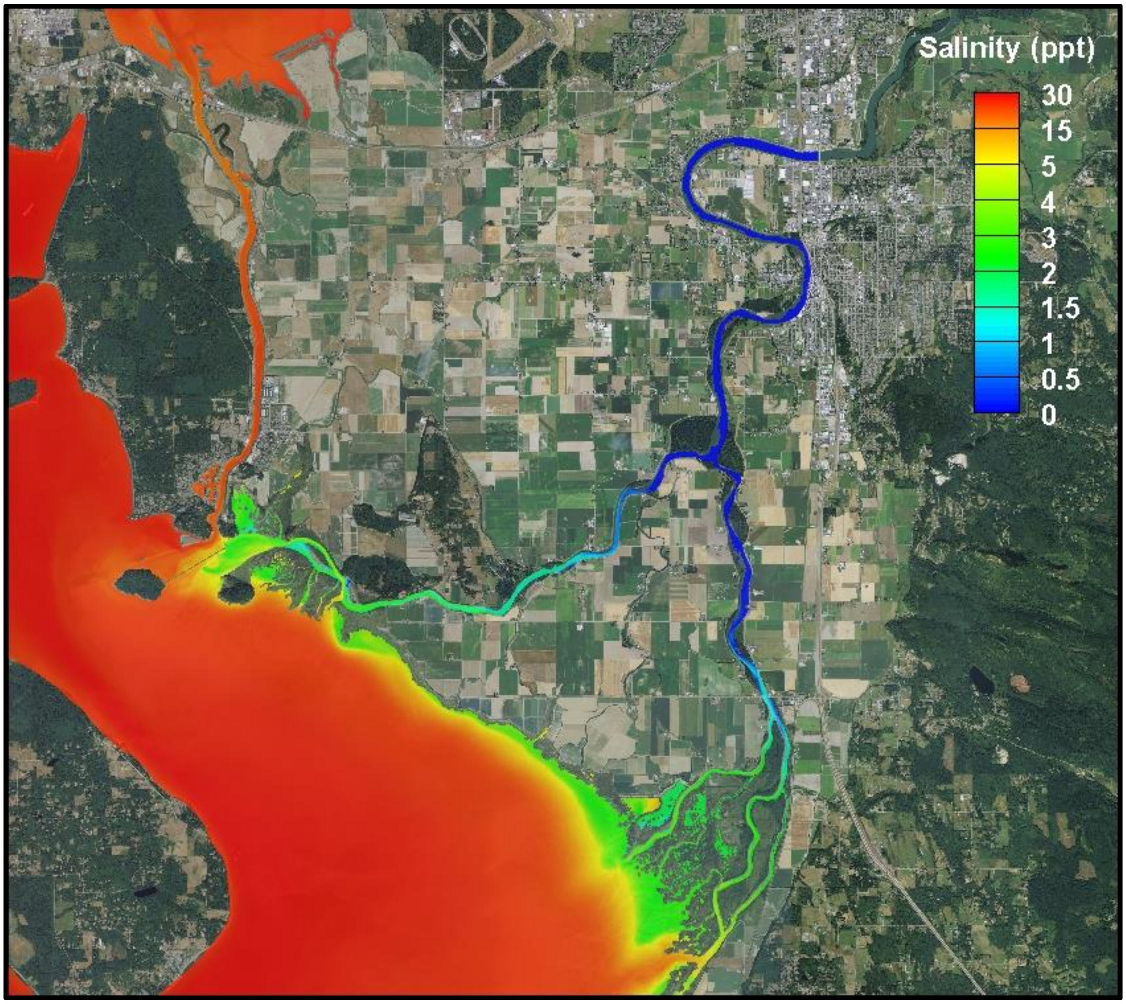


Figure A.12. Contour map of salinity for the full domain during the Baseline Simulation with low flow and high spring tide.

Appendix B

Simulation 1: Small Projects Deliverables

Appendix B

Simulation 1: Small Projects Deliverables

The deliverables listed below are associated with Simulation 1: SF Levee Setbacks, McGlinn Causeway, TNC South Fork, Cottonwood Island, East Cottonwood, Pleasant Ridge South, Hall Slough, Fir Island Farm, Telegraph Slough Full, Sullivan Hacienda, Rawlins Distributary (Figure B.1). These deliverables were created by the SHDM Team to address specific objectives for the alternative analysis (Friebel et al., in preparation).

1. Table entries showing the change in area subject to natural tidal and riverine processes for each sub-basin in the study area during small projects (Simulation 1).

2. Table entries showing the change in area subject to natural tidal and riverine processes for each small project (Simulation 1). Because of error with wetted area calculations, high resolution, georeferenced maps showing the depth of inundation under (1) low flow and high tide and (2) Q2 flow and low tide were also provided (not shown).

3. At points in the main channel and bay front selected by the SHDM Team, cumulative frequency of WSE (for the months of March, April, and May). An Excel file of the data associated with the plot data was also provided (not shown).

4. Contour maps showing water depth for small projects (Simulation 1) during (1) mean river discharge for the month of May and spring high tide. High-resolution, georeferenced map was also provided (not shown).

5. Histograms of water depth with 1 ft bins at each small project (Simulation 1) during (1) mean river discharge for the month of May and high spring tide.

6. Contour maps showing change in WSE from baseline (Simulation 0) to small projects (Simulation 1) during (1) Q2 flow and low spring tide and (2) a flood condition and high tide. High-resolution, georeferenced maps were also provided, including (3) low flow and high spring tide and absolute WSE for all three conditions (not shown).

7. Contour maps showing change in bed shear stress from baseline (Simulation 0) to small projects (Simulation 1) during (1) low flow and the peak shear stress during a full tidal cycle and (2) Q2 flow and low spring tide. High-resolution, georeferenced maps were also provided, including absolute bed shear stress for both conditions (not shown).

8. Contour maps showing change in salinity from baseline (Simulation 0) to small projects (Simulation 1) during (1) low flow and high spring tide. High-resolution, georeferenced maps were also provided, including absolute salinity for both conditions (not shown).

9. Plots of change in WSE and flow from baseline (Simulation 0) to small projects (Simulation 1) for the South Fork, North Fork, Freshwater Slough, and Steamboat Slough to determine the basin effects. An Excel file of the data associated with the plots was also provided.

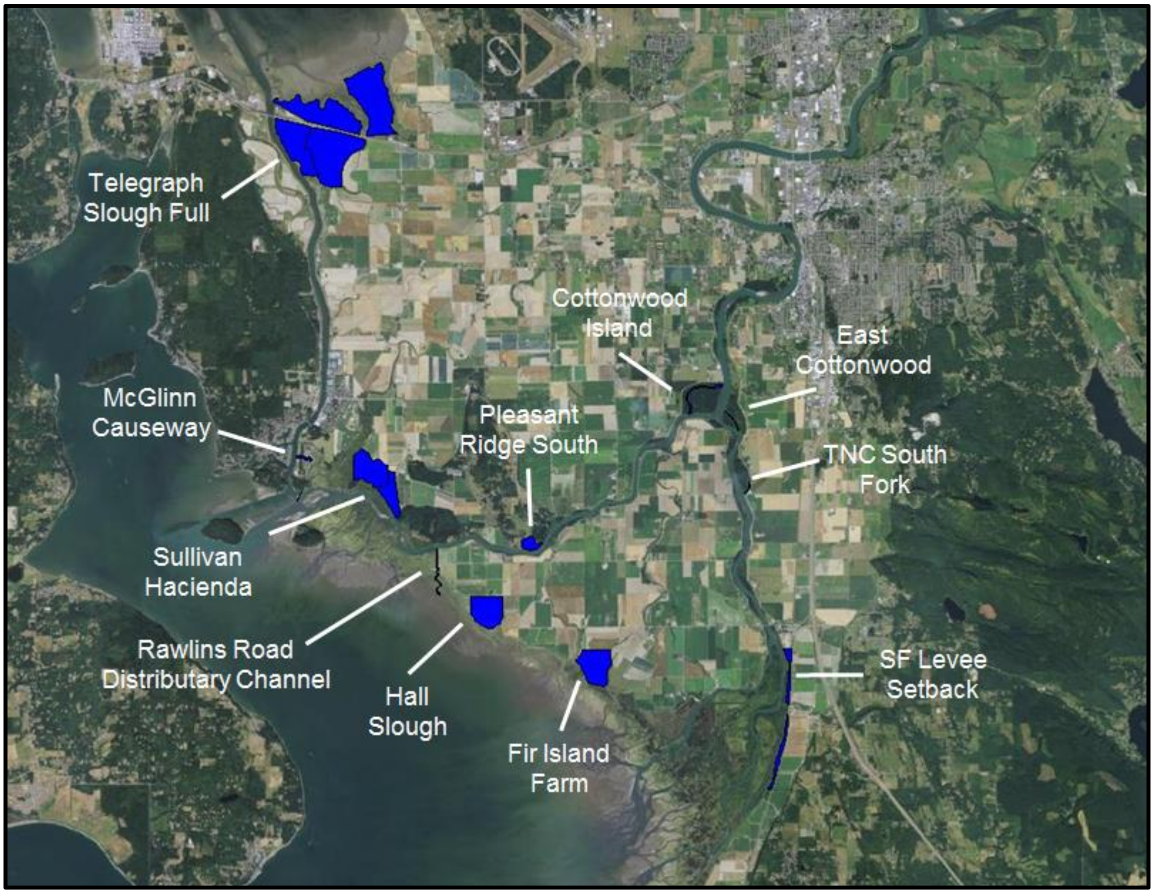


Figure B.1. A map of project areas in the Small Projects simulation.

B.1 Small Projects Deliverable 1

For this deliverable, the area was divided into sub-basins, as seen in Figure B.2. Deliverable 1 is a table showing the increase in inundation area subject to natural tidal and riverine processes within each sub-basin, as seen in Table B.1. The accuracy of area calculation is limited by the spatial resolution of the triangular grid, which varies throughout the model domain. A node is considered wet when the model calculated water depth exceeds the minimum wetting and drying criteria of 10 cm (0.3281 ft). For any wetted node included in the project boundary polygon, its associated computational area was counted toward the total inundated area.

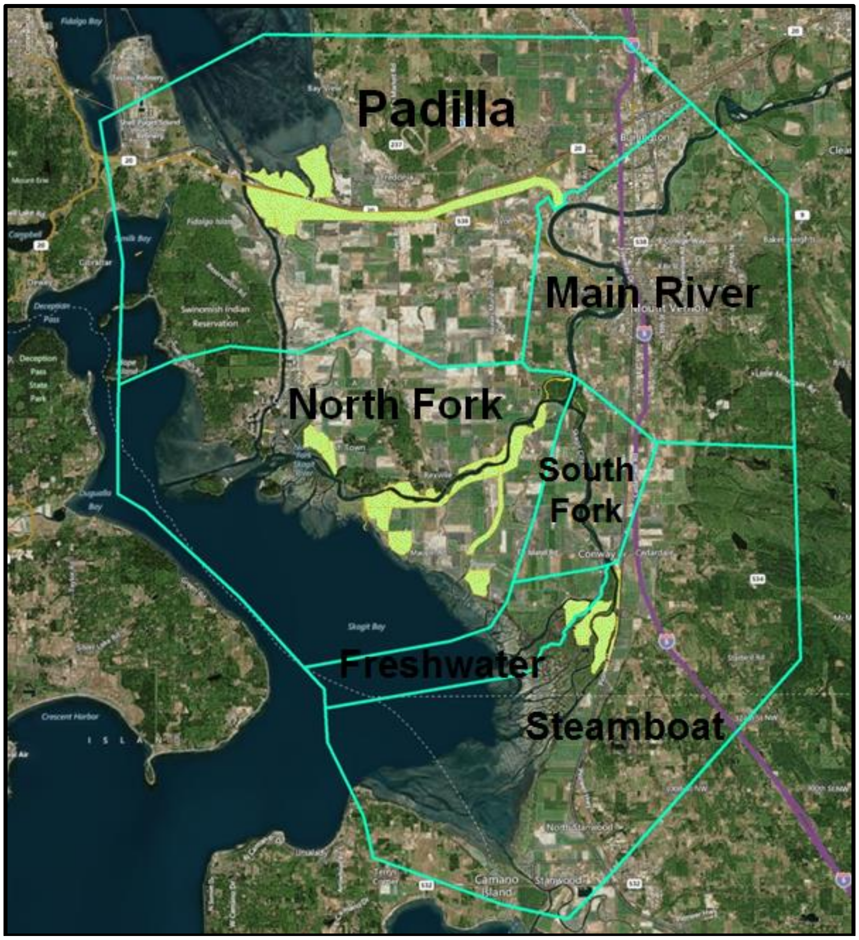


Figure B.2. Sub-basins within the Skagit region used for area calculations.

Table B.1. Table entry showing area increase for each sub-basin under tidal and riverine conditions during the Small Projects simulation.

Sub-basin	Baseline (acres)	With Projects (acres)	Increase in Area (acres)
Tidal Influence: High Spring Tide (10.8 ft) + Low Flow (12,000 cfs)			
Sum	20,256.9	21,896.9	**1,640.0**
Main River	7.8	7.5	**-0.3**
North Fork	8,330.6	8,863.7	**533.1**
South Fork	30.0	33.9	**3.9**
Freshwater	1,944.6	1,945.5	**0.9**
Steamboat	5,827.3	5,896.3	**69.0**
Padilla	4,116.8	5,150.1	**1,033.3**
Riverine Influence: Low Spring Tide (-3.3 ft) + Q2 Flow (62,000 cfs)			
Sum	7,921.4	9,446.6	**1,525.2**
Main River	159.0	154.8	**-4.2**

North Fork	2,998.2	3,701.1	**702.9**
South Fork	171.8	153.9	**-17.9**
Freshwater	1,065.1	1,012.6	**-52.5**
Steamboat	2,640.2	2,779.1	**138.9**
Padilla	887.0	1,645.2	**758.2**

B.2 Small Projects Deliverable 2

Deliverable 2 is a table showing the increase in inundation area subject to natural tidal and riverine processes within each project area, as summarized in Table B.2. Inundation area is counted only within the project footprint. The same limitations and definition of an inundated cell that apply for Deliverable 1 apply here.

Table B.2. Table entry showing area increase for each project under tidal and riverine conditions during the Small Projects simulation. Measurements correspond to a measured area that differs from the true project footprint because of grid resolution.

Project (measured area)	Baseline (acres)	With Projects (acres)	Increase in Area (acres)
Tidal Influence: High Spring Tide (10.8 ft) + Low Flow (12,000 cfs)			
Sum (**1,770.9 acres**)	18.8	1,653.2	**1,634.4**
SF Levee Setbacks 2, 3, 4 (**62.2 acres**)	0.0	50.1	**50.1**
McGlinn Causeway (**7.4 acres**)	5.7	7.4	**1.7**
TNC South Fork (**2.1 acres**)	0.0	2.1	**2.1**
Cottonwood Island (**24.7 acres**)	0.0	24.7	**24.7**
East Cottonwood (**4.5 acres**)	0.0	1.6	**1.6**
Pleasant Ridge South (**30.5 acres**)	0.0	22.3	**22.3**
Hall Slough (**139.6 acres**)	0.0	132.7	**132.7**
Fir Island Farm (**148.0 acres**)	0.1	139.3	**139.2**
Telegraph Slough Full (**1,123.3 acres**)	0.0	1,047.0	**1,047.0**
Sullivan Hacienda (**214.7 acres**)	0.0	212.1	**212.1**
Rawlins Distributary (**13.9 acres**)	13.1	13.9	**0.8**
Riverine Influence: Low Spring Tide (-3.3 ft) + Q2 Flow (62,000 cfs)			
Sum (**1,770.9 acres**)	20.2	1,260.6	**1,240.4**
SF Levee Setbacks 2, 3, 4 (**62.2 acres**)	0.1	50.6	**50.5**
McGlinn Causeway (**7.4 acres**)	2.3	0.5	**-1.8**
TNC South Fork (**2.1 acres**)	2.1	2.1	**0.0**
Cottonwood Island (**24.7 acres**)	11.6	24.7	**13.1**
East Cottonwood (**4.5 acres**)	3.1	4.5	**1.4**

Pleasant Ridge South (**30.5 acres**)	0.4	27.8	**27.4**
Hall Slough (**139.6 acres**)	0.0	118.9	**118.9**
Fir Island Farm (**148.0 acres**)	0.0	137.1	**137.1**
Telegraph Slough Full (**1,123.3 acres**)	0.0	672.7	**672.7**
Sullivan Hacienda (**214.7 acres**)	0.0	207.7	**207.7**
Rawlins Distributary (**13.9 acres**)	0.6	13.9	**13.3**

B.3 Small Projects Deliverable 3

Deliverable 3 is a set of cumulative frequency plots showing WSE at a point in the main channel or Bayfront near each project site. These are from the spring months of the Small Projects simulation (Simulation 1), representing March 1 – May 22, 2015, a time period chosen to coincide with the primary fish outmigration. A red line was added with every plot to represent an approximation of the average elevation of the project area bed. All WSE values are relative to the NAVD88 datum. An Excel file was also generated with WSE at each node location. The plots can be seen in Figure B.3 to Figure B.14.

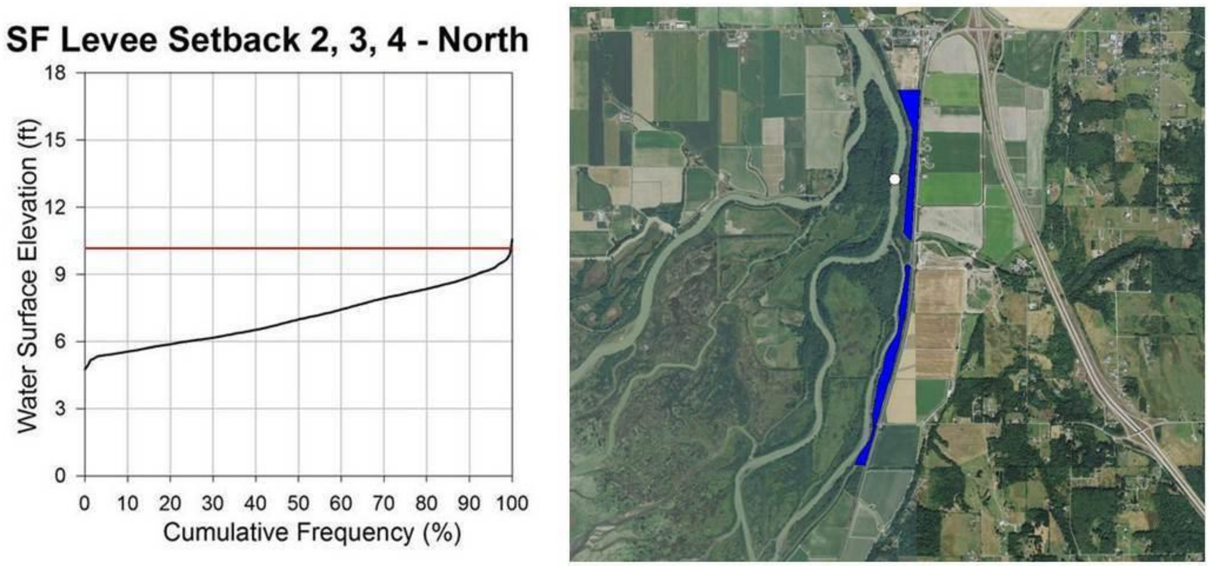


Figure B.3. Cumulative frequency plot and corresponding map for SF Levee Setbacks 2, 3, and 4 (north) during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

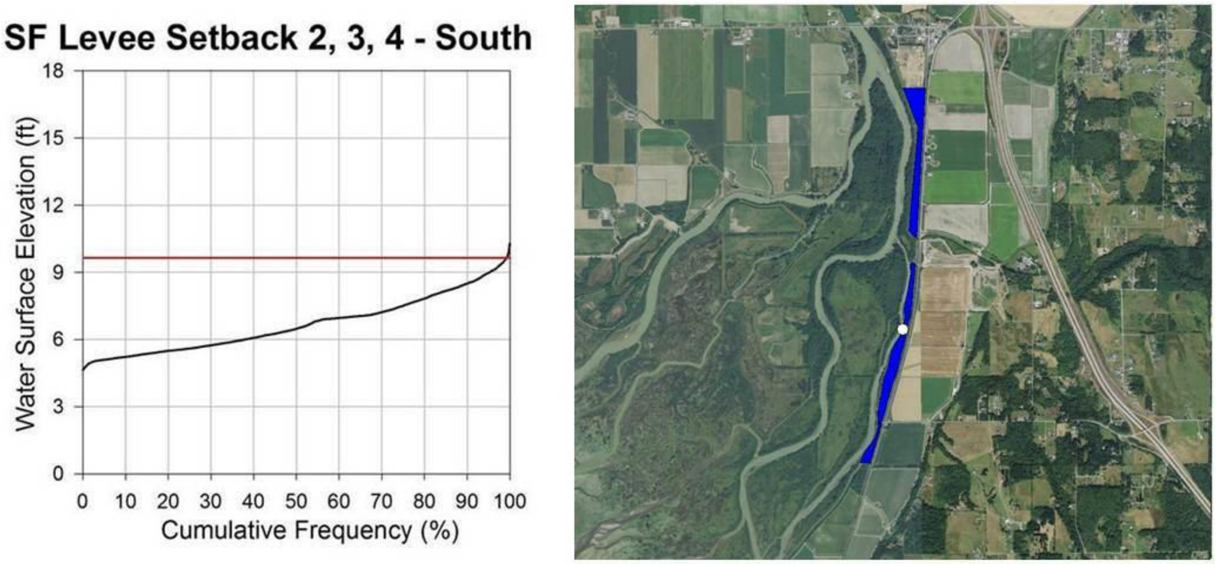


Figure B.4. Cumulative frequency plot and corresponding map for SF Levee Setbacks 2, 3, and 4 (south) during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

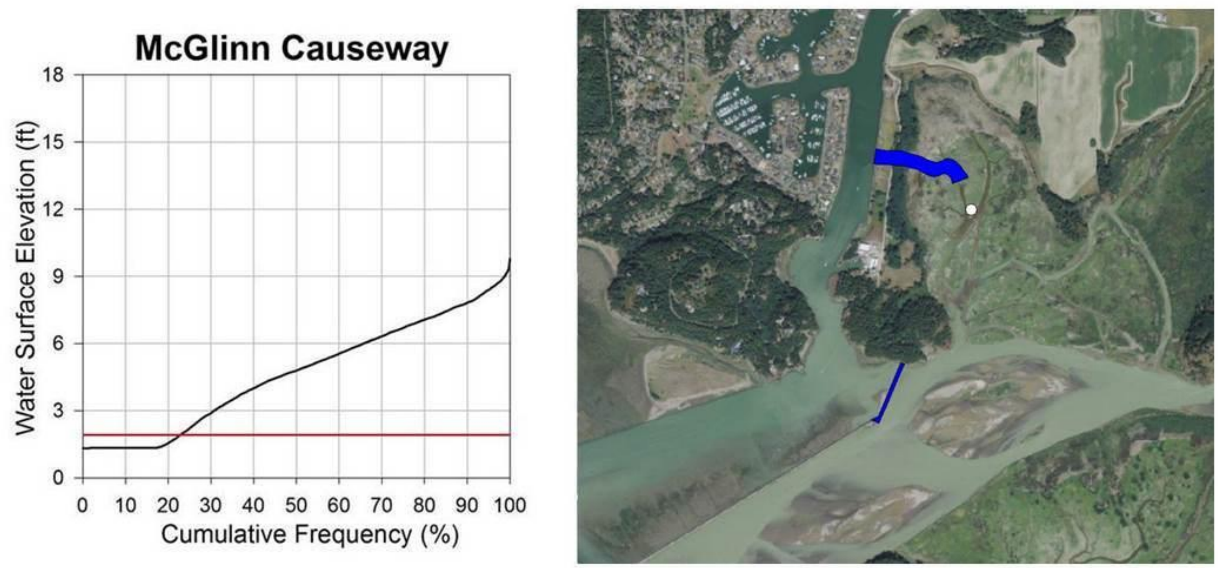


Figure B.5. Cumulative frequency plot and corresponding map for McGlinn Causeway during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

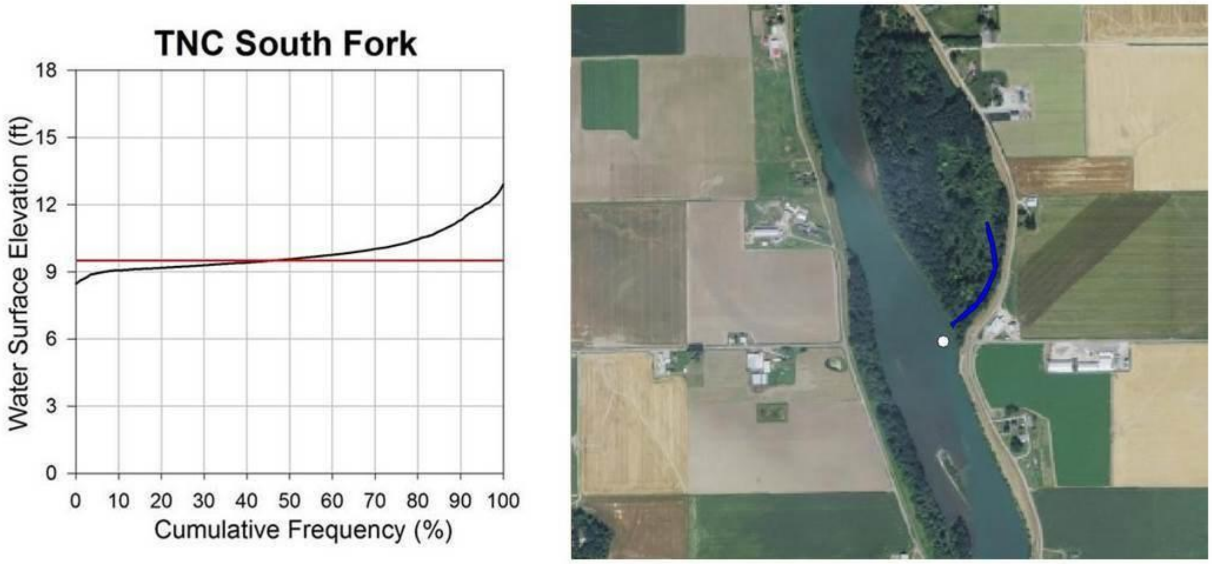


Figure B.6. Cumulative frequency plot and corresponding map for TNC South Fork during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

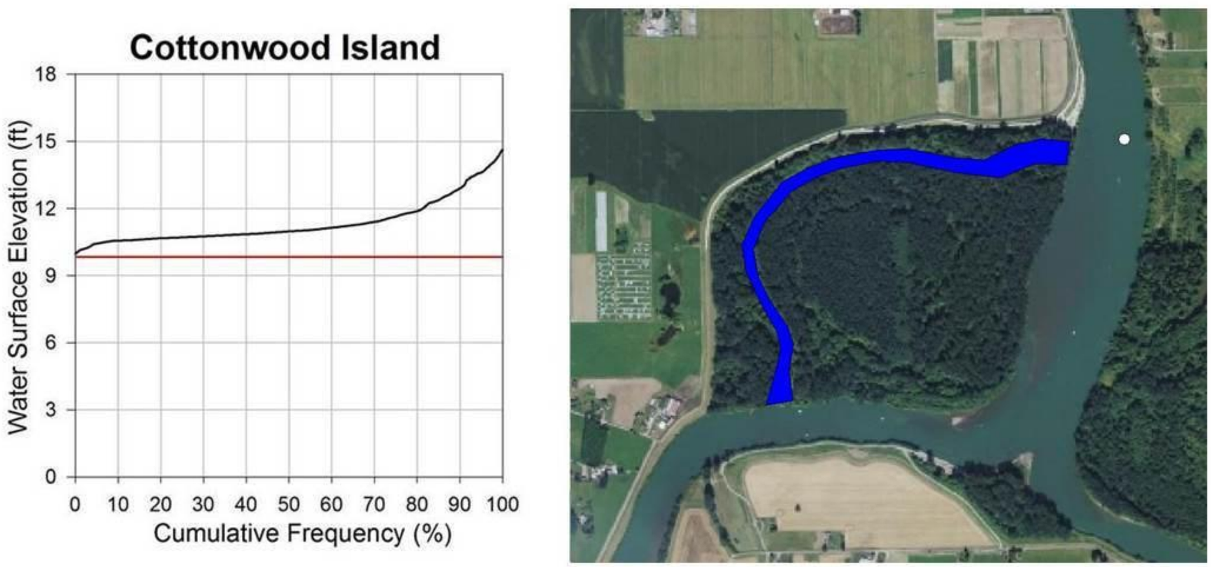


Figure B.7. Cumulative frequency plot and corresponding map for Cottonwood Island during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

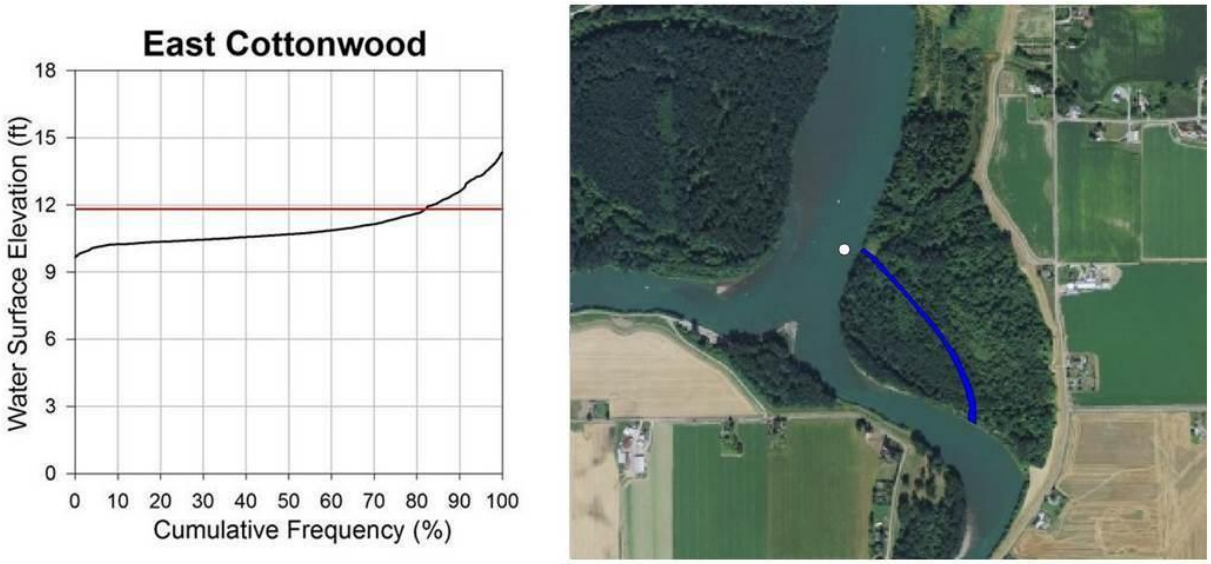


Figure B.8. Cumulative frequency plot and corresponding map for East Cottonwood during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

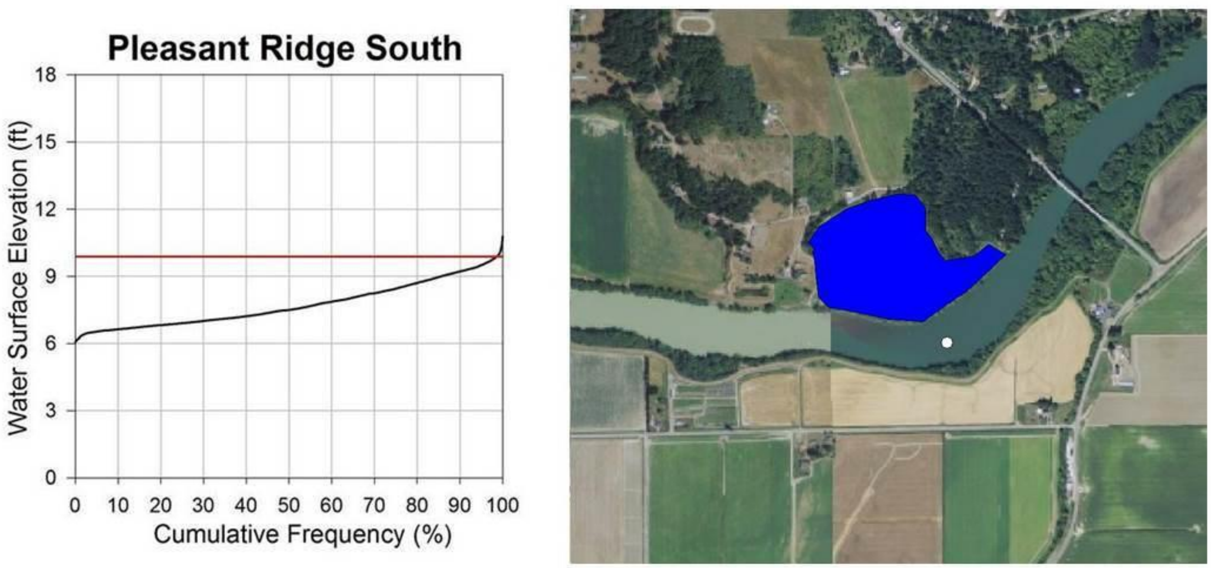


Figure B.9. Cumulative frequency plot and corresponding map for Pleasant Ridge South during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

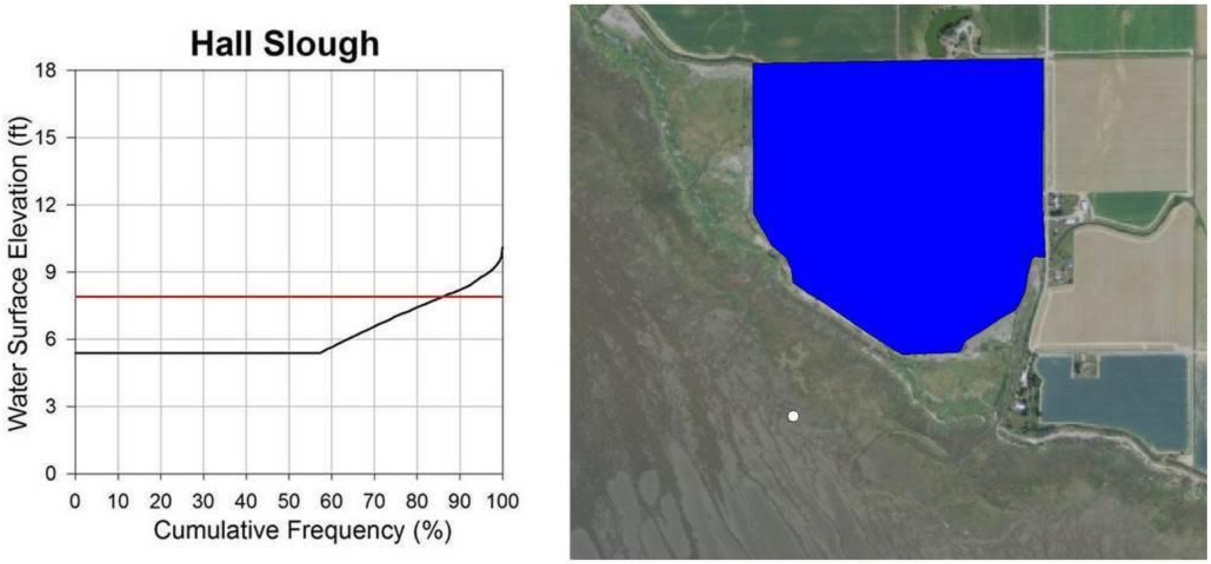


Figure B.10. Cumulative frequency plot and corresponding map for Hall Slough during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

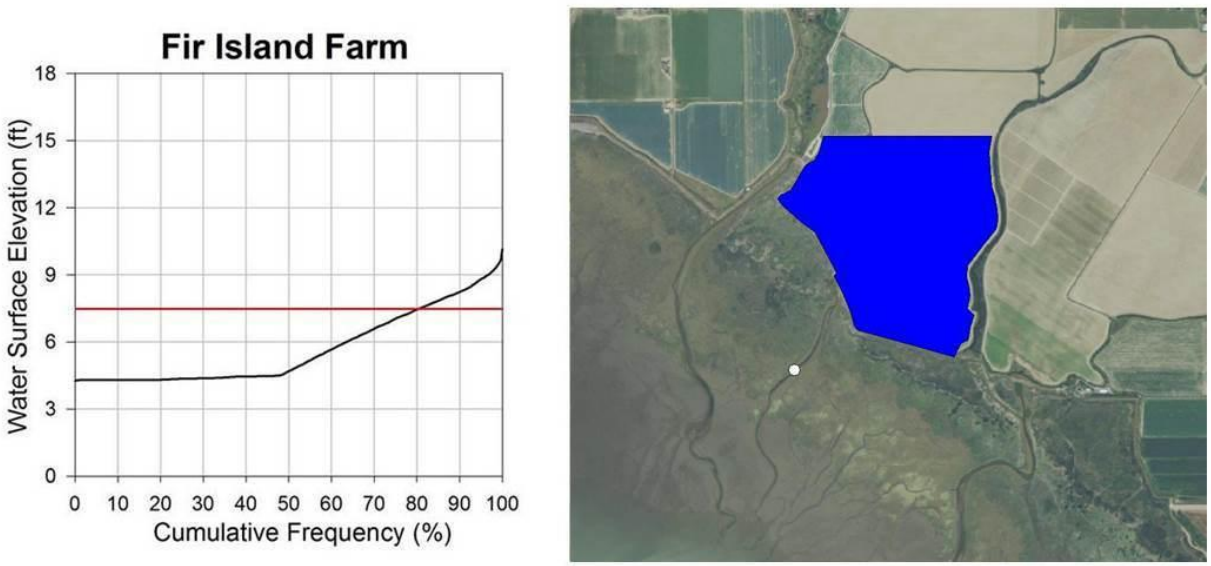


Figure B.11. Cumulative frequency plot and corresponding map for Fir Island Farm during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

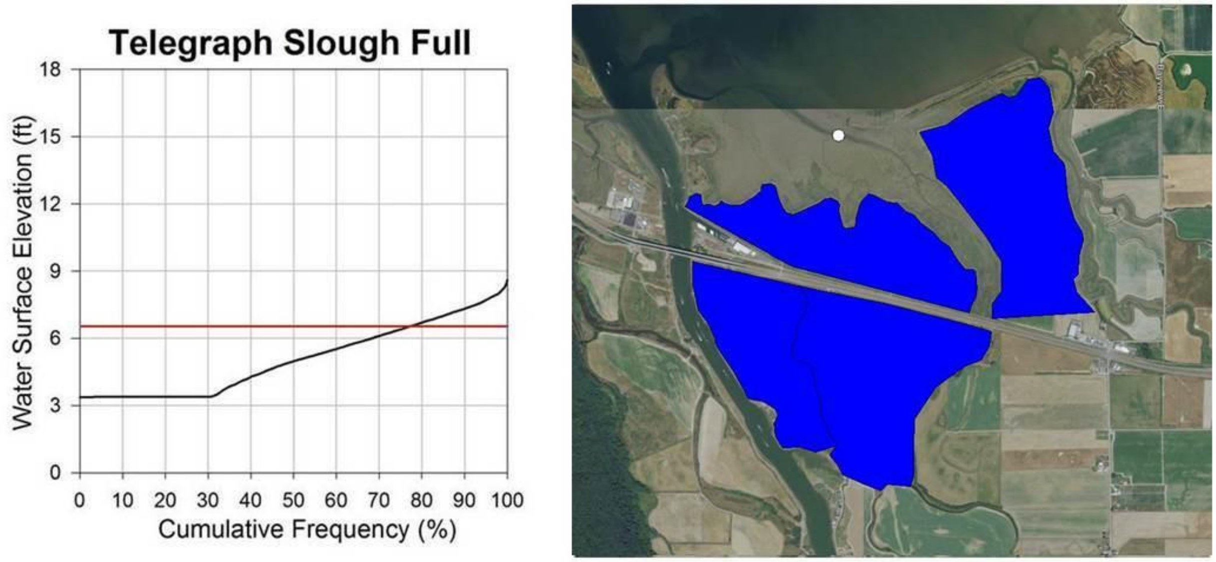


Figure B.12. Cumulative frequency plot and corresponding map for Telegraph Slough Full during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

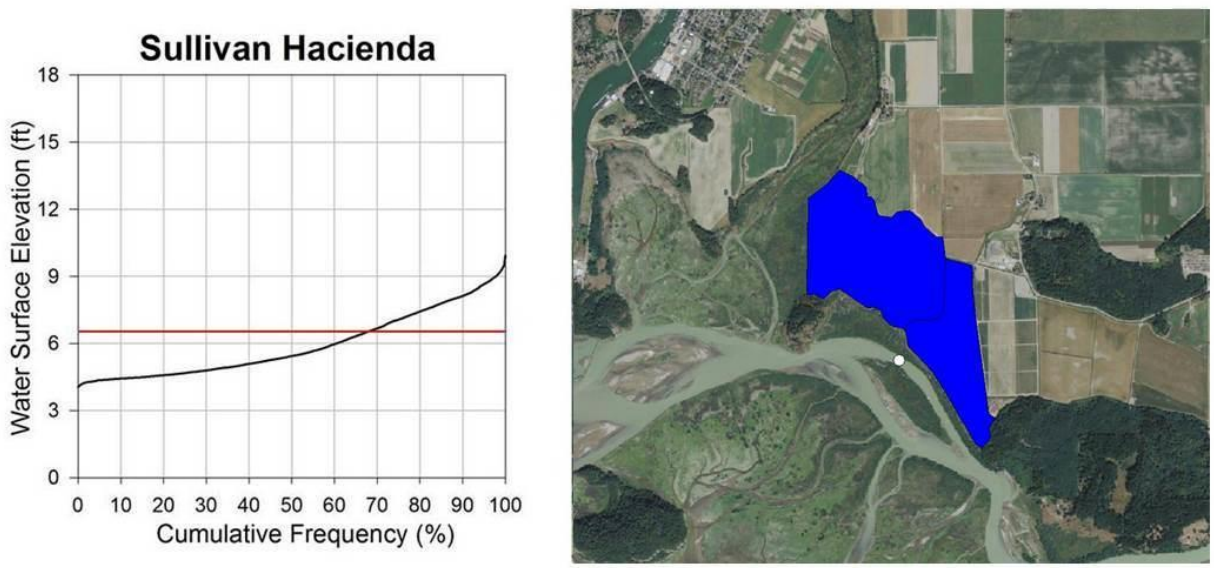


Figure B.13. Cumulative frequency plot and corresponding map for Sullivan Hacienda during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

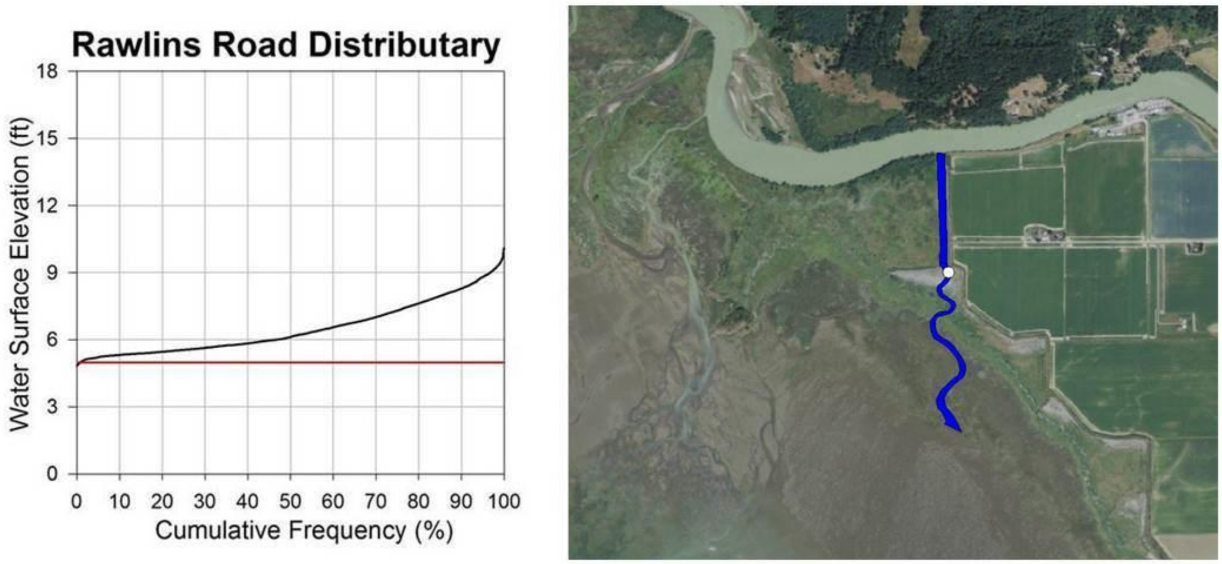


Figure B.14. Cumulative frequency plot and corresponding map for Rawlins Road Distributary during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

B.4 Small Projects Deliverable 4

Deliverable 4 is a set of contour maps showing the depths of inundation during the Small Projects simulation (Simulation 1). The plotted condition was the mean river discharge for the month of May (20,400 cfs) and high spring tide (10.8 ft). All depth values are relative to model bathymetry, which uses linear interpolation to the resolution of the grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure B.15 through Figure B.26.

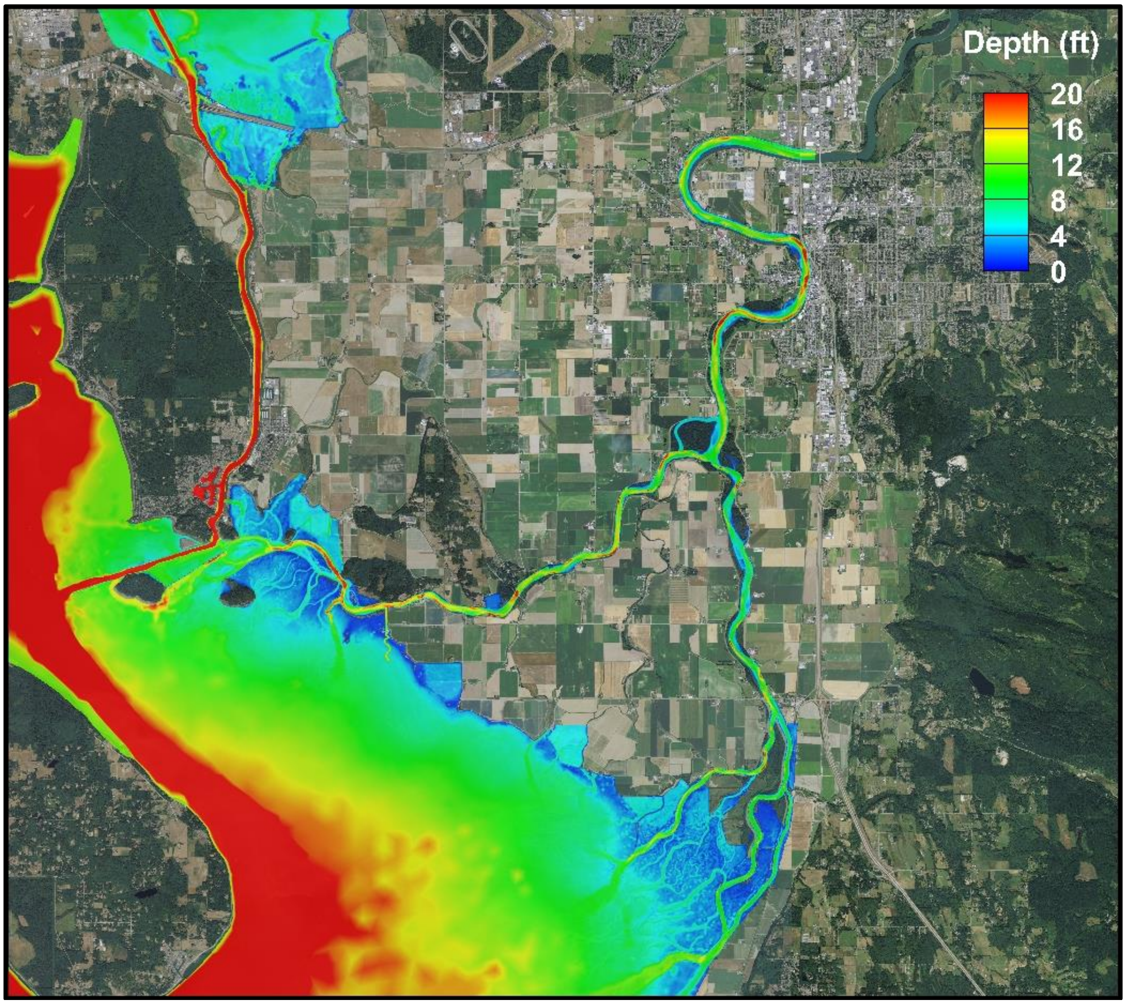


Figure B.15. Contour map of depths for the full domain during the Small Projects simulation with May flow and high spring tide.

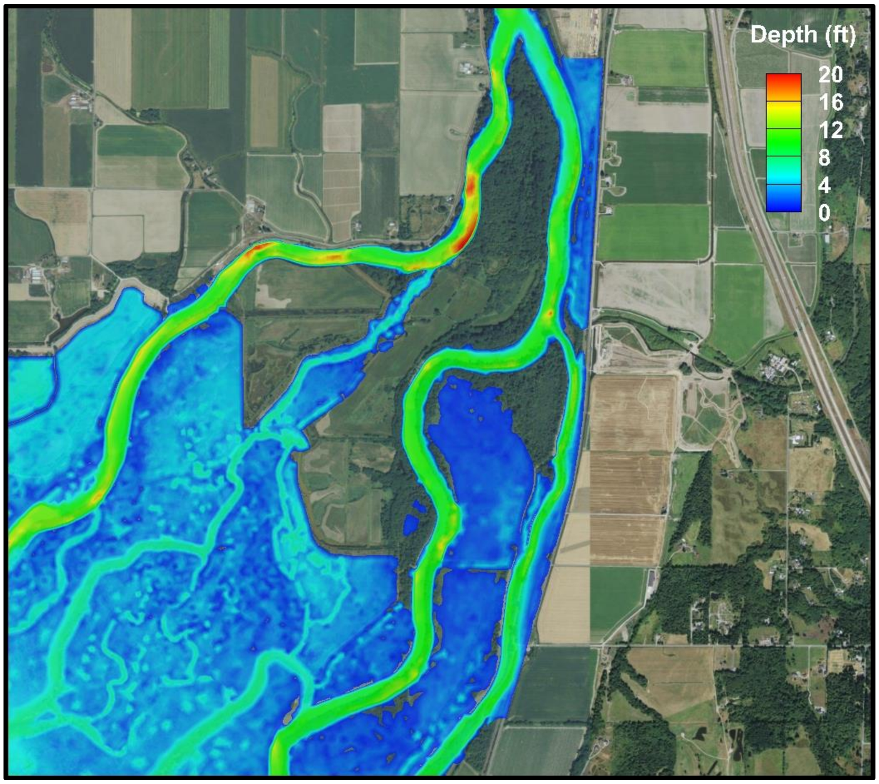


Figure B.16. Contour map of depths for SF Levee Setbacks 2, 3, and 4 during the Small Projects simulation.

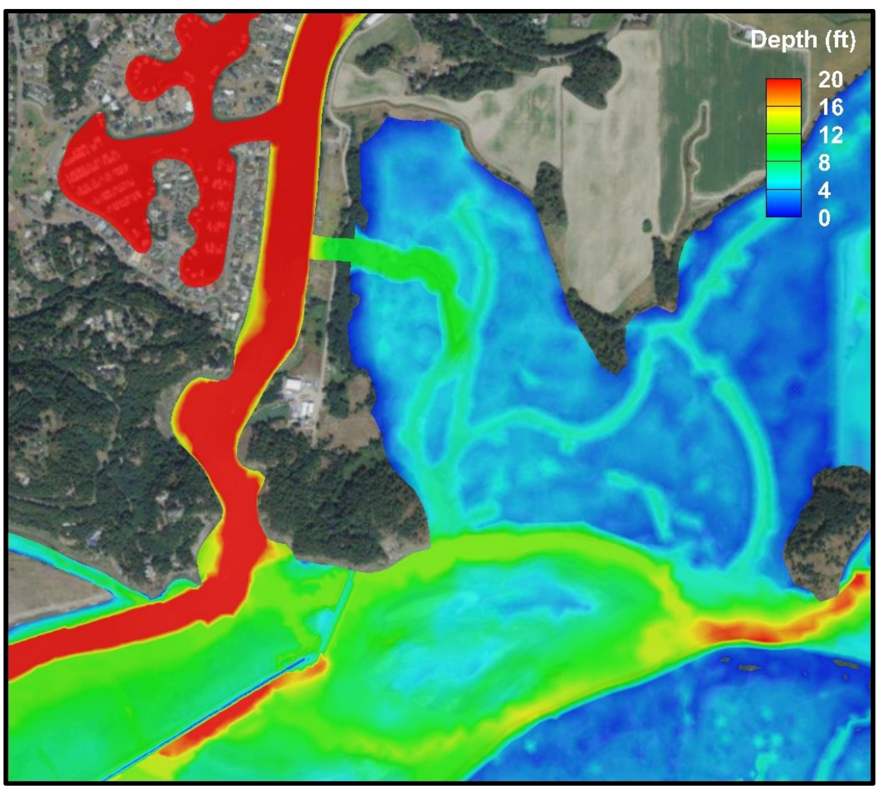


Figure B.17. Contour map of depths for McGlinn Causeway during the Small Projects simulation.

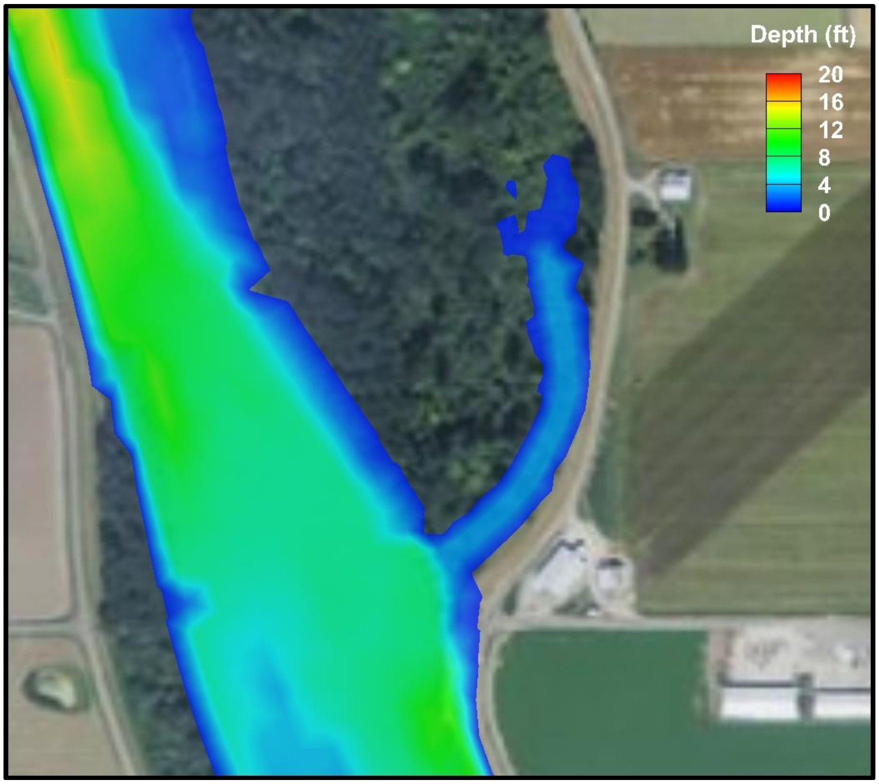


Figure B.18. Contour map of depths for TNC South Fork during the Small Projects simulation.

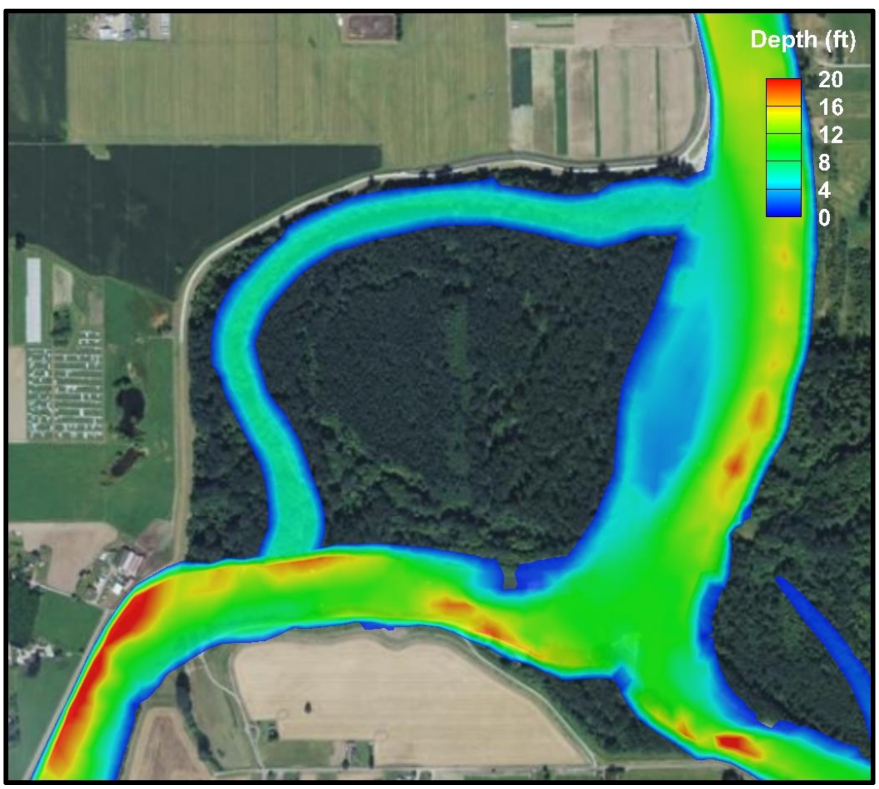


Figure B.19. Contour map of depths for Cottonwood Island during the Small Projects simulation.

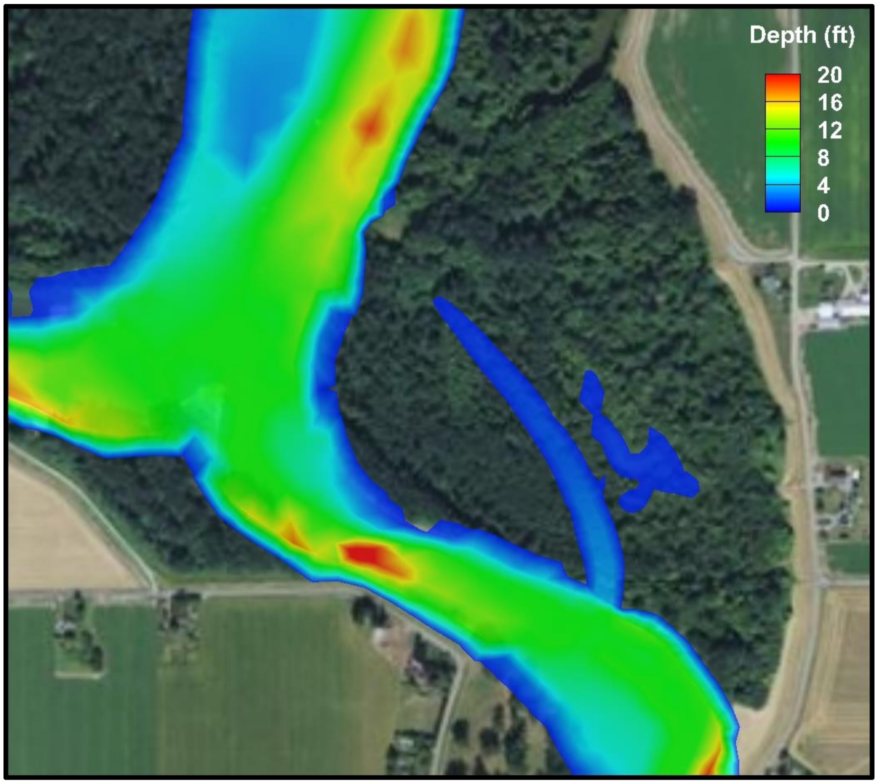


Figure B.20. Contour map of depths for East Cottonwood Island during the Small Projects simulation.

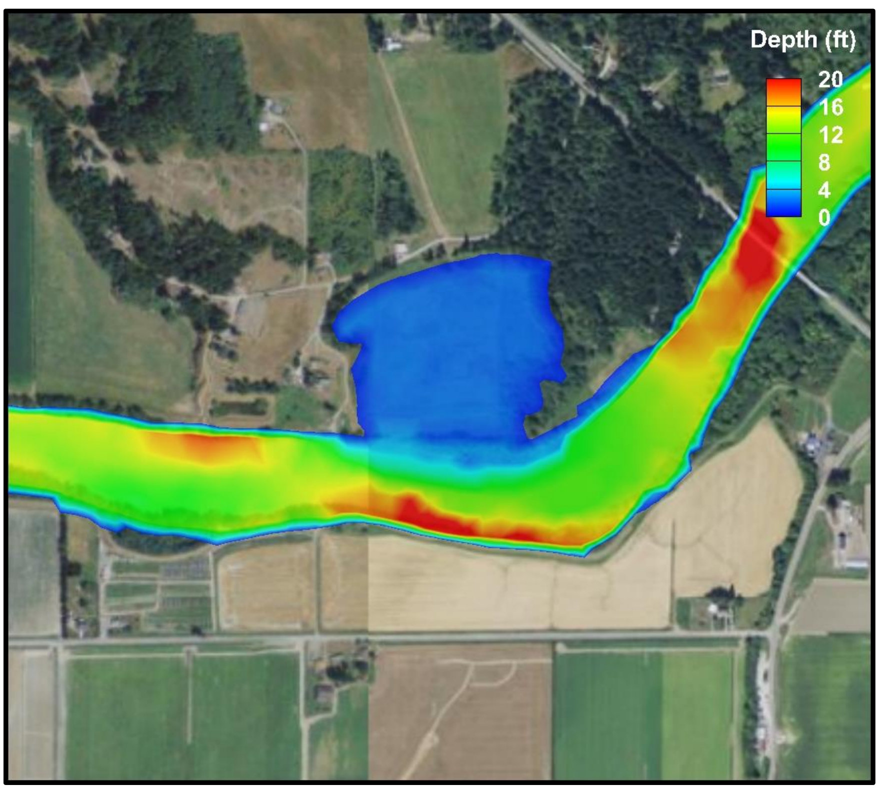


Figure B.21. Contour map of depths for Pleasant Ridge South during the Small Projects simulation.

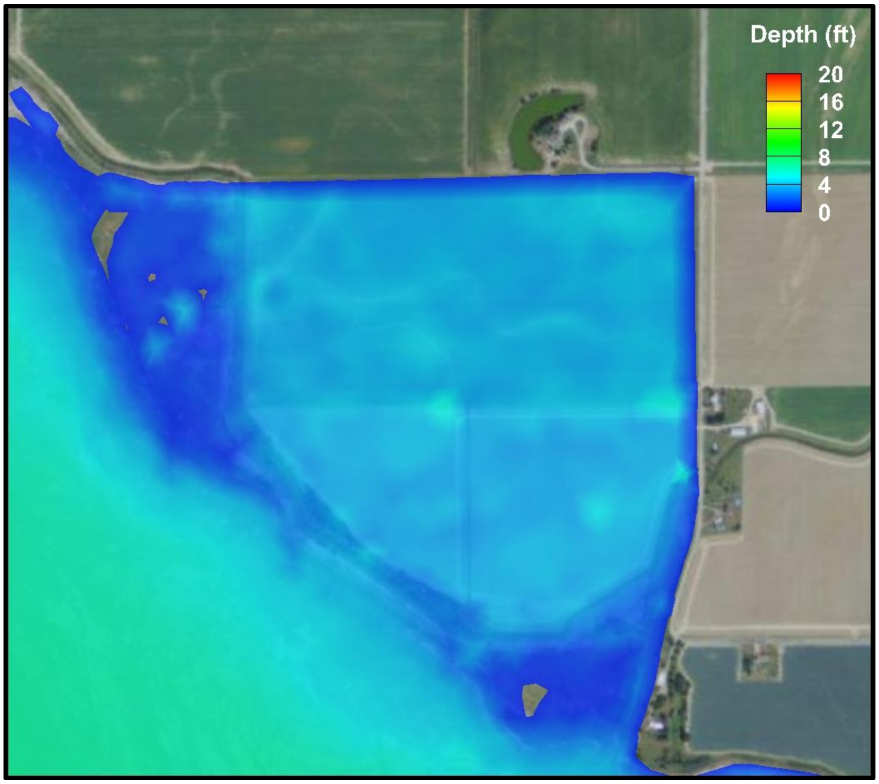


Figure B.22. Contour map of depths for Hall Slough during the Small Projects simulation.

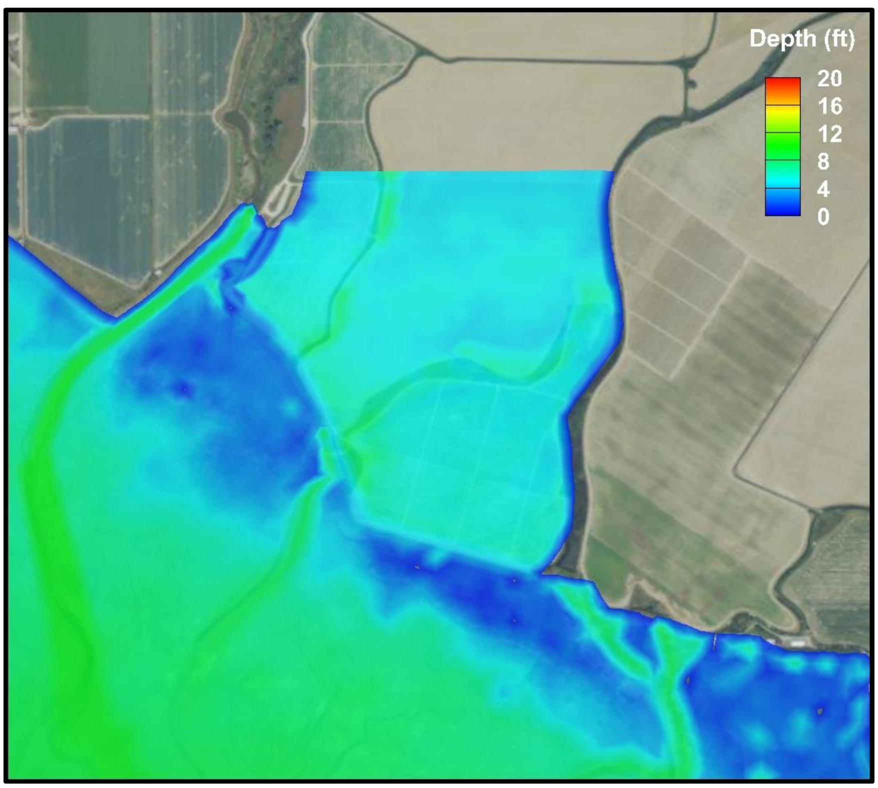


Figure B.23. Contour map of depths for Fir Island Farm during the Small Projects simulation.

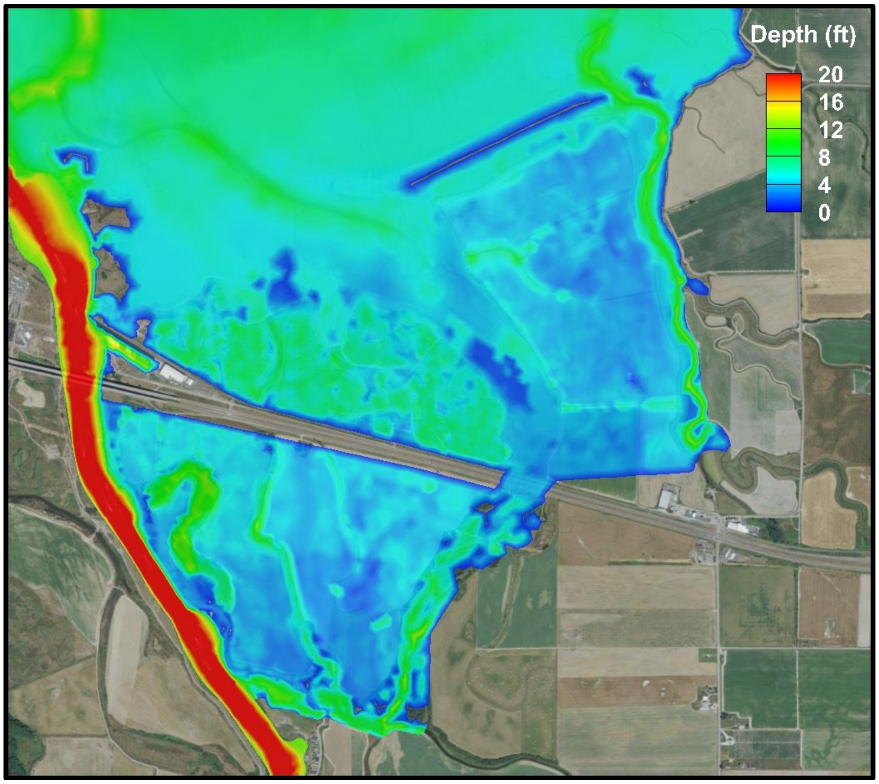


Figure B.24. Contour map of depths for Telegraph Slough Full during the Small Projects simulation.

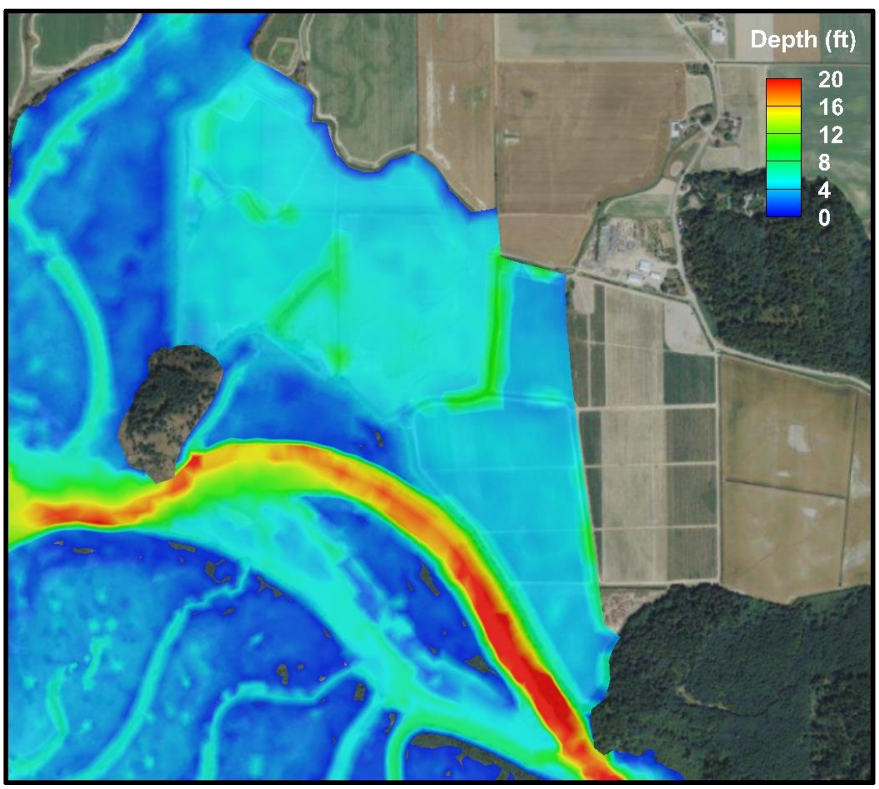


Figure B.25. Contour map of depths for Sullivan Hacienda during the Small Projects simulation.

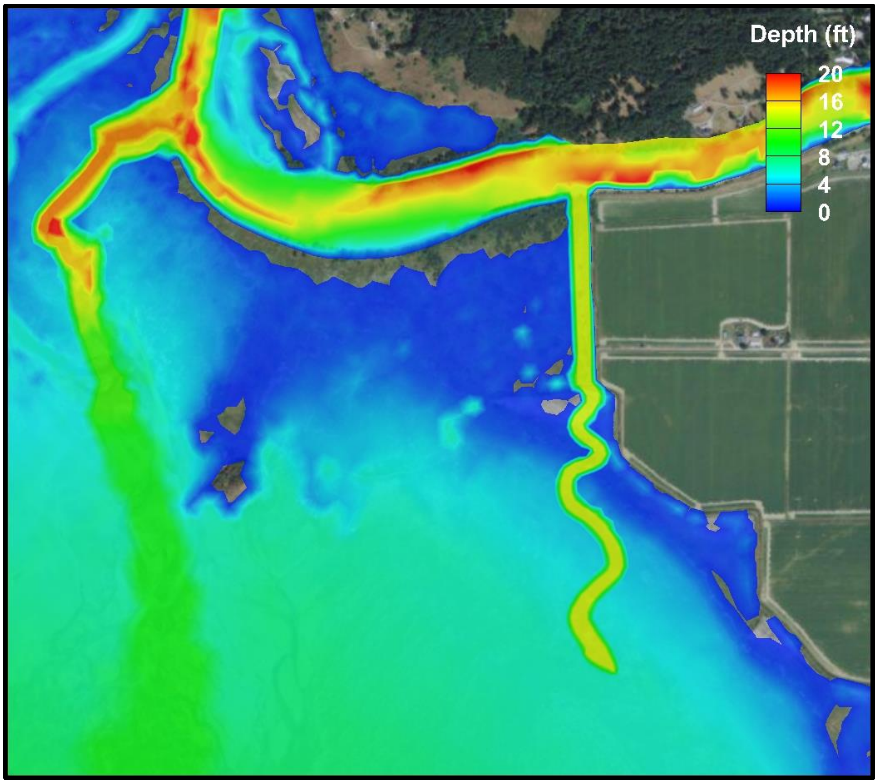


Figure B.26. Contour map of depths for Rawlins Road Distributary during the Small Projects simulation.

B.5 Small Projects Deliverable 5

Deliverable 5 is a set of histograms showing the distribution of water depths in 1 ft bins across each project site during a high spring tide (10.8 ft) and mean river discharge for the month of May (20,400 cfs), the same conditions corresponding to the maps of Deliverable 4. All depth values are relative to model bathymetry, which uses linear interpolation to the resolution of the grid. The histograms can be seen in Figure B.27 through Figure B.37.

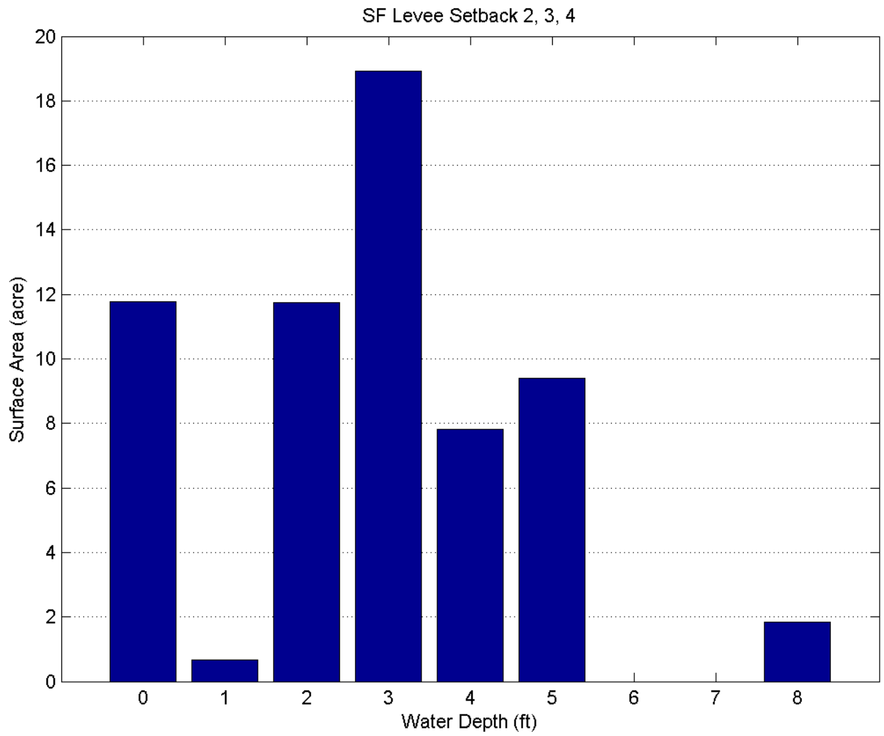


Figure B.27. Histogram of depths for SF Levee Setbacks 2, 3, and 4.

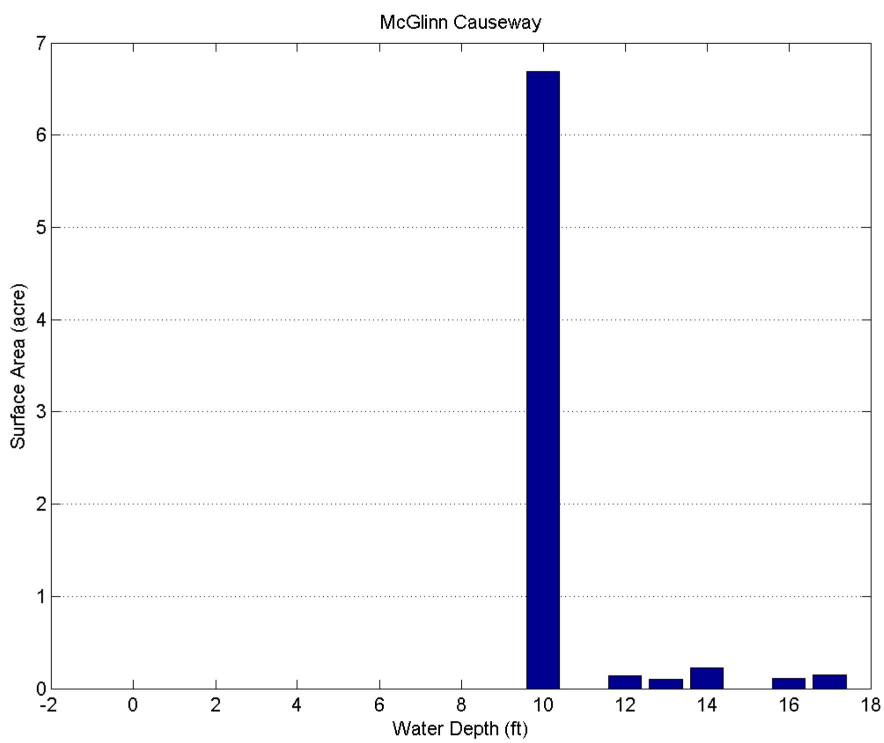


Figure B.28. Histogram of depths for McGlinn Causeway.

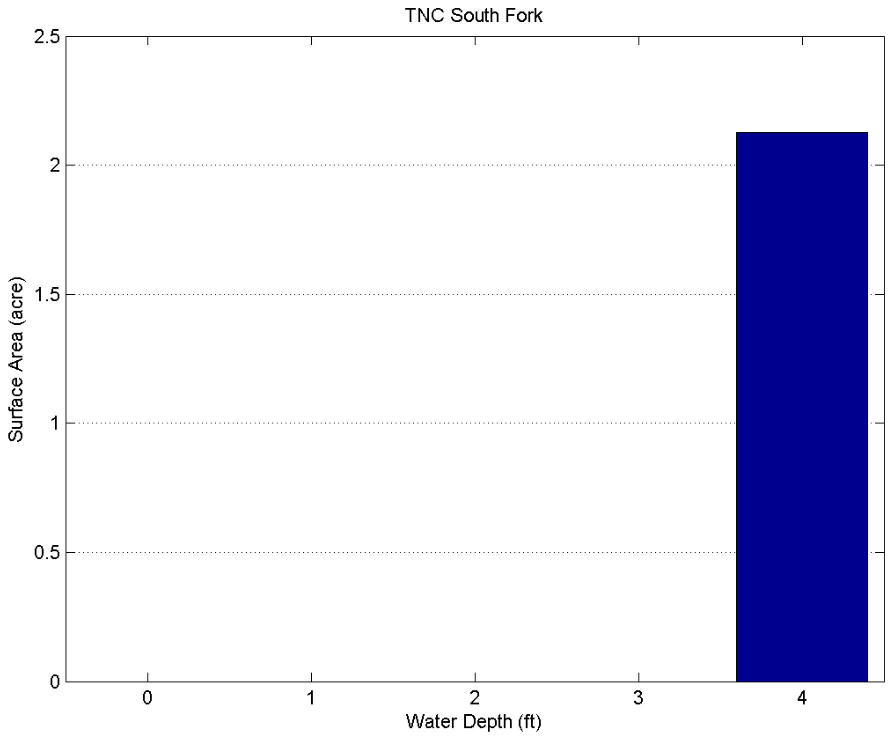


Figure B.29. Histogram of depths for TNC South Fork.

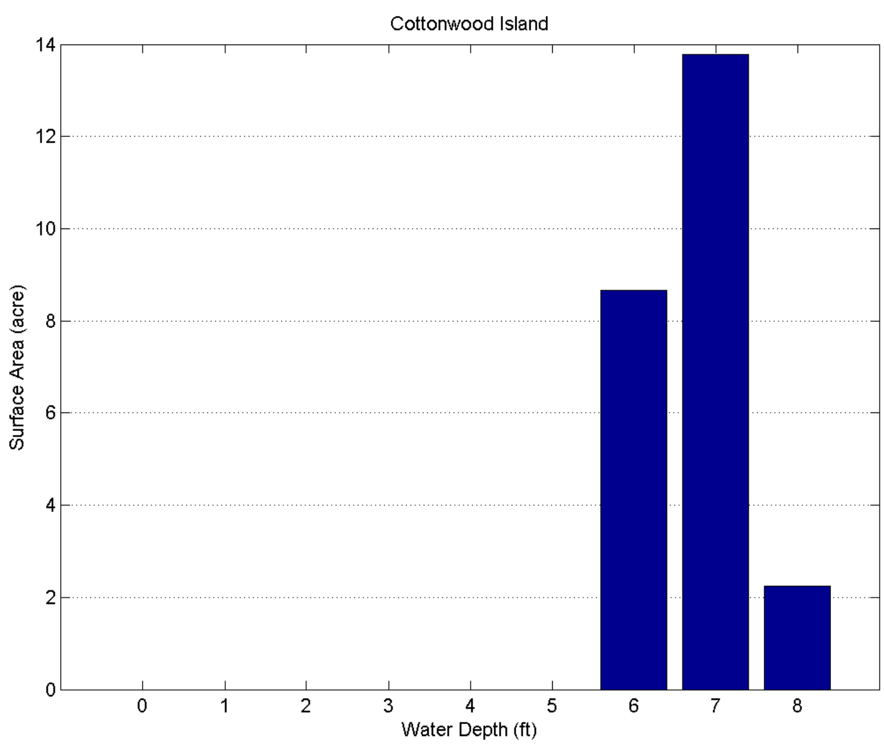


Figure B.30. Histogram of depths for Cottonwood Island.

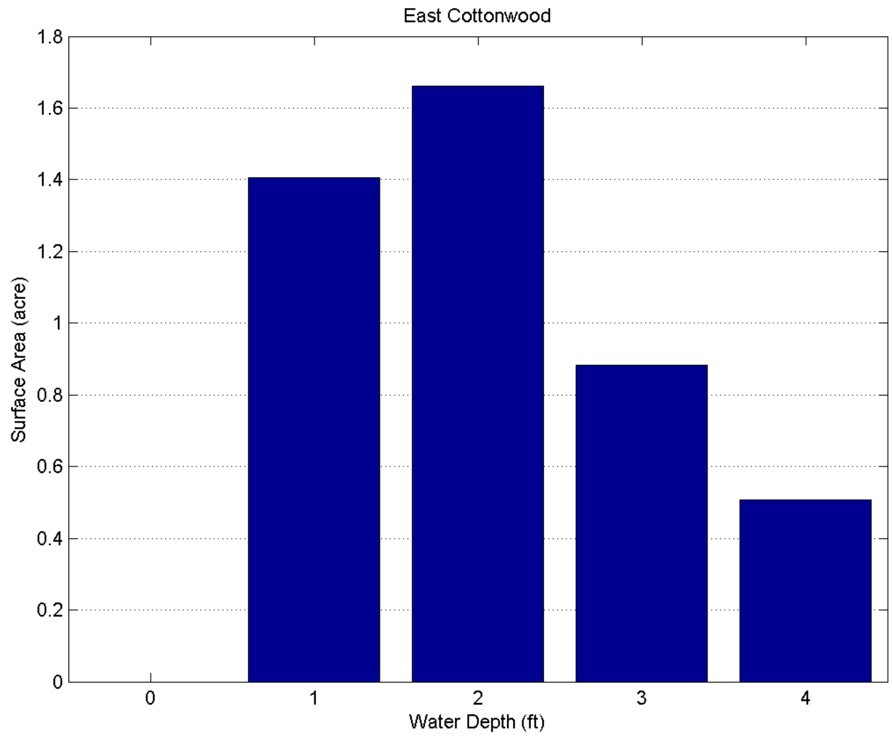


Figure B.31. Histogram of depths for East Cottonwood.

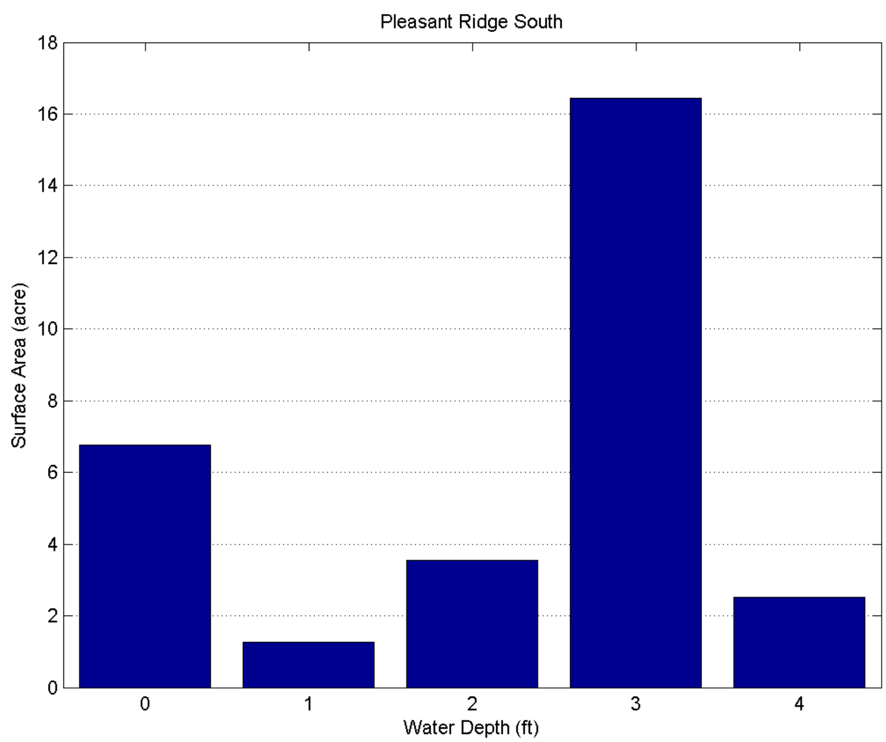


Figure B.32. Histogram of depths for Pleasant Ridge South.

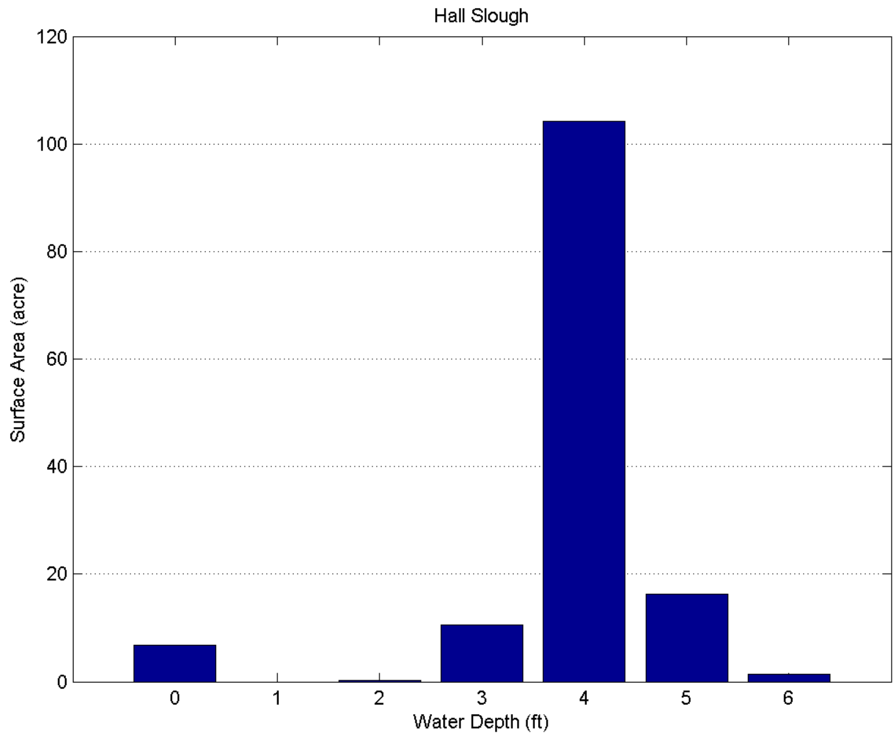


Figure B.33. Histogram of depths for Hall Slough.

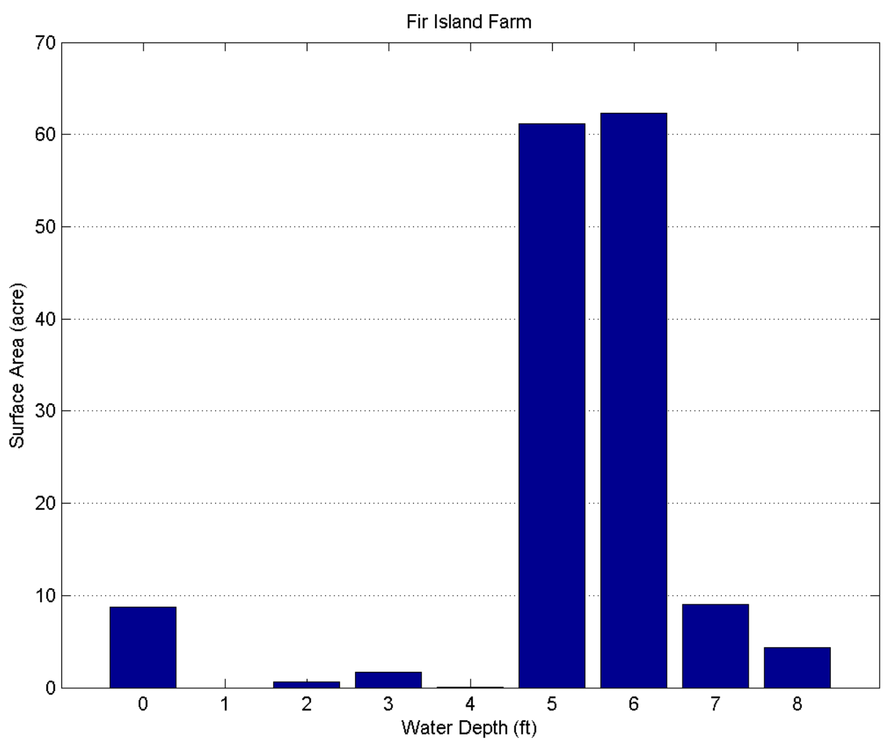


Figure B.34. Histogram of depths for Fir Island Farm.

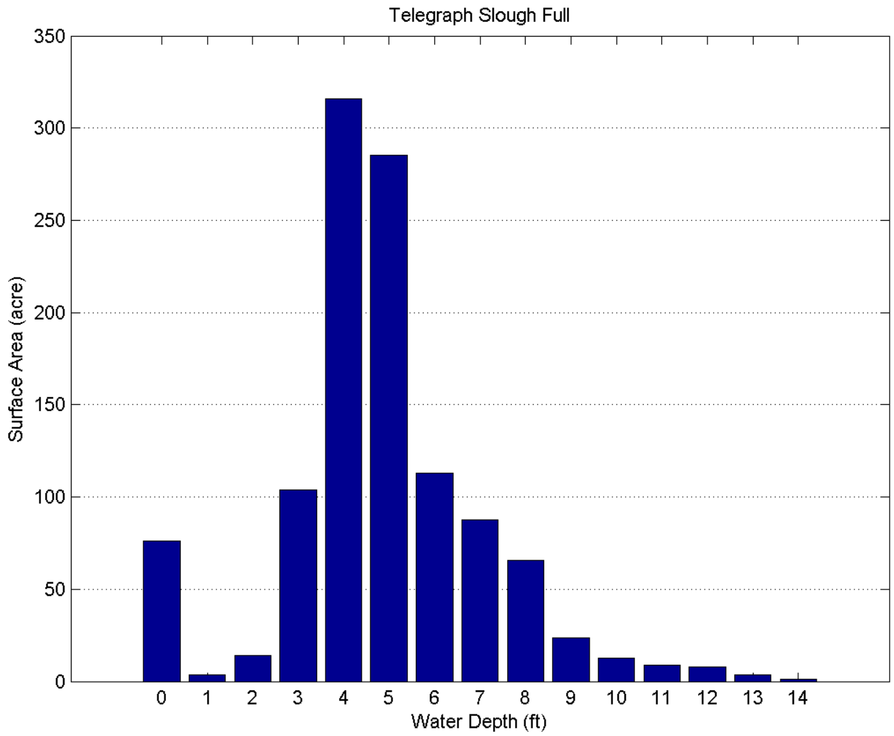


Figure B.35. Histogram of depths for Telegraph Slough Full.

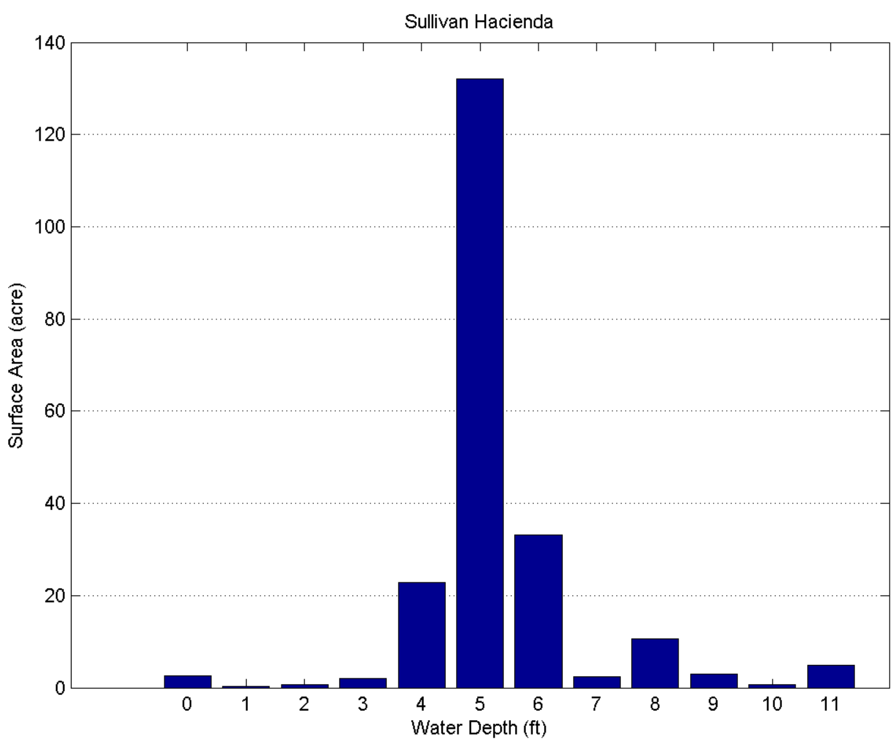


Figure B.36. Histogram of depths for Sullivan Hacienda.

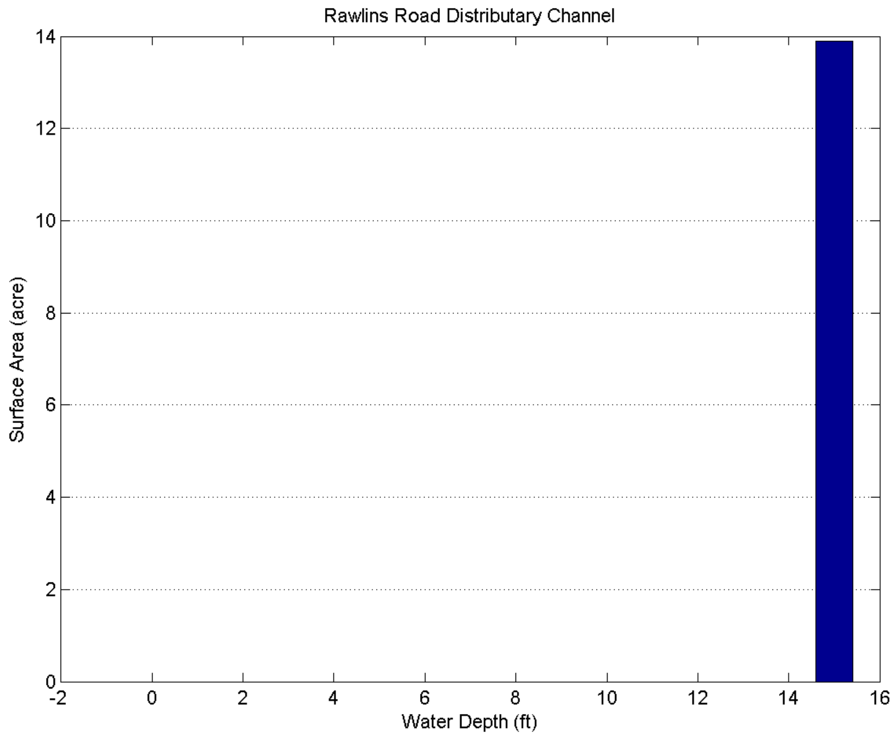


Figure B.37. Histogram of depths for Rawlins Road Distributary Channel.

B.6 Small Projects Deliverable 6

Deliverable 6 is a set of contour maps showing the change in WSE between the Baseline Simulation (Simulation 0) and the Small Projects simulation (Simulation 1). Two conditions were compared: (1) a low spring tide (-3.3 ft) and Q2 flow (62,000 cfs) and (2) a high spring tide (10.4 ft) and a flood condition (93,200 cfs), representing the change from baseline to restored conditions. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure B.38 through Figure B.50.

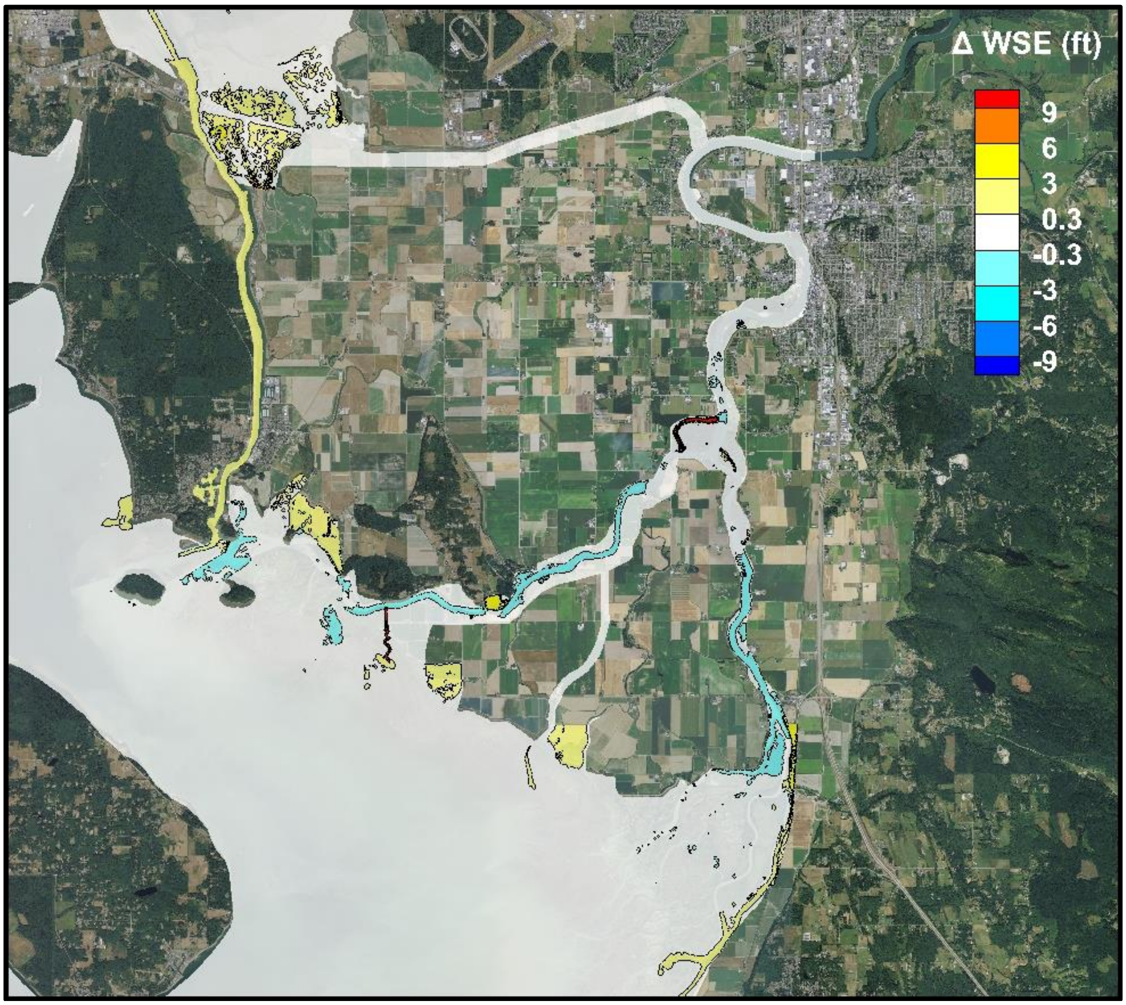


Figure B.38. Contour map of change in WSE from the Baseline to Small Projects simulation with Q2 flow and low tide.

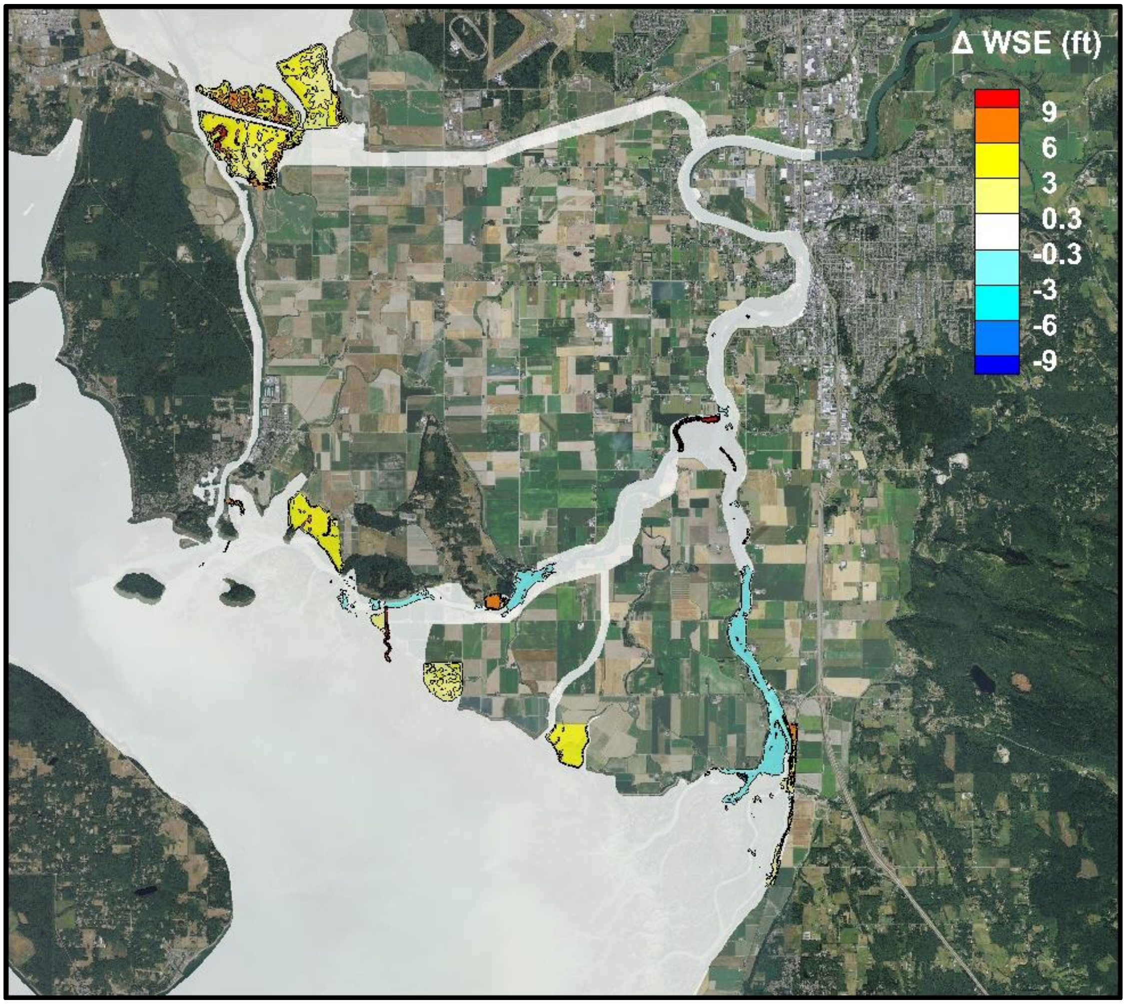


Figure B.39. Contour map of change in WSE from the Baseline to Small Projects simulation with flood flow and high tide.

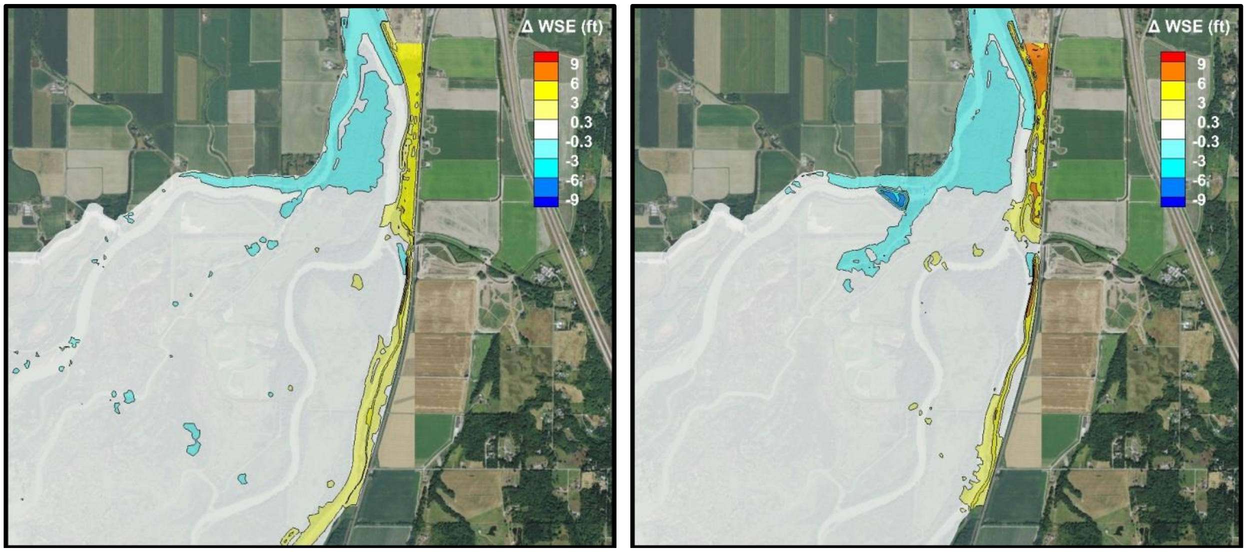


Figure B.40. Contour map of change in WSE from the Baseline to Small Projects simulation for SF Levee Setbacks 2, 3, and 4 with Q2 flow and low tide (left) and flood flow and high tide (right).

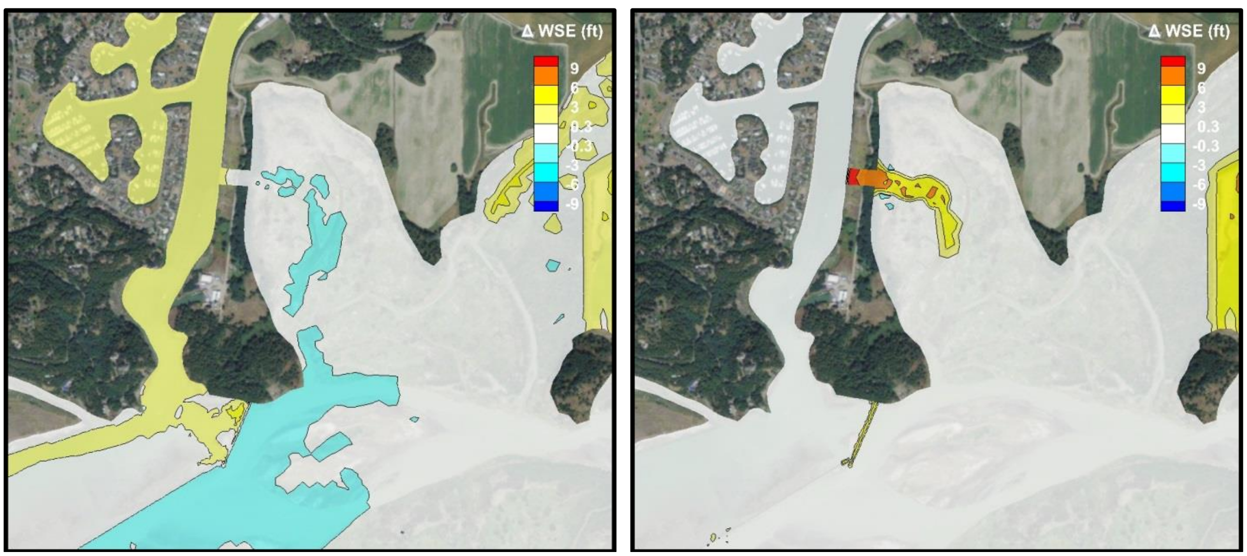


Figure B.41. Contour map of change in WSE from the Baseline to Small Projects simulation for McGlinn Causeway with Q2 flow and low tide (left) and flood flow and high tide (right).

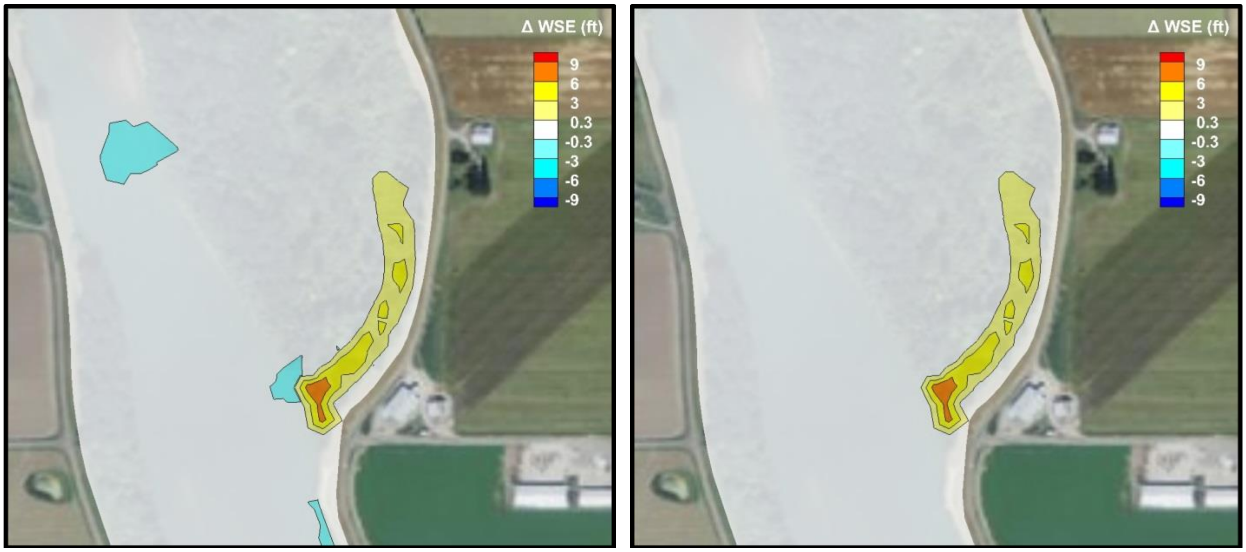


Figure B.42. Contour map of change in WSE from the Baseline to Small Projects simulation for TNC South Fork with Q2 flow and low tide (left) and flood flow and high tide (right).

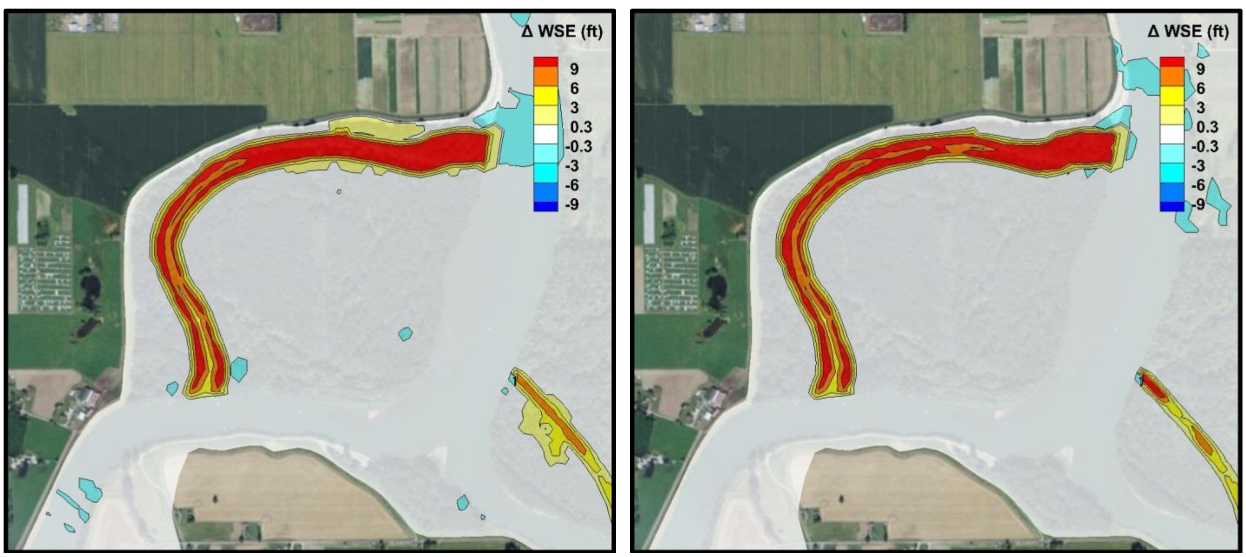


Figure B.43. Contour map of change in WSE from the Baseline to Small Projects simulation for Cottonwood Island with Q2 flow and low tide (left) and flood flow and high tide (right).

Figure B.44. Contour map of change in WSE from the Baseline to Small Projects simulation for East Cottonwood with Q2 flow and low tide (left) and flood flow and high tide (right).

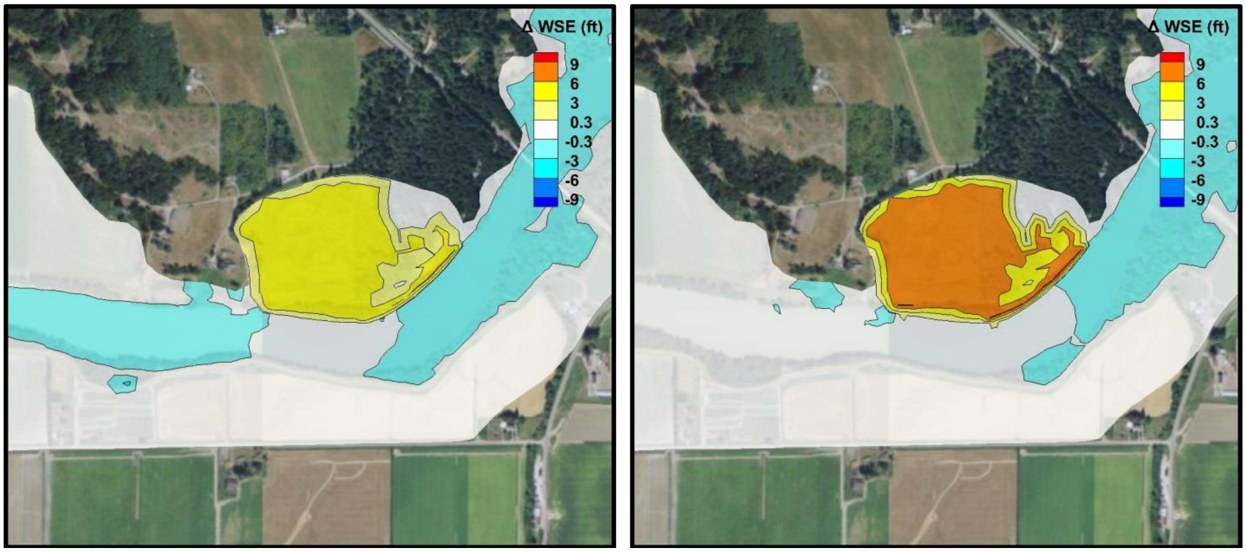


Figure B.45. Contour map of change in WSE from the Baseline to Small Projects simulation for Pleasant Ridge South with Q2 flow and low tide (left) and flood flow and high tide (right).

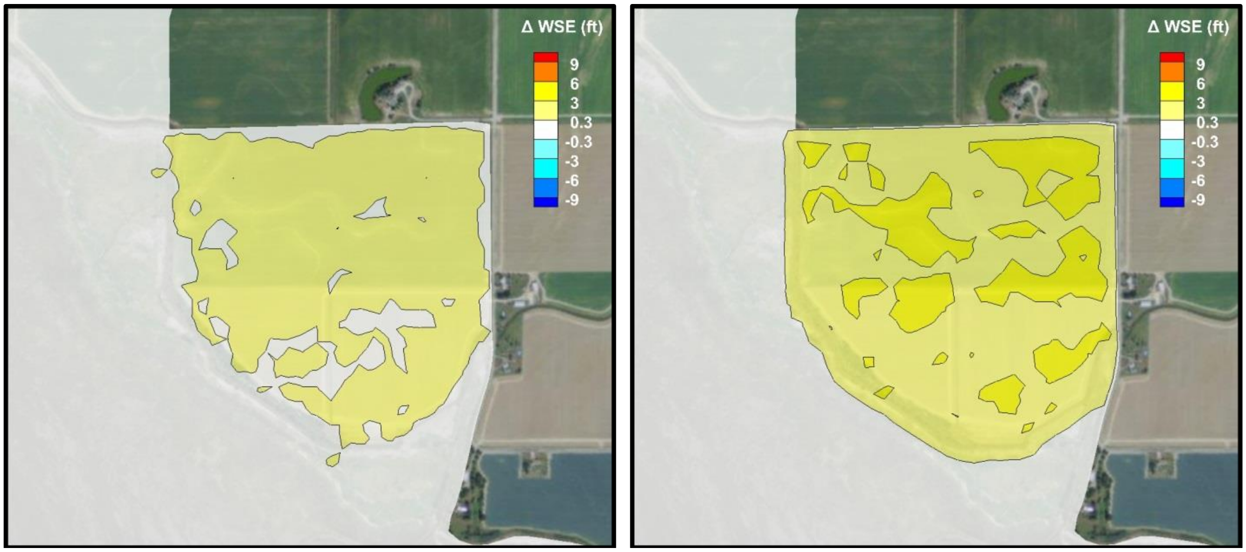


Figure B.46. Contour map of change in WSE from the Baseline to Small Projects simulation for Hall Slough with Q2 flow and low tide (left) and flood flow and high tide (right).

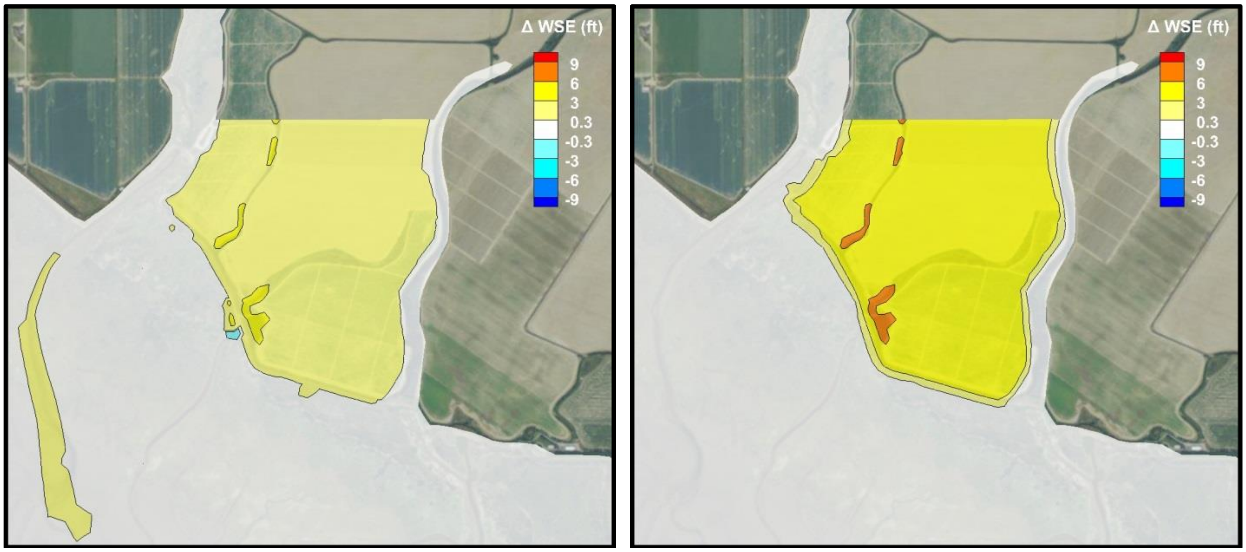


Figure B.47. Contour map of change in WSE from the Baseline to Small Projects simulation for Fir Island Farm with Q2 flow and low tide (left) and flood flow and high tide (right).

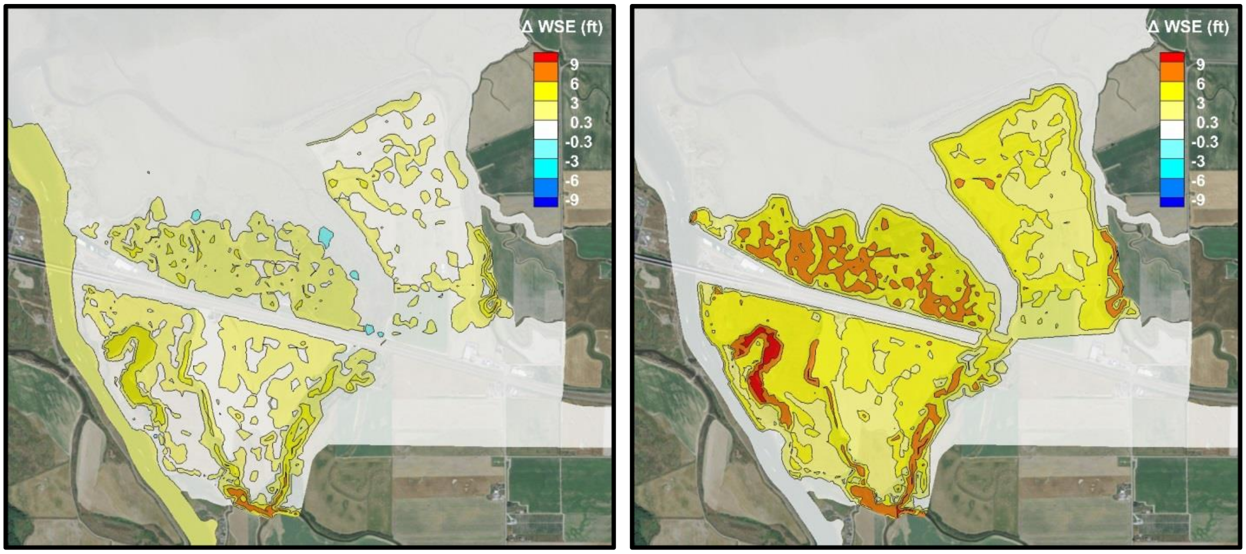


Figure B.48. Contour map of change in WSE from the Baseline to Small Projects simulation for Telegraph Slough Full with Q2 flow and low tide (left) and flood flow and high tide (right).

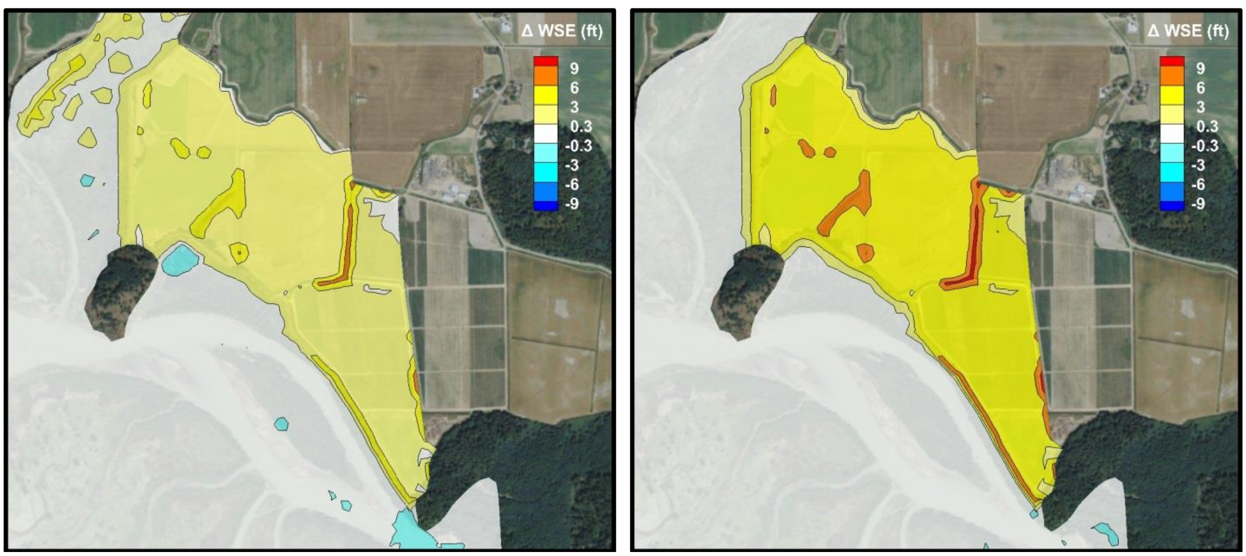


Figure B.49. Contour map of change in WSE from the Baseline to Small Projects simulation for Sullivan Hacienda with Q2 flow and low tide (left) and flood flow and high tide (right).

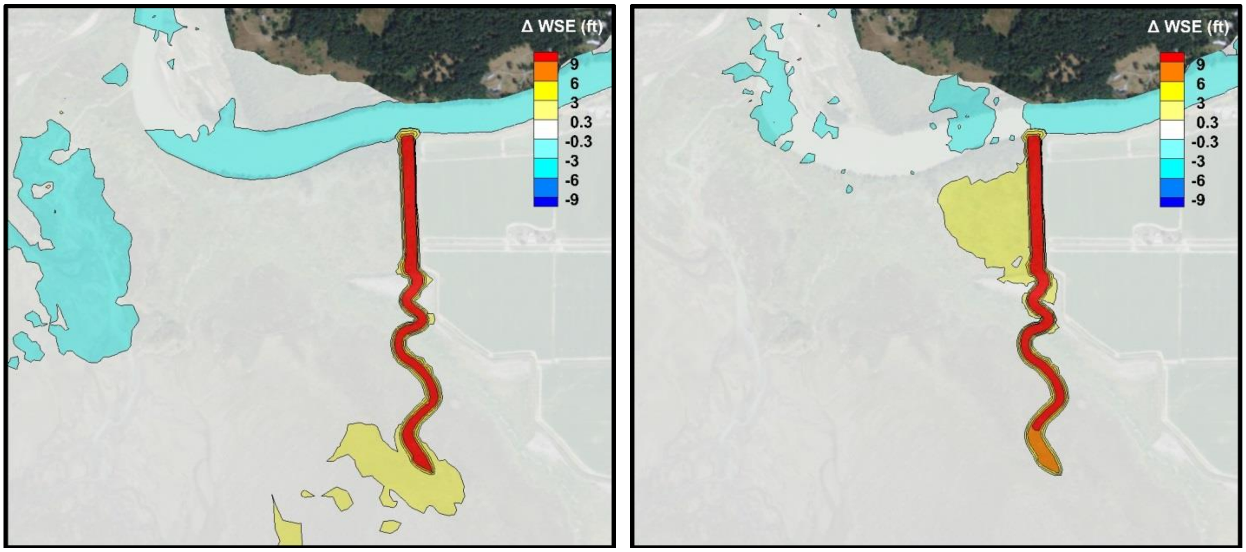


Figure B.50. Contour map of change in WSE from the Baseline to Small Projects simulation for Rawlins Road Distributary Channel with Q2 flow and low tide (left) and flood flow and high tide (right).

B.7 Small Projects Deliverable 7

Deliverable 7 is a set of contour maps showing the change in bed shear stress between the Baseline Simulation (Simulation 0) and the Small Projects simulation (Simulation 1). Two conditions were compared: (1) a full spring tidal cycle during a low flow (12,000 cfs) where the peak shear across the map was recorded and (2) a low spring tide (-3.3 ft) and Q2 flow (62,000 cfs), representing the change from baseline to restored conditions. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure B.51 through Figure B.63.

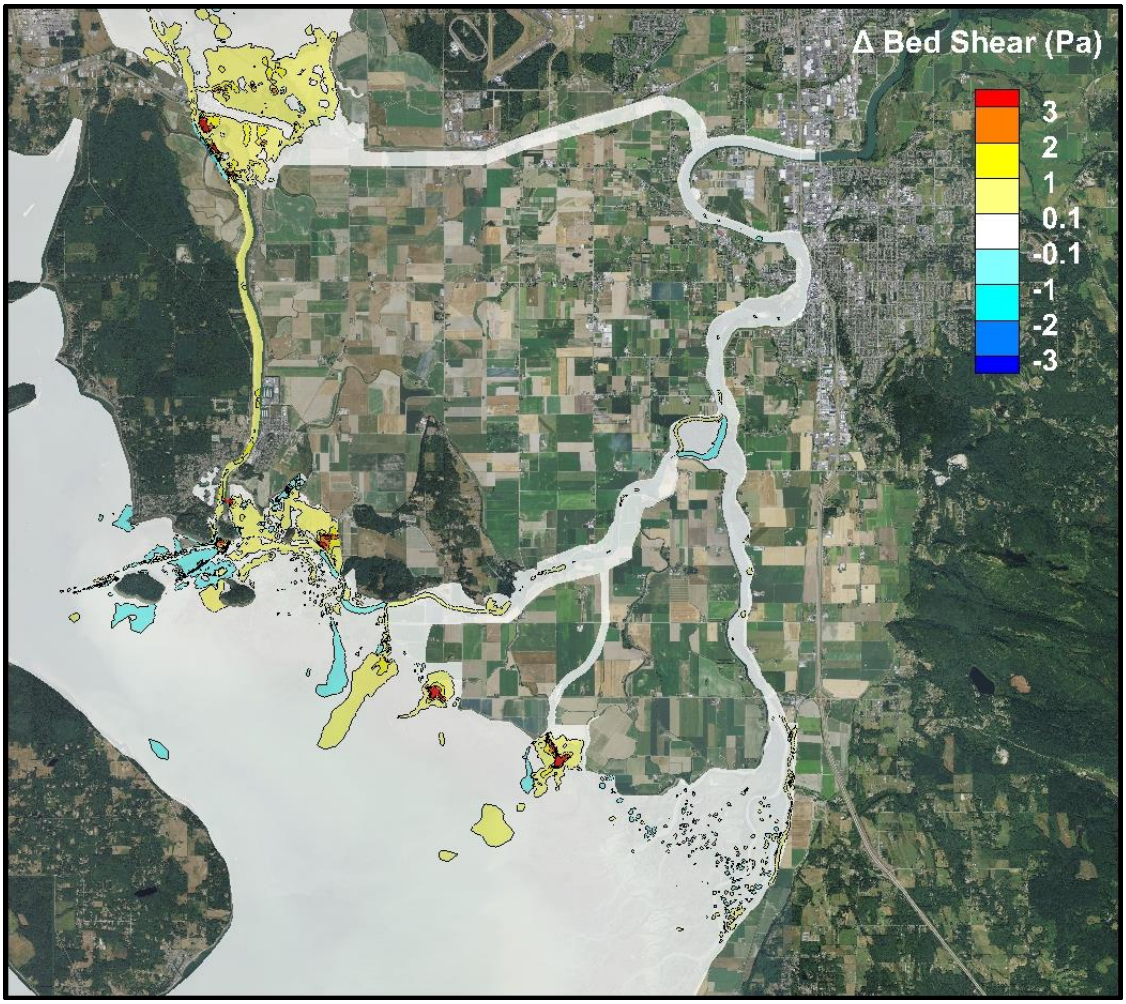


Figure B.51. Contour map of change in shear stress from the Baseline to Small Projects simulation with peak shear across a full tidal cycle at low flow.

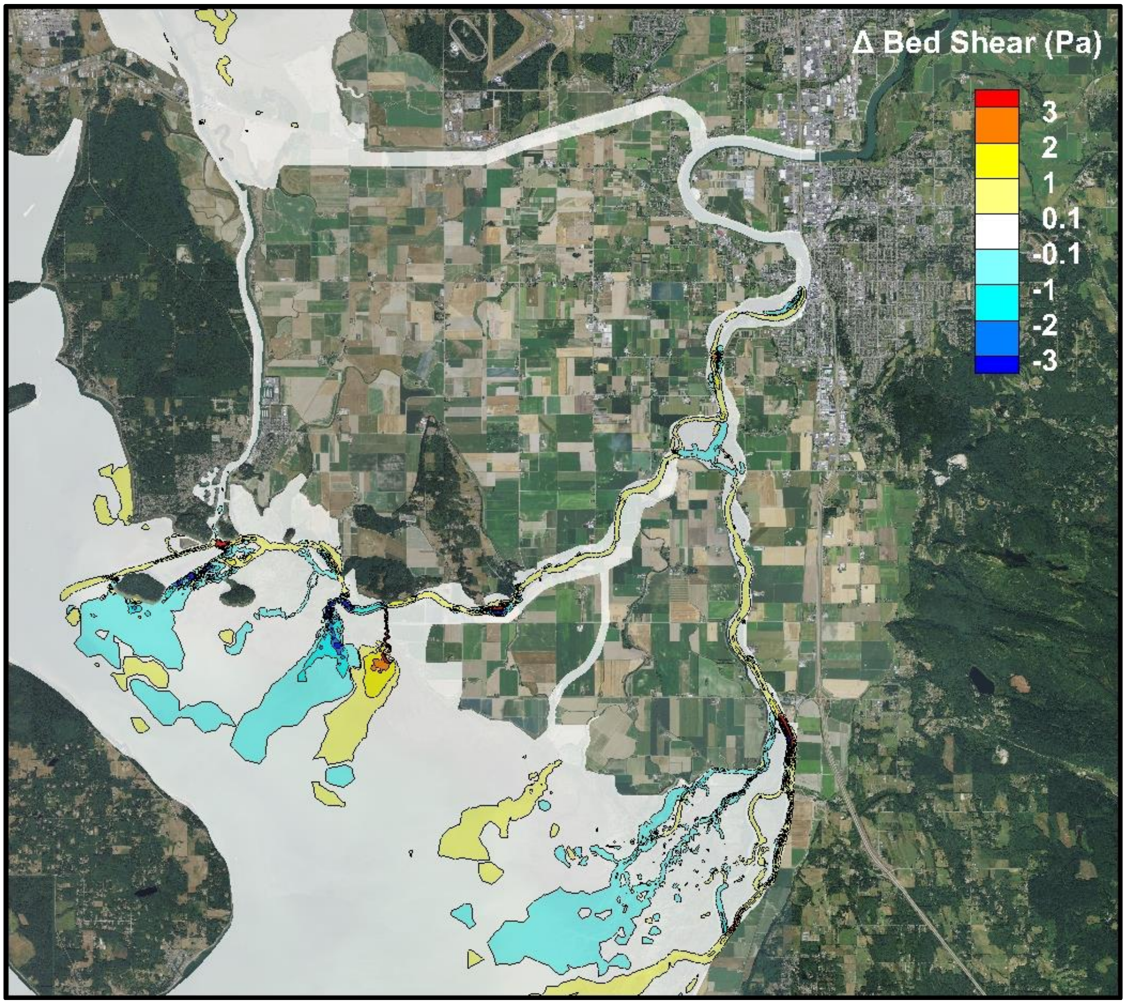


Figure B.52. Contour map of change in shear stress from the Baseline to Small Projects simulation with Q2 flow and low tide.

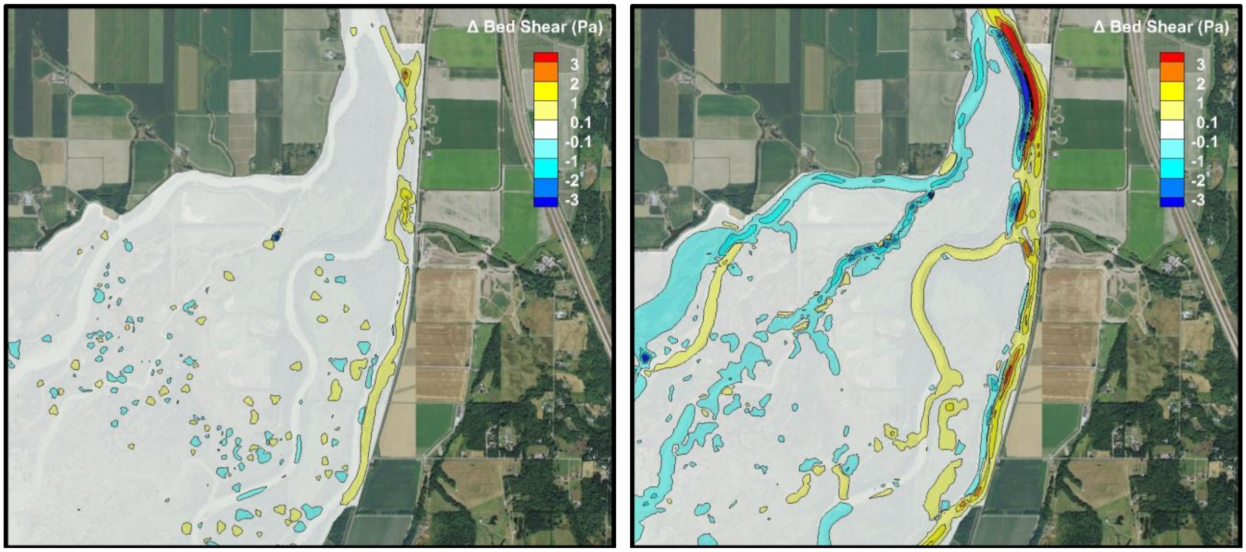


Figure B.53. Contour map of change in shear stress from the Baseline to Small Projects simulation for SF Levee Setbacks 2, 3, and 4 with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

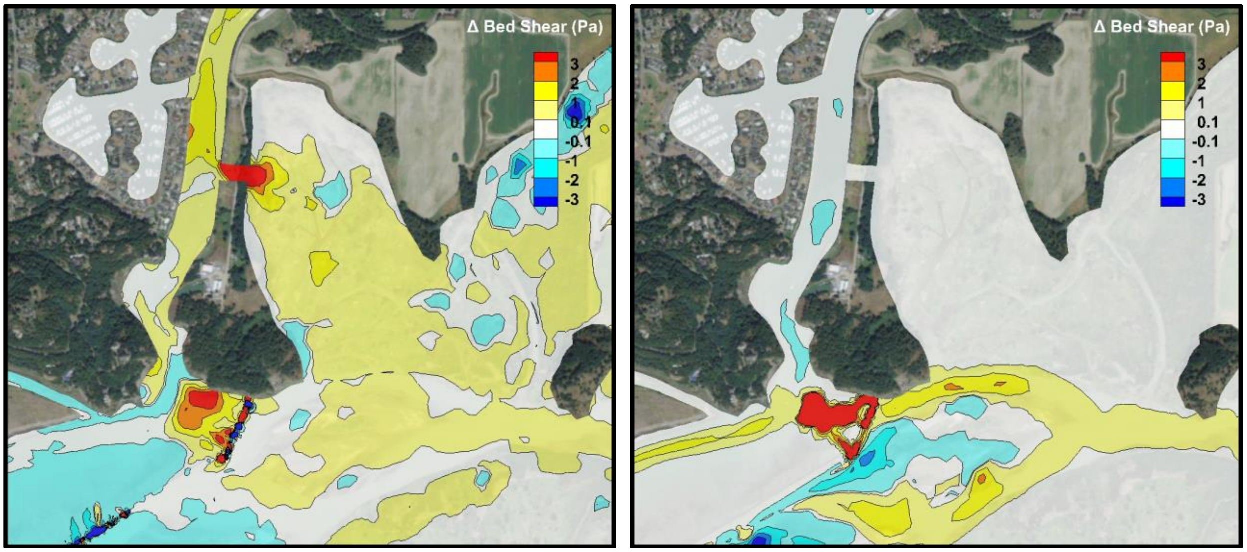


Figure B.54. Contour map of change in shear stress from the Baseline to Small Projects simulation for McGlinn Causeway with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

Figure B.55. Contour map of change in shear stress from the Baseline to Small Projects simulation for TNC South Fork with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

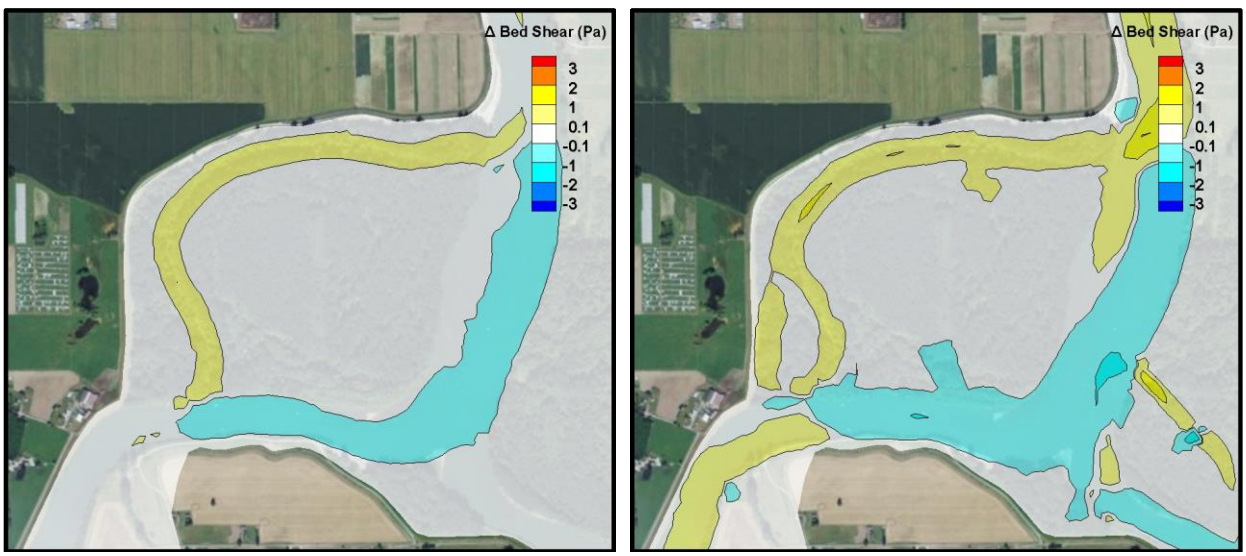


Figure B.56. Contour map of change in shear stress from the Baseline to Small Projects simulation for Cottonwood Island with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

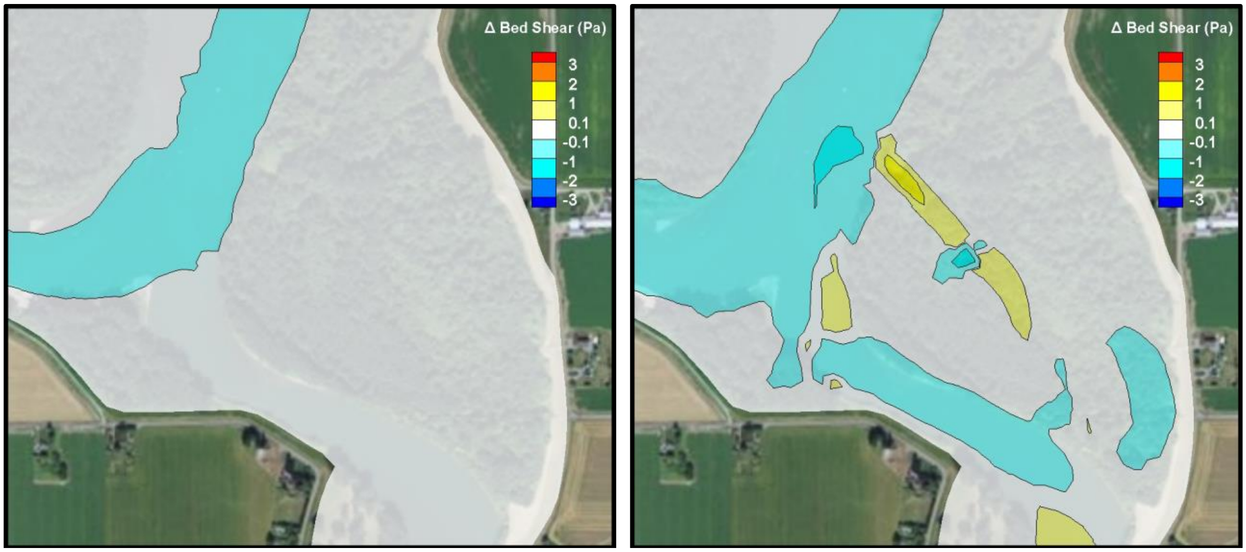


Figure B.57. Contour map of change in shear stress from the Baseline to Small Projects simulation for East Cottonwood with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

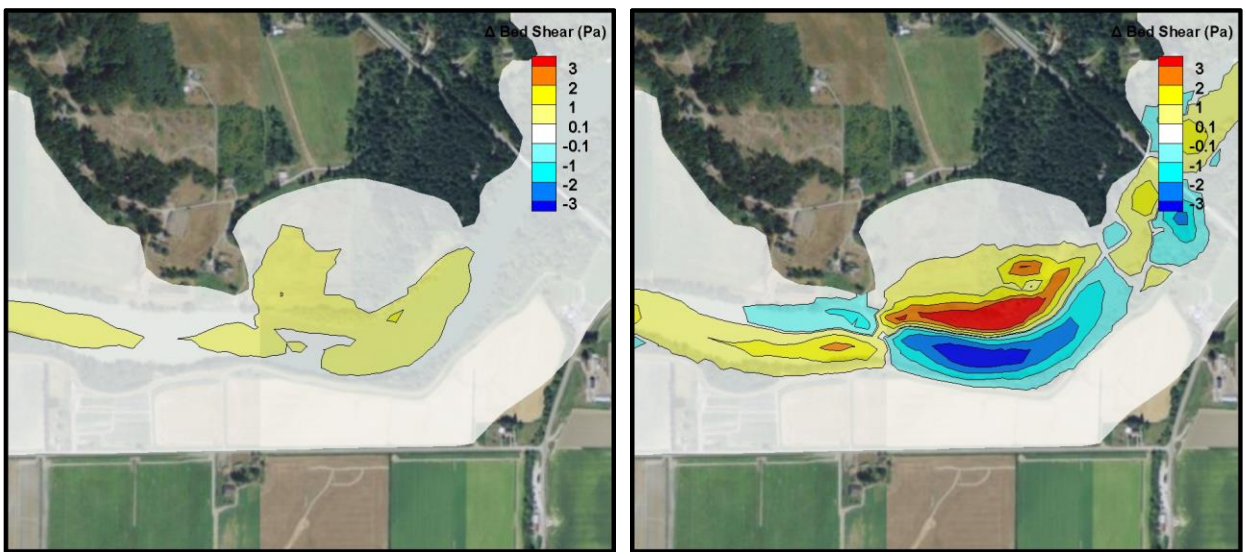


Figure B.58. Contour map of change in shear stress from the Baseline to Small Projects simulation for Pleasant Ridge South with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

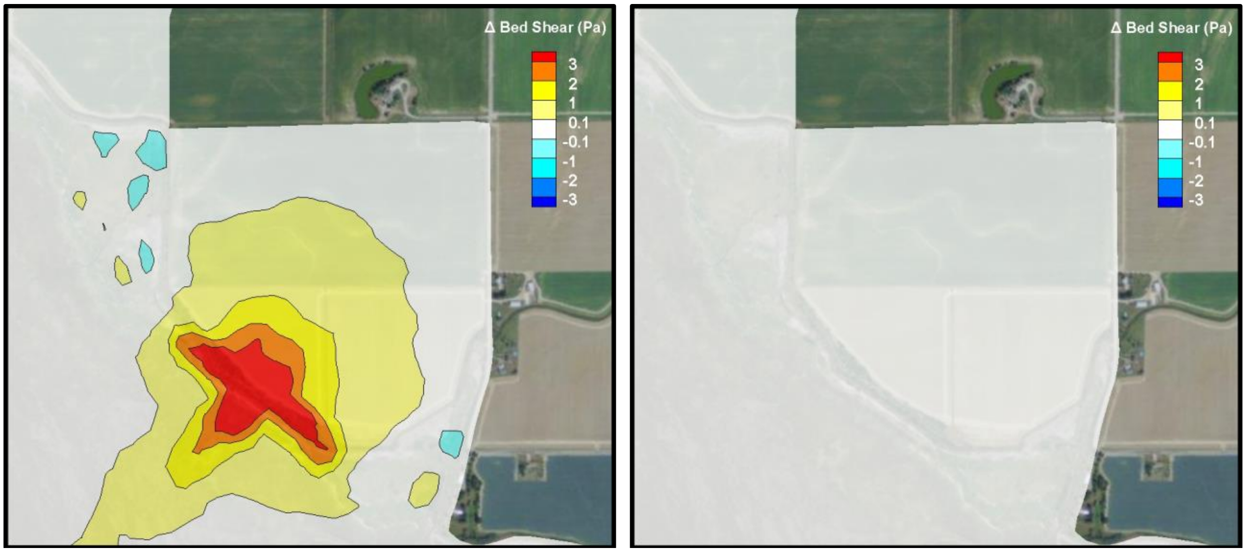


Figure B.59. Contour map of change in shear stress from the Baseline to Small Projects simulation for Hall Slough with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

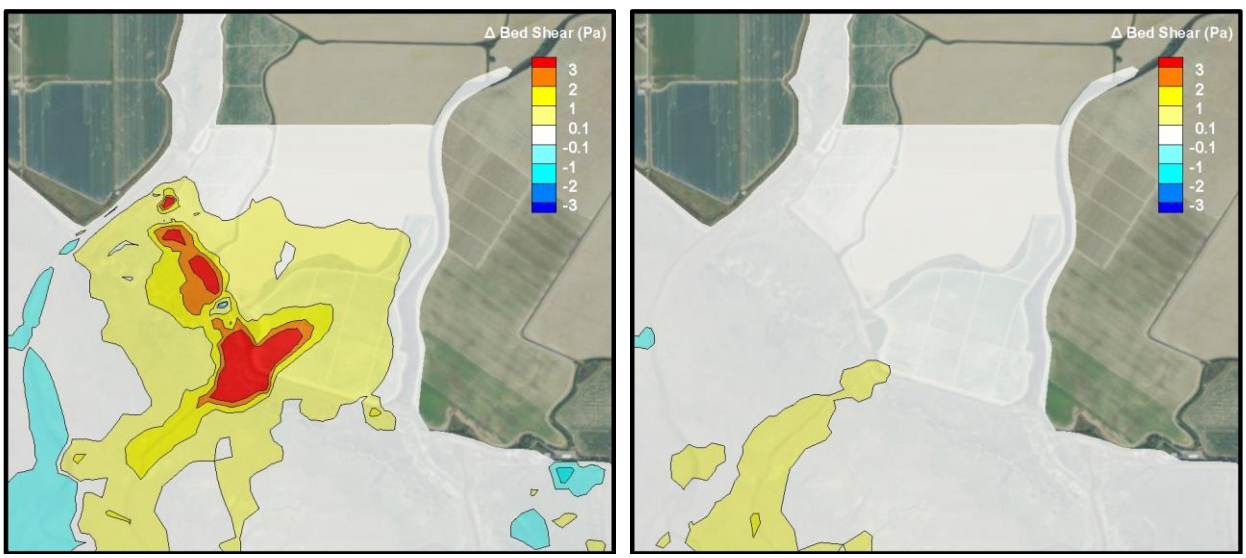


Figure B.60. Contour map of change in shear stress from the Baseline to Small Projects simulation for Fir Island Farm with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

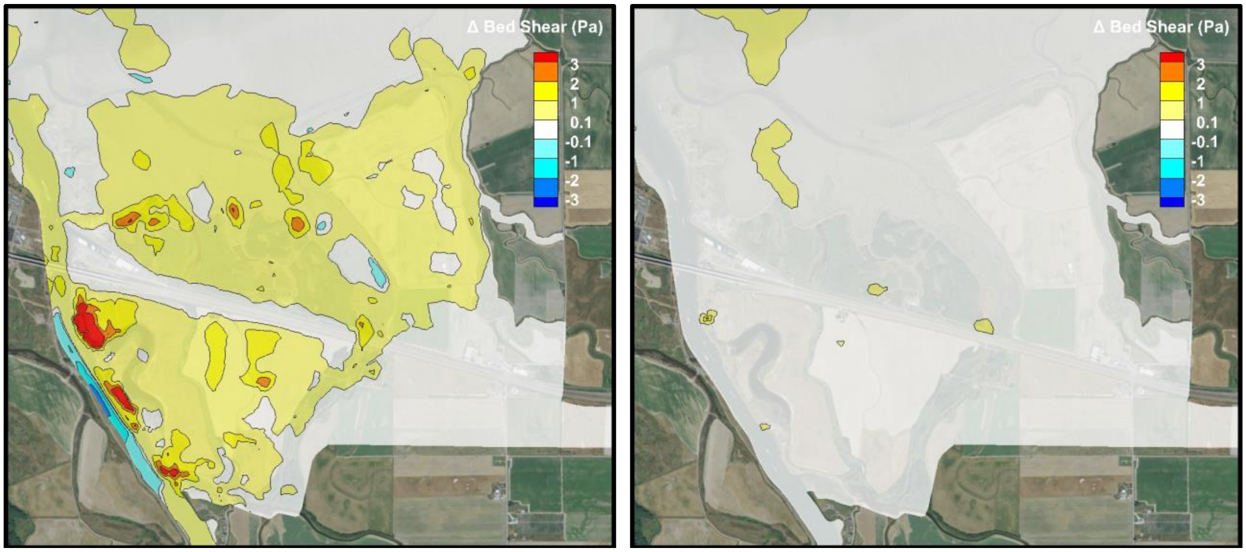


Figure B.61. Contour map of change in shear stress from the Baseline to Small Projects simulation for Fir Island Farm with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

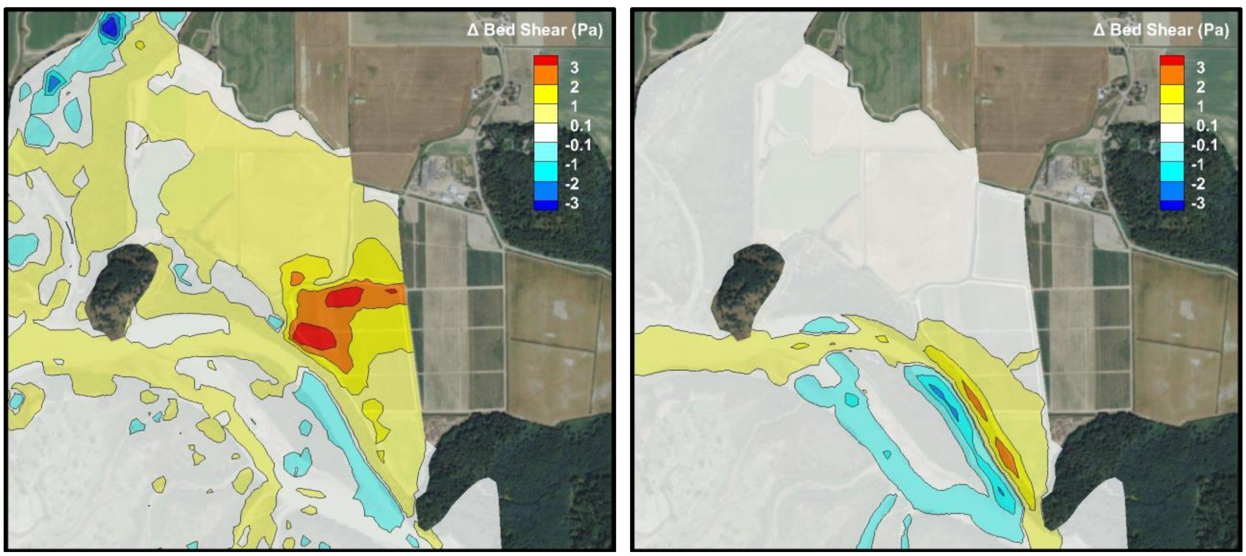


Figure B.62. Contour map of change in shear stress from the Baseline to Small Projects simulation for Sullivan Hacienda with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

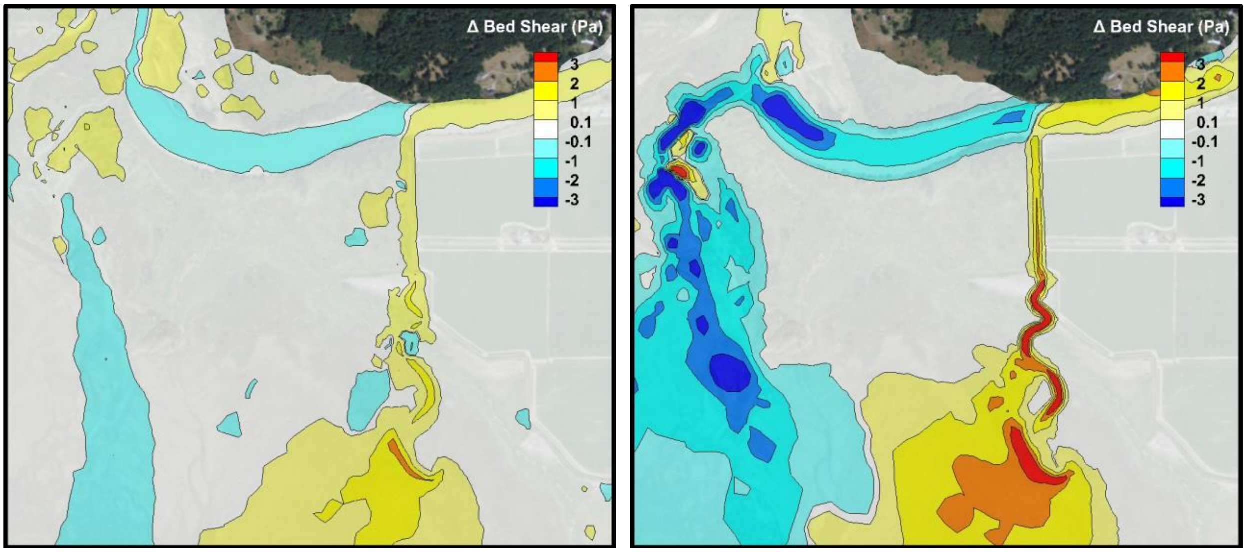


Figure B.63. Contour map of change in shear stress from the Baseline to Small Projects simulation for Rawlins Road Distributary Channel with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

B.8 Small Projects Deliverable 8

Deliverable 8 is a set of contour maps showing the change in salinity between the Baseline Simulation (Simulation 0) and the Small Projects simulation (Simulation 1). The compared conditions were a low flow (12,000 cfs) and high spring tide (10.8 ft), representing the change from baseline to restored conditions. The compared salinity values represent an average of the bottom 10% of the water depth to show the furthest extent of the salt wedge. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. Changes in salinity could affect habitat suitability, the distribution of fish, and have potential effects on agriculture. The maps can be seen in Figure B.64 through Figure B.75.

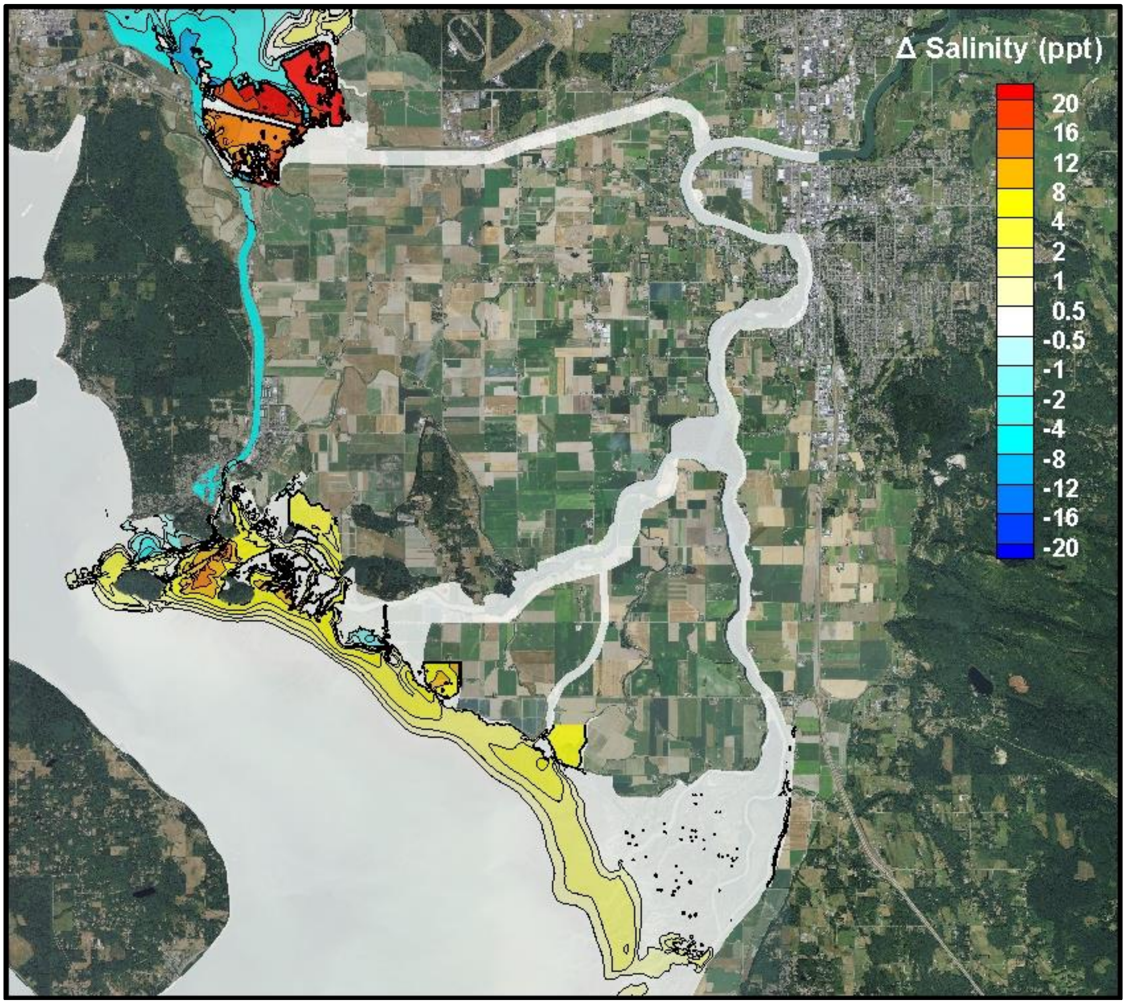


Figure B.64. Contour map of change in salinity from the Baseline to Small Projects simulation with low flow and high tide.

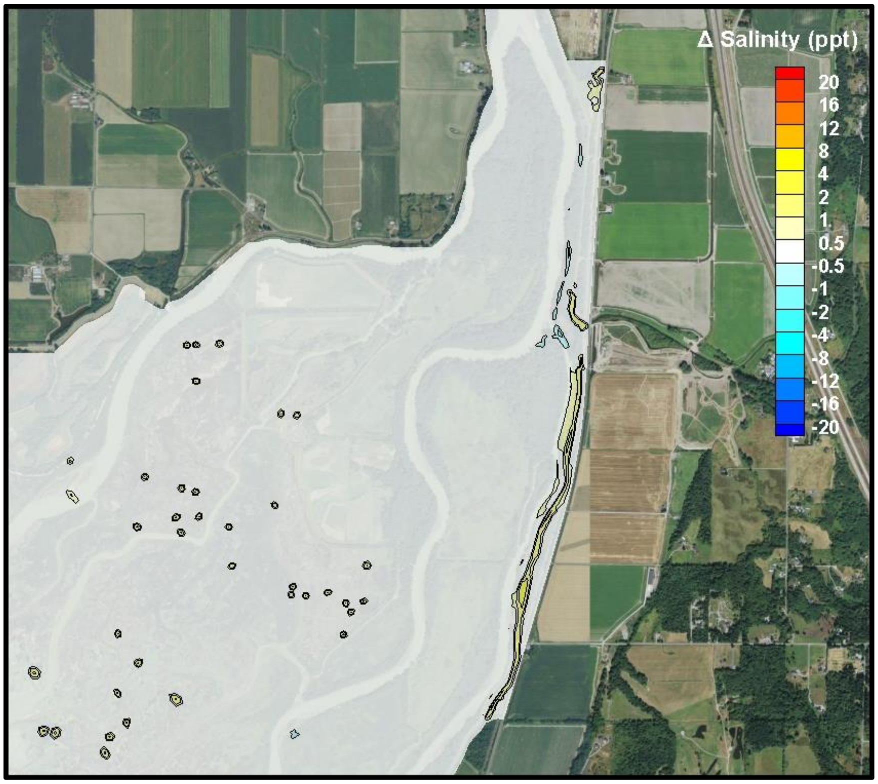


Figure B.65. Contour map of change in salinity from the Baseline to Small Projects simulation for SF Levee Setbacks 2, 3, and 4 with low flow and high tide.

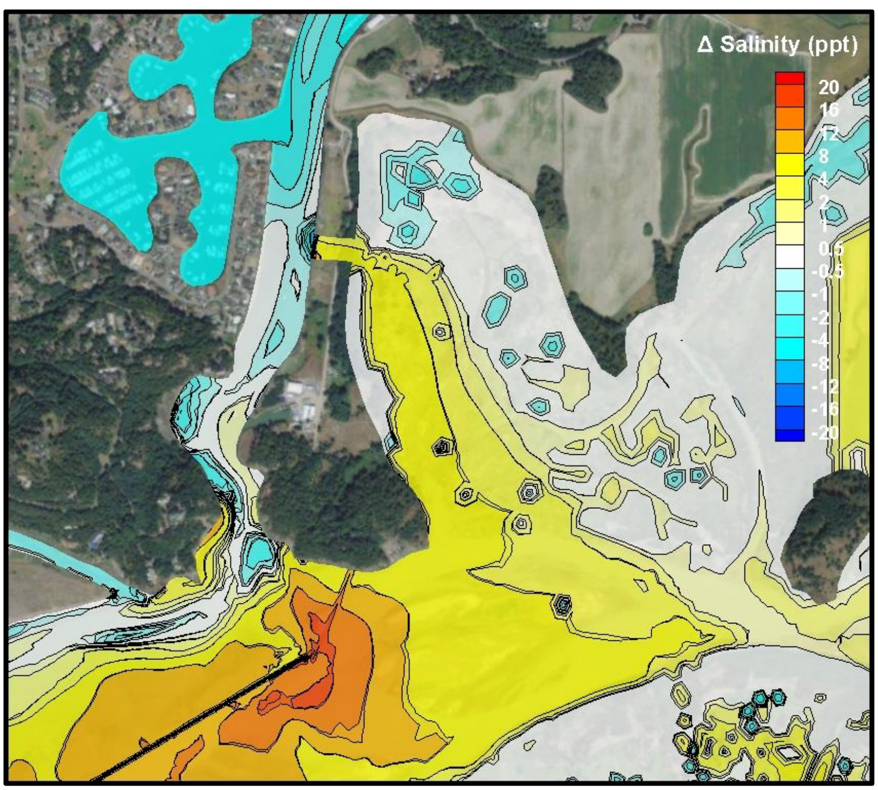


Figure B.66. Contour map of change in salinity from the Baseline to Small Projects simulation for McGlinn Causeway with low flow and high tide.

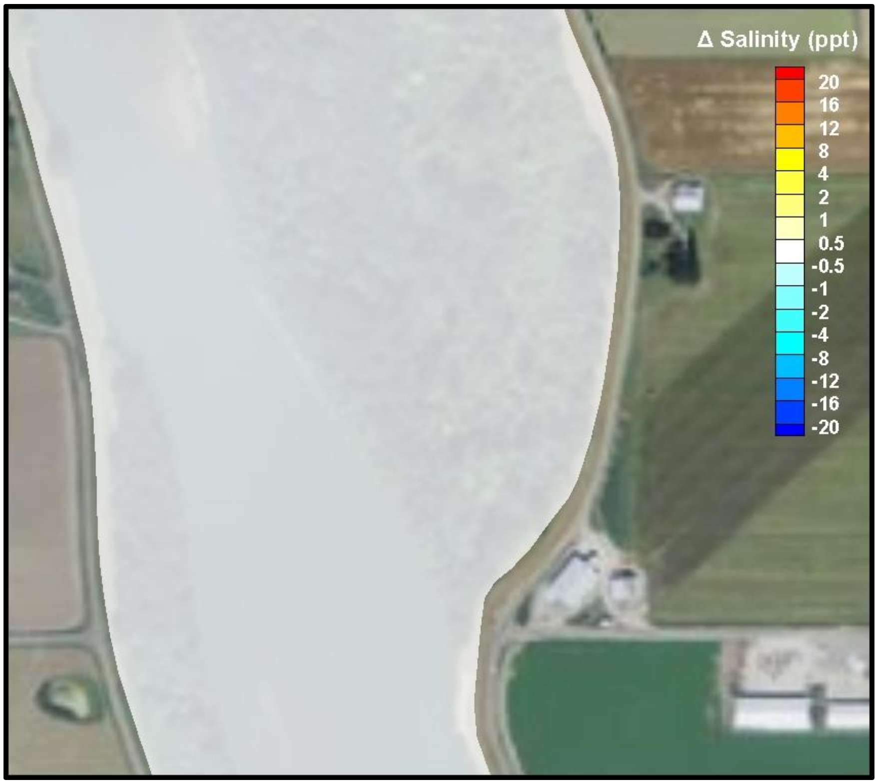


Figure B.67. Contour map of change in salinity from the Baseline to Small Projects simulation for TNC South Fork with low flow and high tide.

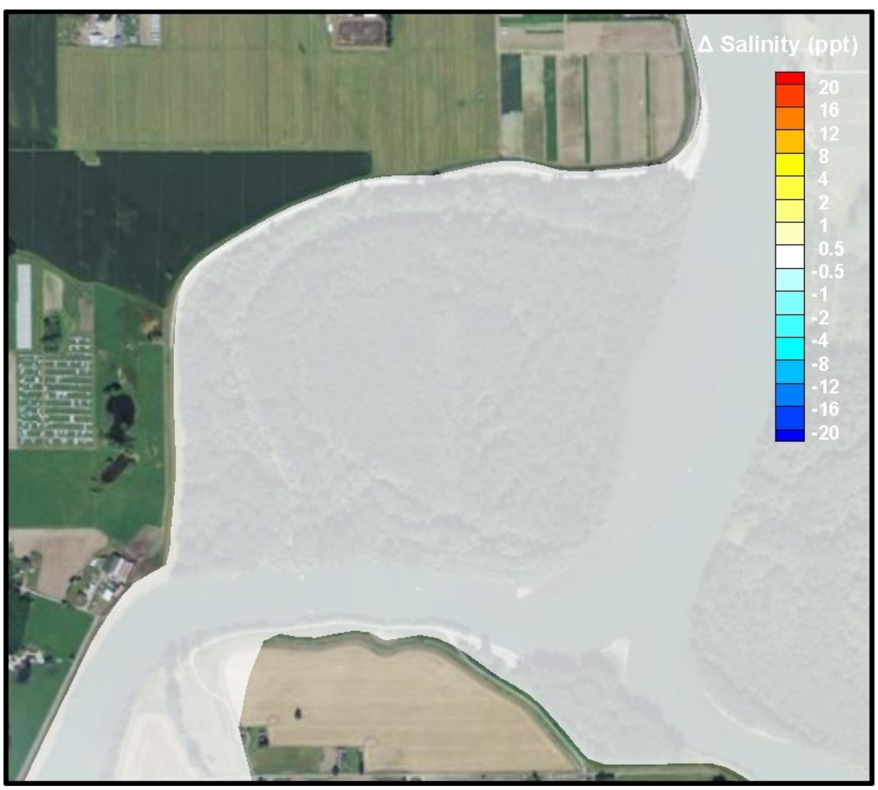


Figure B.68. Contour map of change in salinity from the Baseline to Small Projects simulation for Cottonwood Island with low flow and high tide.

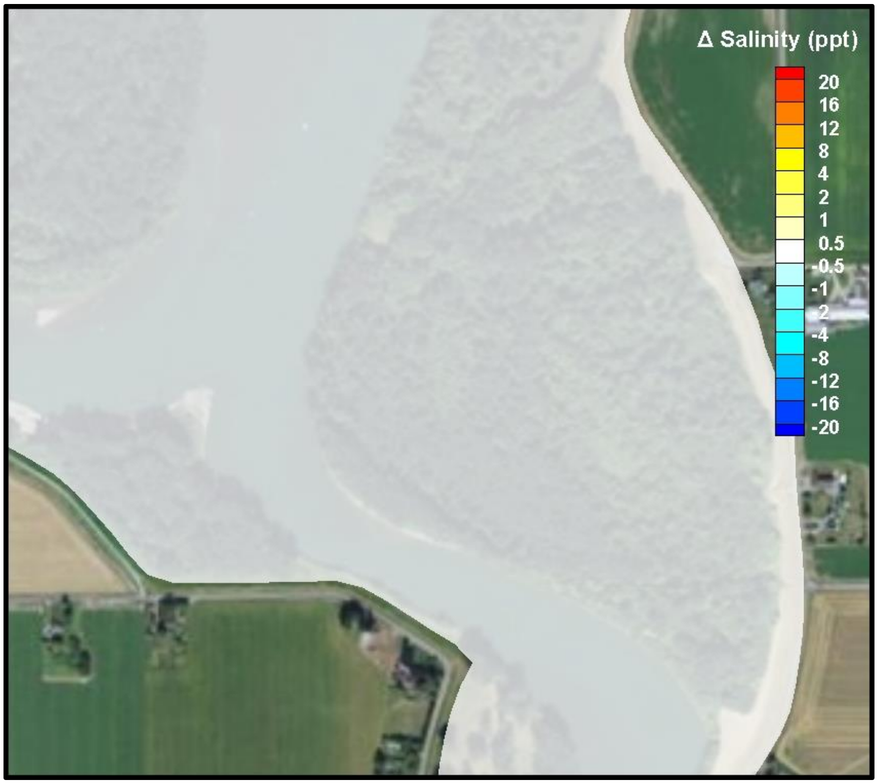


Figure B.69. Contour map of change in salinity from the Baseline to Small Projects simulation for East Cottonwood with low flow and high tide.

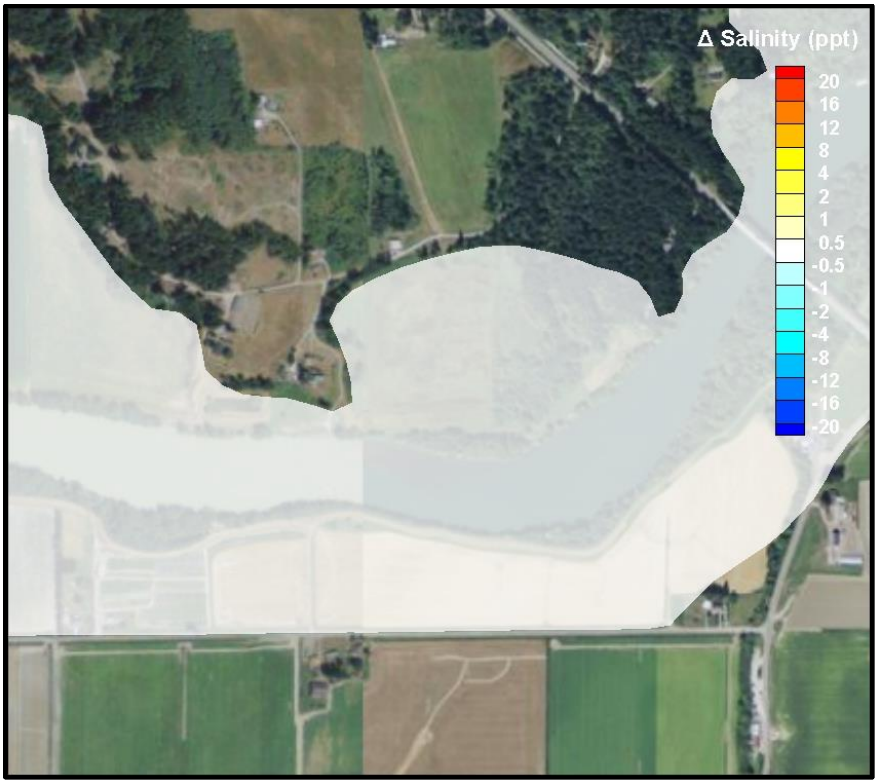


Figure B.70. Contour map of change in salinity from the Baseline to Small Projects simulation for Pleasant Ridge South with low flow and high tide.

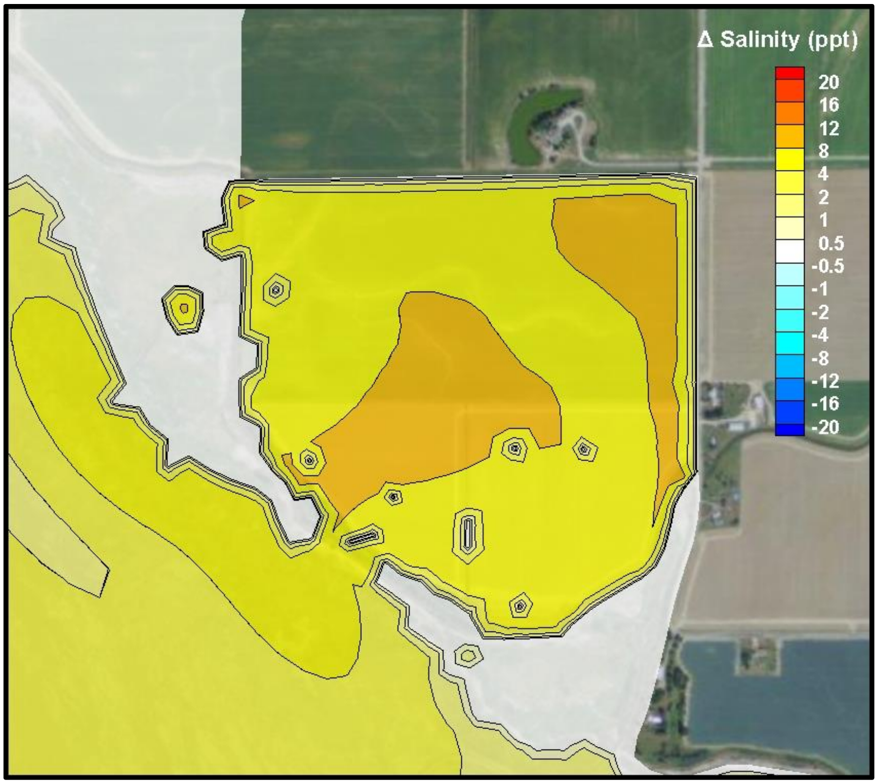


Figure B.71. Contour map of change in salinity from the Baseline to Small Projects simulation for Hall Slough with low flow and high tide.

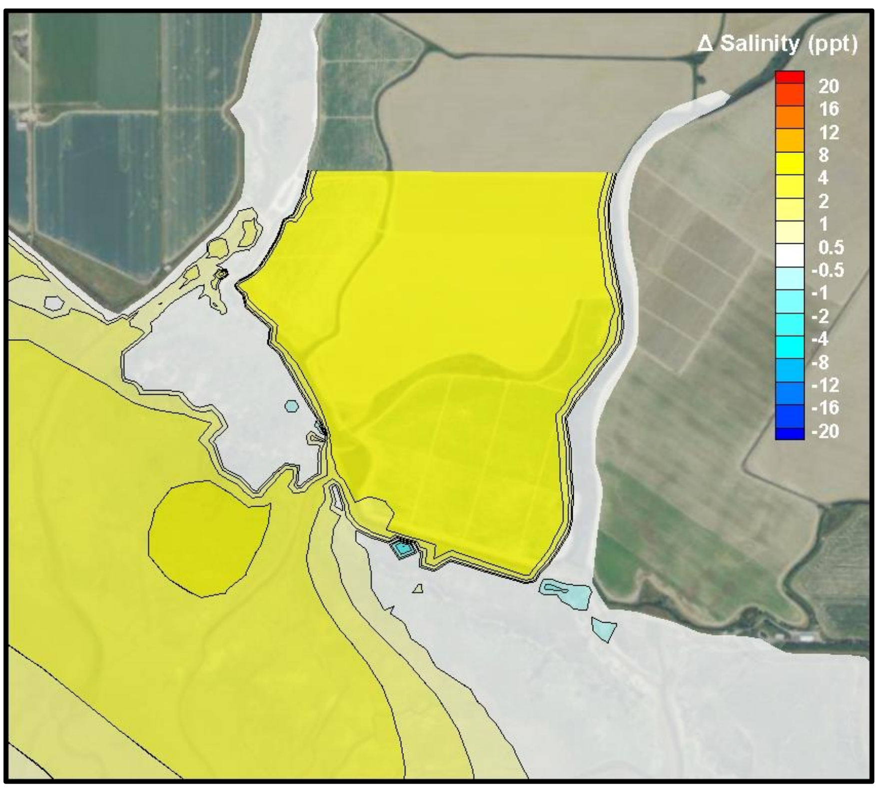


Figure B.72. Contour map of change in salinity from the Baseline to Small Projects simulation for Fir Island Farm with low flow and high tide.

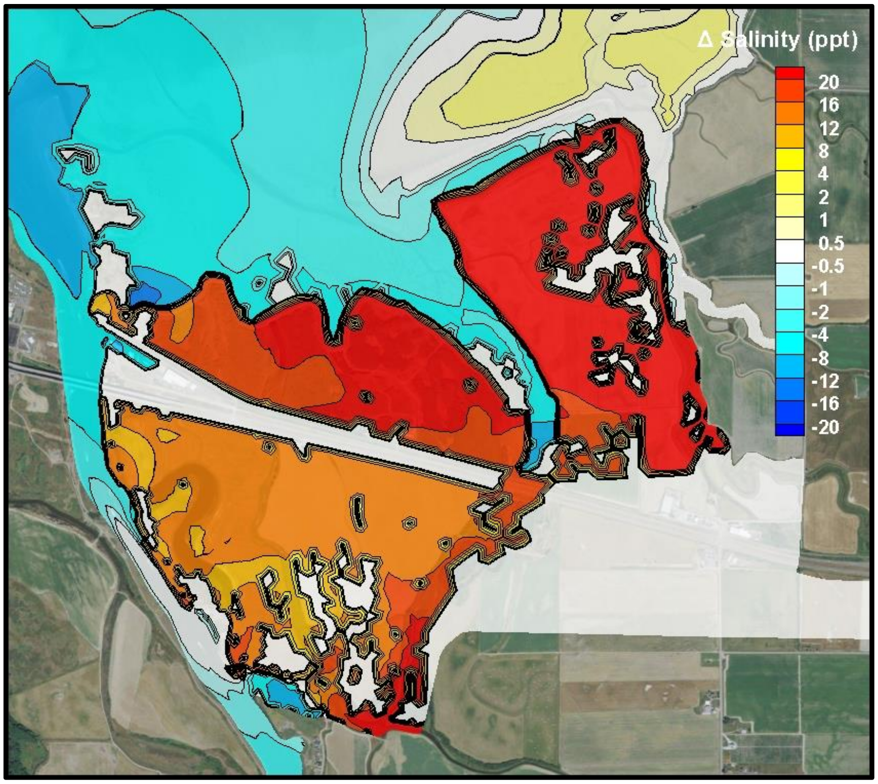


Figure B.73. Contour map of change in salinity from the Baseline to Small Projects simulation for Telegraph Slough Full with low flow and high tide.

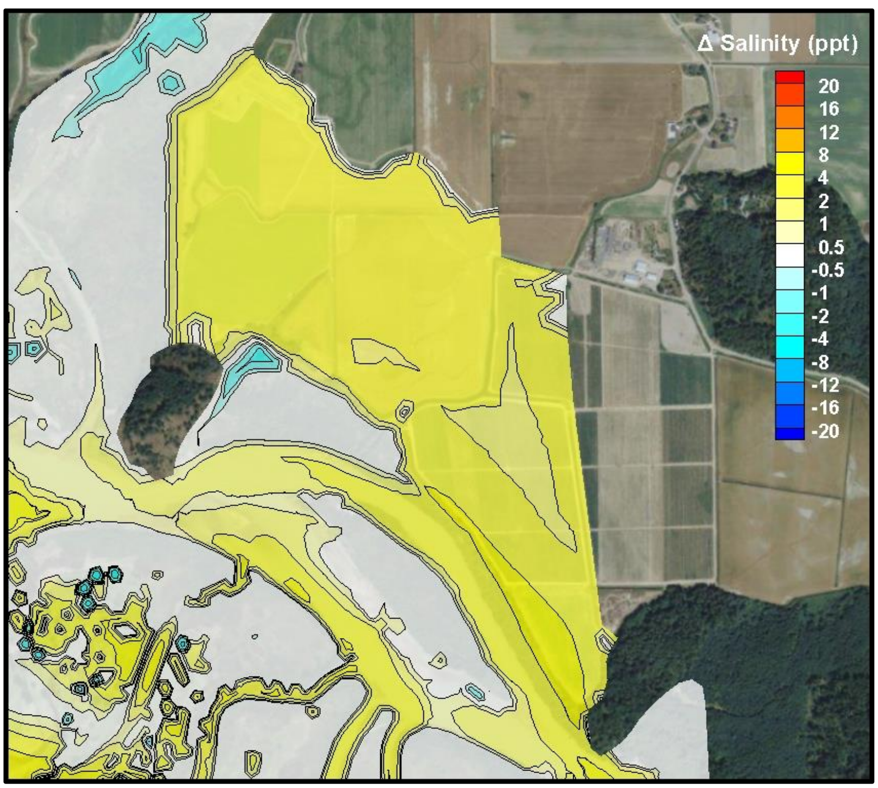


Figure B.74. Contour map of change in salinity from the Baseline to Small Projects simulation for Sullivan Hacienda with low flow and high tide.

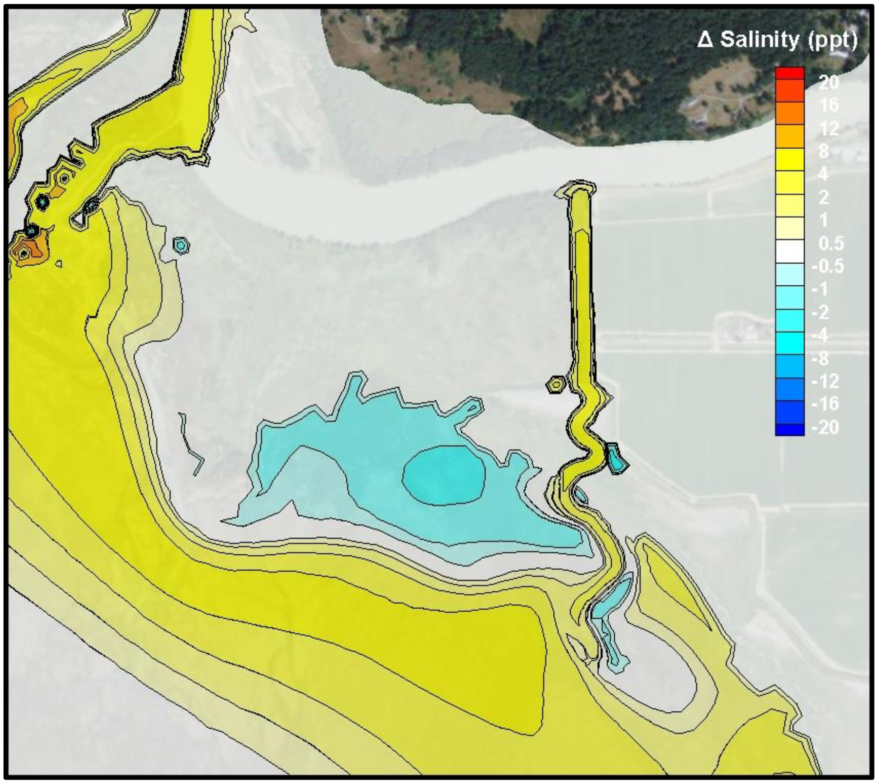


Figure B.75. Contour map of change in salinity from the Baseline to Small Projects simulation for Rawlins Distributary with low flow and high tide.

B.9 Small Projects Deliverable 9

Deliverable 9 is a set of plots that compare WSE and flow between the Baseline Simulation and the Small Projects simulation, plotting all time steps during the entire 7-month simulation from November 2, 2014 through May 29, 2015. Plots are provided for the North Fork, South Fork, Freshwater Slough, and Steamboat Slough gauge locations. Flow was computed at a cross section bisecting the gauge locations. An Excel file was also generated to provide the WSE and flow information at the gauge locations. The maps can be seen in Figure B.76 through Figure B.79.

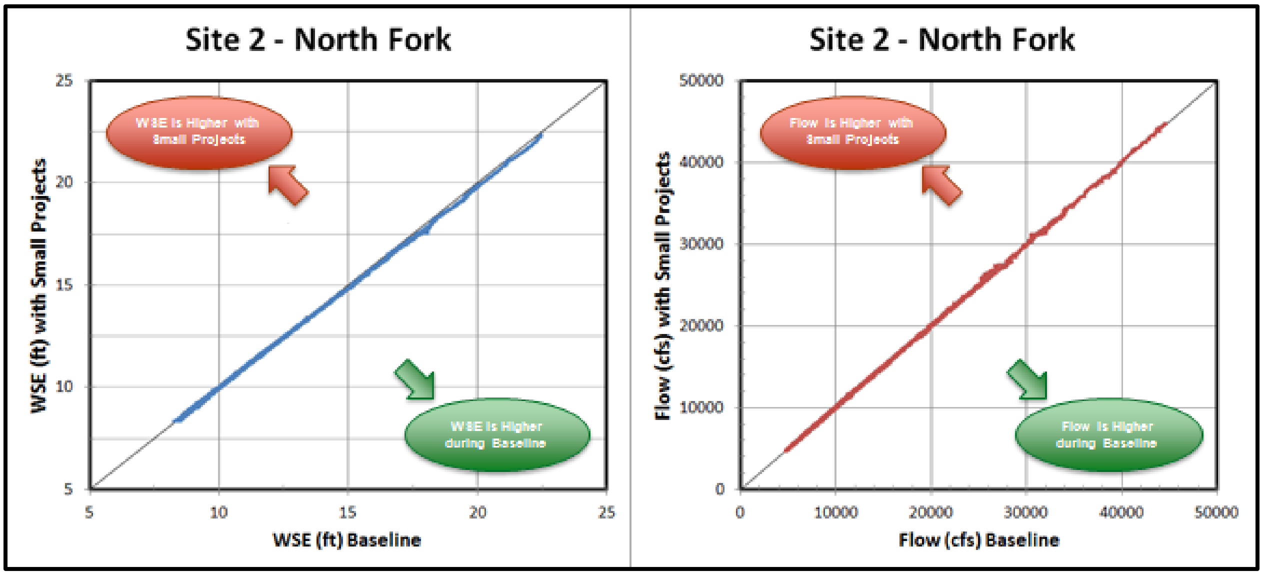


Figure B.76. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Small Projects simulation at the North Fork gauge location compared with the same information under baseline conditions.

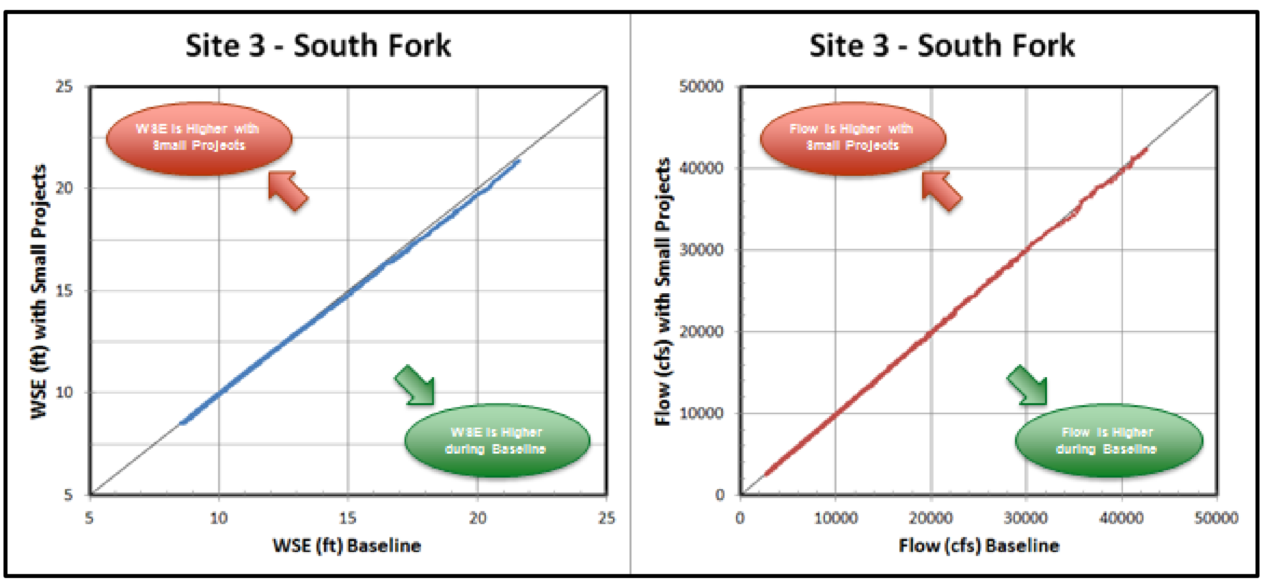


Figure B.77. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Small Projects simulation at the South Fork gauge location compared with the same information under baseline conditions.

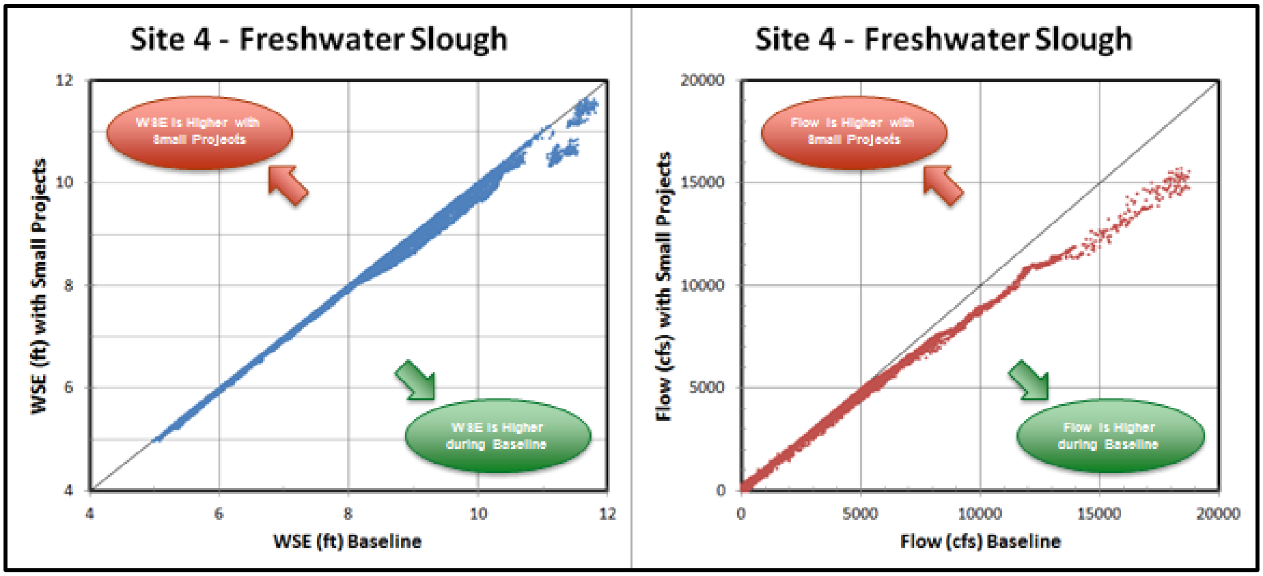


Figure B.78. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Small Projects simulation at the Freshwater Slough gauge location compared with the same information under baseline conditions.

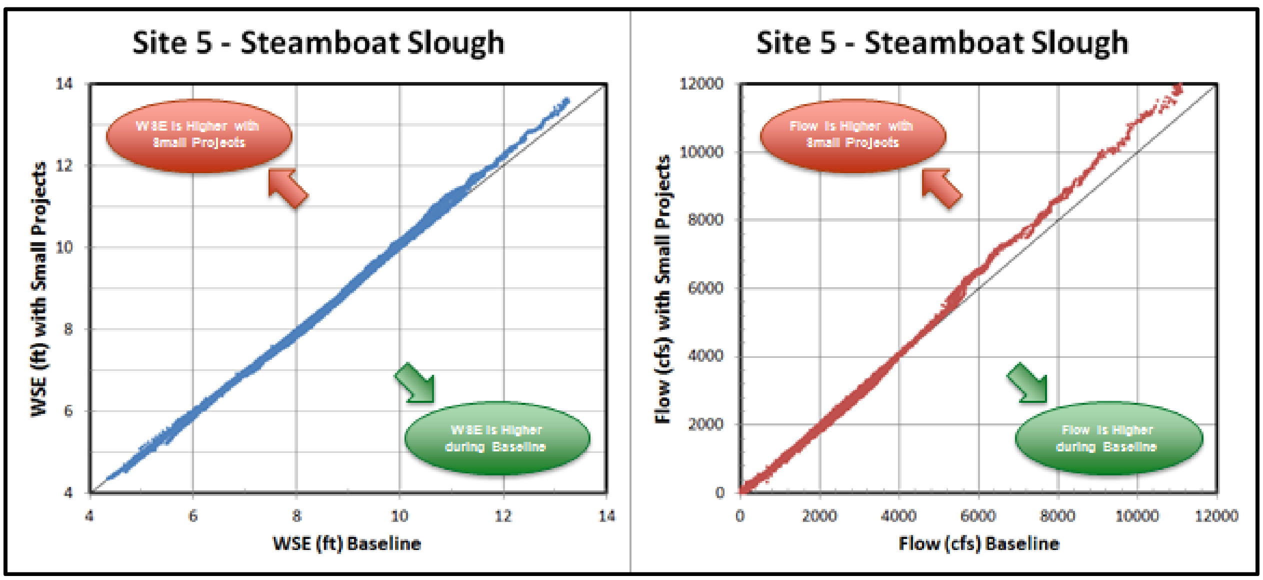


Figure B.79. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Small Projects simulation at the Steamboat Slough gauge location compared with the same information under baseline conditions.

Appendix C

Simulation 2: Major Hydraulic Project: Cross Island Connector Deliverables

Appendix C

Simulation 2: Major Hydraulic Project: Cross Island Connector Deliverables

The following list of deliverables is associated with Simulation 2: Cross Island Connector (Figure C.1). These deliverables were created by the SHDM Team to address specific objectives for the alternative analysis (Friebel et al., in preparation).

1. Table entries showing the change in area subject to natural tidal and riverine processes for each sub-basin in the study area during Cross Island Connector (Simulation 2).
2. Table entries showing the change in area subject to natural tidal and riverine processes for Cross Island Connector (Simulation 2). Because of error with wetted area calculations, high resolution, georeferenced maps showing the depth of inundation under (1) low flow and high tide and (2) Q2 flow and low tide were also provided (not shown).
3. At points in the main channel and bay front selected by the SHDM Team, cumulative frequency of WSE (for the months of March, April, and May). An Excel file of the data associated with the plot data was also provided (not shown).
4. Contour maps showing water depth for Cross Island Connector (Simulation 2) during (1) mean river discharge for the month of May and spring high tide. High-resolution, georeferenced map was also provided (not shown).
5. Histogram of water depth with 1 ft bins at Cross Island Connector (Simulation 2) during (1) mean river discharge for the month of May and high spring tide.
6. Contour maps showing change in WSE from baseline (Simulation 0) to Cross Island Connector (Simulation 2) during (1) Q2 flow and low spring tide and (2) a flood condition and high tide. High-resolution, georeferenced maps were also provided, including (3) low flow and high spring tide and absolute WSE for all three conditions (not shown).
7. Contour maps showing change in bed shear stress from baseline (Simulation 0) to Cross Island Connector (Simulation 2) during (1) low flow and the peak shear stress during a full tidal cycle and (2) Q2 flow and low spring tide. High-resolution, georeferenced maps were also provided, including absolute bed shear stress for both conditions (not shown).
8. Contour maps showing change in salinity from baseline (Simulation 0) to Cross Island Connector (Simulation 2) during (1) low flow and high spring tide. High-resolution, georeferenced maps were also provided, including absolute salinity for both conditions (not shown).
9. Plots of change in WSE and flow from baseline (Simulation 0) to Cross Island Connector (Simulation 2) for the South Fork, North Fork, Freshwater Slough, and Steamboat Slough to determine the basin effects. An Excel file of the data associated with the plots was also provided.

Figure C.1. A map of project area in the Major Hydraulic Project simulation: Cross Island Connector.

C.1 Major Hydraulic Project: Cross Island Connector Deliverable 1

For this deliverable, the area was divided into sub-basins, as seen in Figure C.2. Deliverable 1 is a table showing the increase in inundation area subject to natural tidal and riverine processes within each sub-basin, as seen in Table C.1. The accuracy of area calculation is limited by the spatial resolution of the triangular grid, which varies throughout the model domain. A node is considered wet when the model calculated water depth exceeds the minimum wetting and drying criteria of 10 cm (0.3281 ft). For any wetted node included in the project boundary polygon, its associated computational area was counted toward the total inundated area.

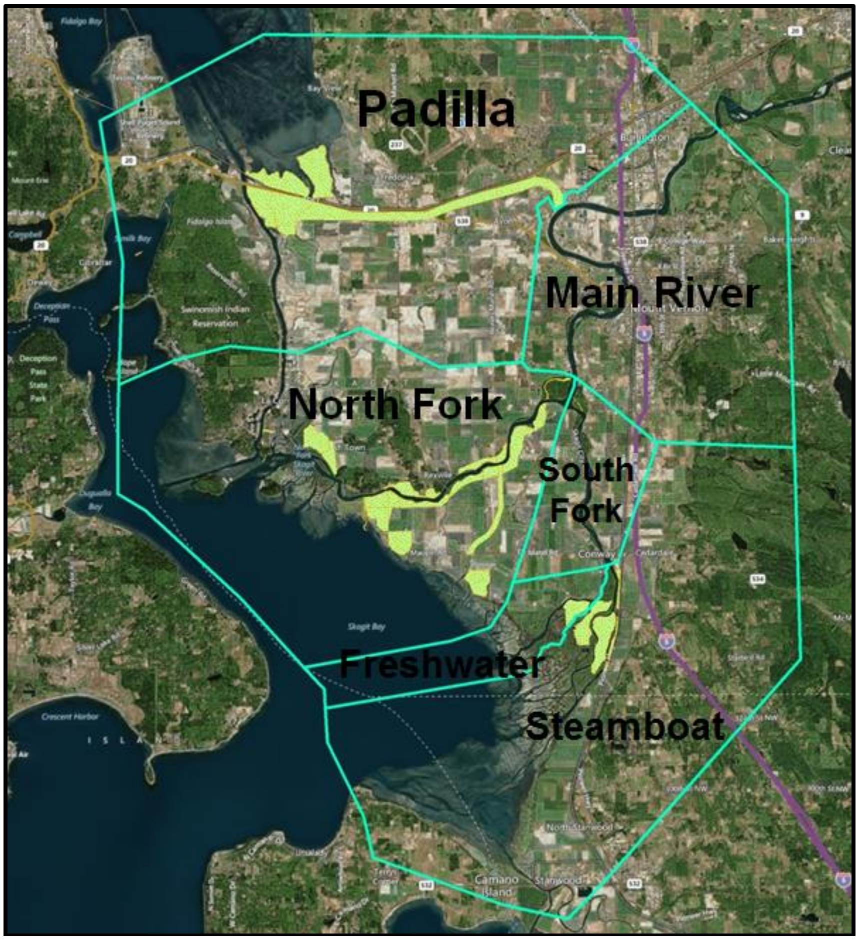


Figure C.2. Sub-basins within the Skagit region used for area calculations.

Table C.1. Table entry showing area increase for each sub-basin under tidal and riverine conditions during the Major Hydraulic Project Cross Island Connector simulation.

Sub-basin	Baseline (acres)	With Projects (acres)	Increase in Area (acres)
Tidal Influence: High Spring Tide (10.8 ft) + Low Flow (12,000 cfs)			
Sum	20,256.9	20,392.9	**136.0**
Main River	7.8	7.4	**-0.4**
North Fork	8,330.6	8,466.6	**136.0**
South Fork	30.0	30.0	**0.0**
Freshwater	1,944.6	1,944.9	**0.3**
Steamboat	5,827.3	5,827.3	**0.0**
Padilla	4,116.8	4,116.8	**0.0**
Riverine Influence: Low Spring Tide (-3.3 ft) + Q2 Flow (62,000 cfs)			
Sum	7,921.4	8,517.3	**595.9**
Main River	159.0	149.0	**-10.0**
North Fork	2,998.2	3,608.2	**610.0**
South Fork	171.8	148.8	**-23.0**
Freshwater	1,065.1	1,149.8	**84.7**
Steamboat	2,640.2	2,572.9	**-67.3**
Padilla	887.0	888.7	**1.7**

C.2 Major Hydraulic Project: Cross Island Connector Deliverable 2

Deliverable 2 is a table showing the increase in inundation area subject to natural tidal and riverine processes within each project area, as seen in Table C.2. Inundation area is counted only within the project footprint. The same limitations and definition of an inundated cell that apply for Deliverable 1 apply here.

Table C.2. Table entry showing area increase for each project under tidal and riverine conditions during the Major Hydraulic Project Cross Island Connector simulation. Measurements correspond to a measured area that differs from the true project footprint because of grid resolution.

Project (measured area)	Baseline (acres)	With Projects (acres)	Increase in Area (acres)
Tidal Influence: High Spring Tide (10.8 ft) + Low Flow (12,000 cfs)			
Cross Island Connector (**152.3 acres**)	0.3	115.1	**114.8**
Riverine Influence: Low Spring Tide (-3.3 ft) + Q2 Flow (62,000 cfs)			
Cross Island Connector (**152.3 acres**)	0.3	117.2	**116.9**

C.3 Major Hydraulic Project: Cross Island Connector Deliverable 3

Deliverable 3 is a set of cumulative frequency plots showing WSE at a point in the main channel or Bayfront near each project site. These are from the spring months of the Major Hydraulic Project simulation (Simulation 2), representing March 1 – May 22, 2015, a time period chosen to coincide with the primary fish outmigration. A red mark line was provided with every point to represent an approximation of the average elevation of the project area bed. All WSE values are relative to the NAVD88 datum. An Excel file was also generated with WSE at each node location. The plots can be seen in Figure C.3 and Figure C.4.

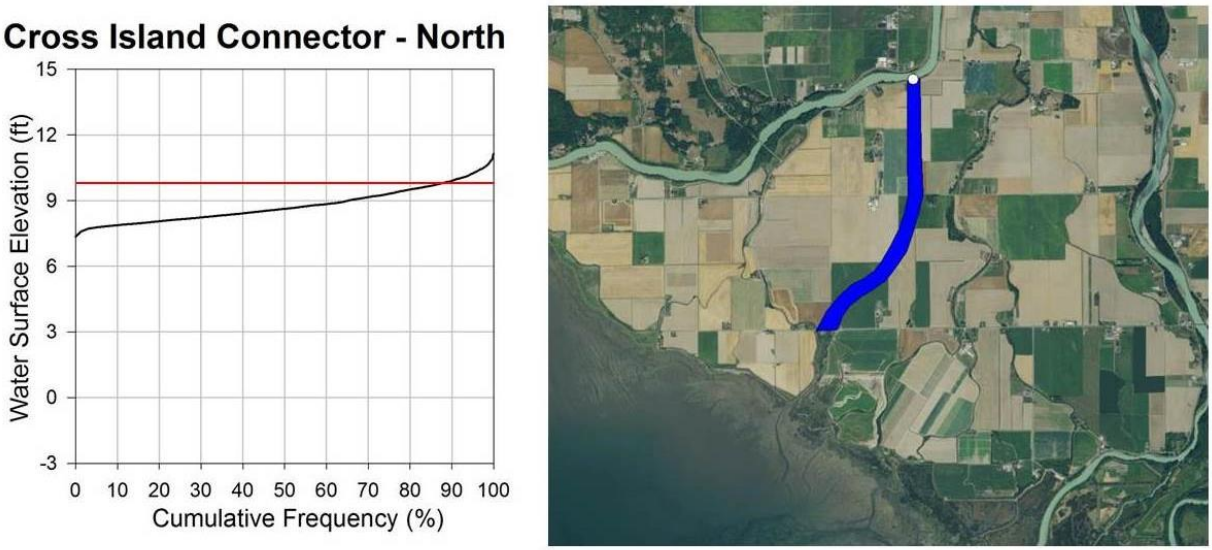


Figure C.3. Cumulative frequency plot and corresponding map for Cross Island Connector (north) during the Major Hydraulic Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

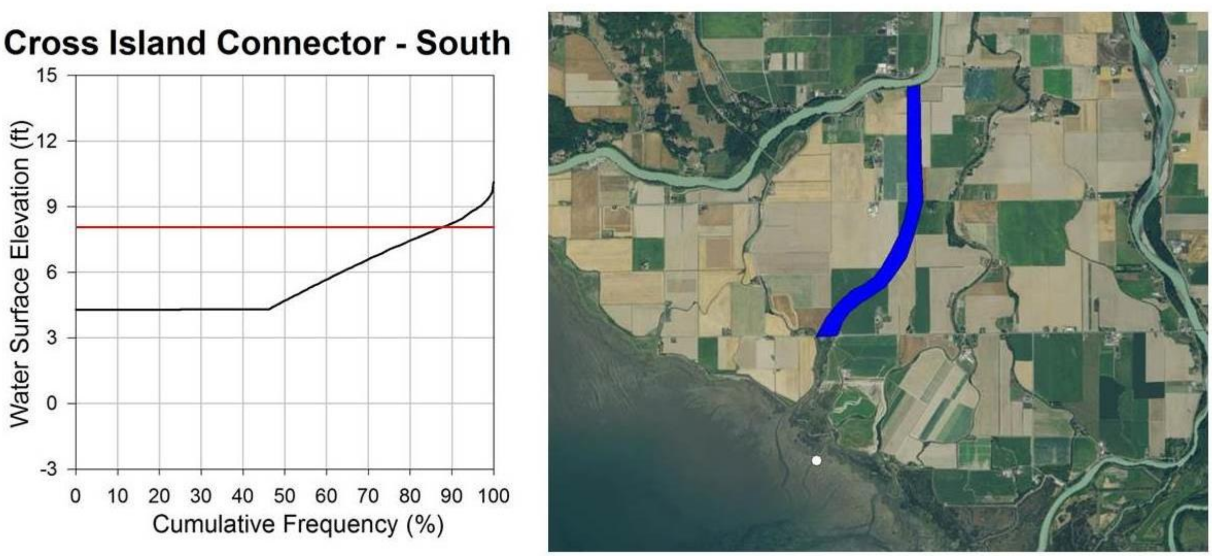


Figure C.4. Cumulative frequency plot and corresponding map for Cross Island Connector (south) during the Major Hydraulic Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

C.4 Major Hydraulic Project: Cross Island Connector Deliverable 4

Deliverable 4 is a set of contour maps showing the depths of inundation during the Major Hydraulic Project simulation (Simulation 2). The plotted condition was the mean river discharge for the month of May (20,400 cfs) and high spring tide (10.8 ft). All depth values are relative to model bathymetry, which uses linear interpolation to the resolution of the grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure C.5 and Figure C.6.

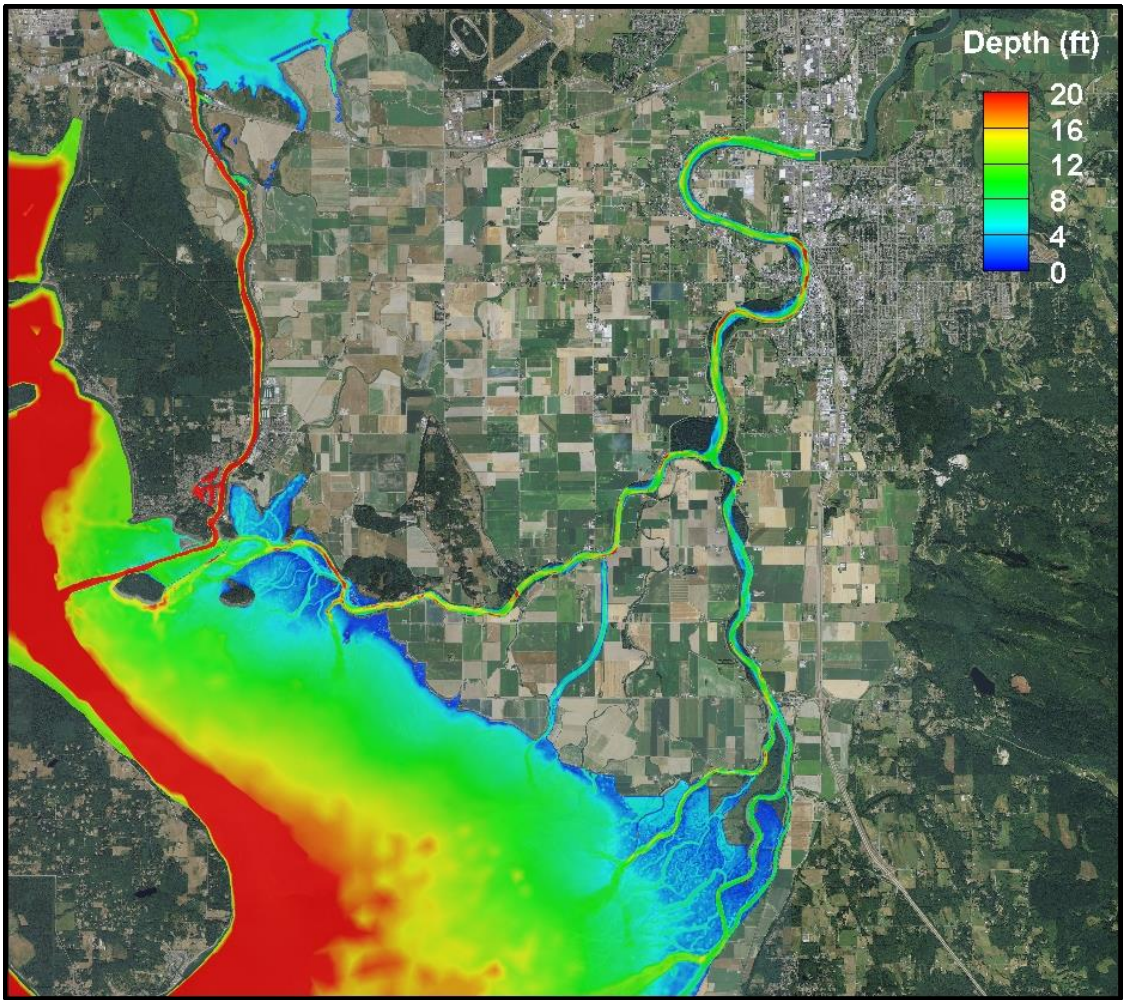


Figure C.5. Contour map of depths for the full domain during the Major Hydraulic Project Cross Island Connector simulation with May flow and high spring tide.

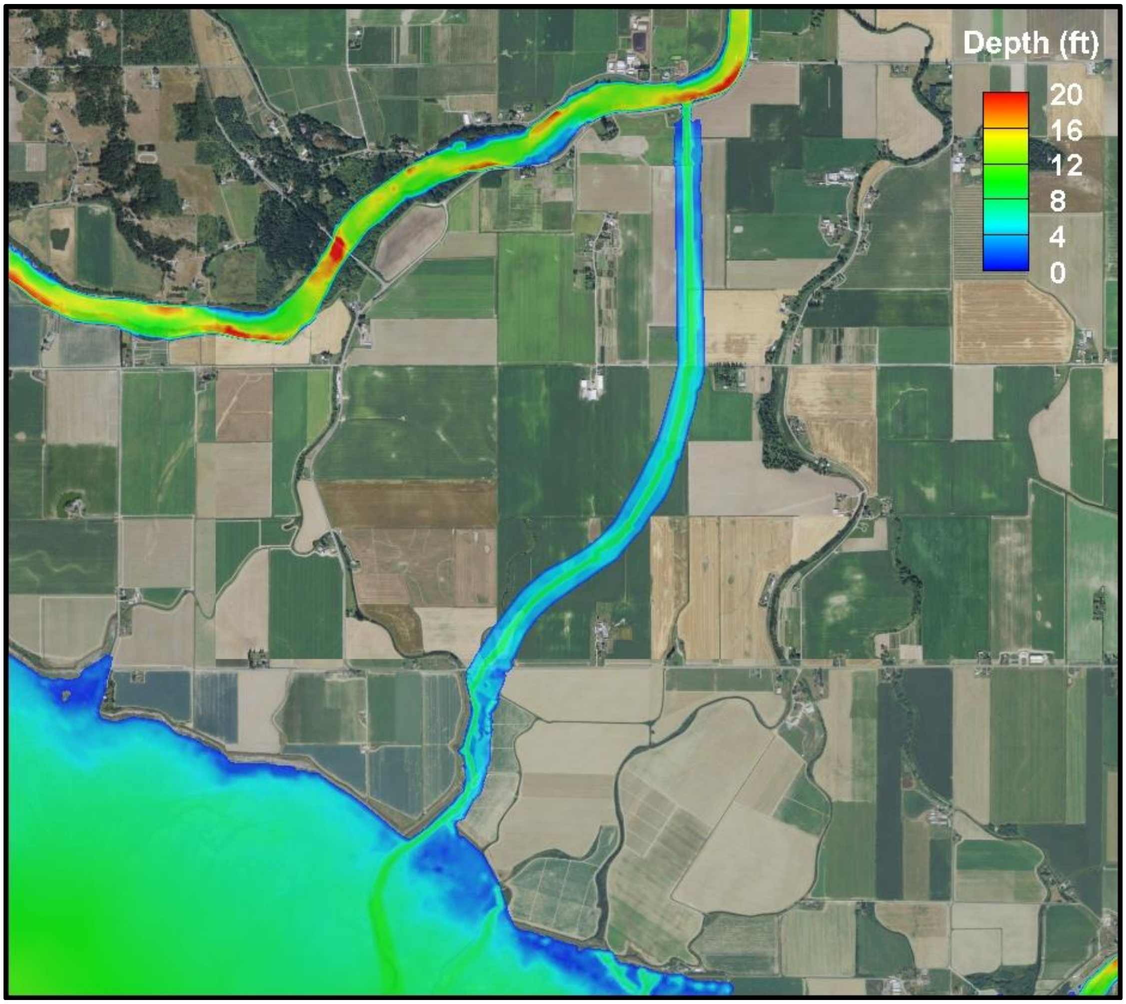


Figure C.6. Contour map of depths for Cross Island Connector during the Major Hydraulic Project simulation.

C.5 Major Hydraulic Project: Cross Island Connector Deliverable 5

Deliverable 5 is a set of histograms showing the distribution of water depths in 1 ft bins across each project site during a high spring tide (10.8 ft) and mean river discharge for the month of May (20,400 cfs), the same conditions corresponding to the maps for Deliverable 4. All depth values are relative to model bathymetry, which uses linear interpolation to the resolution of the grid. The histogram can be seen in Figure C.7.

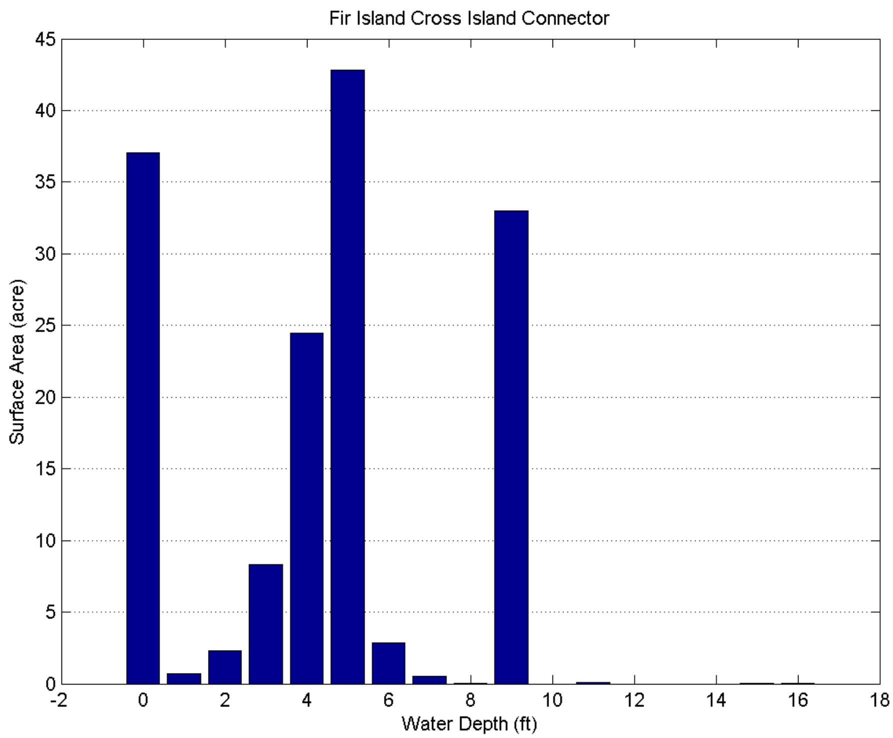


Figure C.7. Histogram of depths for Cross Island Connector.

C.6 Major Hydraulic Project: Cross Island Connector Deliverable 6

Deliverable 6 is a set of contour maps showing the change in water surface elevation between the Baseline Simulation (Simulation 0) and the Major Hydraulic Project simulation (Simulation 2). Two conditions were compared: (1) a low spring tide (-3.3 ft) and Q2 flow (62,000 cfs) and (2) a high spring tide (10.4 ft) and a flood condition (93,200 cfs), representing the change from baseline to restored conditions. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure C.8 through Figure C.10.

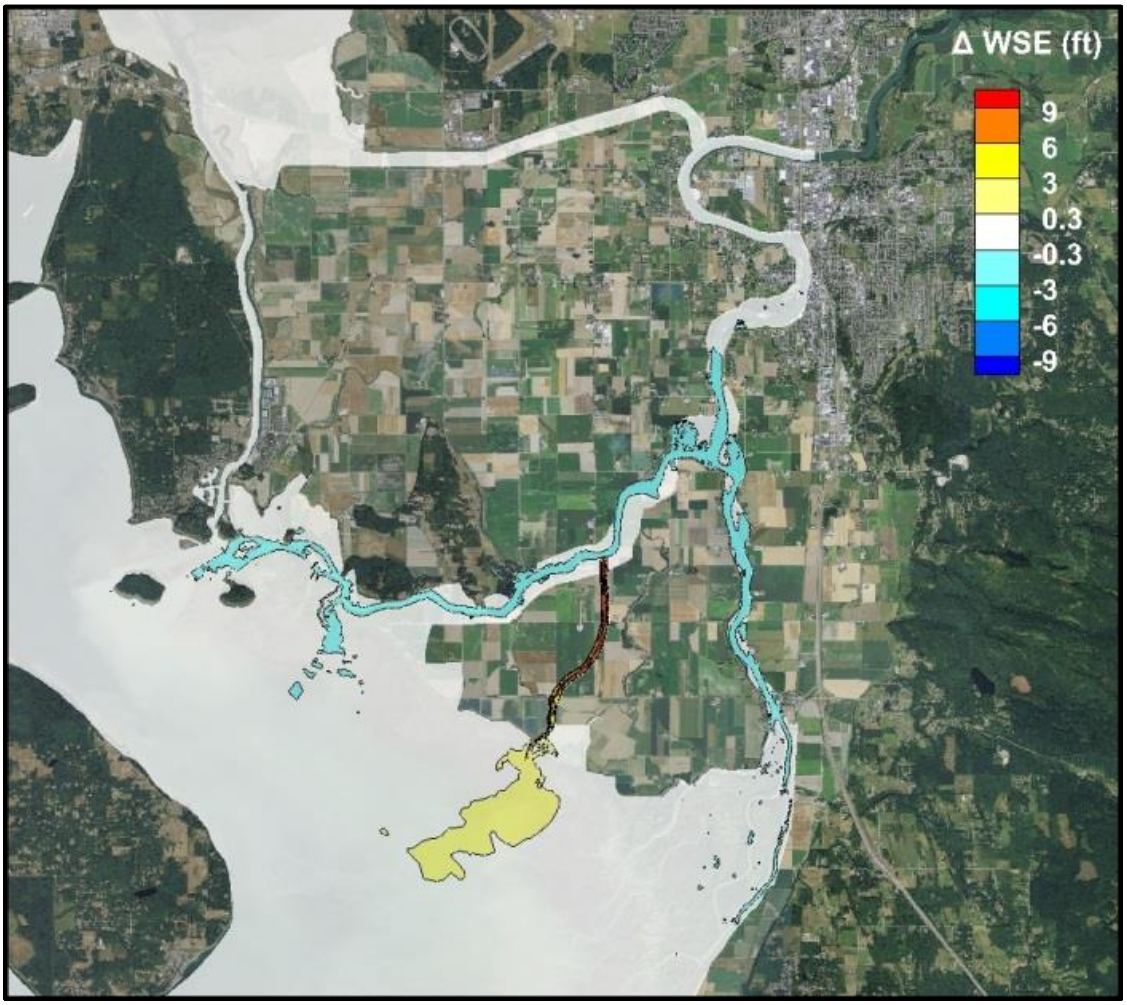


Figure C.8. Contour map of change in WSE from the Baseline to Cross Island Connector simulation with Q2 flow and low tide.

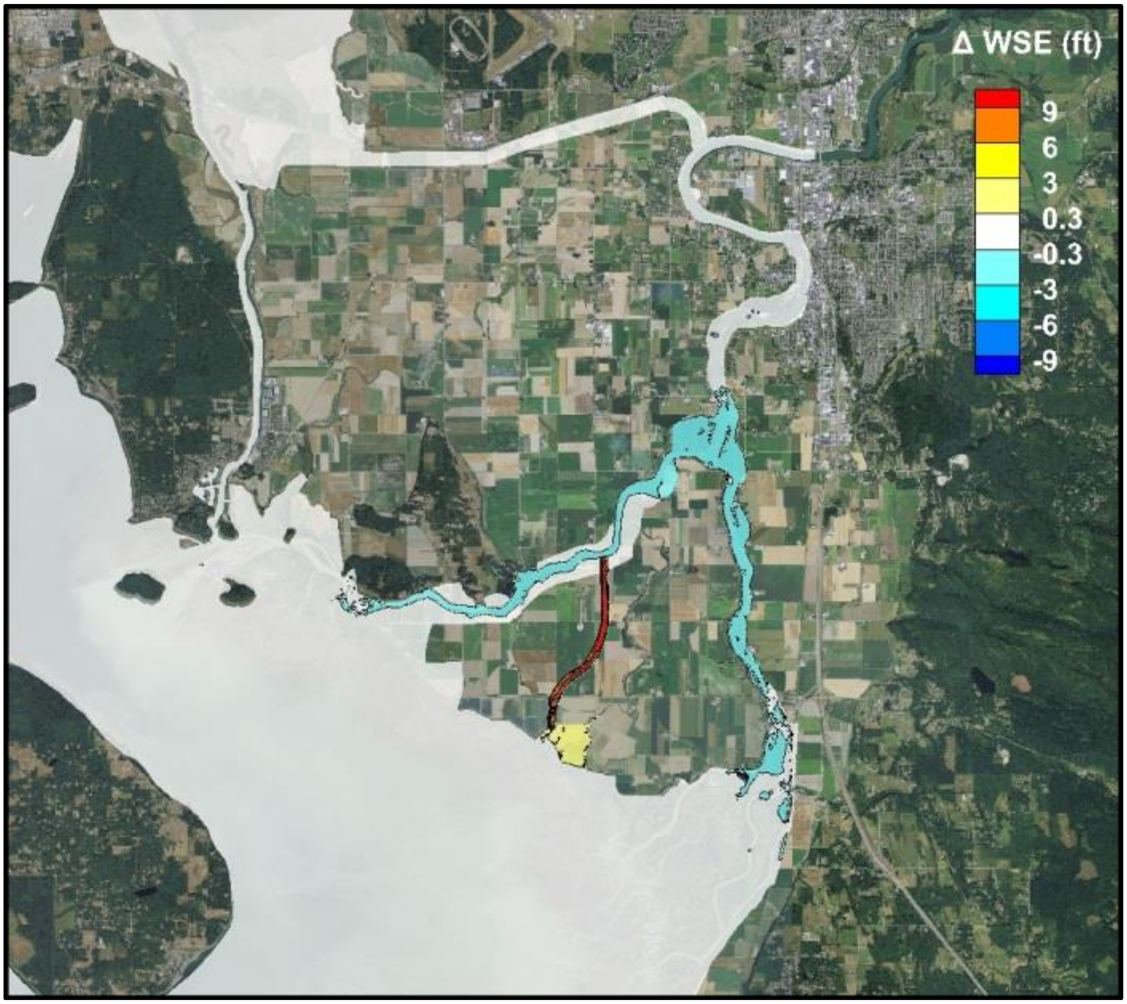
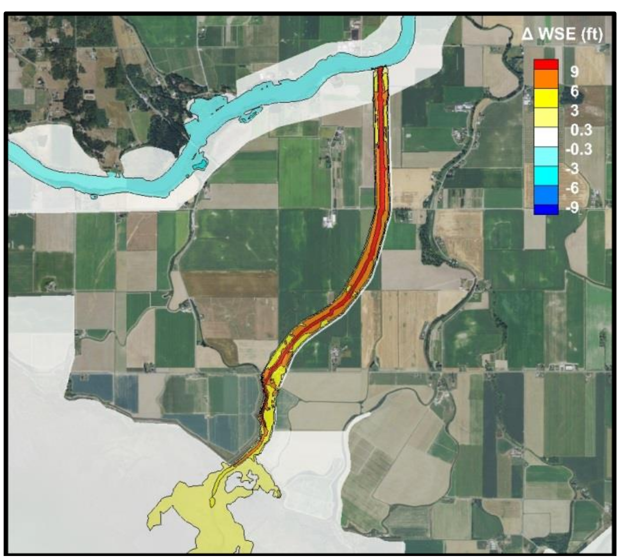


Figure C.9. Contour map of change in WSE from the Baseline to Cross Island Connector simulation with flood flow and high tide.



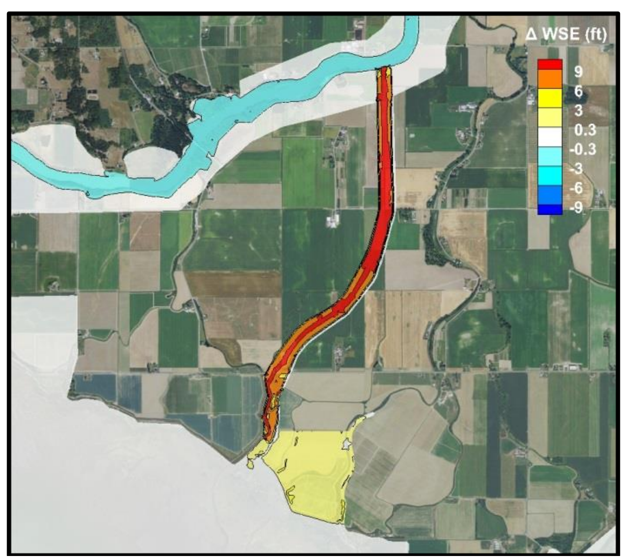


Figure C.10. Contour map of change in WSE from the Baseline simulation for Cross Island Connector with Q2 flow and low tide (left) and flood flow and high tide (right).

C.7 Major Hydraulic Project: Cross Island Connector Deliverable 7

Deliverable 7 is a set of contour maps showing the change in bed shear stress between the Baseline Simulation (Simulation 0) and the Major Hydraulic Project simulation (Simulation 2). Two conditions were compared: (1) a full spring tidal cycle during a low flow (12,000 cfs) where the peak shear across the map was recorded and (2) a low spring tide (-3.3 ft) and Q2 flow (62,000 cfs), representing the change from baseline to restored conditions. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure C.11 through Figure C.13.

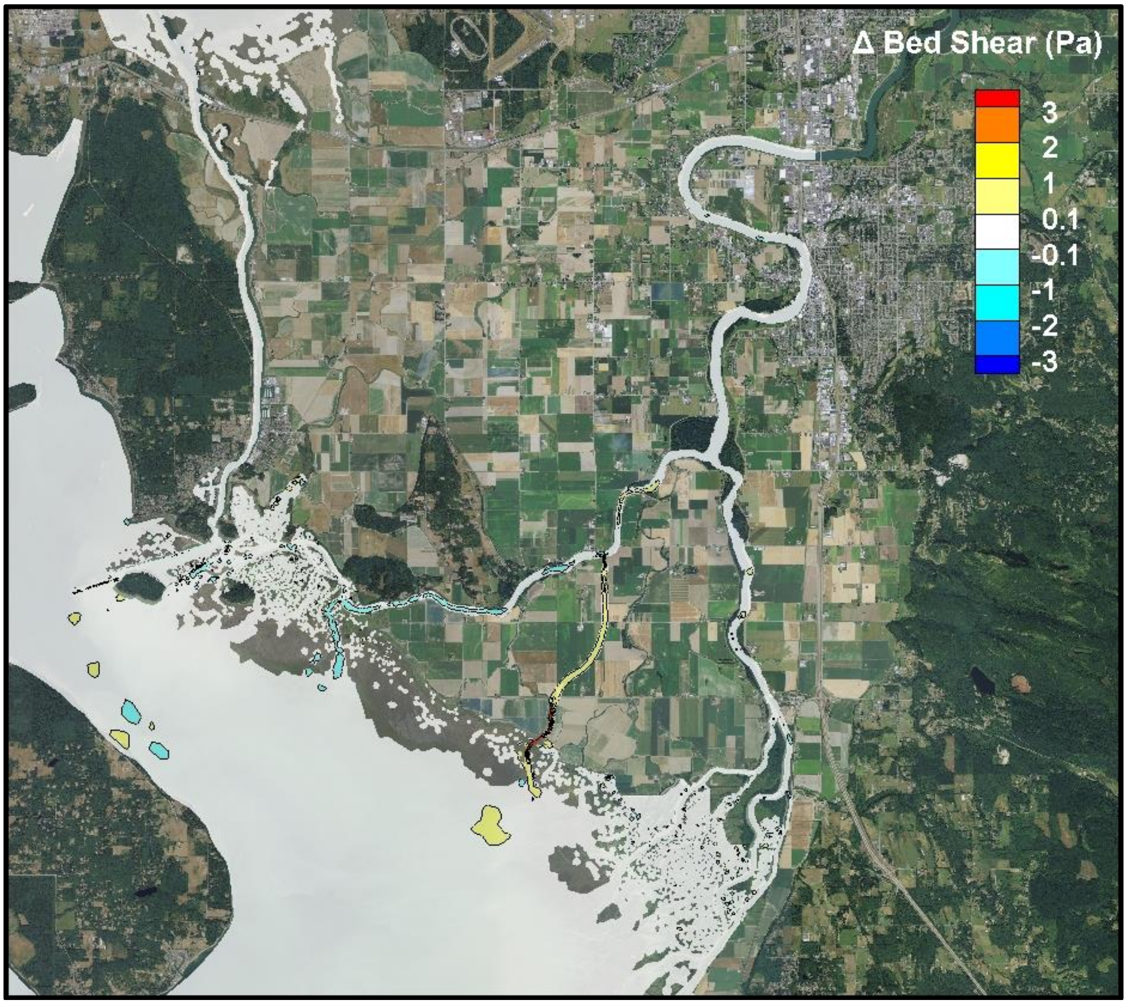


Figure C.11. Contour map of change in shear stress from the Baseline to Cross Island Connector simulation with peak shear across a full tidal cycle at low flow.

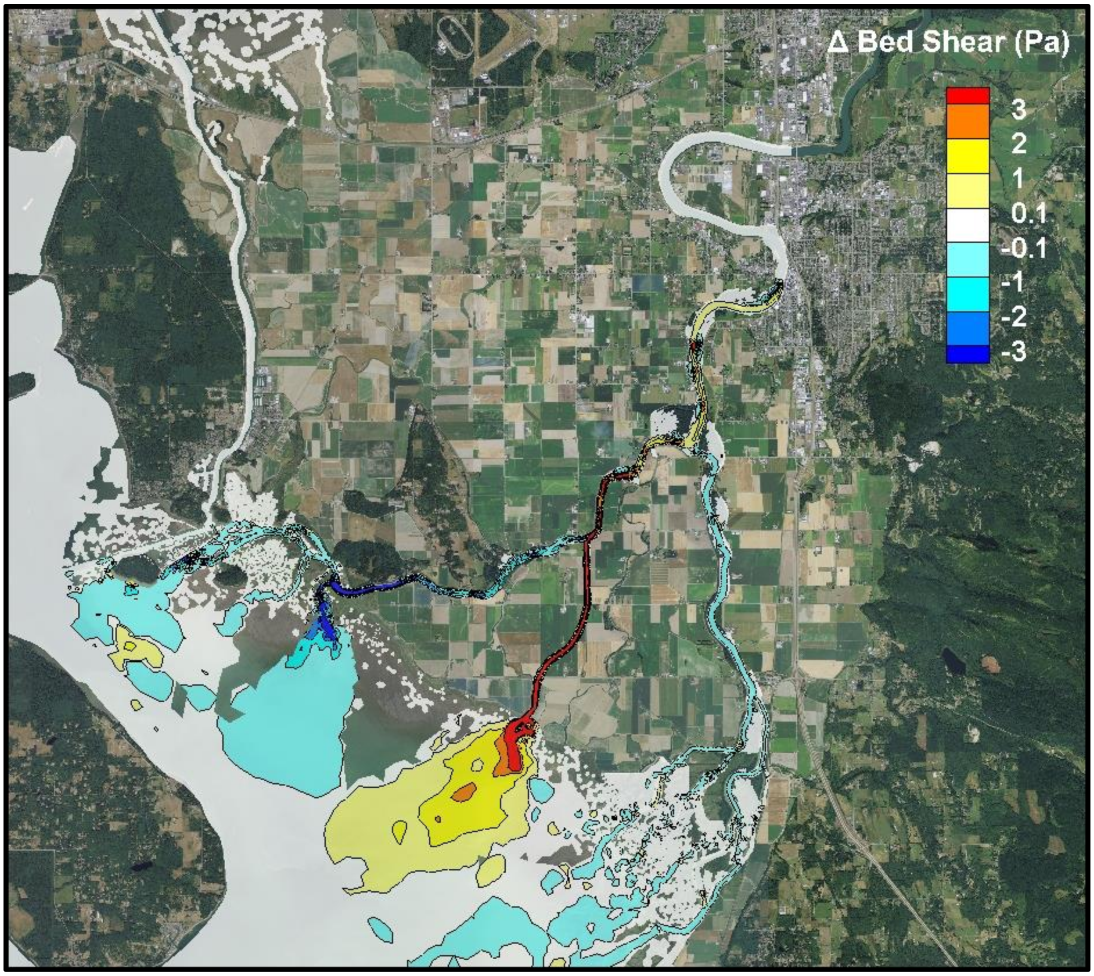


Figure C.12. Contour map of change in shear stress from the Baseline to Cross Island Connector simulation with Q2 flow and low tide.

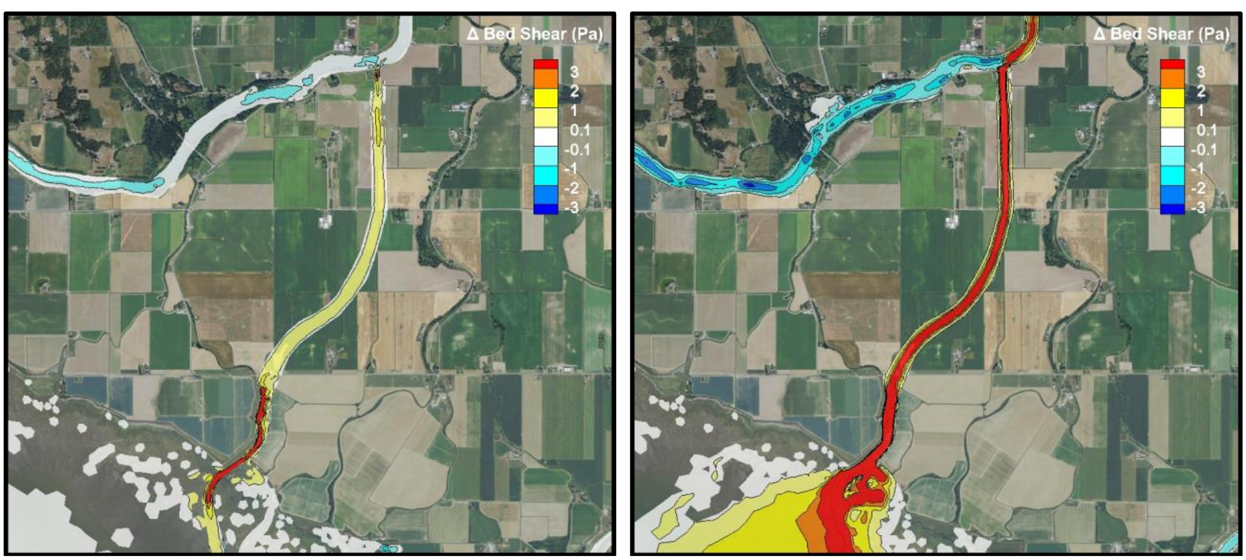


Figure C.13. Contour map of change in shear stress from the Baseline simulation for Cross Island Connector with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

C.8 Major Hydraulic Project: Cross Island Connector Deliverable 8

Deliverable 8 is a set of contour maps showing the change in salinity between the Baseline Simulation (Simulation 0) and the Major Hydraulic Project simulation (Simulation 2). The compared conditions were a low flow (12,000 cfs) and high spring tide (10.8 ft), representing the change from baseline to restored conditions. The compared salinity values represent an average of the bottom 10% of the water depth to show the furthest extent of the salt wedge. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. Changes in salinity could affect habitat suitability, the distribution of fish, and have potential effects on agriculture. The maps can be seen in Figure C.14 through Figure C.15.

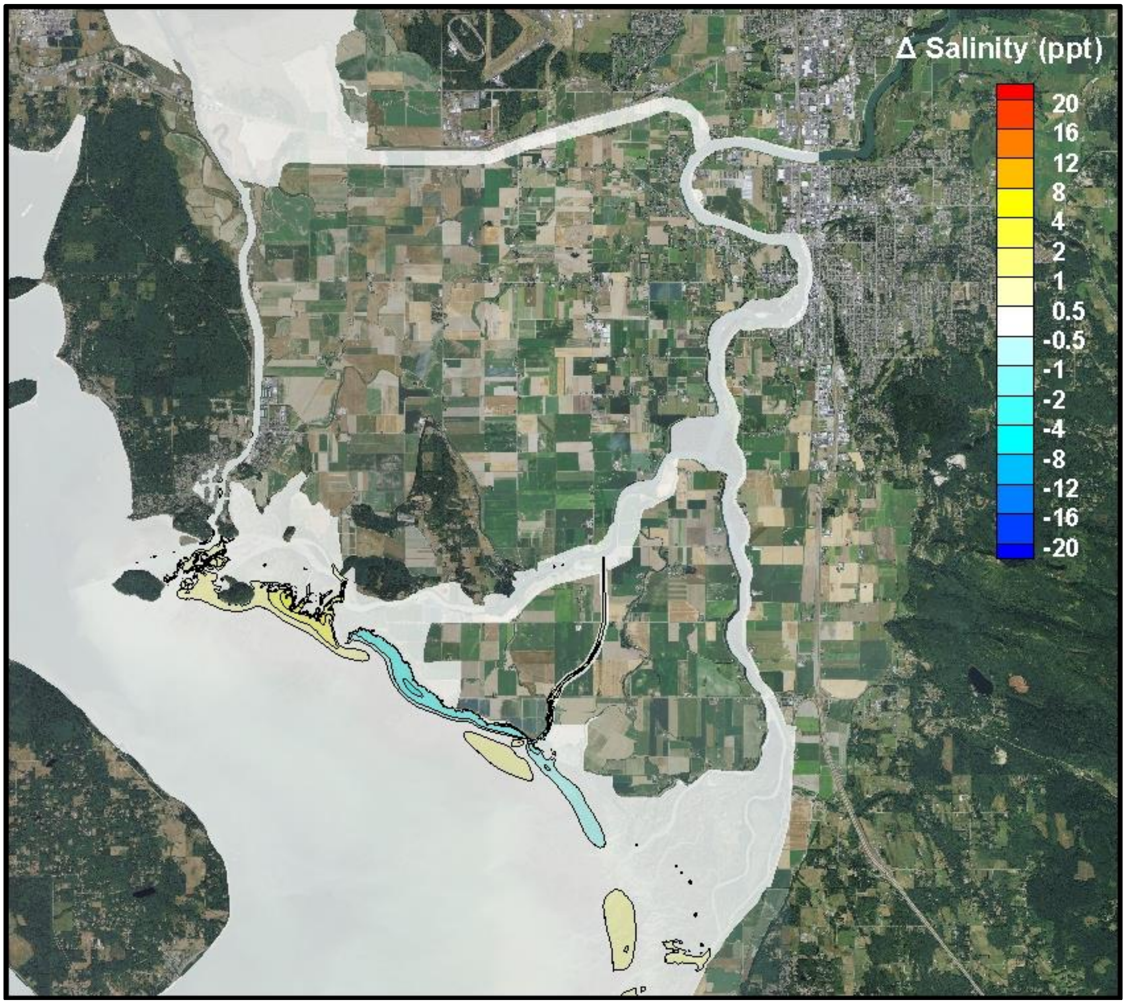


Figure C.14. Contour map of change in salinity from the Baseline to Cross Island Connector simulation with low flow and high tide.

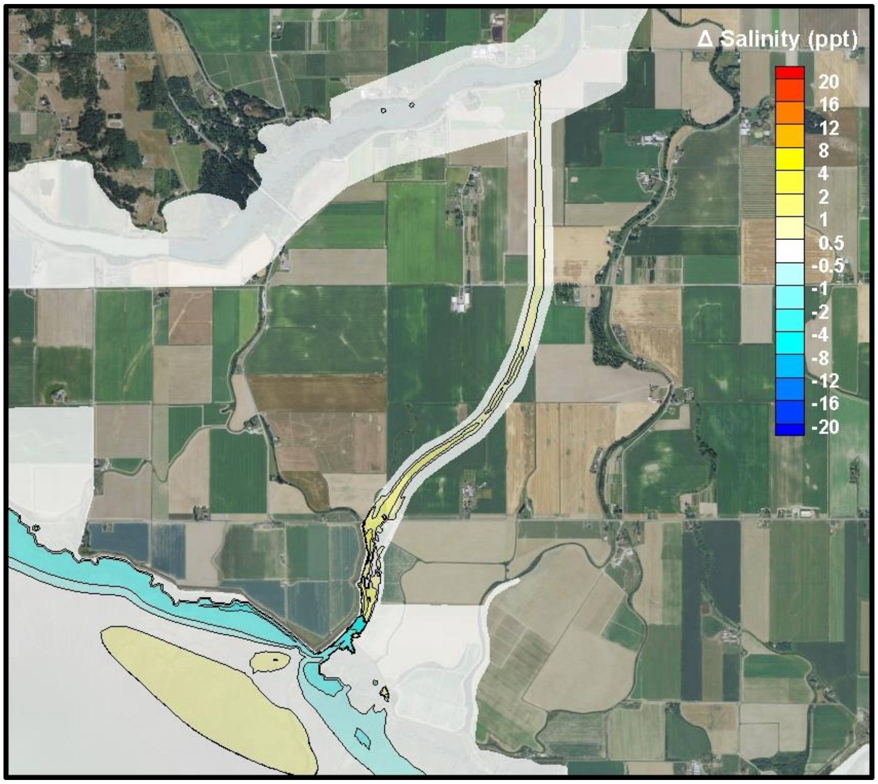


Figure C.15. Contour map of change in salinity from the Baseline to Cross Island Connector simulation for Cross Island Connector with low flow and high tide.

C.9 Major Hydraulic Project: Cross Island Connector Deliverable 9

Deliverable 9 is a set of plots that compare water surface elevation and flow between the Baseline Simulation and the Major Hydraulic Project simulation, plotting all time steps during the entire 7-month simulation from November 2, 2014 through May 29, 2015. Plots are provided for the North Fork, South Fork, Freshwater Slough, and Steamboat Slough gauge locations. Flow was computed at a cross section bisecting the gauge locations. An Excel file was also generated to provide the WSE and flow information at the gauge locations. The maps can be seen in Figure C.16 through Figure C.19.

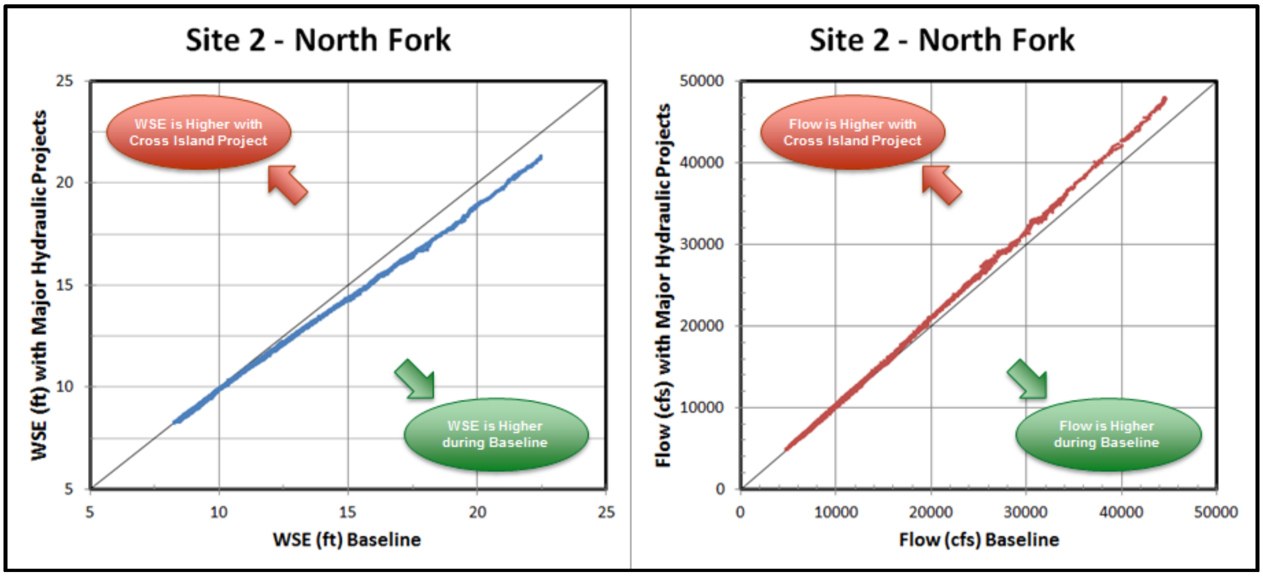


Figure C.16. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Hydraulic Project simulation at the North Fork gauge location compared with the same information under baseline conditions.

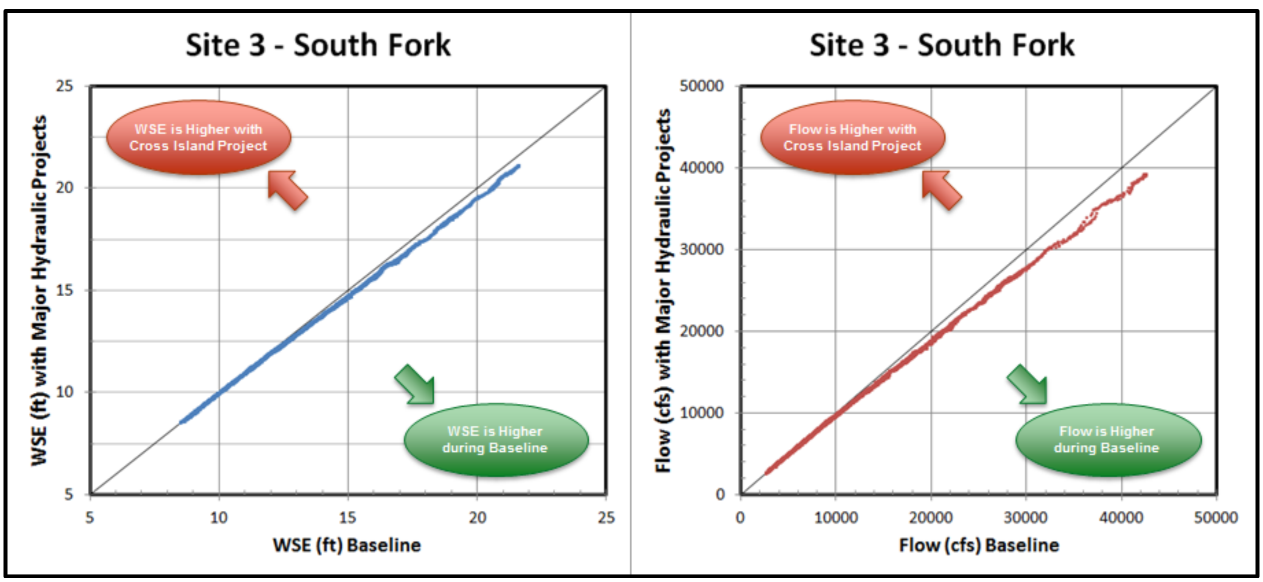


Figure C.17. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Hydraulic Project simulation at the South Fork gauge location compared with the same information under baseline conditions.

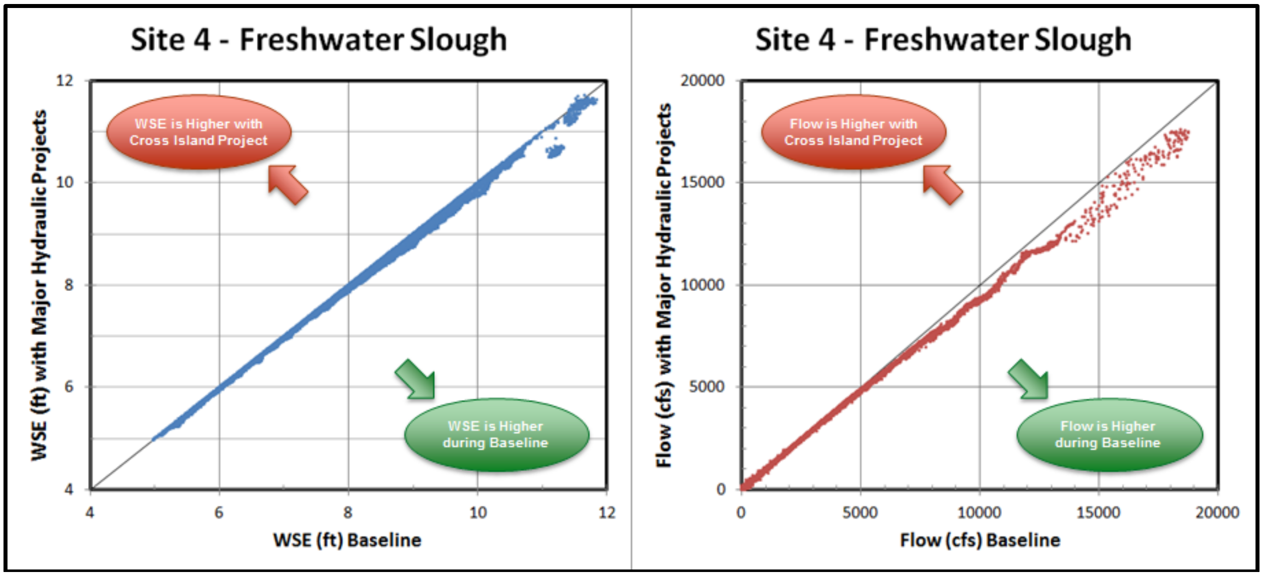


Figure C.18. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Hydraulic Project simulation at the Freshwater Slough gauge location compared with the same information under baseline conditions.

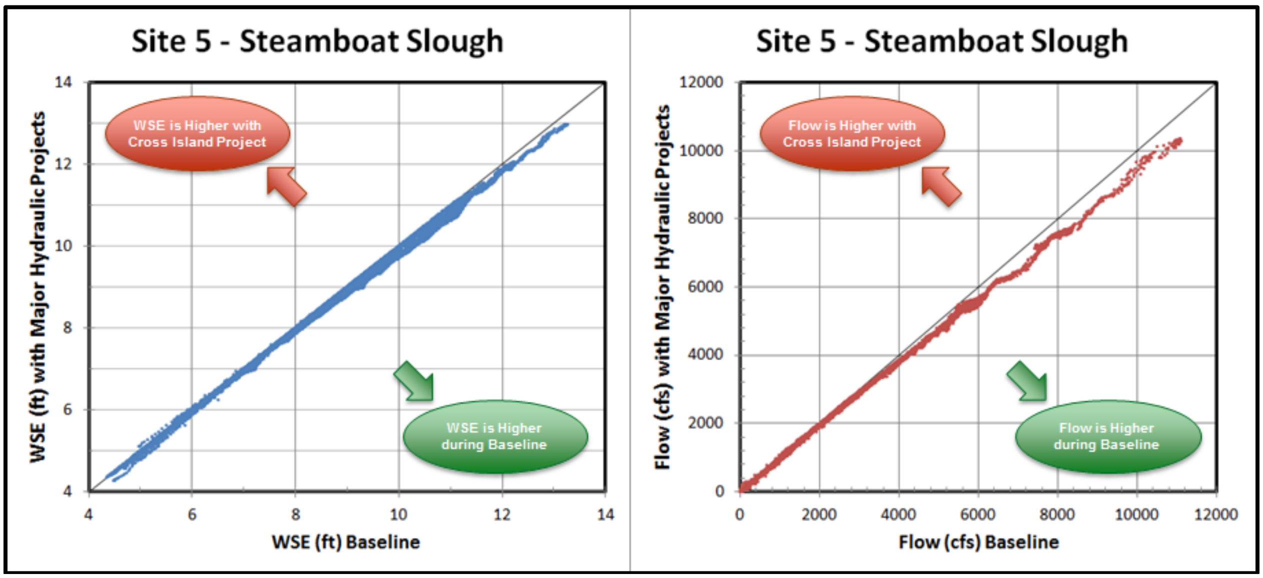


Figure C.19. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Hydraulic Project simulation at the Steamboat Slough gauge location compared with the same information under baseline conditions.

Appendix D

Simulation 3: Major Hydraulic Project: Avon-Swinomish Bypass Deliverables

Appendix D

Simulation 3: Major Hydraulic Project: Avon-Swinomish Bypass Deliverables

The following list of deliverables is associated with Simulation 3: Avon-Swinomish Bypass (Figure D.1). These deliverables were created by the SHDM Team to address specific objectives for the alternative analysis (Friebel et al., in preparation).

1. Table entries showing the change in area subject to natural tidal and riverine processes for each sub-basin in the study area during Avon-Swinomish Bypass (Simulation 3).

2. Table entries showing the change in area subject to natural tidal and riverine processes for Avon-Swinomish Bypass (Simulation 3). Because of error with wetted area calculations, high resolution, georeferenced maps showing the depth of inundation under (1) low flow and high tide and (2) Q2 flow and low tide were also provided (not shown).

3. At points in the main channel and bay front selected by the SHDM Team, cumulative frequency of WSE (for the months of March, April, and May). An Excel file of the data associated with the plot data was also provided (not shown).

4. Contour maps showing water depth for Avon-Swinomish Bypass (Simulation 3) during (1) mean river discharge for the month of May and spring high tide. High-resolution, georeferenced map was also provided (not shown).

5. Histograms of water depth with 1 ft bins at Avon-Swinomish Bypass (Simulation 3) during (1) mean river discharge for the month of May and high spring tide.

6. Contour maps showing change in WSE from baseline (Simulation 0) to Avon-Swinomish Bypass (Simulation 3) during (1) Q2 flow and low spring tide and (2) a flood condition and high tide. High-resolution, georeferenced maps were also provided, including (3) low flow and high spring tide and absolute WSE for all three conditions (not shown).

7. Contour maps showing change in bed shear stress from baseline (Simulation 0) to Avon-Swinomish Bypass (Simulation 3) during (1) low flow and the peak shear stress during a full tidal cycle and (2) Q2 flow and low spring tide. High-resolution, georeferenced maps were also provided, including absolute bed shear stress for both conditions (not shown).

8. Plots of change in WSE and flow from baseline (Simulation 0) to Avon-Swinomish Bypass (Simulation 3) for the South Fork, North Fork, Freshwater Slough, and Steamboat Slough to determine the basin effects. An Excel file of the data associated with the plots was also provided.

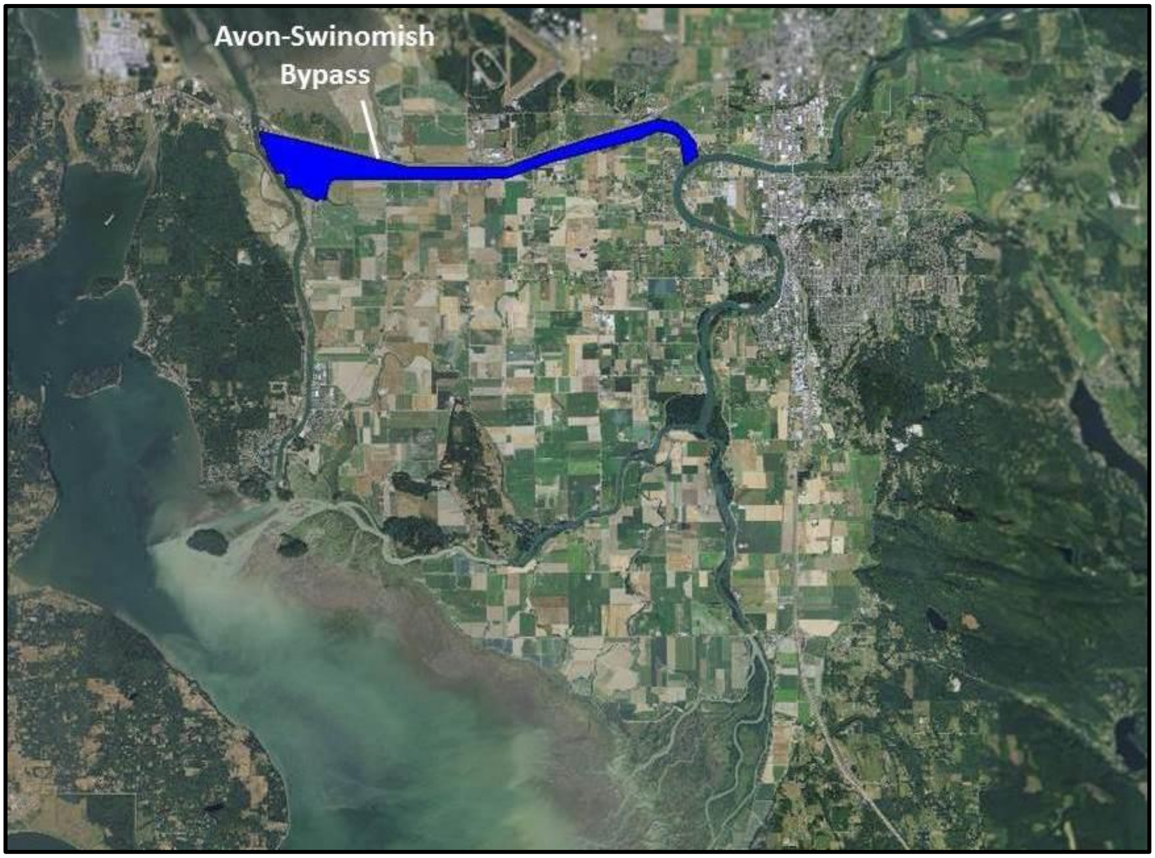


Figure D.1. A map of project area in the Major Hydraulic Project simulation: Avon-Swinomish Bypass.

D.1 Major Hydraulic Project: Avon-Swinomish Bypass Deliverable 1

For this deliverable, the area was divided into sub-basins, as seen in Figure D.2. Deliverable 1 is a table showing the increase in inundation area subject to natural tidal and riverine processes within each sub-basin, as seen in Table D.1. The accuracy of area calculation is limited by the spatial resolution of the triangular grid, which varies throughout the model domain. A node is considered wet when the model calculated water depth exceeds the minimum wetting and drying criteria of 10 cm (0.3281 ft). For any wetted node included in the project boundary polygon, its associated computational area was counted toward the total inundated area.

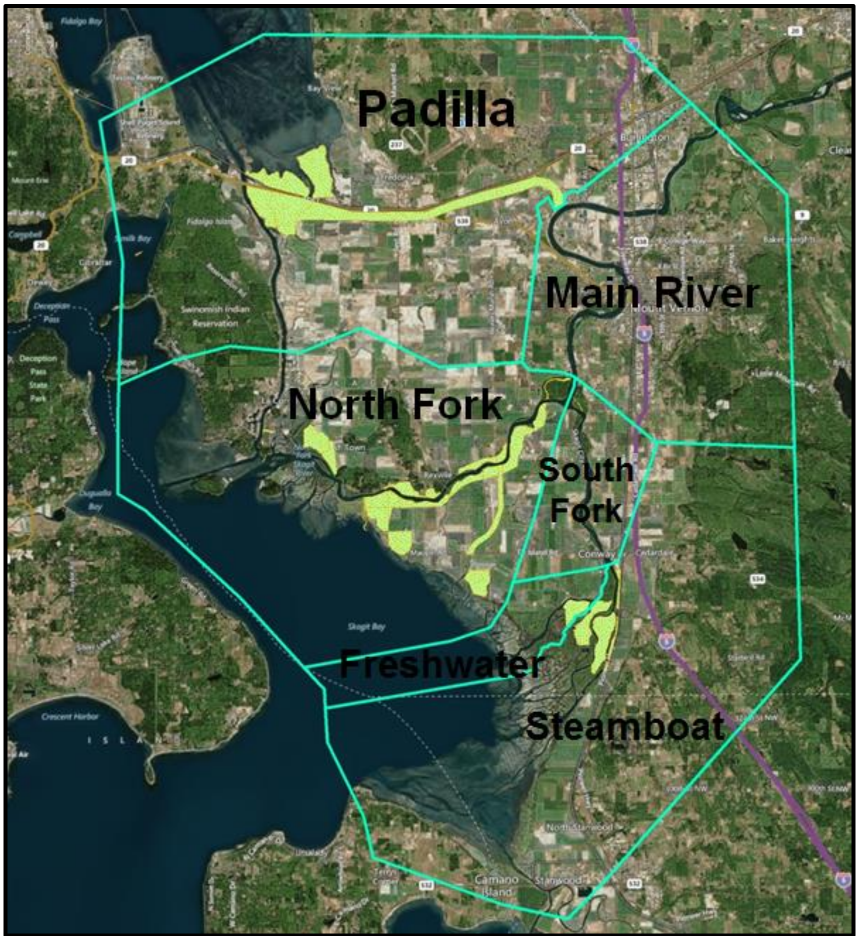


Figure D.2. Sub-basins within the Skagit region used for area calculations.

Table D.1. Table entry showing area increase for each sub-basin under tidal and riverine conditions during the Major Hydraulic Project Avon-Swinomish Bypass simulation.

Sub-basin	Baseline (acres)	With Projects (acres)	Increase in Area (acres)
Tidal Influence: High Spring Tide (10.8 ft) + Low Flow (12,000 cfs)			
Sum	20,256.9	21,151.7	**894.8**
Main River	7.8	5.3	**-2.5**
North Fork	8,330.6	8,330.6	**0.0**
South Fork	30.0	30.0	**0.0**
Freshwater	1,944.6	1,944.6	**0.0**
Steamboat	5,827.3	5,827.3	**0.0**
Padilla	4,116.8	5,014.0	**897.2**

Riverine Influence: Low Spring Tide (-3.3 ft) + Q2 Flow (62,000 cfs)			
Sum	7,921.4	8,125.3	**203.9**
Main River	159.0	98.0	**-61.0**
North Fork	2,998.2	2,460.0	**-538.2**
South Fork	171.8	106.6	**-65.2**
Freshwater	1,065.1	961.8	**-103.3**
Steamboat	2,640.2	2,345.6	**-294.6**
Padilla	887.0	2,153.4	**1,266.4**

D.2 Major Hydraulic Project: Avon-Swinomish Bypass Deliverable 2

Deliverable 2 is a table showing the increase in inundation area subject to natural tidal and riverine processes within each project area, as seen in Table D.2. Inundation area is counted only within the project footprint. The same limitations and definition of an inundated cell apply here as with Deliverable 1.

Table D.2. Table entry showing area increase for each project under tidal and riverine conditions during the Major Hydraulic Project Avon-Swinomish Bypass simulation. Measurements correspond to a measured area that differs from the true project footprint because of grid resolution.

Project (measured area)	Baseline (acres)	With Projects (acres)	Increase in Area (acres)
Tidal Influence: High Spring Tide (10.8 ft) + Low Flow (12,000 cfs)			
Avon-Swinomish Bypass (**1,318.2 acres**)	17.9	921.7	**903.8**
Riverine Influence: Low Spring Tide (-3.3 ft) + Q2 Flow (62,000 cfs)			
Avon-Swinomish Bypass (**1,318.2 acres**)	17.9	1,222.3	**1,204.4**

D.3 Major Hydraulic Project: Avon-Swinomish Bypass Deliverable 3

Deliverable 3 is a set of cumulative frequency plots showing water surface elevation at a point in the main channel or Bayfront near each project site. These are from the spring months of the Major Hydraulic Project simulation (Simulation 3), representing March 1 – May 22, 2015, a time period chosen to coincide with the primary fish outmigration. A red mark line was provided with every point to represent an approximation of the average elevation of the project area bed. All WSE values are relative to the NAVD88 datum. An Excel file was also generated with WSE at each node location. The plots can be seen in Figure D.3 and Figure D.4.

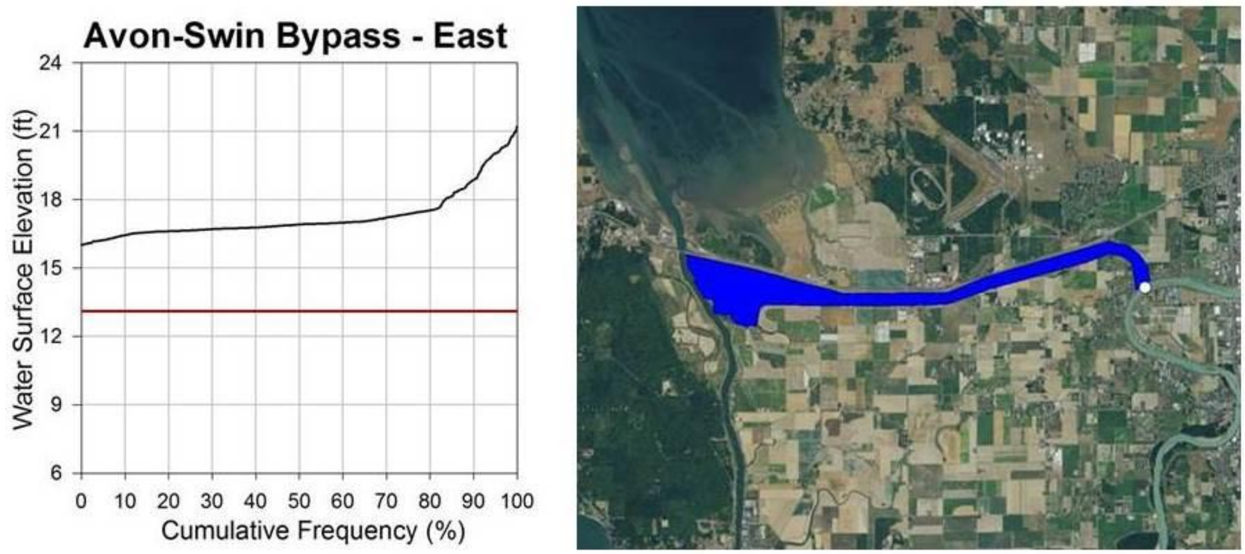


Figure D.3. Cumulative frequency plot and corresponding map for Avon-Swinomish Bypass (east) during the Major Hydraulic Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

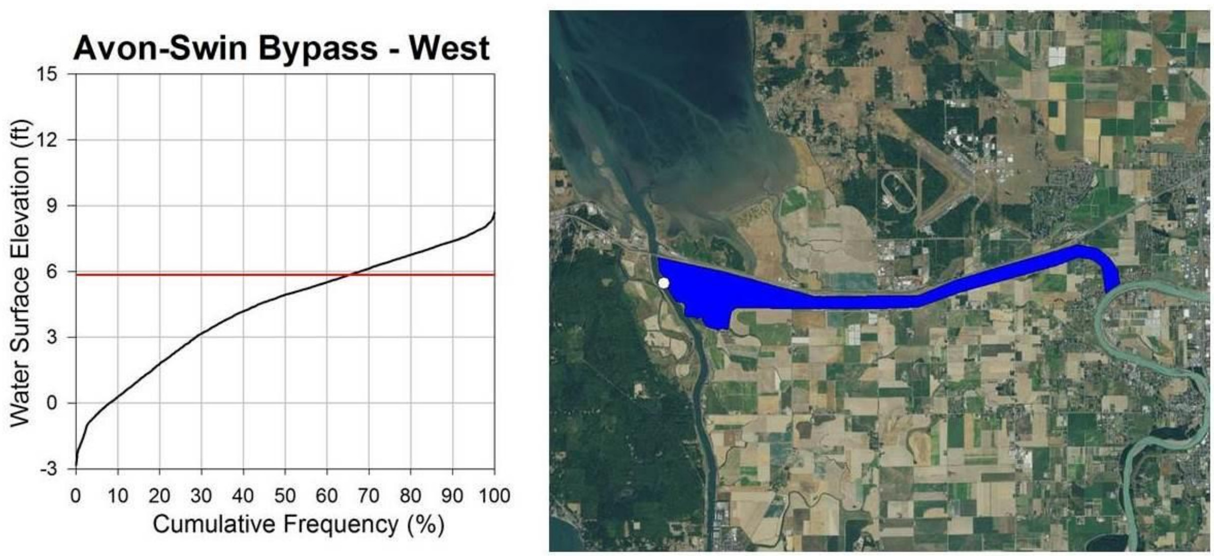


Figure D.4. Cumulative frequency plot and corresponding map for Avon-Swinomish Bypass (west) during the Major Hydraulic Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

D.4 Major Hydraulic Project: Avon-Swinomish Bypass Deliverable 4

Deliverable 4 is a set of contour maps showing the depths of inundation during the Major Hydraulic Project simulation (Simulation 3). The plotted condition was the mean river discharge for the month of May (20,400 cfs) and high spring tide (10.8 ft). All depth values are relative to model bathymetry, which uses linear interpolation to the resolution of the grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure D.5 and Figure D.6.

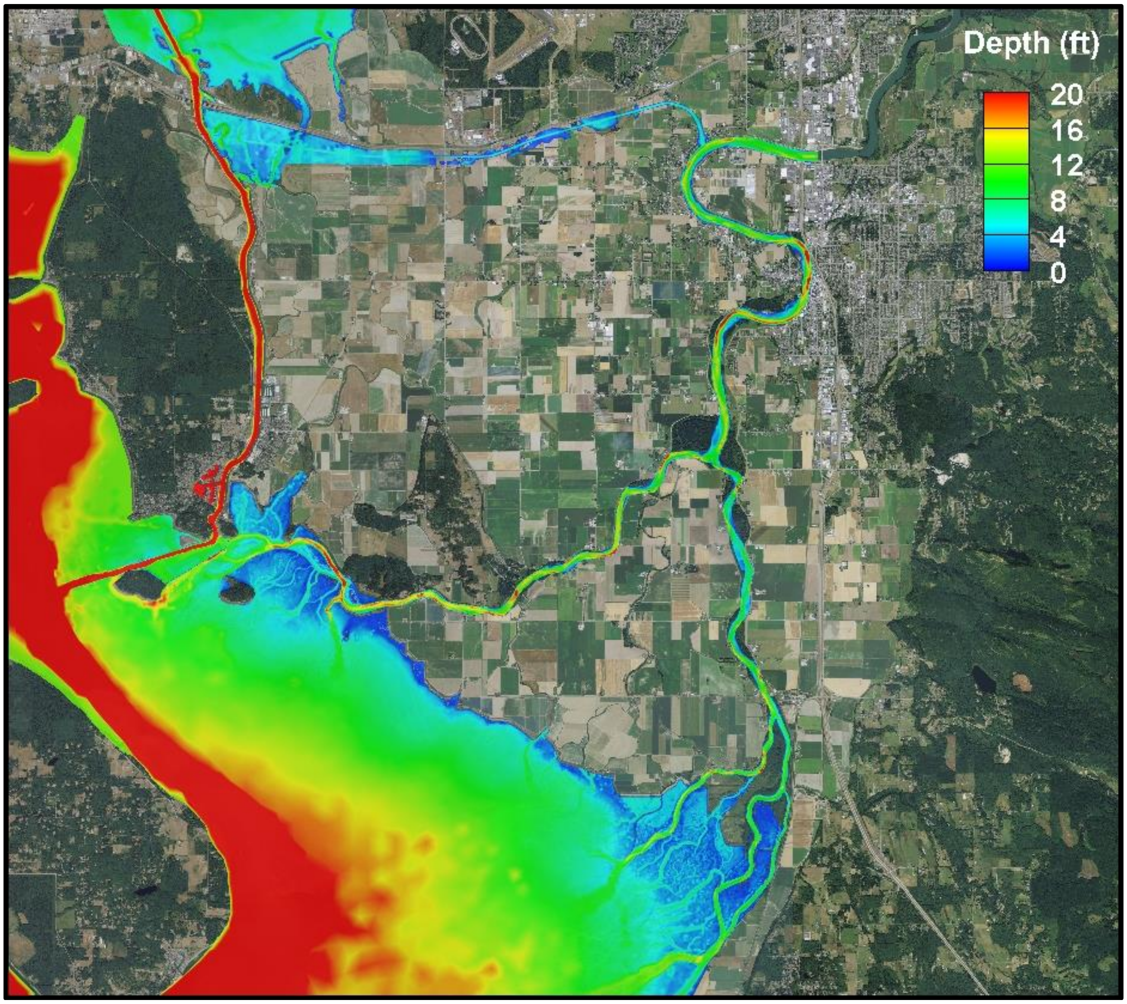


Figure D.5. Contour map of depths for the full domain during the Major Hydraulic Project Avon-Swinomish ByPass simulation with May flow and high spring tide.

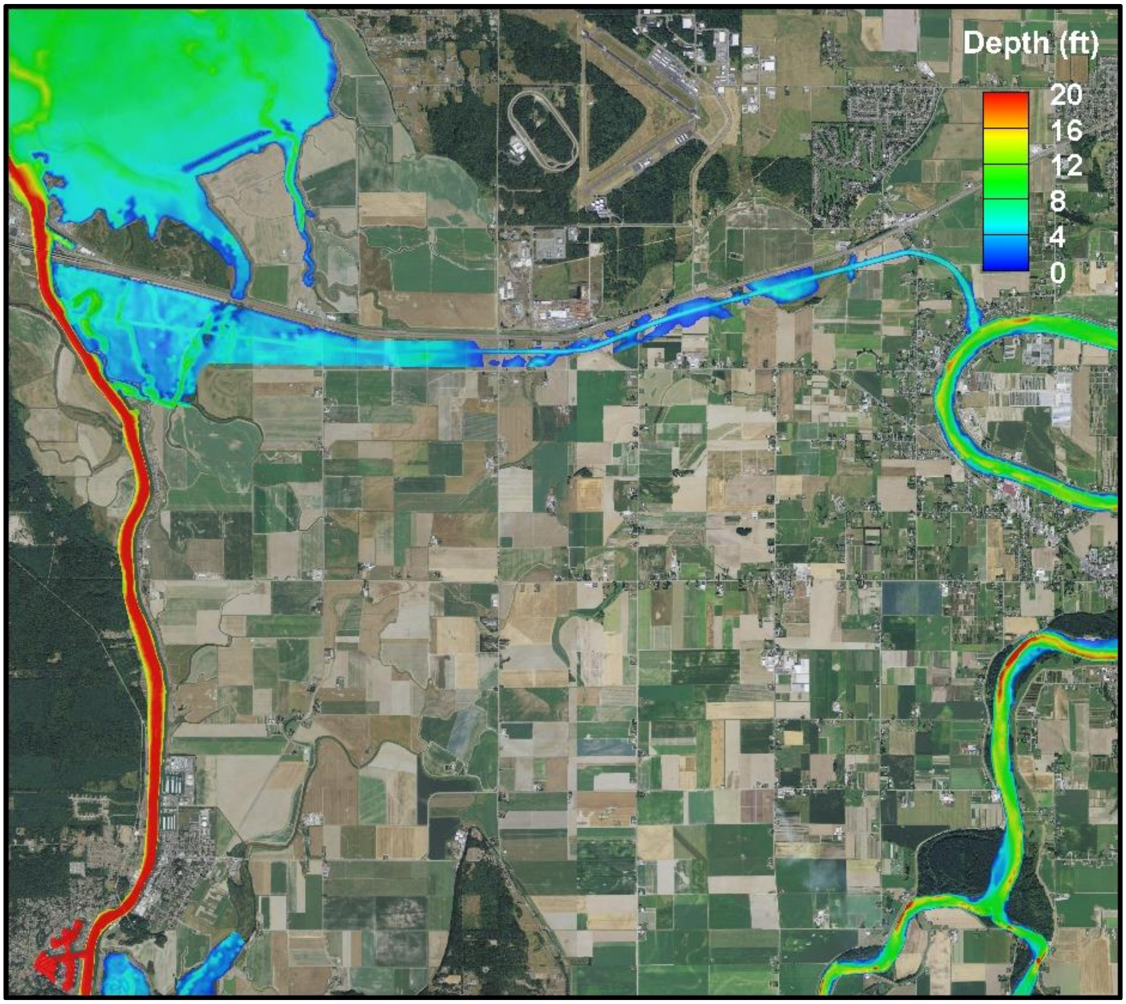


Figure D.6. Contour map of depths for Avon-Swinomish Bypass during the Major Hydraulic Project simulation.

D.5 Major Hydraulic Project: Avon-Swinomish Bypass Deliverable 5

Deliverable 5 is a set of histograms showing the distribution of water depths in 1 ft bins across each project site during a high spring tide (10.8 ft) and mean river discharge for the month of May (20,400 cfs), the same conditions corresponding to the maps of Deliverable 4. All depth values are relative to model bathymetry, which uses linear interpolation to the resolution of the grid. The histogram can be seen in Figure D.7.

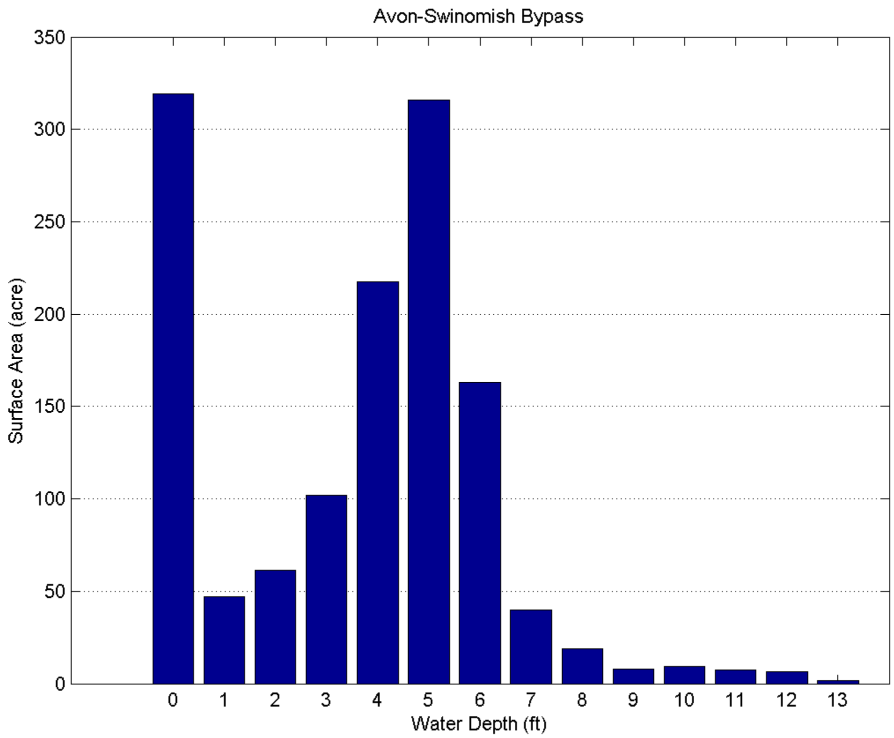


Figure D.7. Histogram of depths for Avon-Swinomish Bypass.

D.6 Major Hydraulic Project: Avon-Swinomish Bypass Deliverable 6

Deliverable 6 is a set of contour maps showing the change in water surface elevation between the Baseline Simulation (Simulation 0) and the Major Hydraulic Project simulation (Simulation 3). Two conditions were compared: (1) a low spring tide (-3.3 ft) and Q2 flow (62,000 cfs) and (2) a high spring tide (10.4 ft) and a flood condition (93,200 cfs), representing the change from baseline to restored conditions. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure D.8 through Figure D.10.

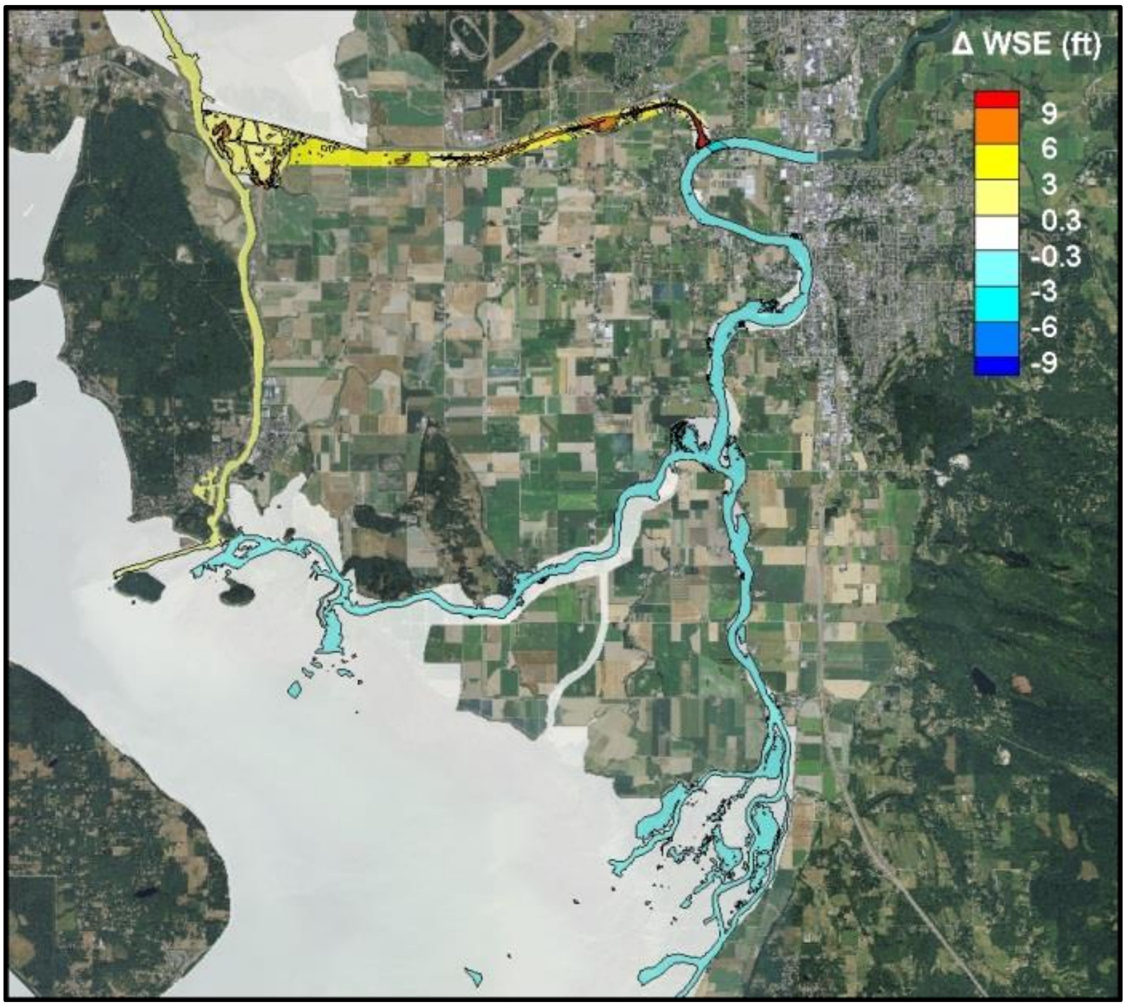


Figure D.8. Contour map of change in WSE from the Baseline to Avon-Swinomish Bypass simulation with Q2 flow and low tide.

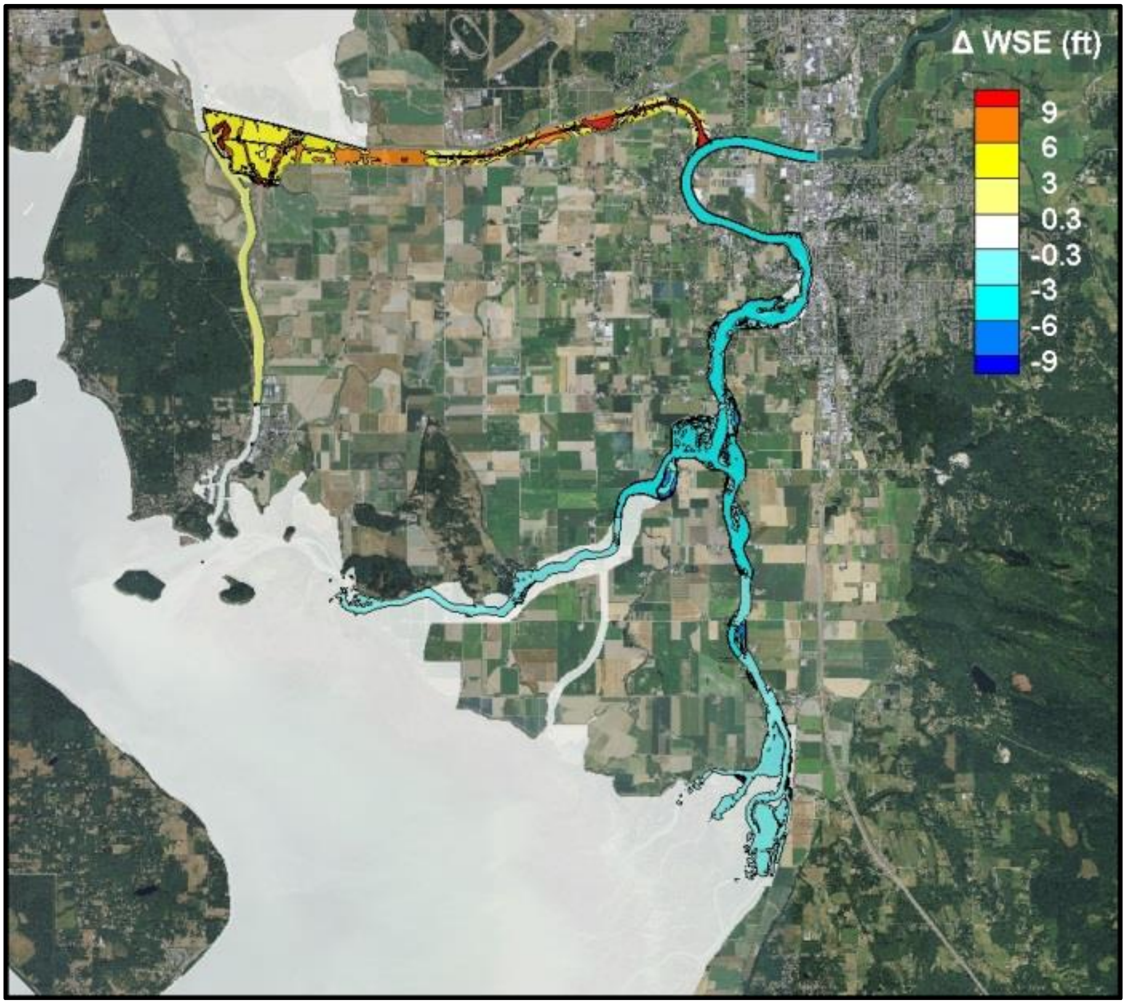


Figure D.9. Contour map of change in WSE from the Baseline to Avon-Swinomish Bypass simulation with flood flow and high tide.

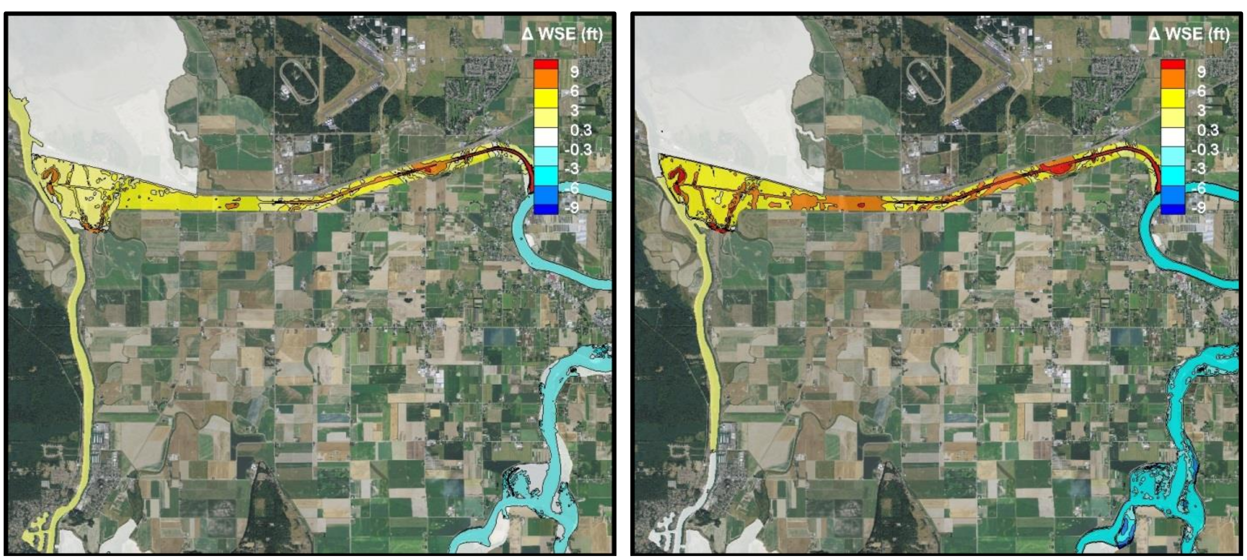


Figure D.10. Contour map of change in WSE from the Baseline simulation for Avon-Swinomish Bypass with Q2 flow and low tide (left) and flood flow and high tide (right).

D.7 Major Hydraulic Project: Avon-Swinomish Bypass Deliverable 7

Deliverable 7 is a set of contour maps showing the change in bed shear stress between the Baseline Simulation (Simulation 0) and the Major Hydraulic Project simulation (Simulation 3). Two conditions were compared: (1) a full spring tidal cycle during a low flow (12,000 cfs) where the peak shear across the map was recorded and (2) a low spring tide (-3.3 ft) and Q2 flow (62,000 cfs), representing the change from baseline to restored conditions. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure D.11 through Figure D.13.

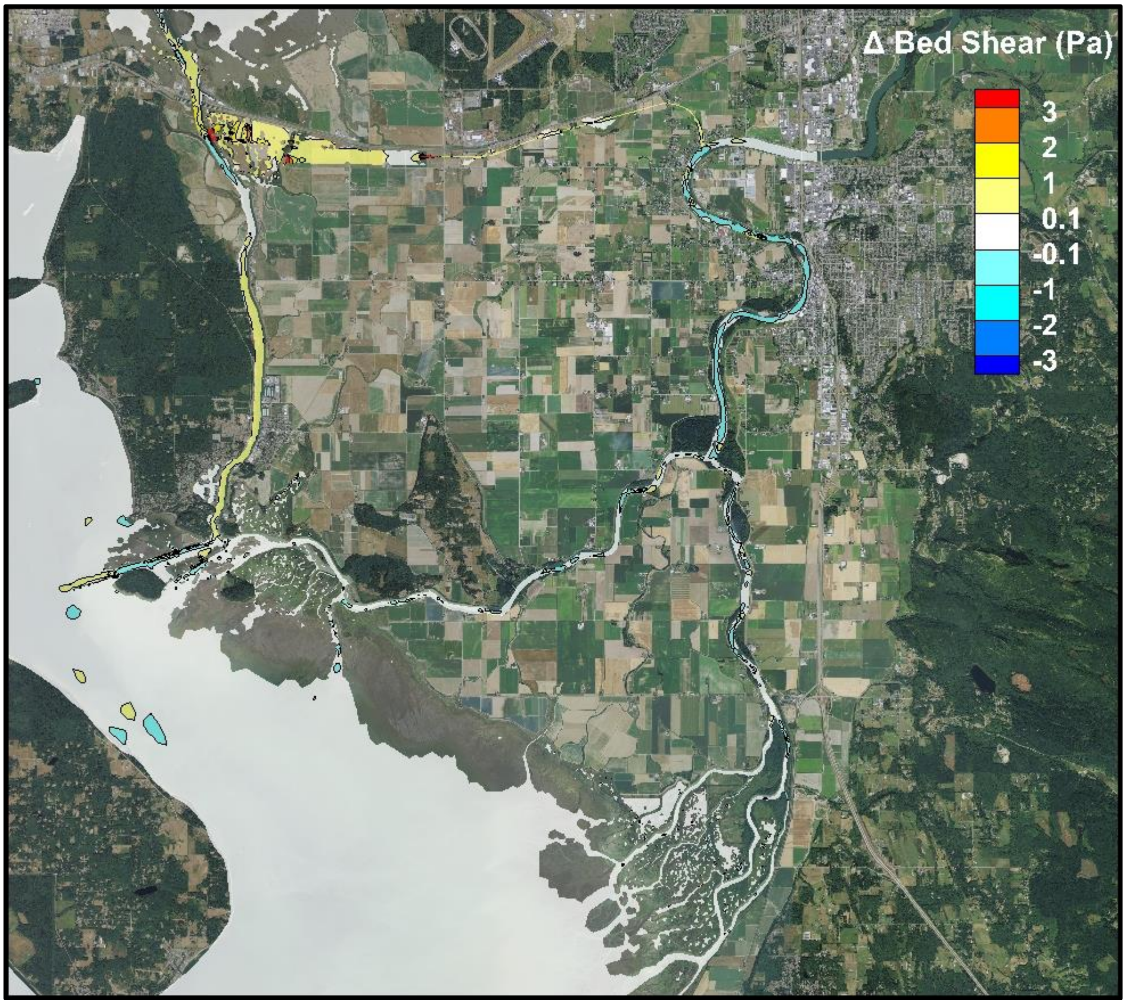


Figure D.11. Contour map of change in shear stress from the Baseline to Avon-Swinomish Bypass simulation with peak shear across a full tidal cycle at low flow.

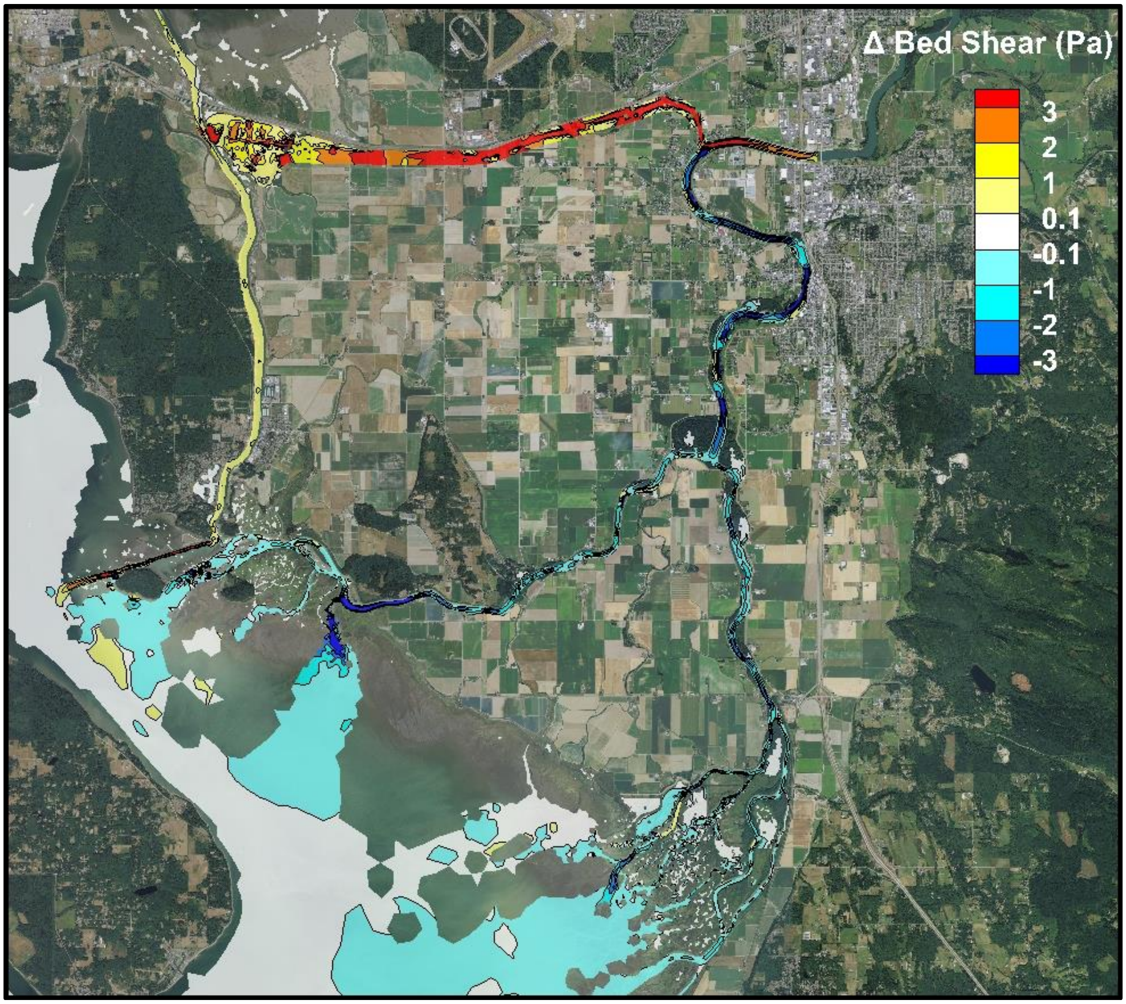


Figure D.12. Contour map of change in shear stress from the Baseline to Avon-Swinomish Bypass simulation with Q2 flow and low tide.

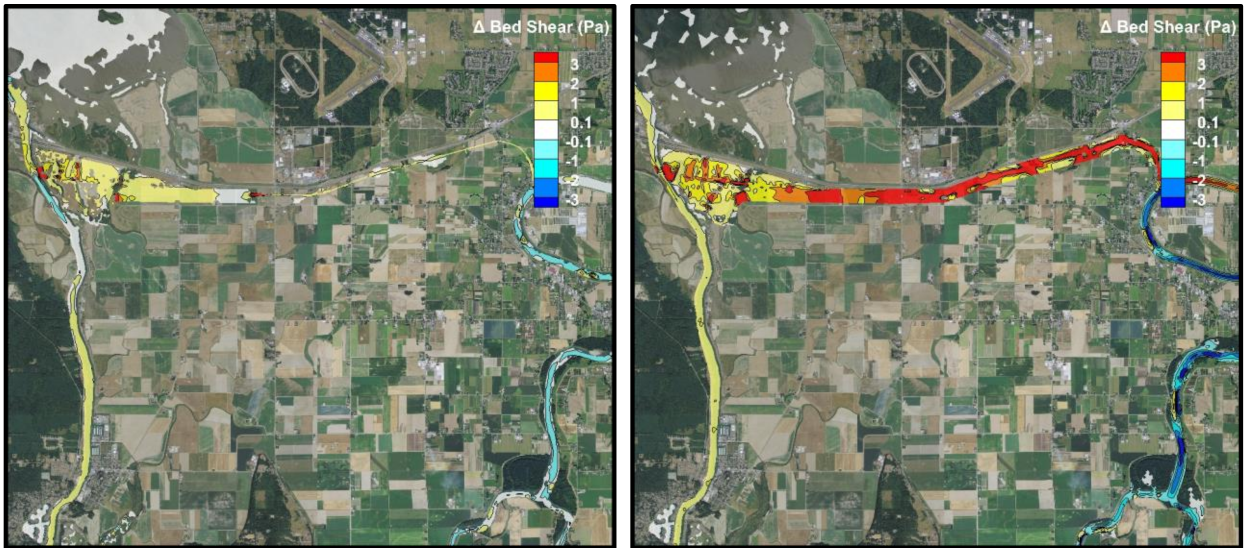


Figure D.13. Contour map of change in shear stress from the Baseline simulation for Avon-Swinomish Bypass with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

D.8 Major Hydraulic Project: Avon-Swinomish Bypass Deliverable 8

Deliverable 8 is a set of plots that compare water surface elevation and flow between the Baseline Simulation and the Major Hydraulic Project simulation, plotting all time steps during the entire 7-month simulation from November 2, 2014 through May 29, 2015. Plots are provided for the North Fork, South Fork, Freshwater Slough, and Steamboat Slough gauge locations. Flow was computed at a cross section bisecting the gauge locations. An Excel file was also generated to provide the WSE and flow information at the gauge locations. The maps can be seen in Figure D.14 through Figure D.17.

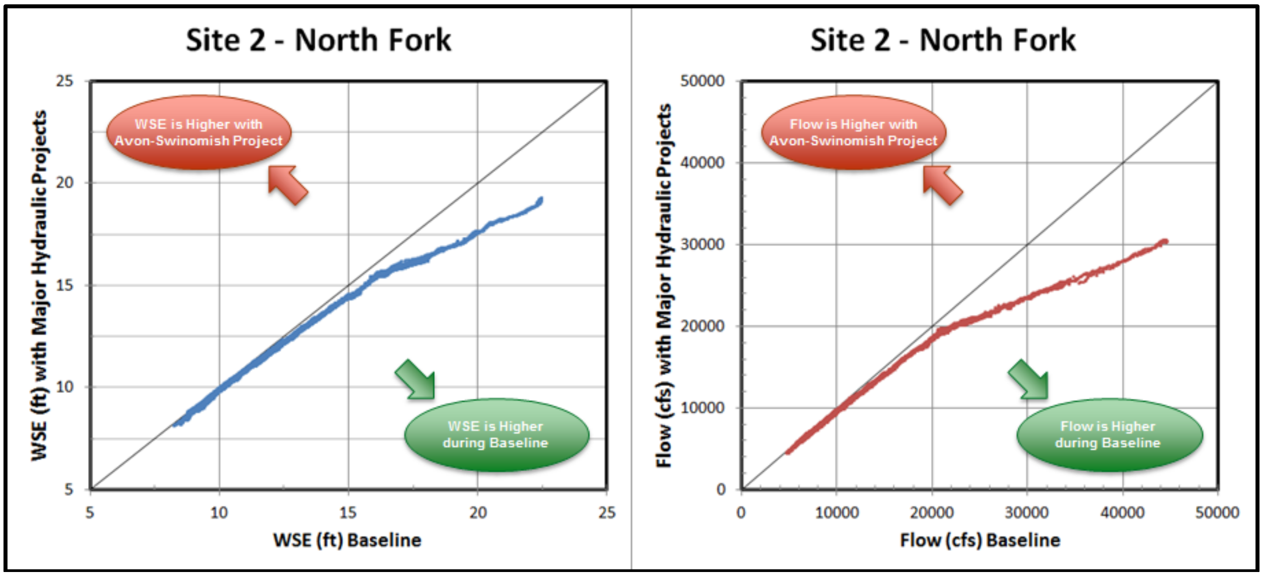


Figure D.14. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Hydraulic Project simulation at the North Fork gauge location compared with the same information under baseline conditions.

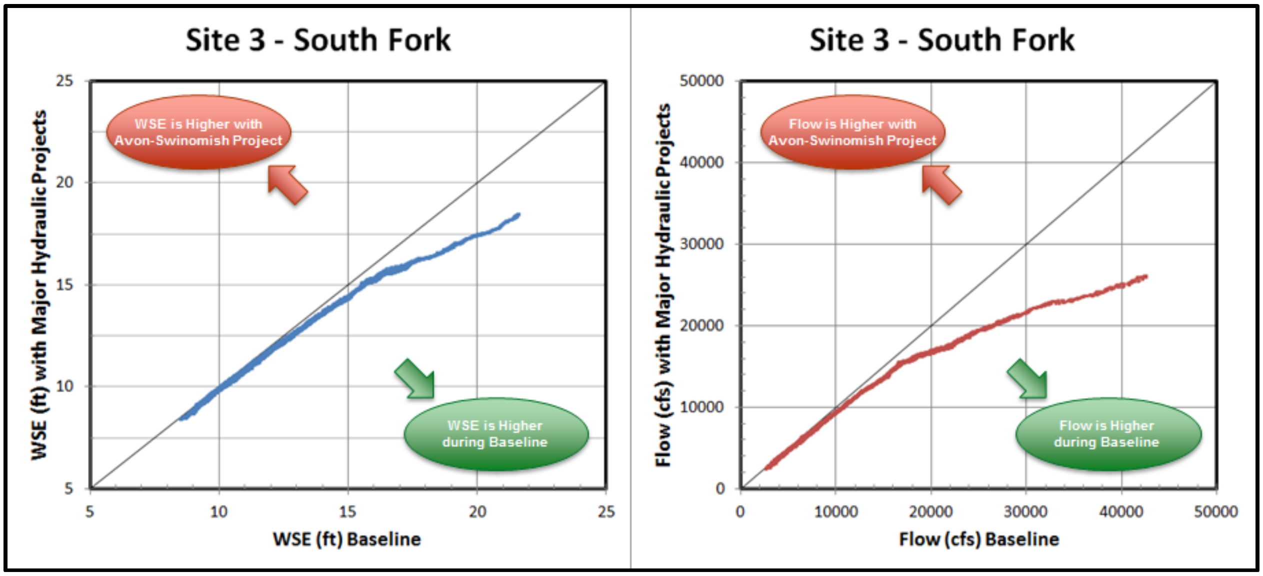


Figure D.15. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Hydraulic Project simulation at the South Fork gauge location compared with the same information under baseline conditions.

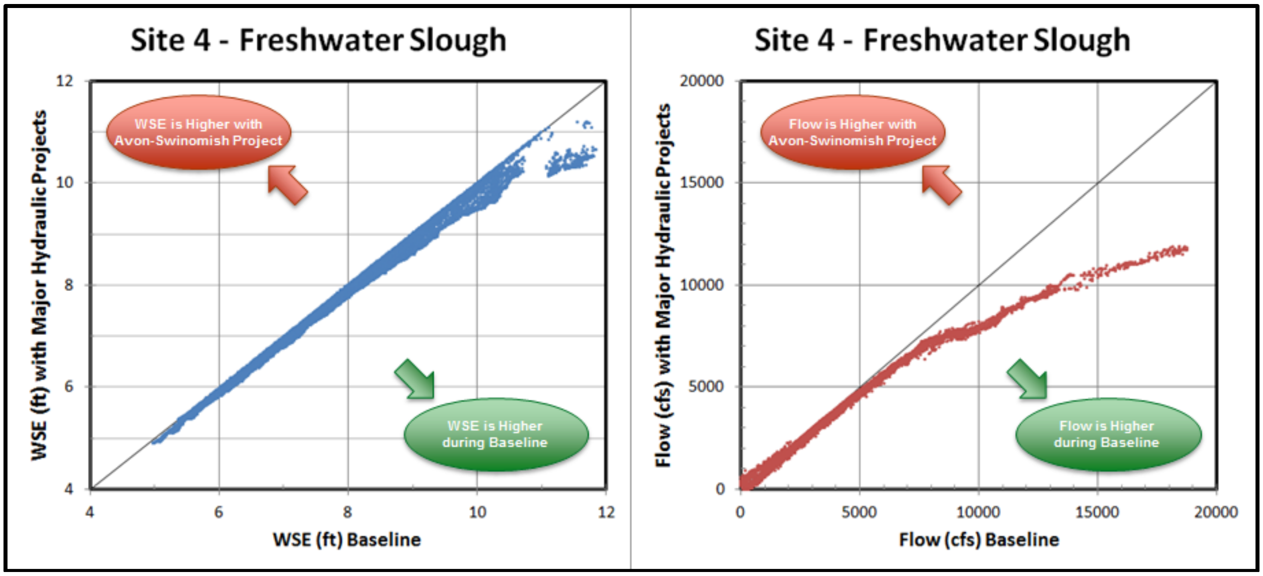


Figure D.16. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Hydraulic Project simulation at the Freshwater Slough gauge location compared with the same information under baseline conditions.

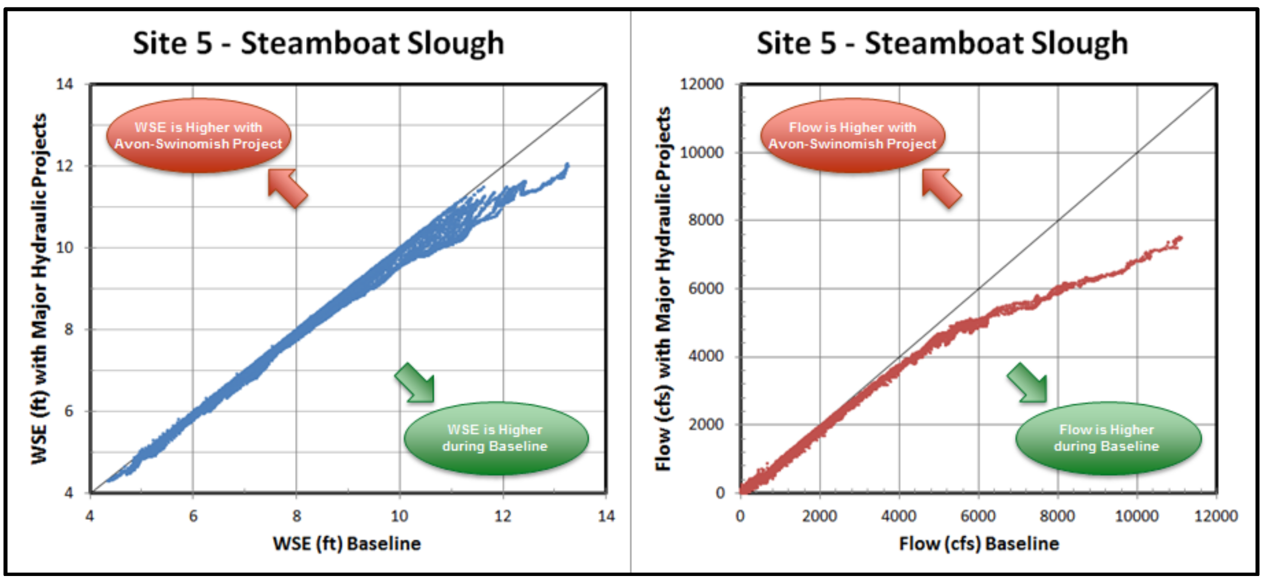


Figure D.17. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Hydraulic Project simulation at the Steamboat Slough gauge location compared with the same information under baseline conditions.

Appendix E

Simulation 4: Major Setback Project: North Fork Levee Setback C Deliverables

Appendix E

Simulation 4: Major Setback Project: North Fork Levee Setback C Deliverables

The following list of deliverables is associated with Simulation 4: NF Levee Setback C (Figure E.1). These deliverables were created by the SHDM Team to address specific objectives for the alternative analysis (Friebel et al., in preparation).

1. Table entries showing the change in area subject to natural tidal and riverine processes for each sub-basin in the study area during NF Levee Setback C (Simulation 4).

2. Table entries showing the change in area subject to natural tidal and riverine processes for NF Levee Setback C (Simulation 4). Because of error with wetted area calculations, high resolution, georeferenced maps showing the depth of inundation under (1) low flow and high tide and (2) Q2 flow and low tide were also provided (not shown).

3. At points in the main channel and bay front selected by the SHDM Team, cumulative frequency of WSE (for the months of March, April, and May). An Excel file of the data associated with the plot data was also provided (not shown).

4. Contour maps showing water depth for NF Levee Setback C (Simulation 4) during (1) mean river discharge for the month of May and spring high tide. High-resolution, georeferenced map was also provided (not shown).

5. Histograms of water depth with 1 ft bins at NF Levee Setback C (Simulation 4) during (1) mean river discharge for the month of May and high spring tide.

6. Contour maps showing change in WSE from baseline (Simulation 0) to NF Levee Setback C (Simulation 4) during (1) Q2 flow and low spring tide and (2) a flood condition and high tide. High-resolution, georeferenced maps were also provided, including (3) low flow and high spring tide and absolute WSE for all three conditions (not shown).

7. Contour maps showing change in bed shear stress from baseline (Simulation 0) to NF Levee Setback C (Simulation 4) during (1) low flow and the peak shear stress during a full tidal cycle and (2) Q2 flow and low spring tide. High-resolution, georeferenced maps were also provided, including absolute bed shear stress for both conditions (not shown).

8. Contour maps showing change in salinity from baseline (Simulation 0) to NF Levee Setback C (Simulation 4) during (1) low flow and high spring tide. High-resolution, georeferenced maps were also provided, including absolute salinity for both conditions (not shown).

9. Plots of change in WSE and flow from baseline (Simulation 0) to NF Levee Setback C (Simulation 4) for the South Fork, North Fork, Freshwater Slough, and Steamboat Slough to determine the basin effects. An Excel file of the data associated with the plots was also provided.

Figure E.1. A map of project area in the Major Setback Project simulation: NF Setback C.

E.1 Major Setback Project: NF Levee Setback C Deliverable 1

For this deliverable, the area was divided into sub-basins, as seen in Figure E.2. Deliverable 1 is a table showing the increase in inundation area subject to natural tidal and riverine processes within each sub-basin, as seen in Table E.1. The accuracy of area calculation is limited by the spatial resolution of the triangular grid, which varies throughout the model domain. A node is considered wet when the model calculated water depth exceeds the minimum wetting and drying criteria of 10 cm (0.3281 ft). For any wetted node included in the project boundary polygon, its associated computational area was counted toward the total inundated area.

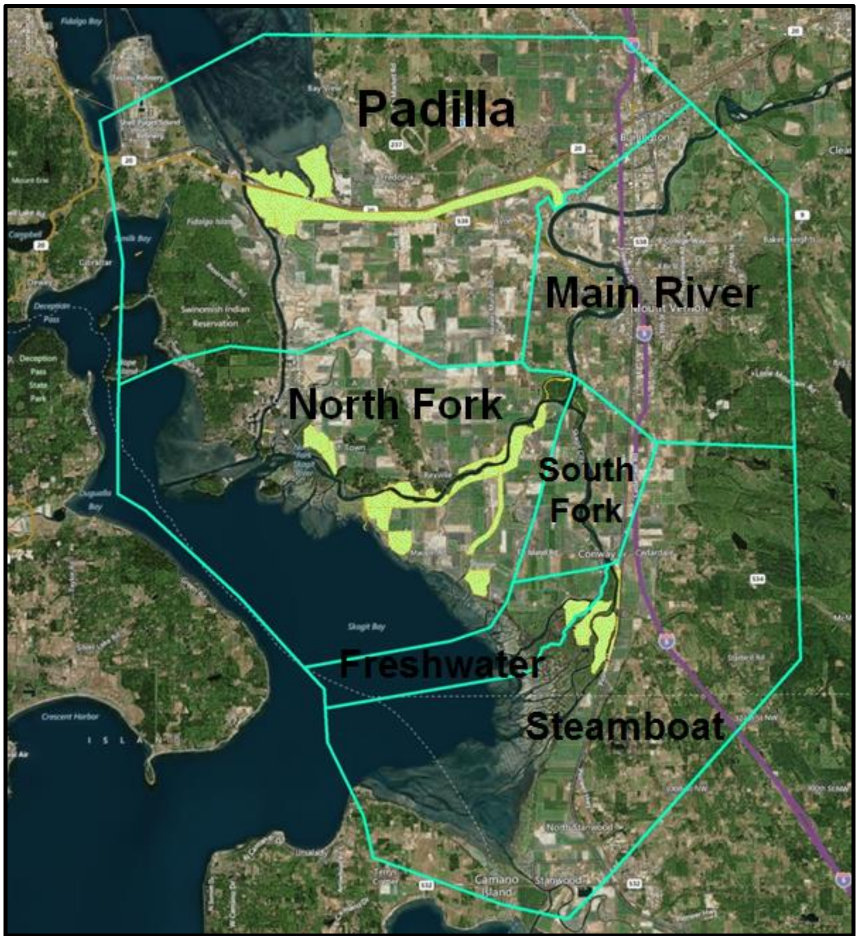


Figure E.2. Sub-basins within the Skagit region used for area calculations.

Table E.1. Table entry showing area increase for each sub-basin under tidal and riverine conditions during the Major Setback Project NF Levee Setback C simulation.

Sub-basin	Baseline (acres)	With Projects (acres)	Increase in Area (acres)
Tidal Influence: High Spring Tide (10.8 ft) + Low Flow (12,000 cfs)			
Sum	20,256.9	20,525.5	**268.6**
Main River	7.8	7.8	**0.0**
North Fork	8,330.6	8,598.7	**268.1**
South Fork	30.0	30.0	**0.0**
Freshwater	1,944.6	1,944.9	**0.3**
Steamboat	5,827.3	5,827.4	**0.1**
Padilla	4,116.8	4,116.8	**0.0**

Riverine Influence: Low Spring Tide (-3.3 ft) + Q2 Flow (62,000 cfs)			
Sum	7,921.4	8,180.0	**258.6**
Main River	159.0	155.5	**-3.5**
North Fork	2,998.2	3,198.7	**200.5**
South Fork	171.8	154.1	**-17.7**
Freshwater	1,065.1	1,067.9	**2.8**
Steamboat	2,640.2	2,714.7	**74.5**
Padilla	887.0	889.2	**2.2**

E.2 Major Setback Project: NF Levee Setback C Deliverable 2

Deliverable 2 is a table showing the increase in inundation area subject to natural tidal and riverine processes within each project area, as seen in Table E.2. Inundation area is counted only within the project footprint. The same limitations and definition of an inundated cell that apply for Deliverable 1 apply here.

Table E.2. Table entry showing area increase for each project under tidal and riverine conditions during the Major Setback Project NF Levee Setback C simulation. Measurements correspond to a measured area that differs from the true project footprint because of grid resolution.

Project (measured area)	Baseline (acres)	With Projects (acres)	Increase in Area (acres)
Tidal Influence: High Spring Tide (10.8 ft) + Low Flow (12,000 cfs)			
NF Levee Setback C (**292.5 acres**)	0.0	266.5	**266.5**
Riverine Influence: Low Spring Tide (-3.3 ft) + Q2 Flow (62,000 cfs)			
NF Levee Setback C (**292.5 acres**)	0.0	280.4	**280.4**

E.3 Major Setback Project: NF Levee Setback C Deliverable 3

Deliverable 3 is a set of cumulative frequency plots showing water surface elevation at a point in the main channel or Bayfront near each project site. These are from the spring months of the Major Setback Project simulation (Simulation 4), representing March 1 – May 22, 2015, a time period chosen to coincide with the primary fish outmigration. A red mark line was provided with every point to represent an approximation of the average elevation of the project area bed. All WSE values are relative to the NAVD88 datum. An Excel file was also generated with WSE at each node location. The plots can be seen in Figure E.3 and Figure E.4.

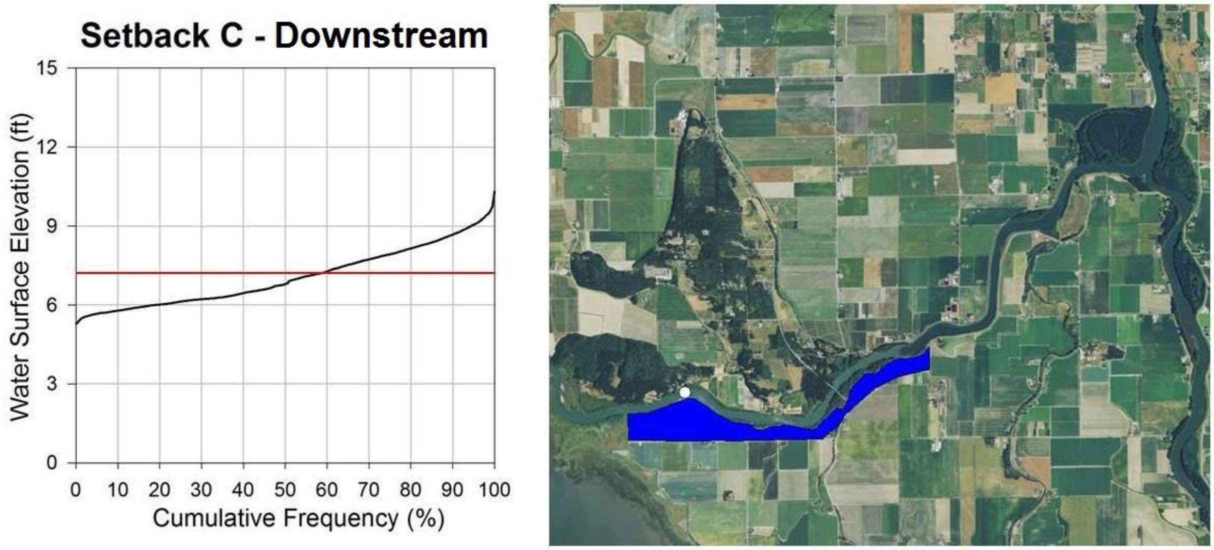


Figure E.3. Cumulative frequency plot and corresponding map for NF Levee Setback C (downstream) during the Major Setback Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

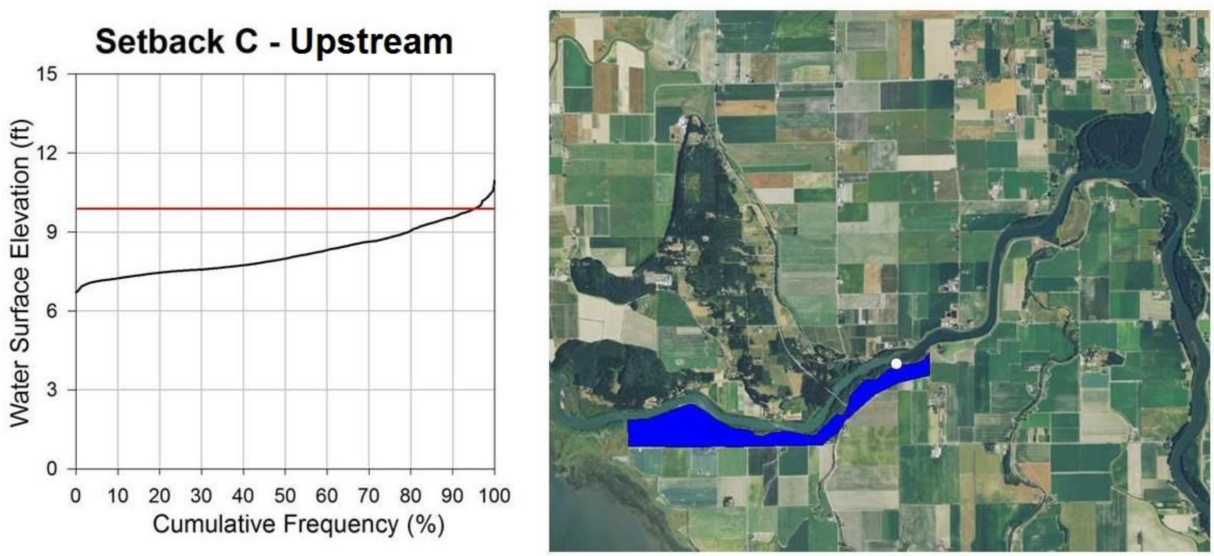


Figure E.4. Cumulative frequency plot and corresponding map for NF Levee Setback C (upstream) during the Major Setback Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

E.4 Major Setback Project: NF Levee Setback C Deliverable 4

Deliverable 4 is a set of contour maps showing the depth of inundation during the Major Setback Project simulation (Simulation 4). The plotted condition was the mean river discharge for the month of May (20,400 cfs) and high spring tide (10.8 ft). All depth values are relative to model bathymetry, which uses linear interpolation to the resolution of the grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure E.5 and Figure E.6.

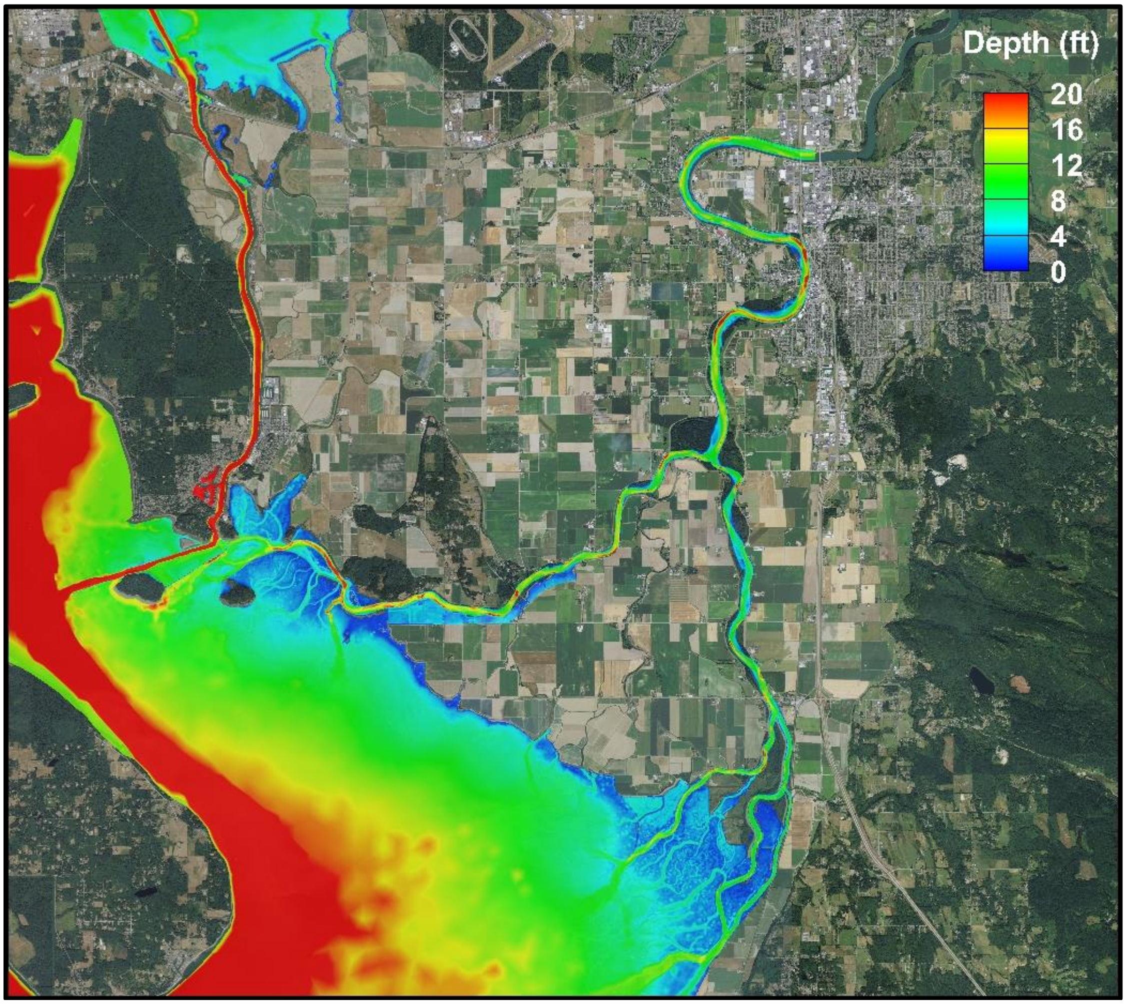


Figure E.5. Contour map of depths for the full domain during the Major Setback Project North Fork Levee Setback C simulation with May flow and high spring tide.

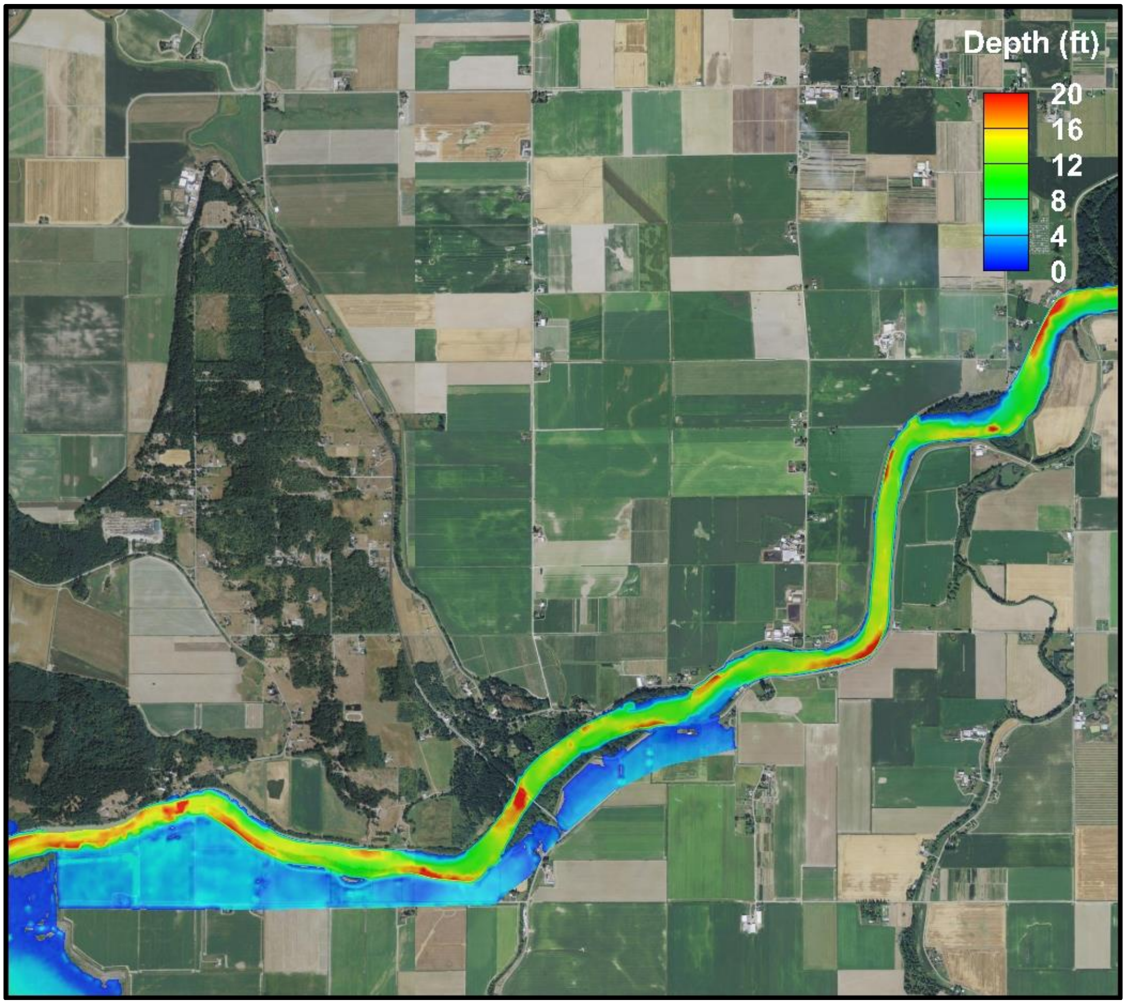


Figure E.6. Contour map of depths for NF Levee Setback C during the Major Setback Project simulation.

E.5 Major Setback Project: NF Levee Setback C Deliverable 5

Deliverable 5 is a set of histograms showing the distribution of water depths in 1 ft bins across each project site during a high spring tide (10.8 ft) and mean river discharge for the month of May (20,400 cfs), the same conditions corresponding to the maps of Deliverable 4. All depth values are relative to model bathymetry, which uses linear interpolation to the resolution of the grid. The histogram can be seen in Figure E.7.

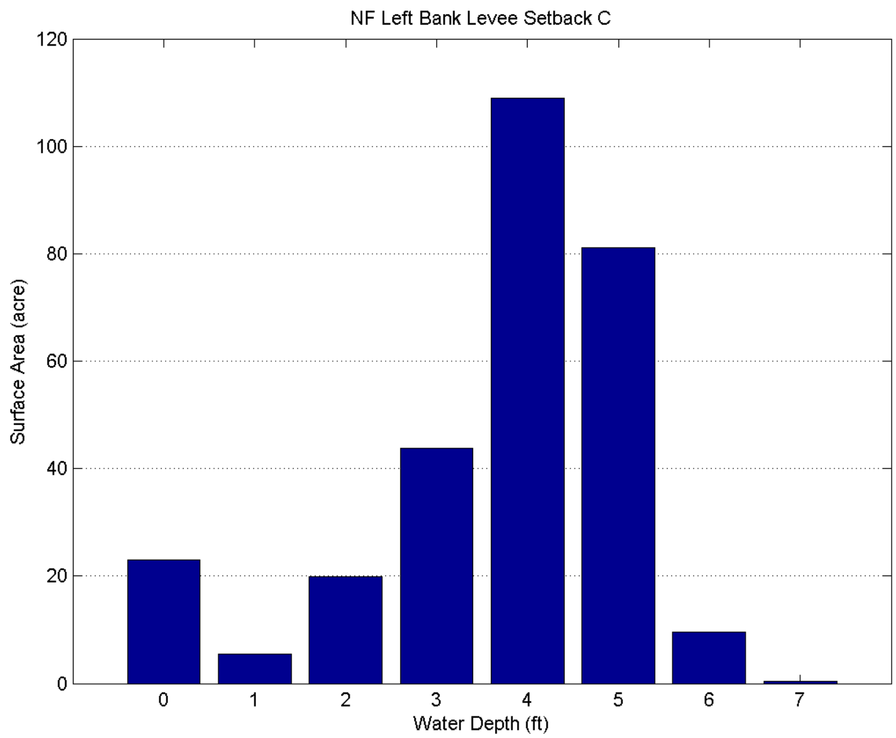


Figure E.7. Histogram of depths for NF Levee Setback C.

E.6 Major Setback Project: NF Levee Setback C Deliverable 6

Deliverable 6 is a set of contour maps showing the change in water surface elevation between the Baseline Simulation (Simulation 0) and the Major Setback Project simulation (Simulation 4). Two conditions were compared: (1) a low spring tide (-3.3 ft) and Q2 flow (62,000 cfs) and (2) a high spring tide (10.4 ft) and a flood condition (93,200 cfs), representing the change from baseline to restored conditions. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure E.8 through Figure E.10.

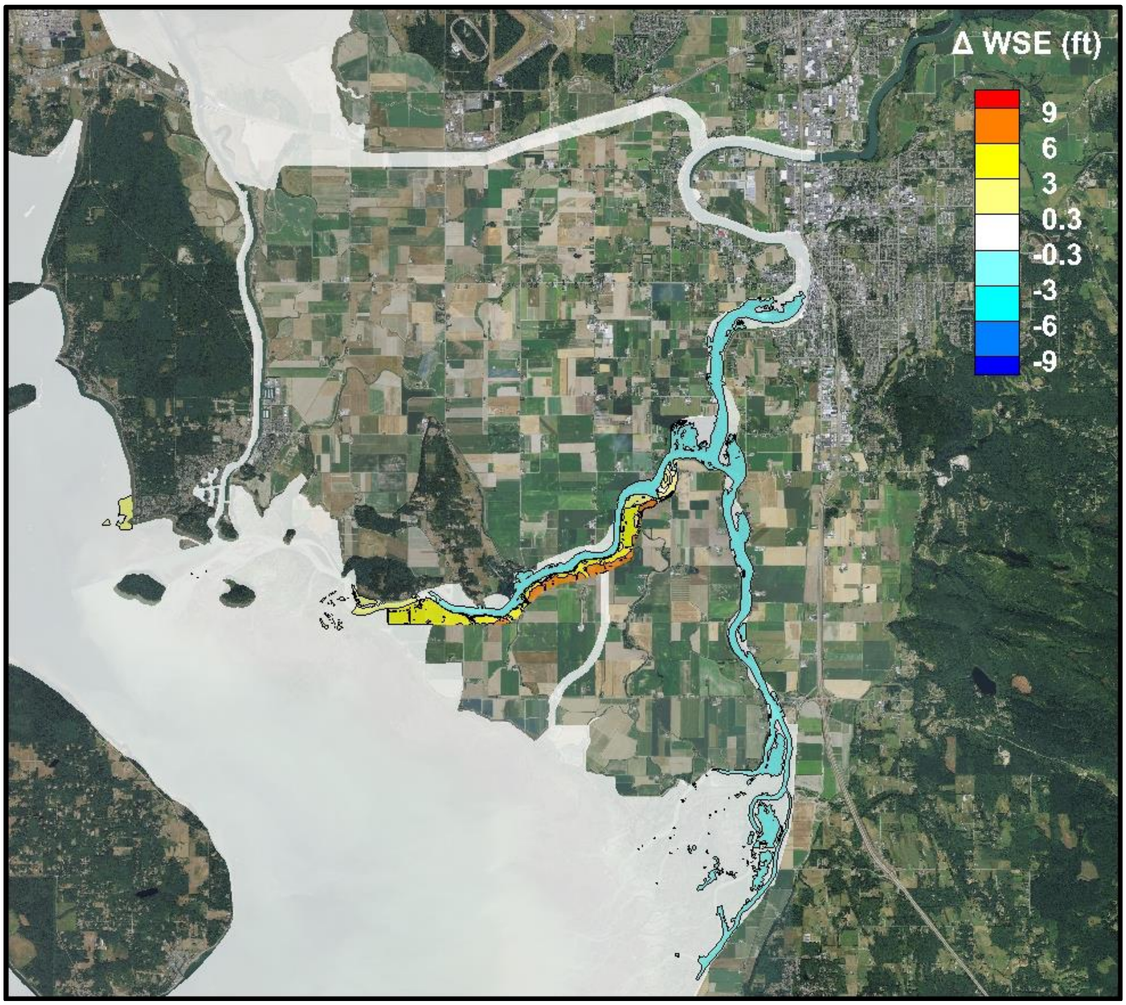


Figure E.8. Contour map of change in WSE from the Baseline to NF Levee Setback C simulation with Q2 flow and low tide.

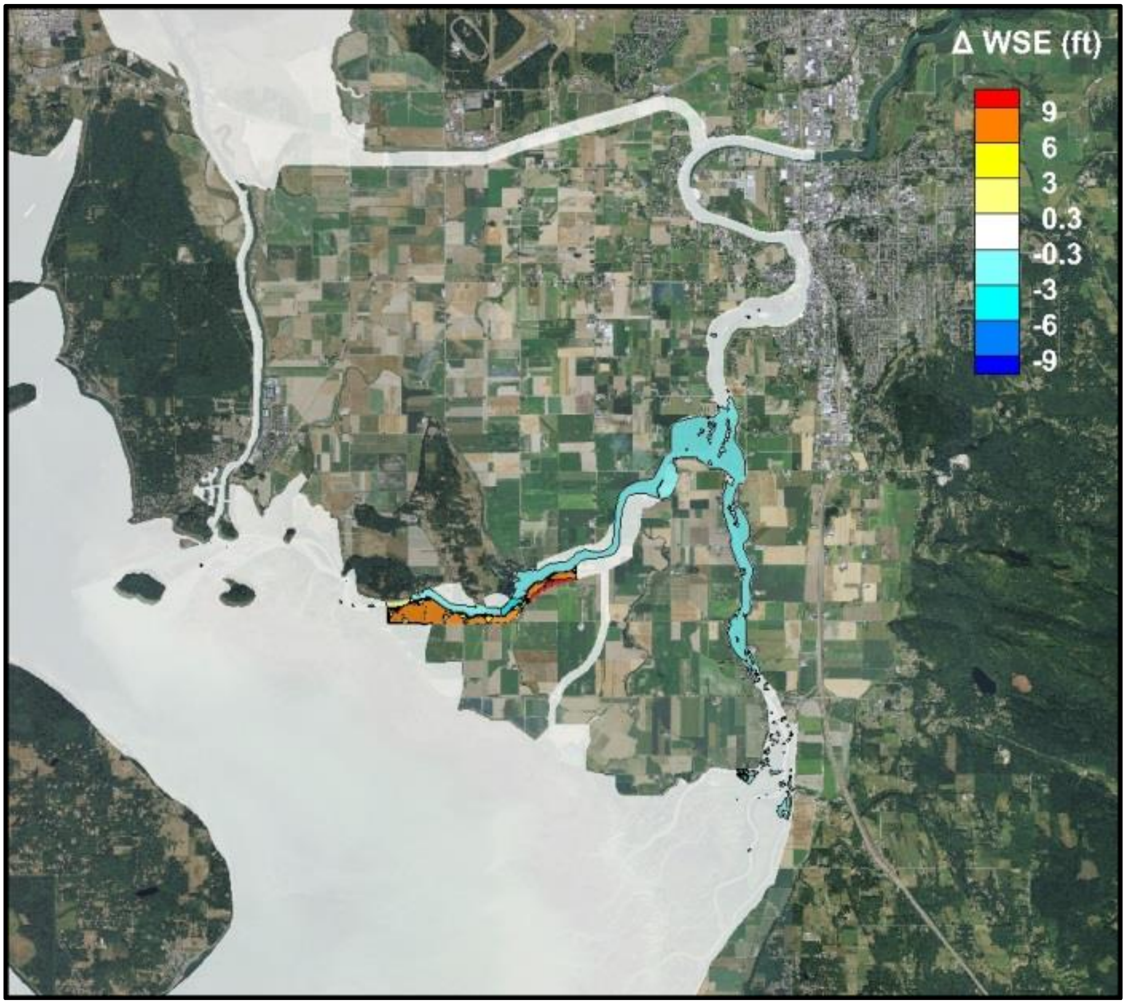


Figure E.9. Contour map of change in WSE from the Baseline to NF Levee Setback C simulation with flood flow and high tide.

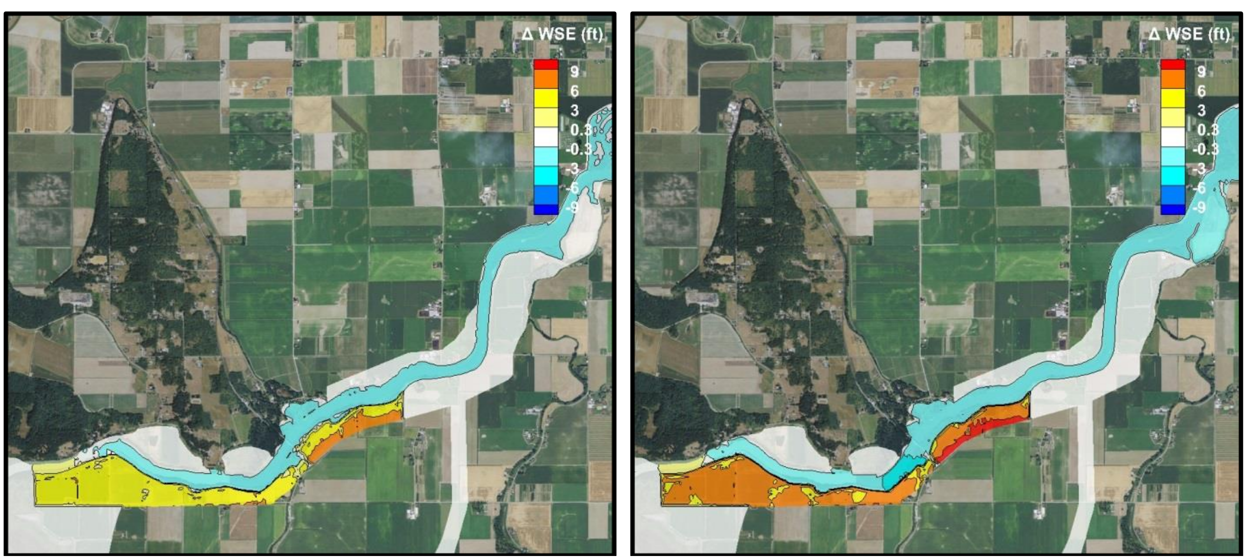


Figure E.10. Contour map of change in WSE from the Baseline simulation for NF Levee Setback C with Q2 flow and low tide (left) and flood flow and high tide (right).

E.7 Major Setback Project: NF Levee Setback C Deliverable 7

Deliverable 7 is a set of contour maps showing the change in bed shear stress between the Baseline Simulation (Simulation 0) and the Major Setback Project simulation (Simulation 4). Two conditions were compared: (1) a full spring tidal cycle during a low flow (12,000 cfs) where the peak shear across the map was recorded and (2) a low spring tide (-3.3 ft) and Q2 flow (62,000 cfs), representing the change from baseline to restored conditions. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure E.11 through Figure E.13.

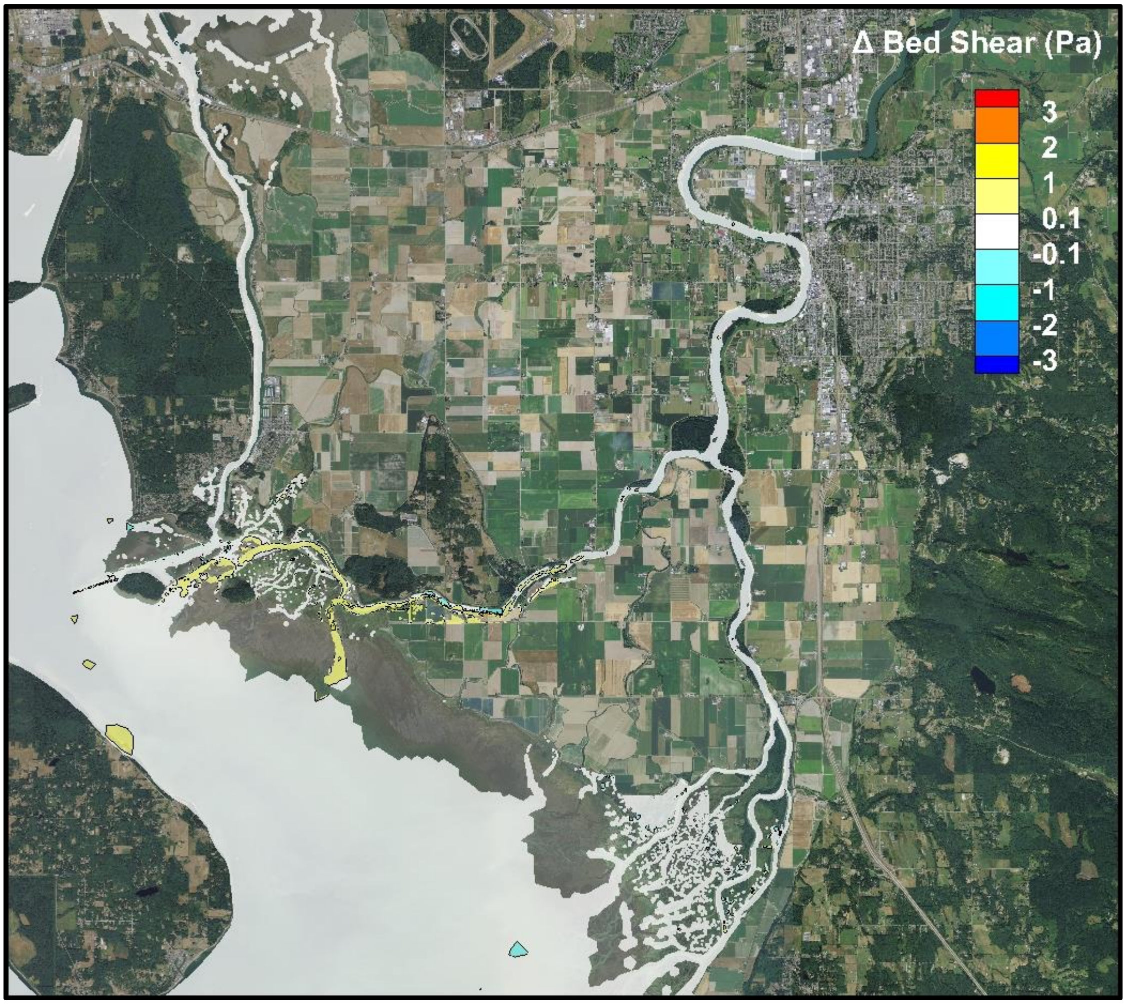


Figure E.11. Contour map of change in shear stress from the Baseline to NF Levee Setback C simulation with peak shear across a full tidal cycle at low flow**.**

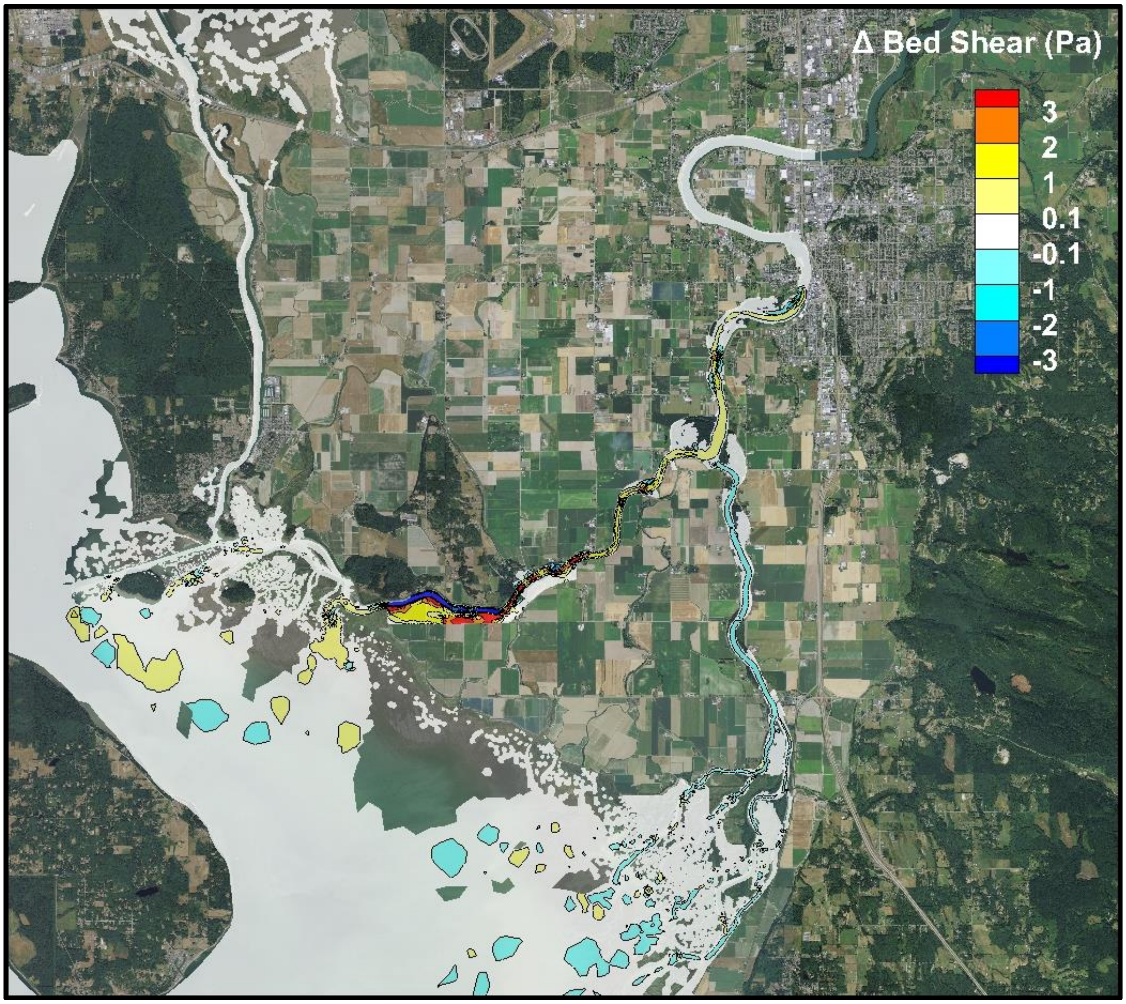


Figure E.12. Contour map of change in shear stress from the Baseline to NF Levee Setback C simulation with Q2 flow and low tide.

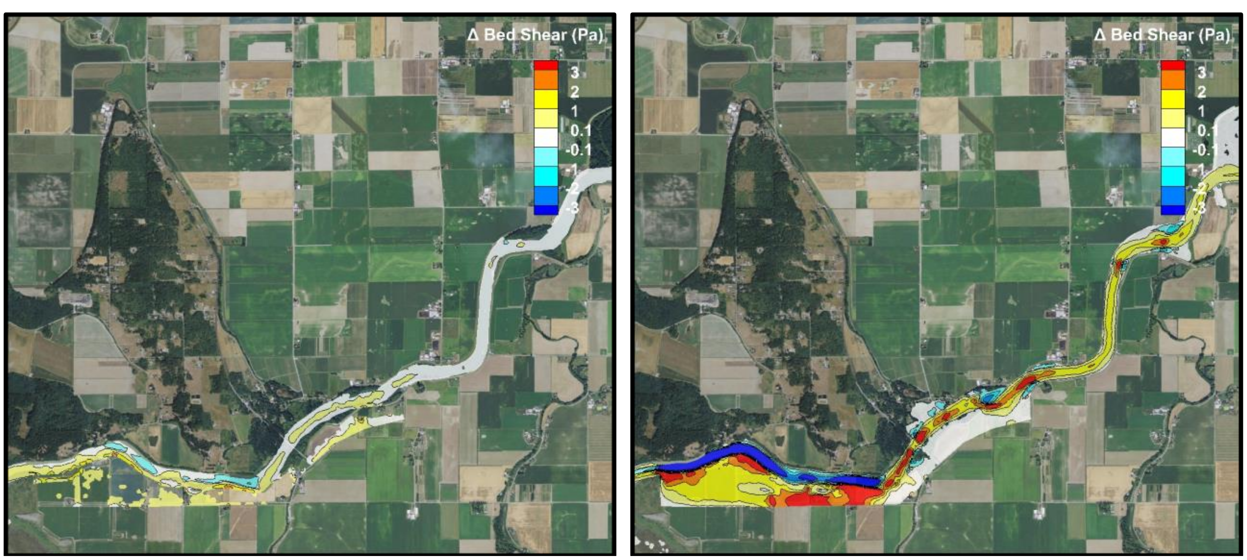


Figure E.13. Contour map of change in shear stress from Baseline for NF Levee Setback C with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

E.8 Major Setback Project: NF Levee Setback C Deliverable 8

Deliverable 8 is a set of contour maps showing the change in salinity between the Baseline Simulation (Simulation 0) and the Major Setback Project simulation (Simulation 4). The compared conditions were a low flow (12,000 cfs) and high spring tide (10.8 ft), representing the change from baseline to restored conditions. The compared salinity values represent an average of the bottom 10% of the water depth to show the furthest extent of the salt wedge. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. Changes in salinity could affect habitat suitability, the distribution of fish, and have potential effects on agriculture. The maps can be seen in Figure E.14 and Figure E.15.

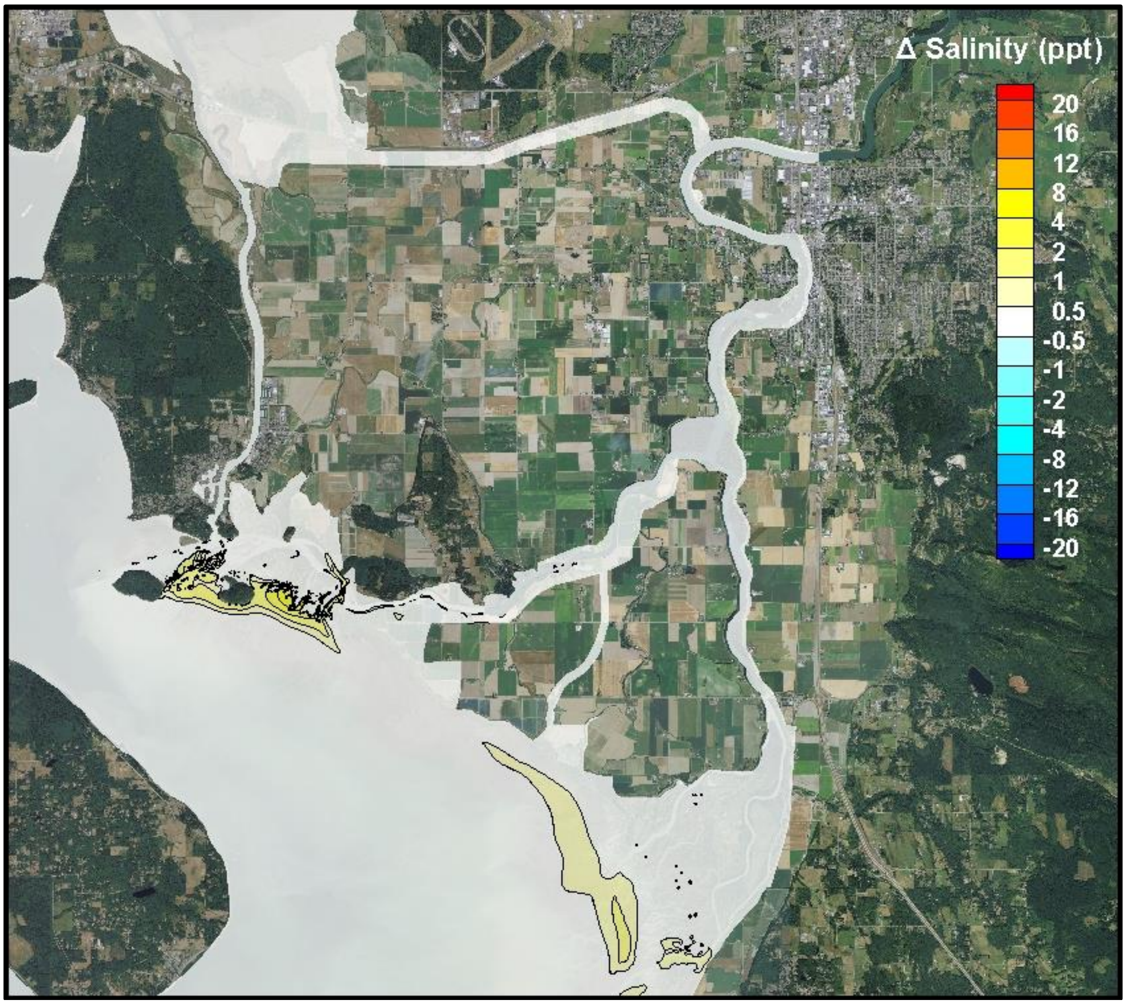


Figure E.14. Contour map of change in salinity from the Baseline to NF Levee Setback C simulation with low flow and high tide.

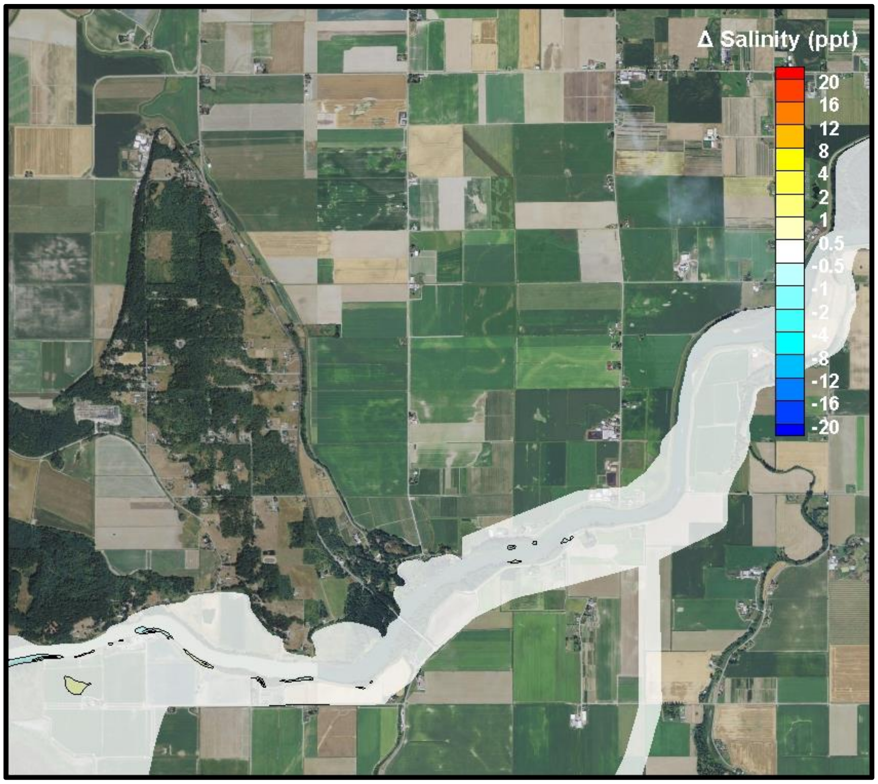


Figure E.15. Contour map of change in salinity from the Baseline simulation for NF Levee Setback C with low flow and high tide.

E.9 Major Setback Project: NF Levee Setback C Deliverable 9

Deliverable 9 is a set of plots that compare water surface elevation and flow between the Baseline Simulation and the Major Setback Project simulation, plotting all time steps during the entire 7-month simulation from November 2, 2014 through May 29, 2015. Plots are provided for the North Fork, South Fork, Freshwater Slough, and Steamboat Slough gauge locations. Flow was computed at a cross section bisecting the gauge locations. An Excel file was also generated to provide the WSE and flow information at the gauge locations. The maps can be seen in Figure E.16 through Figure E.19.

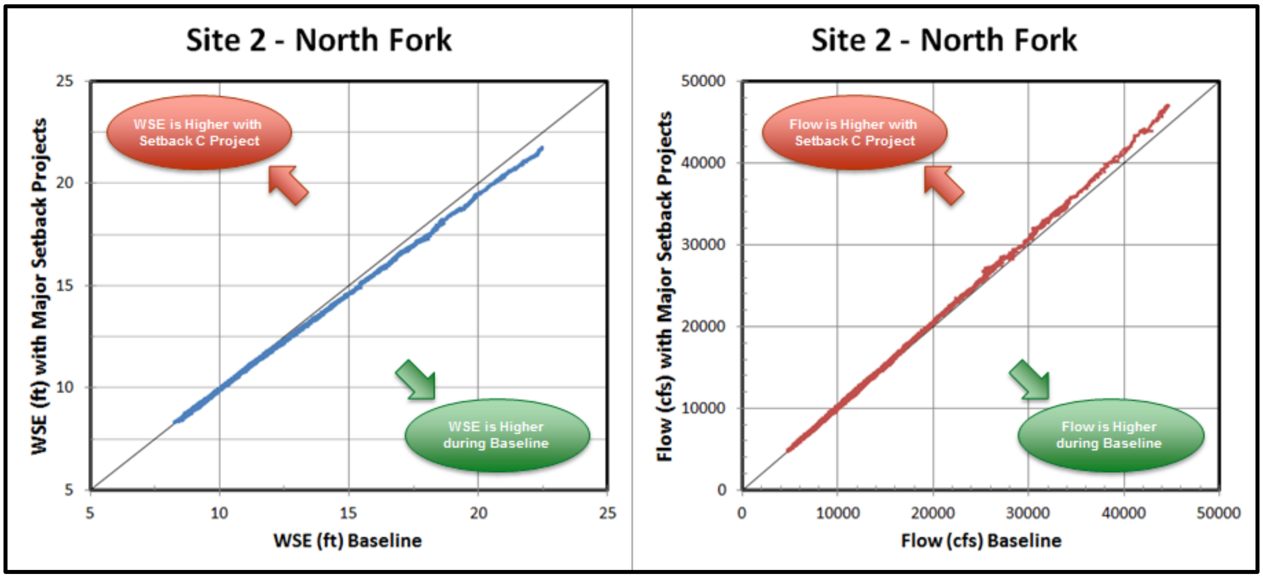


Figure E.16. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Setback Project simulation at the North Fork gauge location compared with the same information under baseline conditions.

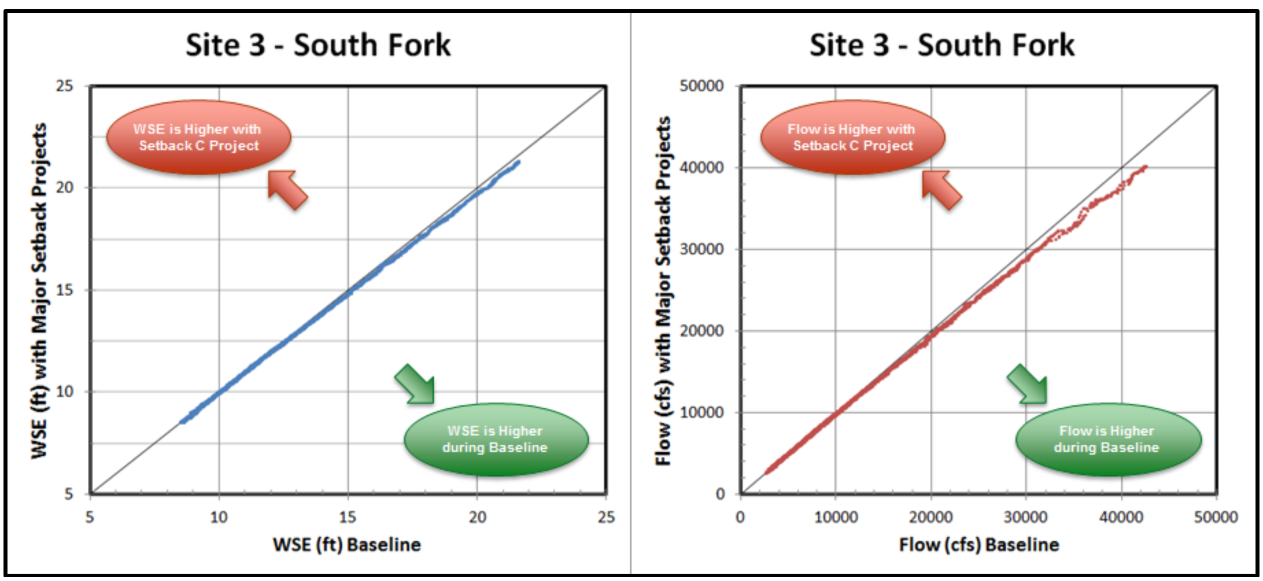


Figure E.17. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Setback Project simulation at the South Fork gauge location compared with the same information under baseline conditions.

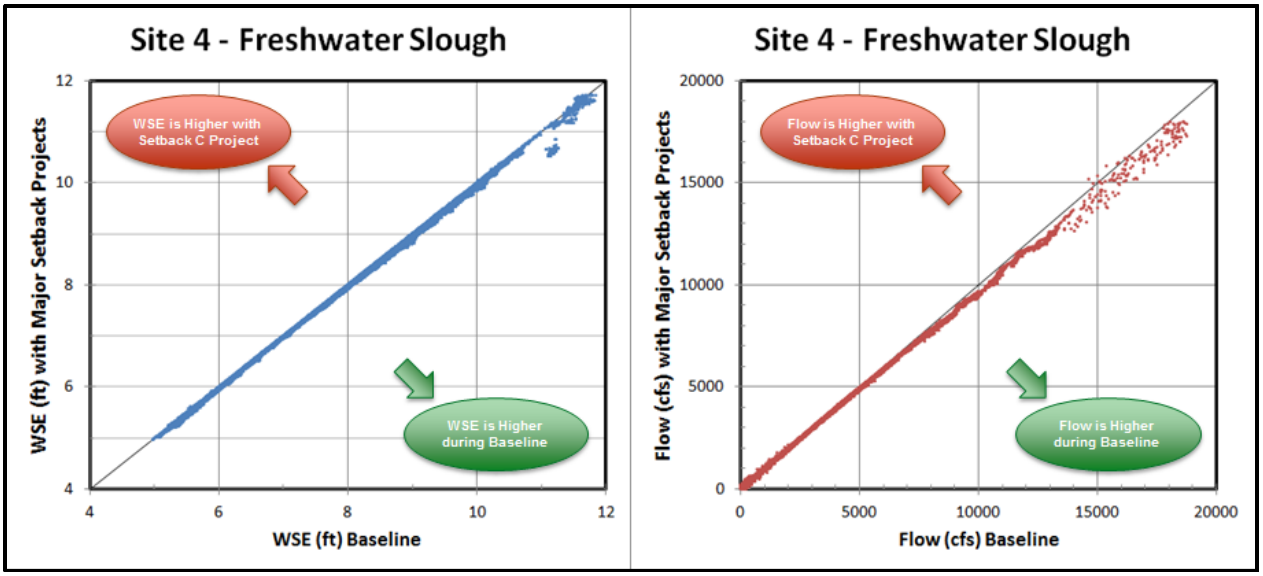


Figure E.18. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Setback Project simulation at the Freshwater Slough gauge location compared with the same information under baseline conditions.

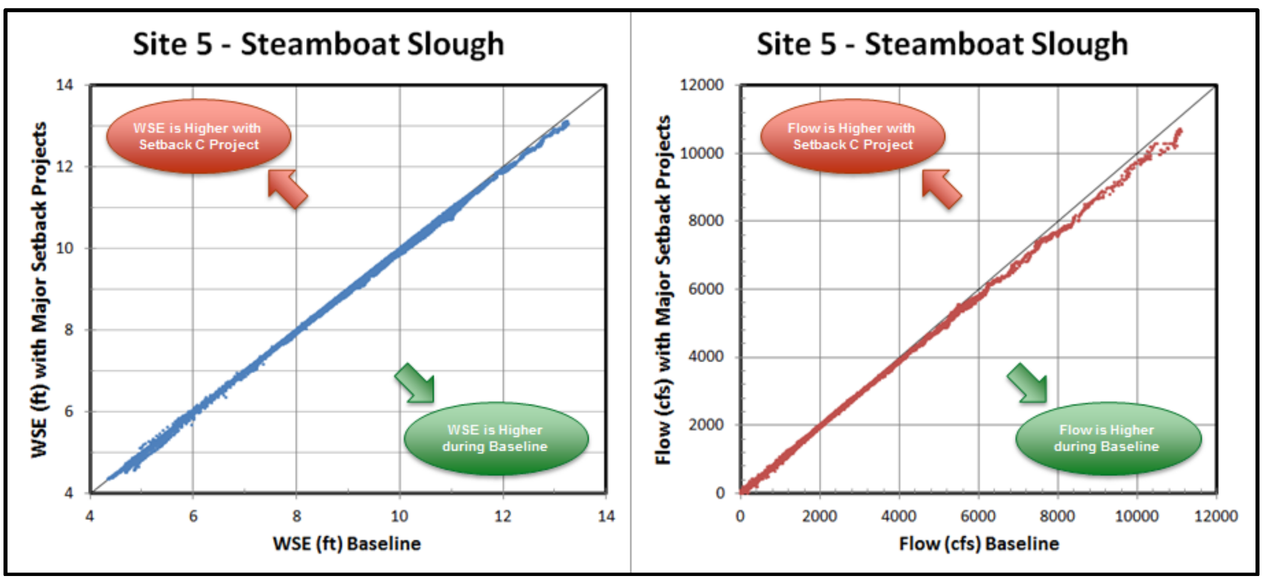


Figure E.19. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Setback Project simulation at the Steamboat Slough gauge location compared with the same information under baseline conditions.

Appendix F

Simulation 5: Major Setback Project: North Fork Levee Setback A Deliverables

Appendix F

Simulation 5: Major Setback Project: North Fork Levee Setback A Deliverables

The following list of deliverables is associated with Simulation 5: NF Levee Setback A (Figure F.1). These deliverables were created by the SHDM Team to address specific objectives for the alternative analysis (Friebel et al., in preparation).

1. Table entries showing the change in area subject to natural tidal and riverine processes for each sub-basin in the study area during NF Levee Setback A (Simulation 5).
2. Table entries showing the change in area subject to natural tidal and riverine processes for NF Levee Setback A (Simulation 5). Because of error with wetted area calculations, high resolution, georeferenced maps showing the depth of inundation under (1) low flow and high tide and (2) Q2 flow and low tide were also provided (not shown).
3. At points in the main channel and bay front selected by the SHDM Team, cumulative frequency of WSE (for the months of March, April, and May). An Excel file of the data associated with the plot data was also provided (not shown).
4. Contour maps showing water depth for NF Levee Setback A (Simulation 5) during (1) mean river discharge for the month of May and spring high tide. High-resolution, georeferenced map was also provided (not shown).
5. Histograms of water depth with 1 ft bins at NF Levee Setback A (Simulation 5) during (1) mean river discharge for the month of May and high spring tide.
6. Contour maps showing change in WSE from baseline (Simulation 0) to NF Levee Setback A (Simulation 5) during (1) Q2 flow and low spring tide and (2) a flood condition and high tide. High-resolution, georeferenced maps were also provided, including (3) low flow and high spring tide and absolute WSE for all three conditions (not shown).
7. Contour maps showing change in bed shear stress from baseline (Simulation 0) to NF Levee Setback A (Simulation 5) during (1) low flow and the peak shear stress during a full tidal cycle and (2) Q2 flow and low spring tide. High-resolution, georeferenced maps were also provided, including absolute bed shear stress for both conditions (not shown).
8. Contour maps showing change in salinity from baseline (Simulation 0) to NF Levee Setback A (Simulation 5) during (1) low flow and high spring tide. High-resolution, georeferenced maps were also provided, including absolute salinity for both conditions (not shown).
9. Plots of change in WSE and flow from baseline (Simulation 0) to NF Levee Setback A (Simulation 5) for the South Fork, North Fork, Freshwater Slough, and Steamboat Slough to determine the basin effects. An Excel file of the data associated with the plots was also provided.

Figure F.1. A map of project area in the Major Setback Project simulation: NF Setback A.

F.1 Major Setback Project: NF Levee Setback A Deliverable 1

For this deliverable, the area was divided into sub-basins, as seen in Figure F.2. Deliverable 1 is a table showing the increase in inundation area subject to natural tidal and riverine processes within each sub-basin, as seen in Table F.1. The accuracy of area calculation is limited by the spatial resolution of the triangular grid, which varies throughout the model domain. A node is considered wet when the model calculated water depth exceeds the minimum wetting and drying criteria of 10 cm (0.3281 ft). For any wetted node included in the project boundary polygon, its associated computational area was counted toward the total inundated area.

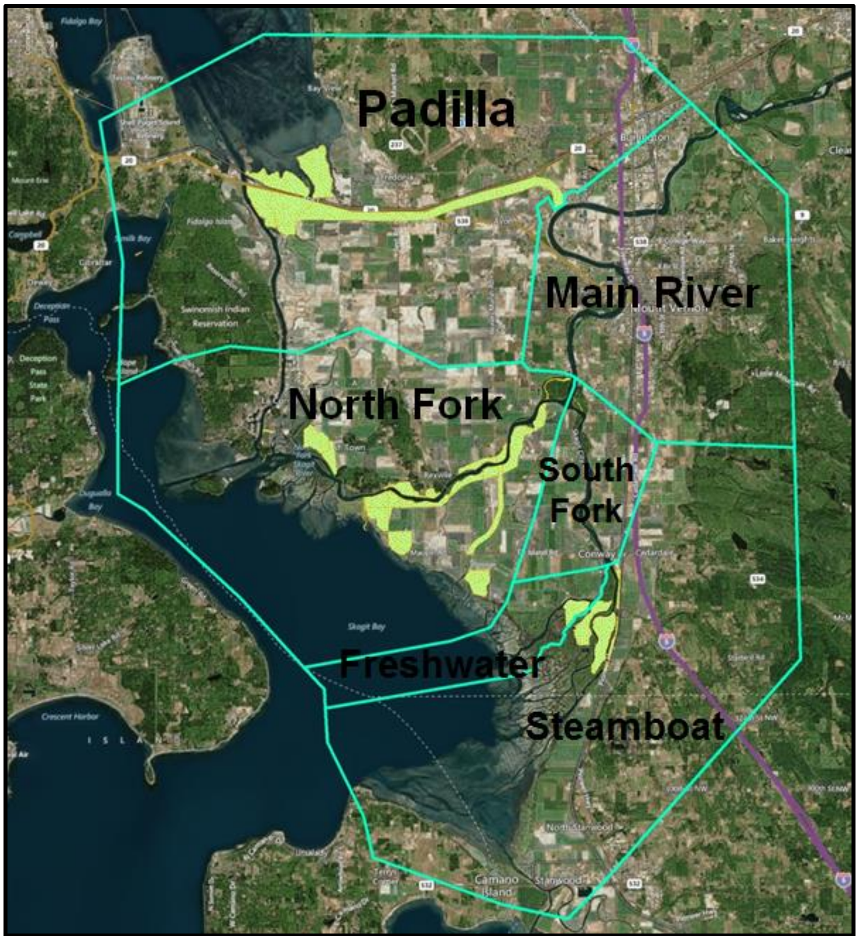


Figure F.2. Sub-basins within the Skagit region used for area calculations.

Table F.1. Table entry showing area increase for each sub-basin under tidal and riverine conditions during the Major Setback Project NF Levee Setback A simulation.

Sub-basin	Baseline (acres)	With Projects (acres)	Increase in Area (acres)
Tidal Influence: High Spring Tide (10.8 ft) + Low Flow (12,000 cfs)			
Sum	20,256.9	20,530.5	**273.6**
Main River	7.8	7.4	**-0.4**
North Fork	8,330.6	8,604.0	**273.4**
South Fork	30.0	30.0	**0.0**
Freshwater	1,944.6	1,944.9	**0.3**
Steamboat	5,827.3	5,827.8	**0.5**
Padilla	4,116.8	4,116.5	**-0.3**

Riverine Influence: Low Spring Tide (-3.3 ft) + Q2 Flow (62,000 cfs)			
Sum	7,921.4	8,381.3	**459.9**
Main River	159.0	145.4	**-13.6**
North Fork	2,998.2	3,685.0	**686.8**
South Fork	171.8	132.8	**-39.0**
Freshwater	1,065.1	1,014.4	**-50.7**
Steamboat	2,640.2	2,509.2	**-131.0**
Padilla	887.0	894.5	**7.5**

F.2 Major Setback Project: NF Levee Setback A Deliverable 2

Deliverable 2 is a table showing the increase in inundation area subject to natural tidal and riverine processes within each project area, as seen in Table F.2. Inundation area is counted only within the project footprint. The same limitations and definition of an inundated cell that apply to Deliverable 1 apply here.

Table F.2. Table entry showing area increase for each project under tidal and riverine conditions during the Major Setback Project NF Levee Setback A simulation. Measurements correspond to a measured area that differs from the true project footprint because of grid resolution.

Project (measured area)	Baseline (acres)	With Projects (acres)	Increase in Area (acres)
Tidal Influence: High Spring Tide (10.8 ft) + Low Flow (12,000 cfs)			
NF Levee Setback A (**578.7 acres**)	1.2	273.1	**271.9**
Riverine Influence: Low Spring Tide (-3.3 ft) + Q2 Flow (62,000 cfs)			
NF Levee Setback A (**578.7 acres**)	5.6	551.8	**546.2**

F.3 Major Setback Project: NF Levee Setback A Deliverable 3

Deliverable 3 is a set of cumulative frequency plots showing water surface elevation at a point in the main channel or Bayfront near each project site. These are from the spring months of the Major Setback Project simulation (Simulation 5), representing March 1 – May 22, 2015, a time period chosen to coincide with the primary fish outmigration. A red mark line was provided with every point to represent an approximation of the average elevation of the project area bed. All WSE values are relative to the NAVD88 datum. An Excel file was also generated with WSE at each node location. The plots can be seen in Figure F.3 through Figure F.6.

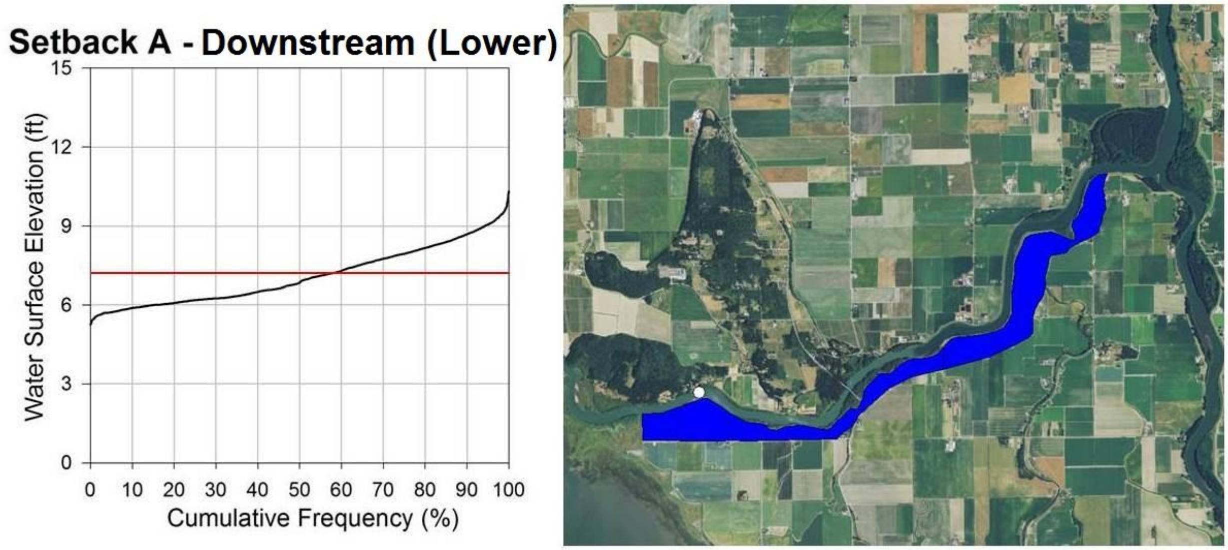


Figure F.3. Cumulative frequency plot and corresponding map for NF Levee Setback A - Downstream (Lower) during the Major Setback Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

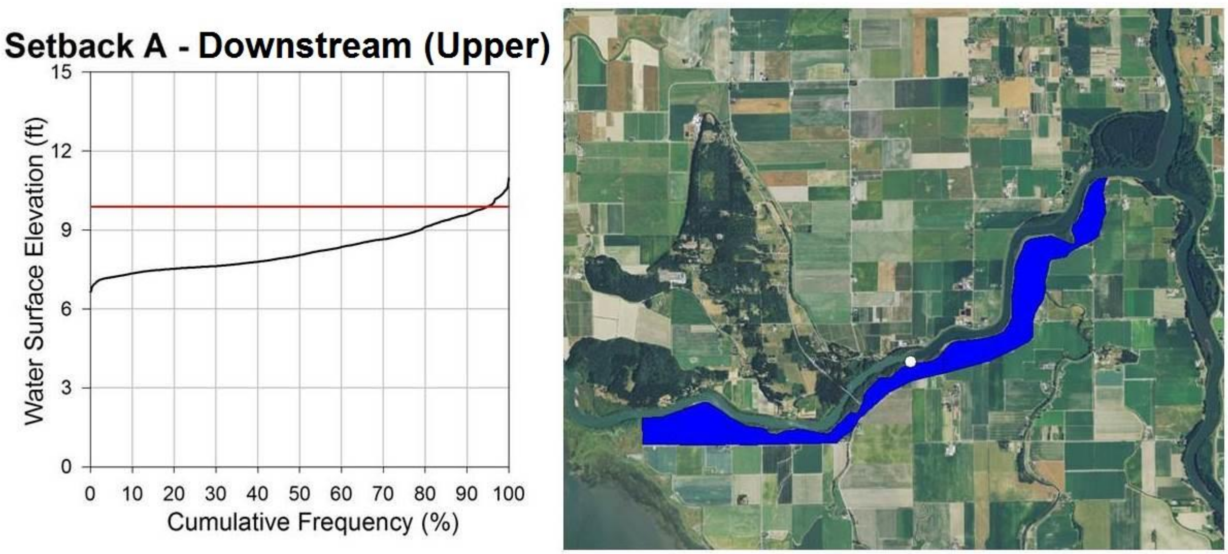


Figure F.4. Cumulative frequency plot and corresponding map for NF Levee Setback A - Downstream (Upper) during the Major Setback Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

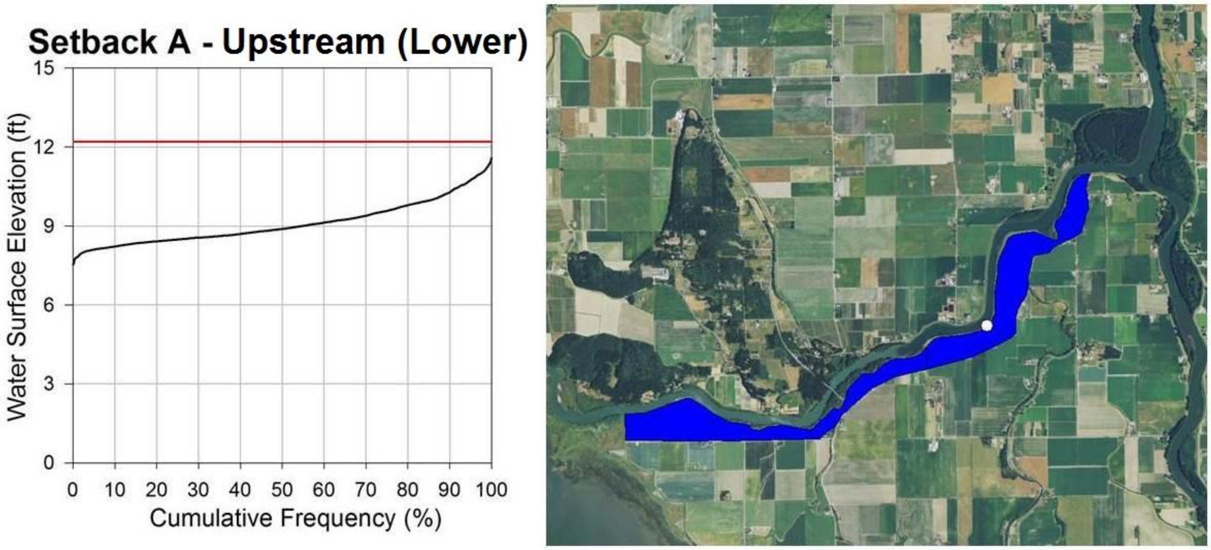


Figure F.5. Cumulative frequency plot and corresponding map for NF Levee Setback A - Upstream (Lower) during the Major Setback Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

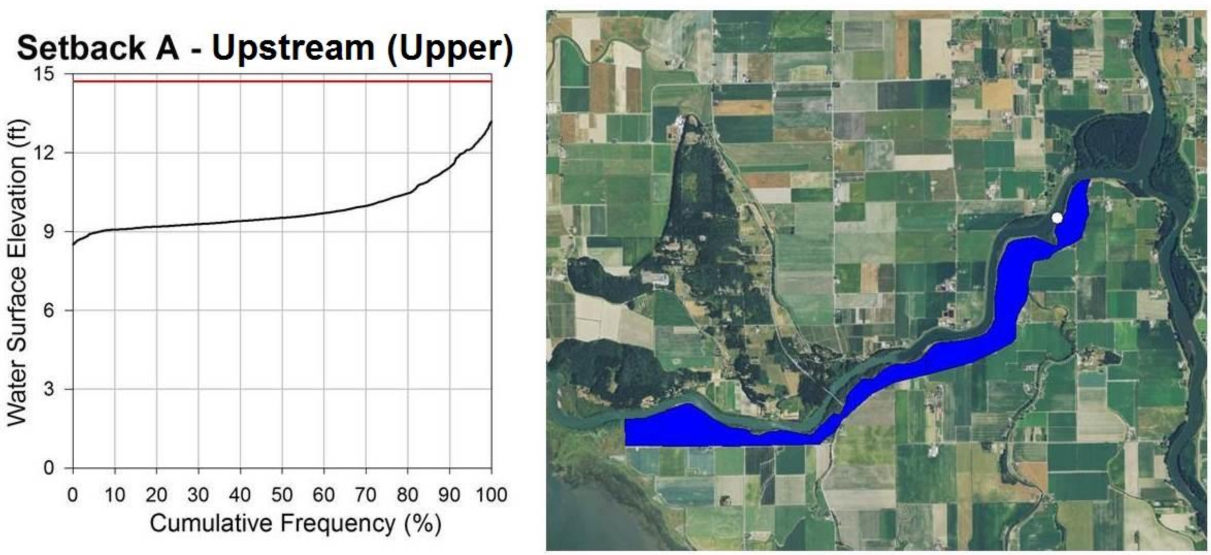


Figure F.6. Cumulative frequency plot and corresponding map for NF Levee Setback A - Upstream (Upper) during the Major Setback Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

F.4 Major Setback Project: NF Levee Setback A Deliverable 4

Deliverable 4 is a set of contour maps showing the depth of inundation during the Major Setback Project simulation (Simulation 5). The plotted condition was the mean river discharge for the month of May (20,400 cfs) and high spring tide (10.8 ft). All depth values are relative to model bathymetry, which uses linear interpolation to the resolution of the grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure F.7 and Figure F.8.

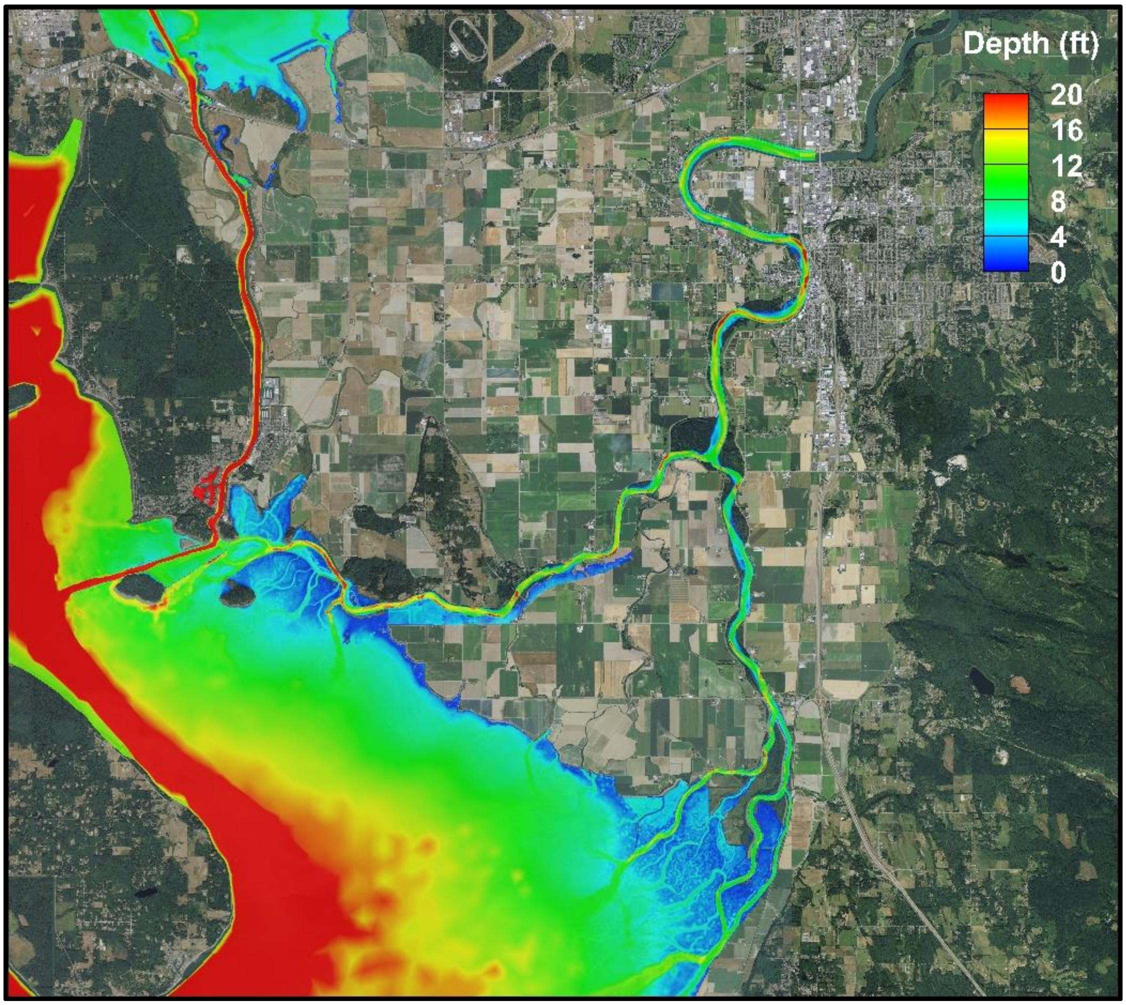


Figure F.7. Contour map of depths for the full domain during the Major Setback Project North Fork Levee Setback A simulation with May flow and high spring tide.

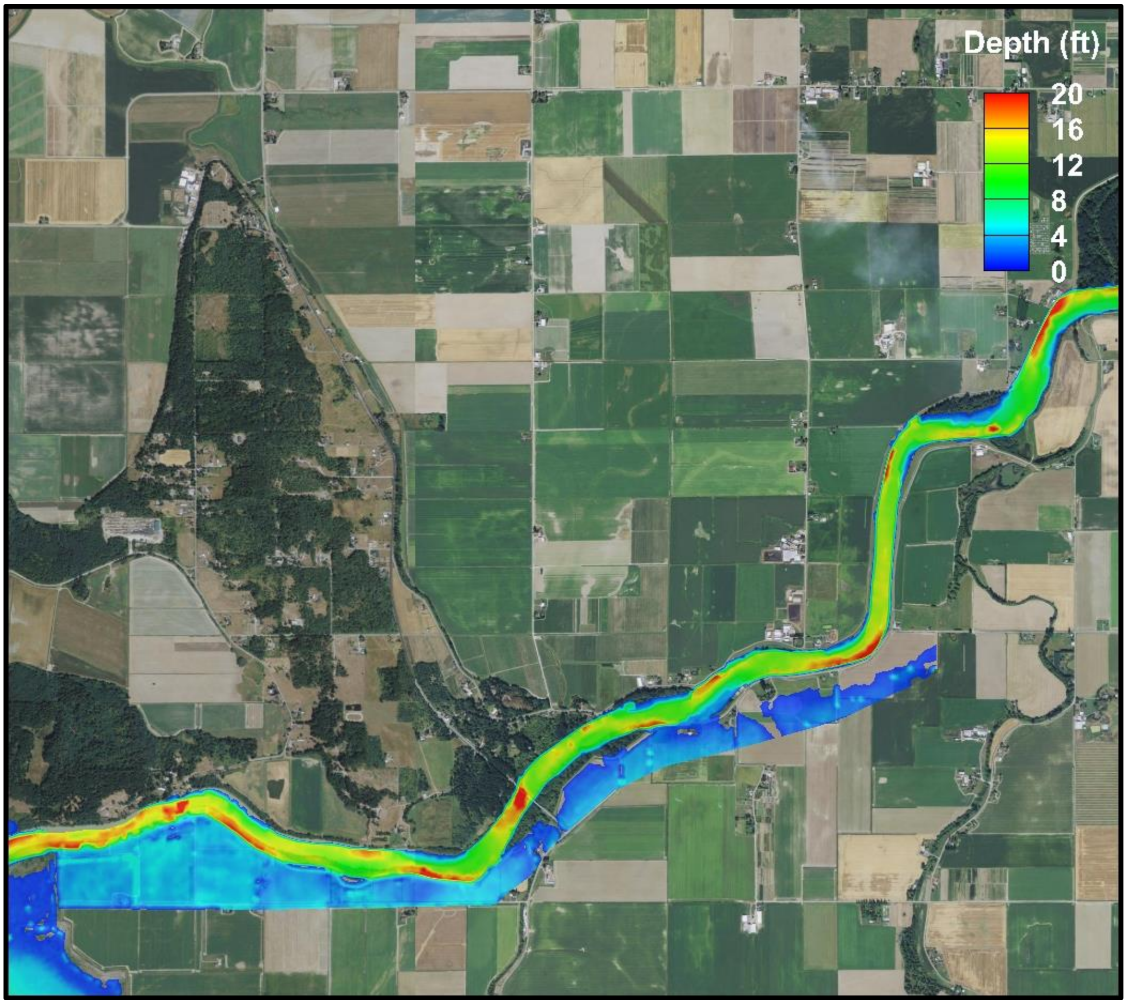


Figure F.8. Contour map of depths for NF Levee Setback A during the Major Setback Project simulation.

F.5 Major Setback Project: NF Levee Setback A Deliverable 5

Deliverable 5 is a set of histograms showing the distribution of water depths in 1 ft bins across each project site during a high spring tide (10.8 ft) and mean river discharge for the month of May (20,400 cfs), the same conditions corresponding to the maps for Deliverable 4. All depth values are relative to model bathymetry, which uses linear interpolation to the resolution of the grid. The histogram can be seen in Figure F.9.

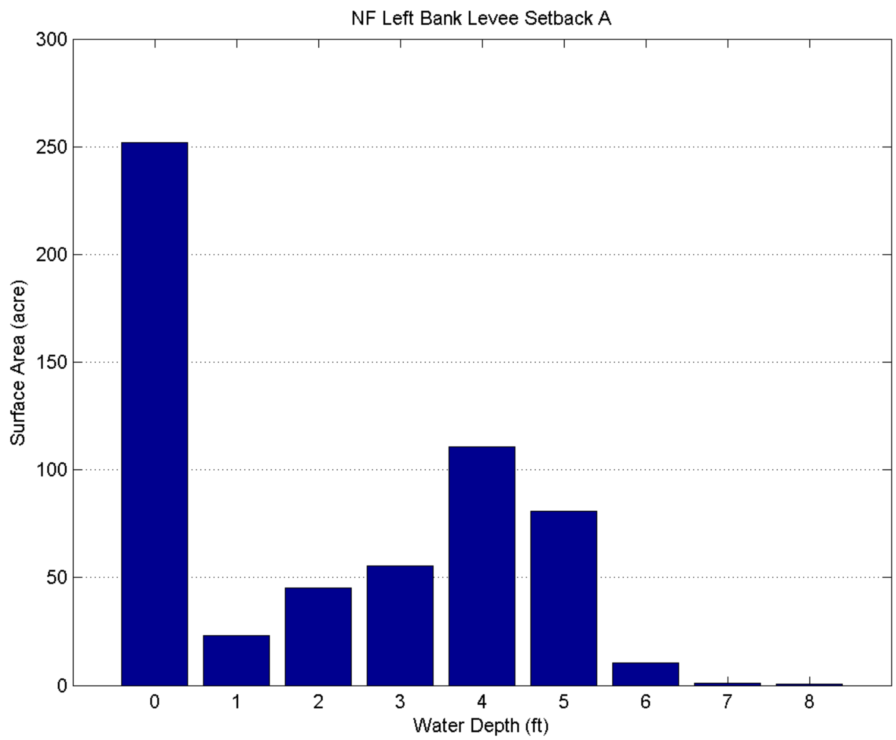


Figure F.9. Histogram of depths for NF Levee Setback A.

F.6 Major Setback Project: NF Levee Setback A Deliverable 6

Deliverable 6 is a set of contour maps showing the change in water surface elevation between the Baseline Simulation (Simulation 0) and the Major Setback Project simulation (Simulation 5). Two conditions were compared: (1) a low spring tide (-3.3 ft) and Q2 flow (62,000 cfs) and (2) a high spring tide (10.4 ft) and a flood condition (93,200 cfs), representing the change from baseline to restored conditions. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure F.10 through Figure F.12.

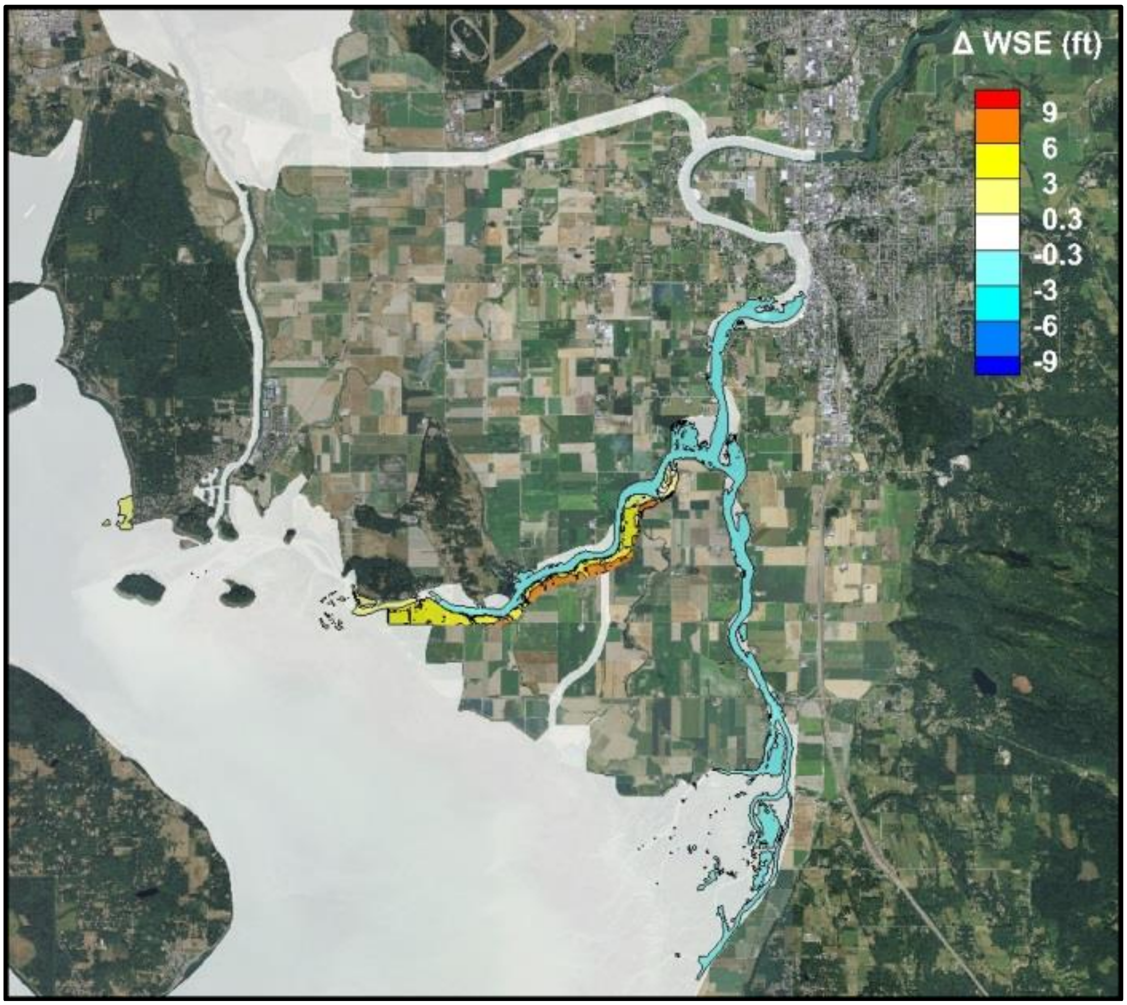


Figure F.10. Contour map of change in WSE from the Baseline to NF Levee Setback A simulation with Q2 flow and low tide.

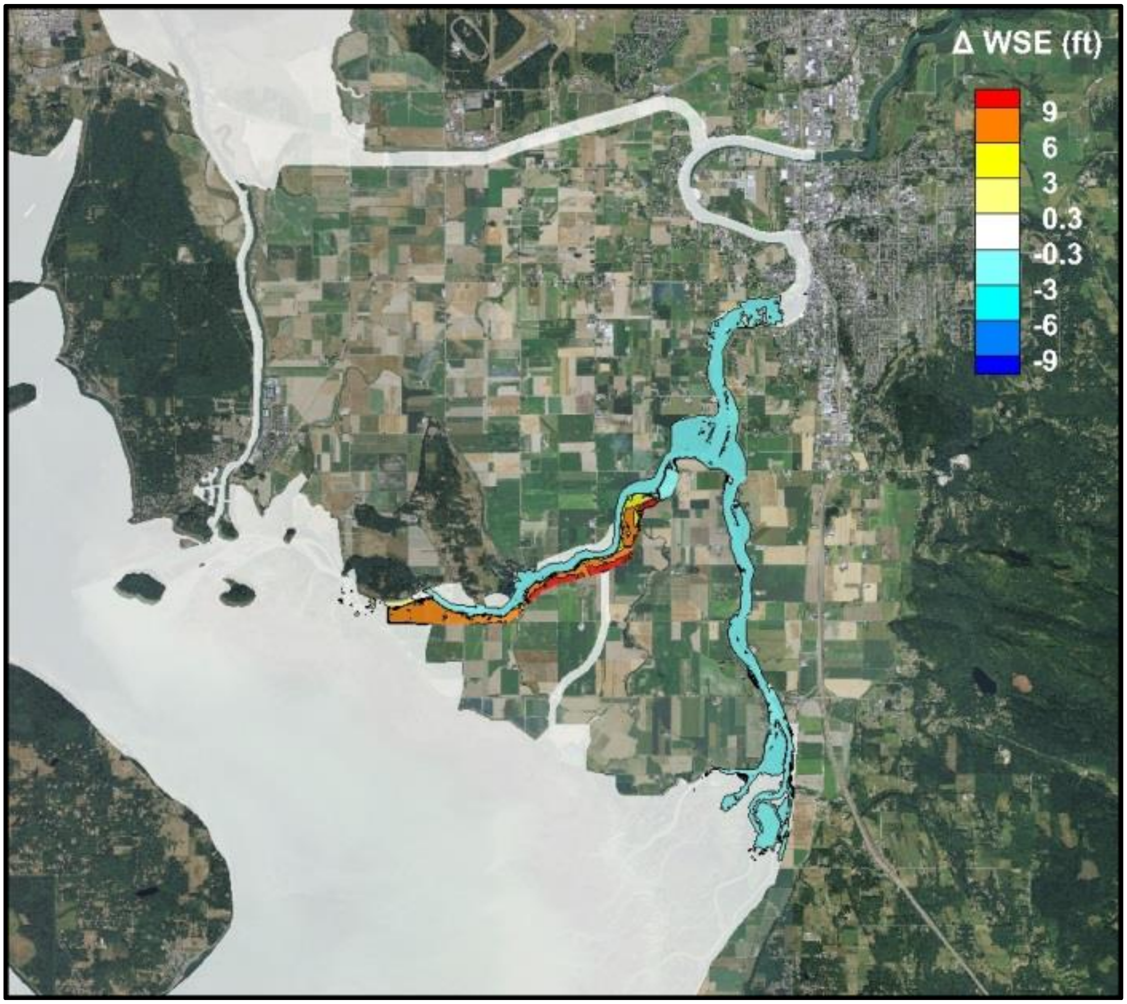


Figure F.11. Contour map of change in WSE from the Baseline to NF Levee Setback A simulation with flood flow and high tide.

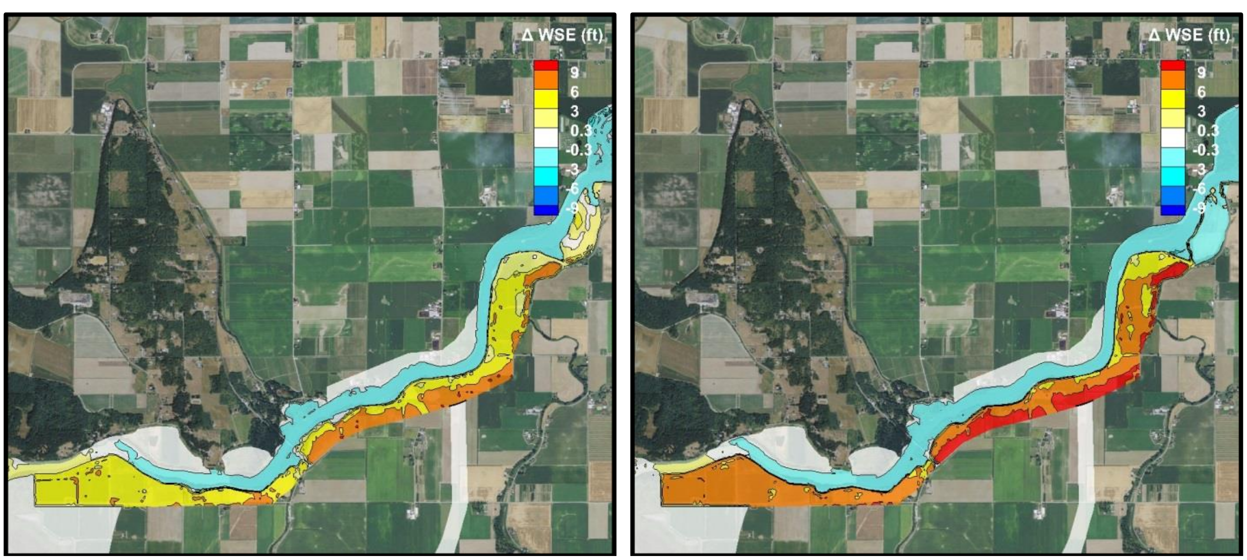


Figure F.12. Contour map of change in WSE from the Baseline simulation for NF Levee Setback A with Q2 flow and low tide (left) and flood flow and high tide (right).

F.7 Major Setback Project: NF Levee Setback A Deliverable 7

Deliverable 7 is a set of contour maps showing the change in bed shear stress between the Baseline Simulation (Simulation 0) and the Major Setback Project simulation (Simulation 5). Two conditions were compared: (1) a full spring tidal cycle during a low flow (12,000 cfs) where the peak shear across the map was recorded and (2) a low spring tide (-3.3 ft) and Q2 flow (62,000 cfs), representing the change from baseline to restored conditions. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure F.13 through Figure F.15.

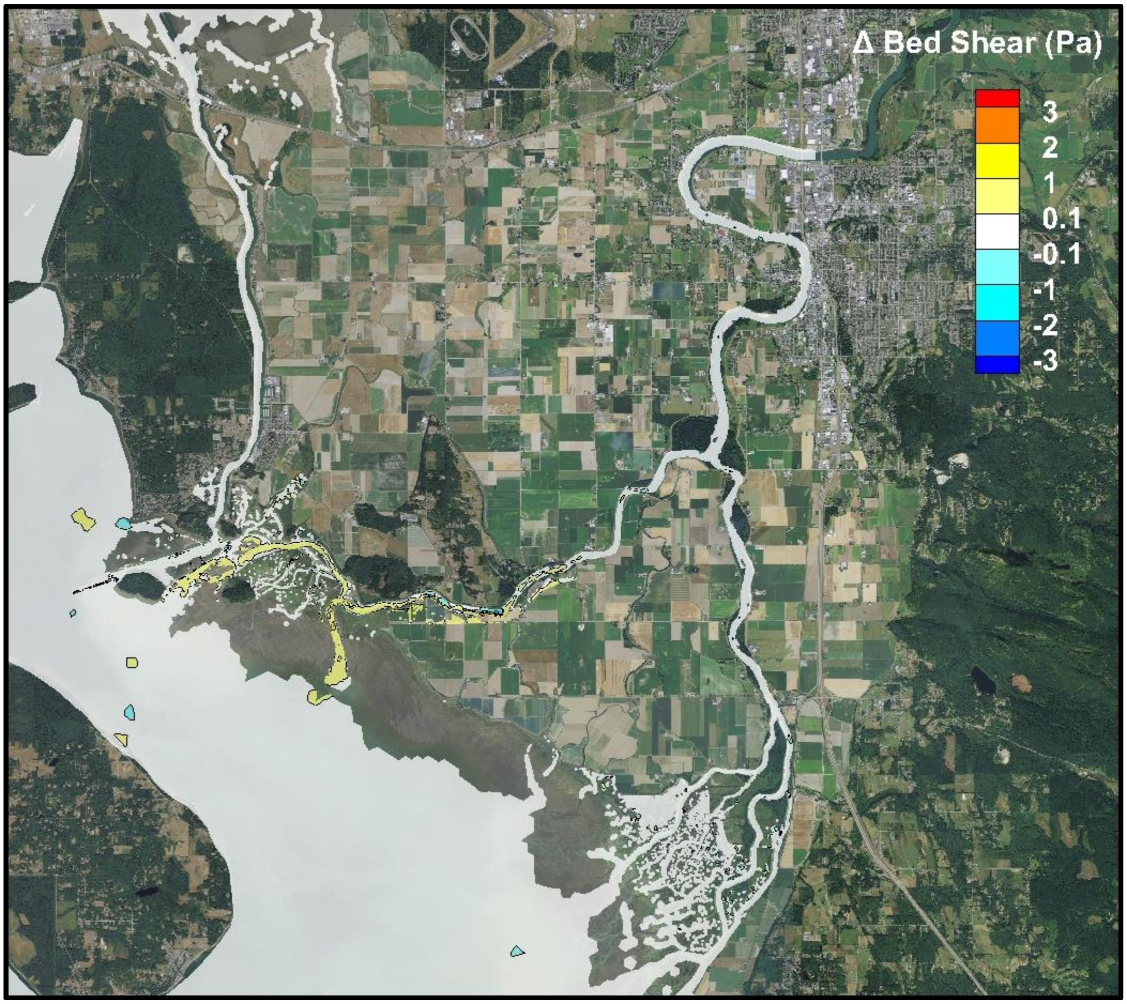


Figure F.13. Contour map of change in shear stress from the Baseline to NF Levee Setback A simulation with peak shear across a full tidal cycle at low flow.

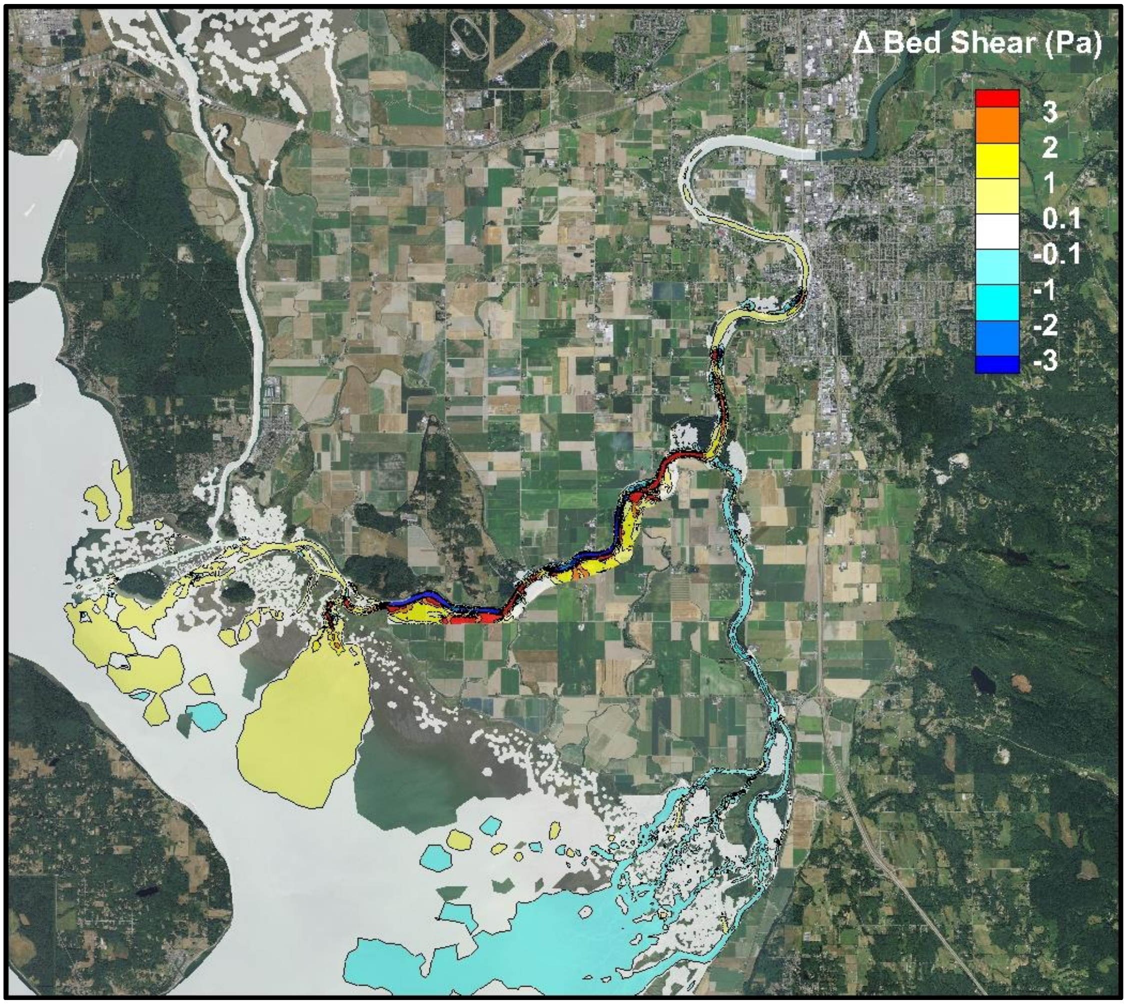


Figure F.14. Contour map of change in shear stress from the Baseline to NF Levee Setback A simulation with Q2 flow and low tide.

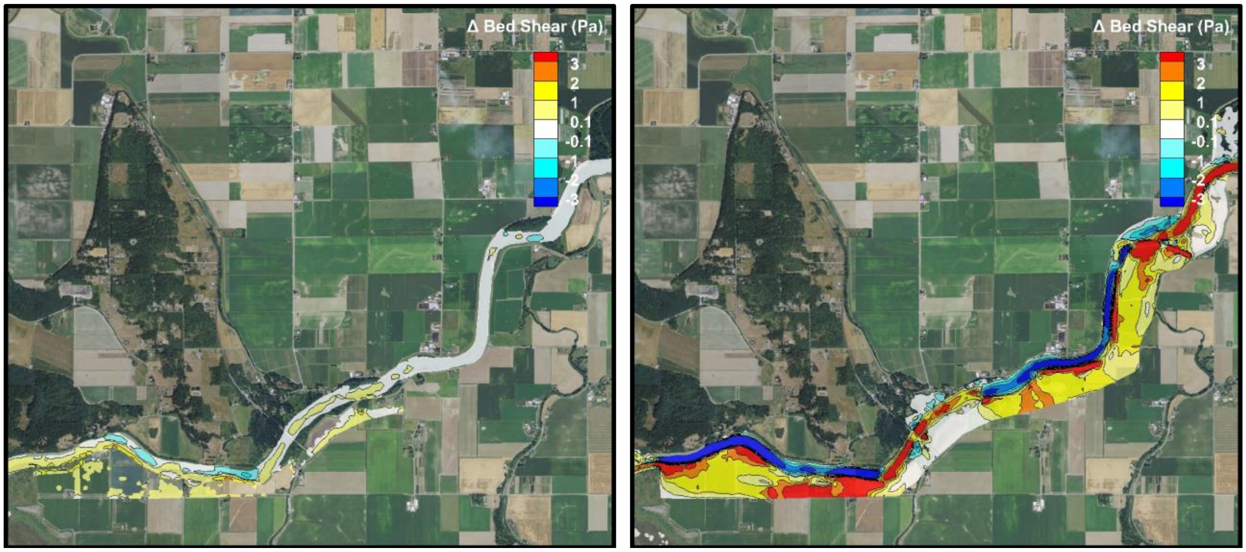


Figure F.15. Contour map of change in shear stress from Baseline for NF Levee Setback A with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

F.8 Major Setback Project: NF Levee Setback A Deliverable 8

Deliverable 8 is a set of contour maps showing the change in salinity between the Baseline Simulation (Simulation 0) and the Major Setback Project simulation (Simulation 5). The compared conditions were a low flow (12,000 cfs) and high spring tide (10.8 ft), representing the change from baseline to restored conditions. The compared salinity values represent an average of the bottom 10% of the water depth to show the furthest extent of the salt wedge. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. Changes in salinity could affect habitat suitability, the distribution of fish, and have potential effects on agriculture. The maps can be seen in Figure F.16 and Figure F.17.

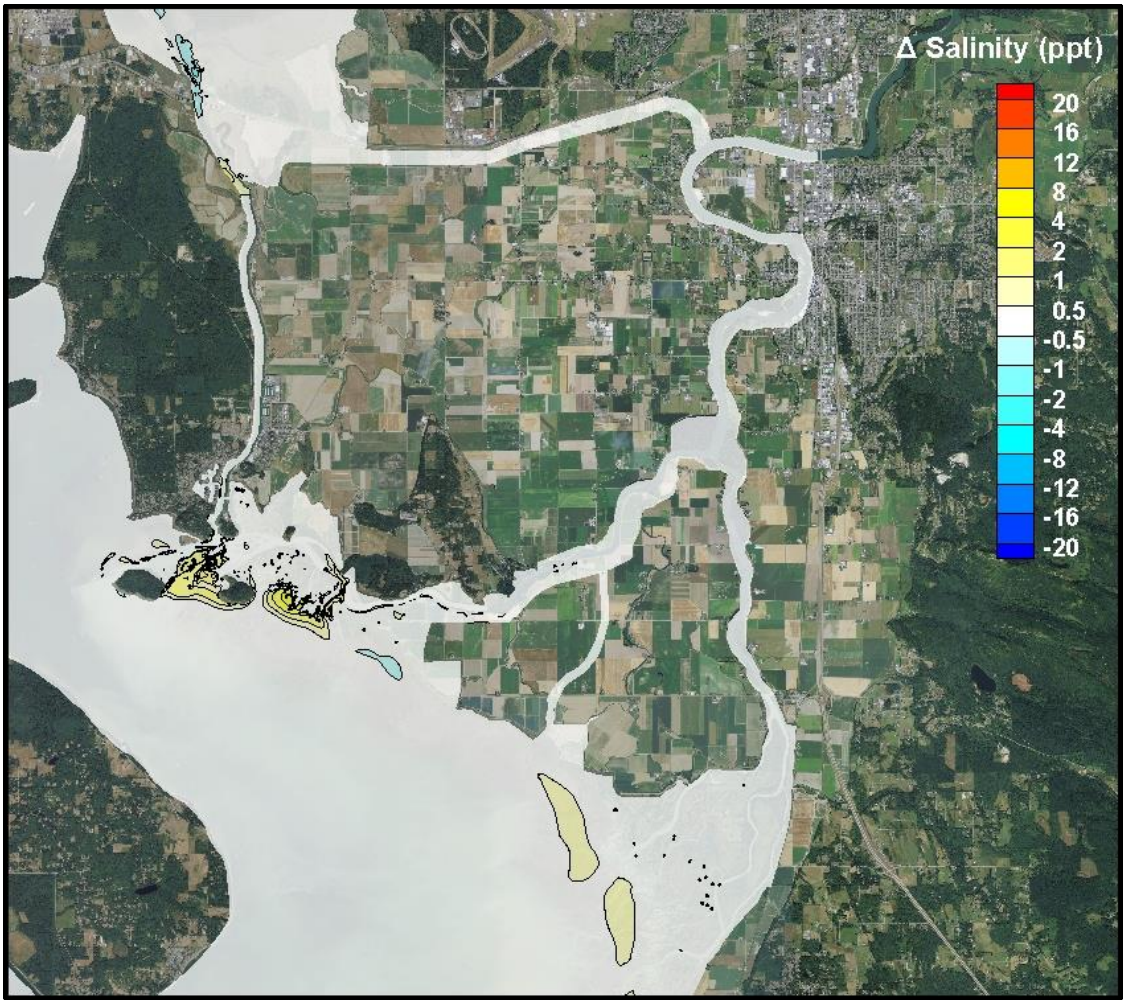


Figure F.16. Contour map of change in salinity from the Baseline to NF Levee Setback A simulation with low flow and high tide.

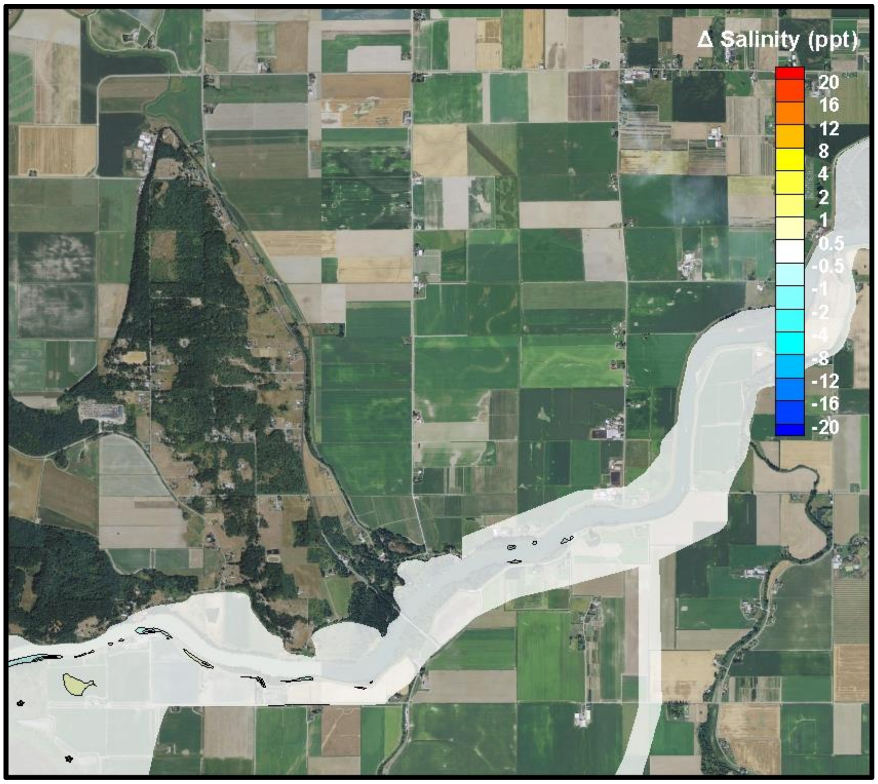


Figure F.17. Contour map of change in salinity from the Baseline simulation for NF Levee Setback A with low flow and high tide.

F.9 Major Setback Project: NF Levee Setback A Deliverable 9

Deliverable 9 is a set of plots that compare water surface elevation and flow between the Baseline Simulation and the Major Setback Project simulation, plotting all time steps during the entire 7-month simulation from November 2, 2014 through May 29, 2015. Plots are provided for the North Fork, South Fork, Freshwater Slough, and Steamboat Slough gauge locations. Flow was computed at a cross section bisecting the gauge locations. An Excel file was also generated to provide the WSE and flow information at the gauge locations. The maps can be seen in Figure F.18 through Figure F.21.

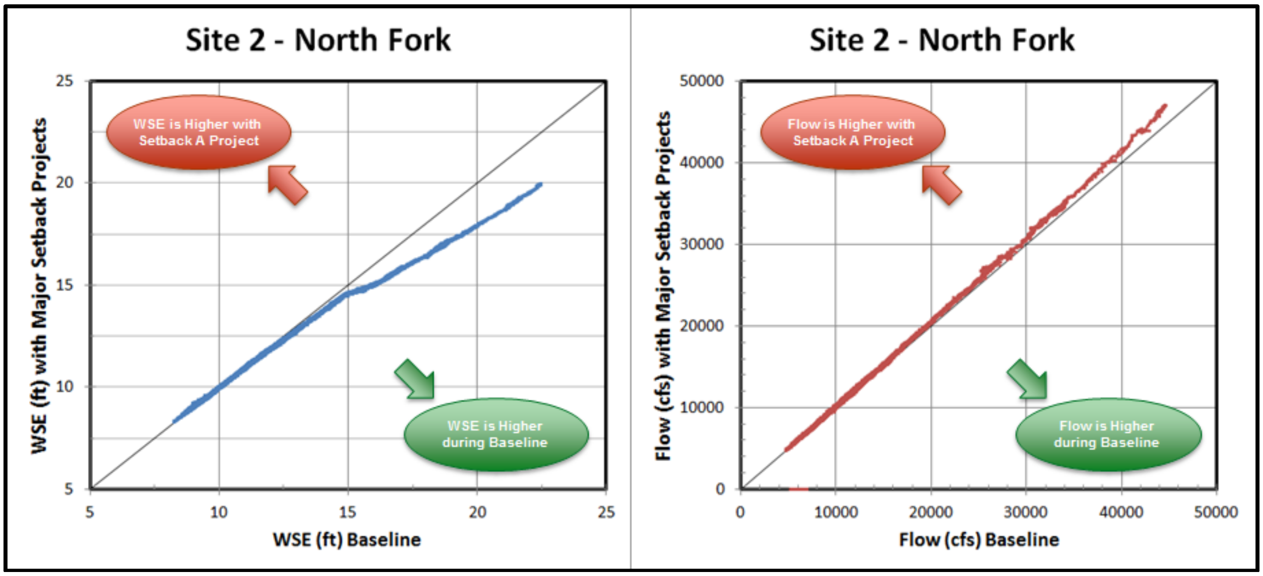


Figure F.18. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Setback Project simulation at the North Fork gauge location compared with the same information under baseline conditions.

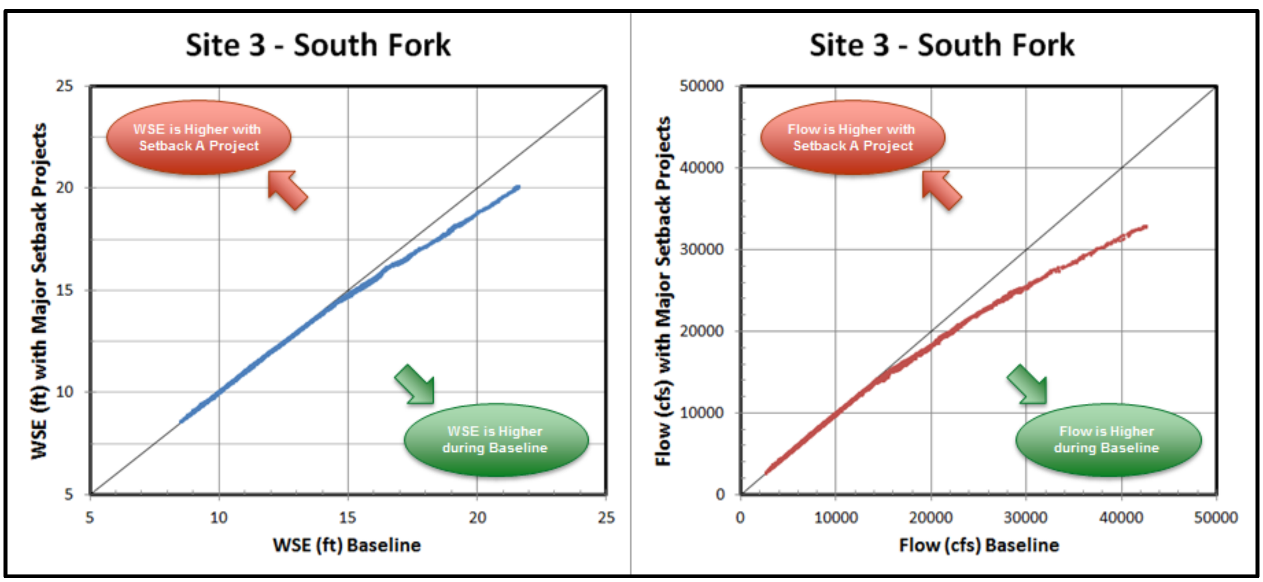


Figure F.19. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Setback Project simulation at the South Fork gauge location compared with the same information under baseline conditions.

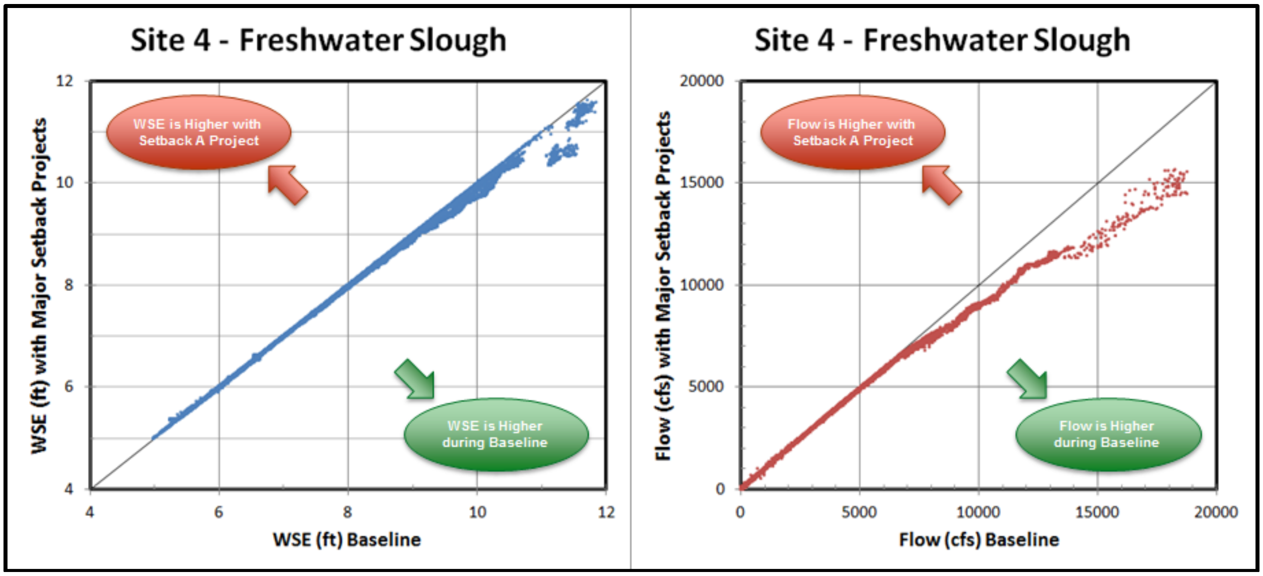


Figure F.20. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Setback Project simulation at the Freshwater Slough gauge location compared with the same information under baseline conditions.

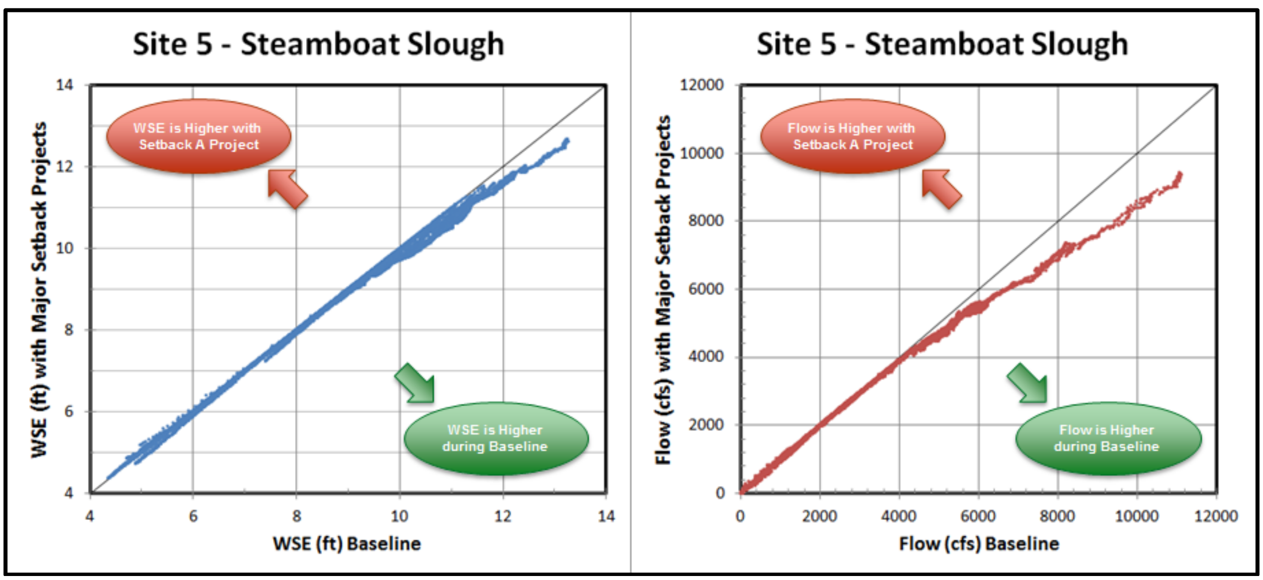


Figure F.21. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Setback Project simulation at the Steamboat Slough gauge location compared with the same information under baseline conditions.

Appendix G

Simulation 6: Moderate Influence Projects Group 1 Deliverables

Appendix G

Simulation 6: Moderate Influence Projects Group #1 Deliverables

The following list of deliverables is associated with Simulation 6: NF Right Bank Levee Setback, Milltown Island, Telegraph Slough 1, Thein Farm (Figure G.1). These deliverables were created by the SHDM Team to address specific objectives for the alternative analysis (Friebel et al., in preparation).

1. Table entries showing the change in area subject to natural tidal and riverine processes for each sub-basin in the study area during moderate influence projects (Simulation 6).

2. Table entries showing the change in area subject to natural tidal and riverine processes for each moderate influence project (Simulation 6). Because of error with wetted area calculations, high resolution, georeferenced maps showing the depth of inundation under (1) low flow and high tide and (2) Q2 flow and low tide were also provided (not shown).

3. At points in the main channel and bay front selected by the SHDM Team, cumulative frequency of WSE (for the months of March, April, and May). An Excel file of the data associated with the plot data was also provided (not shown).

4. Contour maps showing water depth for moderate influence projects (Simulation 6) during (1) mean river discharge for the month of May and spring high tide. High-resolution, georeferenced map was also provided (not shown).

5. Histograms of water depth with 1 ft bins at each moderate influence project (Simulation 6) during (1) mean river discharge for the month of May and high spring tide.

6. Contour maps showing change in WSE from baseline (Simulation 0) to moderate influence projects (Simulation 6) during (1) Q2 flow and low spring tide and (2) a flood condition and high tide. High-resolution, georeferenced maps were also provided, including (3) low flow and high spring tide and absolute WSE for all three conditions (not shown).

7. Contour maps showing change in bed shear stress from baseline (Simulation 0) to moderate influence projects (Simulation 6) during (1) low flow and the peak shear stress during a full tidal cycle and (2) Q2 flow and low spring tide. High-resolution, georeferenced maps were also provided, including absolute bed shear stress for both conditions (not shown).

8. Contour maps showing change in salinity from baseline (Simulation 0) to moderate influence projects (Simulation 6) during (1) low flow and high spring tide. High-resolution, georeferenced maps were also provided, including absolute salinity for both conditions (not shown).

9. Plots of change in WSE and flow from baseline (Simulation 0) to moderate influence projects (Simulation 6) for the South Fork, North Fork, Freshwater Slough, and Steamboat Slough to determine the basin effects. An Excel file of the data associated with the plots was also provided.

Figure G.1. A map of project area in the Moderate Influence Projects simulation Group #1.

G.1 Moderate Influence Projects Deliverable 1

For this deliverable, the area was divided into sub-basins, as seen in Figure G.2. Deliverable 1 is a table showing the increase in inundation area subject to natural tidal and riverine processes within each sub-basin, as seen in Table G.1. The accuracy of area calculation is limited by the spatial resolution of the triangular grid, which varies throughout the model domain. A node is considered wet when the model calculated water depth exceeds the minimum wetting and drying criteria of 10 cm (0.3281 ft). For any wetted node included in the project boundary polygon, its associated computational area was counted toward the total inundated area.

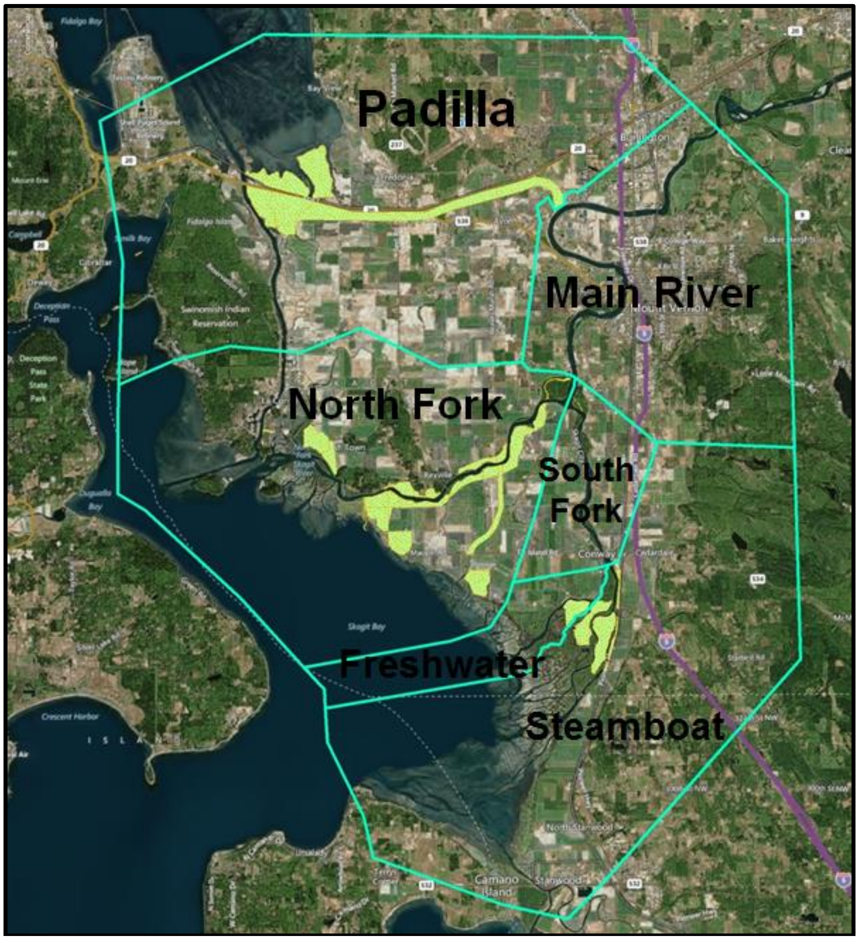


Figure G.2. Sub-basins within the Skagit region used for area calculations.

Table G.1. Table entry showing area increase for each sub-basin under tidal and riverine conditions during the Moderate Influence Projects simulation.

Sub-basin	Baseline (acres)	With Projects (acres)	Increase in Area (acres)
Tidal Influence: High Spring Tide (10.8 ft) + Low Flow (12,000 cfs)			
Sum	20,256.9	20,516.3	**259.4**
Main River	7.8	7.4	**-0.4**
North Fork	8,330.6	8,419.3	**88.7**
South Fork	30.0	30.0	**0.0**
Freshwater	1,944.6	1,944.6	**0.0**
Steamboat	5,827.3	5,834.2	**6.9**
Padilla	4,116.8	4,280.8	**164.0**
Riverine Influence: Low Spring Tide (-3.3 ft) + Q2 Flow (62,000 cfs)			
Sum	7,921.4	8,059.6	**138.2**
Main River	159.0	151.9	**-7.1**

North Fork	2,998.2	3,129.2	**131.0**
South Fork	171.8	149.9	**-21.9**
Freshwater	1,065.1	1,054.6	**-10.5**
Steamboat	2,640.2	2,596.1	**-44.1**
Padilla	887.0	977.9	**90.9**

G.2 Moderate Influence Projects Deliverable 2

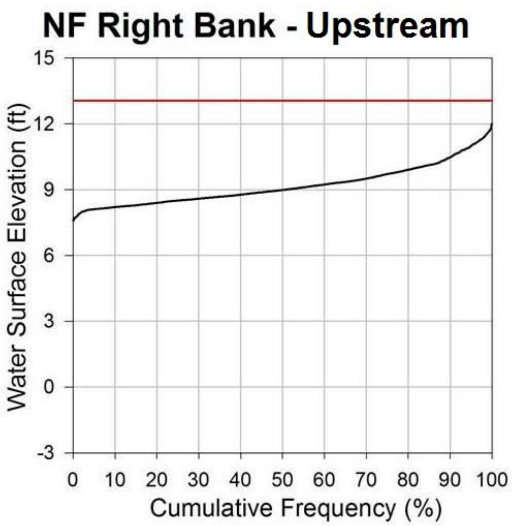
Deliverable 2 is a table showing the increase in inundation area subject to natural tidal and riverine processes within each project area, as seen in Table G.2. Inundation area is counted only within the project footprint. The same limitations and definition of an inundated cell apply here as with Deliverable 1.

Table G.2. Table entry showing area increase for each project under tidal and riverine conditions during the Moderate Influence Projects simulation. Measurements correspond to a measured area that differs from the true project footprint because of grid resolution.

Project (measured area)	Baseline (acres)	With Projects (acres)	Increase in Area (acres)
Tidal Influence: High Spring Tide (10.8 ft) + Low Flow (12,000 cfs)			
Sum (**599.5 acres**)	186.7	445.6	**258.9**
NF Right Levee Setback (**92.0 acres**)	2.4	27.1	**24.7**
Milltown Island (**232.9 acres**)	165.1	171.1	**6.0**
Telegraph Slough 1 (**195.4 acres**)	15.2	179.4	**164.2**
Thein Farm (**79.2 acres**)	3.9	68.0	**64.1**
Riverine Influence: Low Spring Tide (-3.3 ft) + Q2 Flow (62,000 cfs)			
Sum (**599.5 acres**)	185.4	431.9	**246.5**
NF Right Levee Setback (**92.0 acres**)	8.5	90.7	**82.2**
Milltown Island (**232.9 acres**)	156.1	160.1	**4.0**
Telegraph Slough 1 (**195.4 acres**)	15.2	111.2	**96.0**
Thein Farm (**79.2 acres**)	5.6	69.9	**64.3**

G.3 Moderate Influence Projects Deliverable 3

Deliverable 3 is a set of cumulative frequency plots showing water surface elevation at a point in the main channel or Bayfront near each project site. These are from the spring months of the Moderate Influence Projects simulation (Simulation 6), representing March 1 – May 22, 2015, a time period chosen to coincide with the primary fish outmigration. All WSE values are relative to the NAVD88 datum. A red mark line was provided with every point to represent an approximation of the average elevation of the project area bed. An Excel file was also generated with WSE at each node location. The plots can be seen in Figure G.3 through Figure G.9.



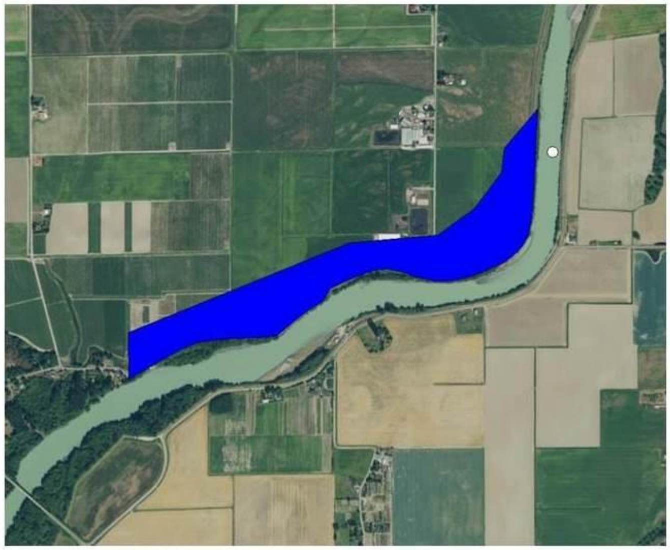
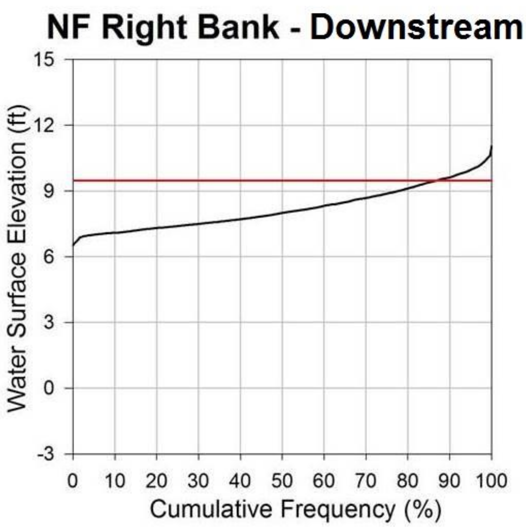


Figure G.3. Cumulative frequency plot and corresponding map for NF Right Bank Levee Setback (upstream) during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.



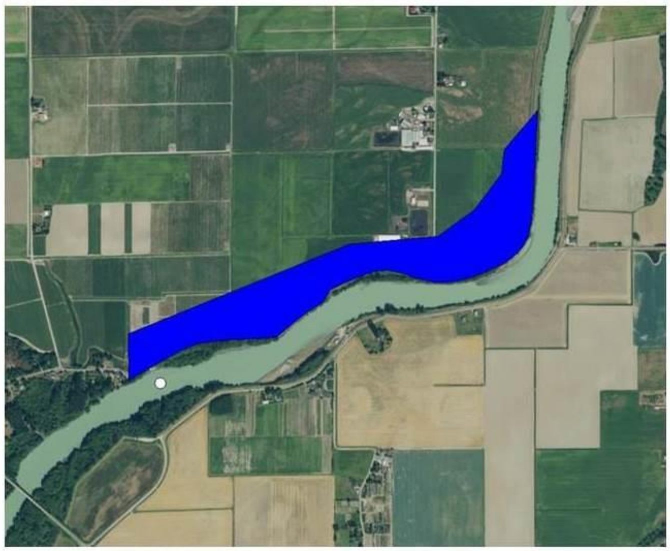


Figure G.4. Cumulative frequency plot and corresponding map for NF Right Bank Levee Setback (downstream) during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

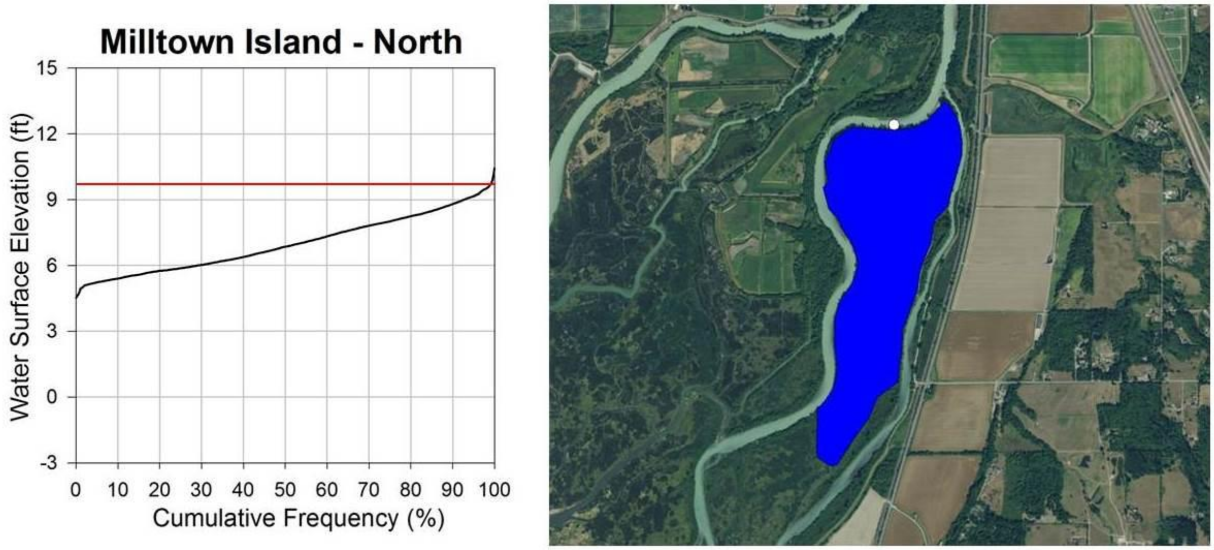


Figure G.5. Cumulative frequency plot and corresponding map for Milltown Island (north) during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

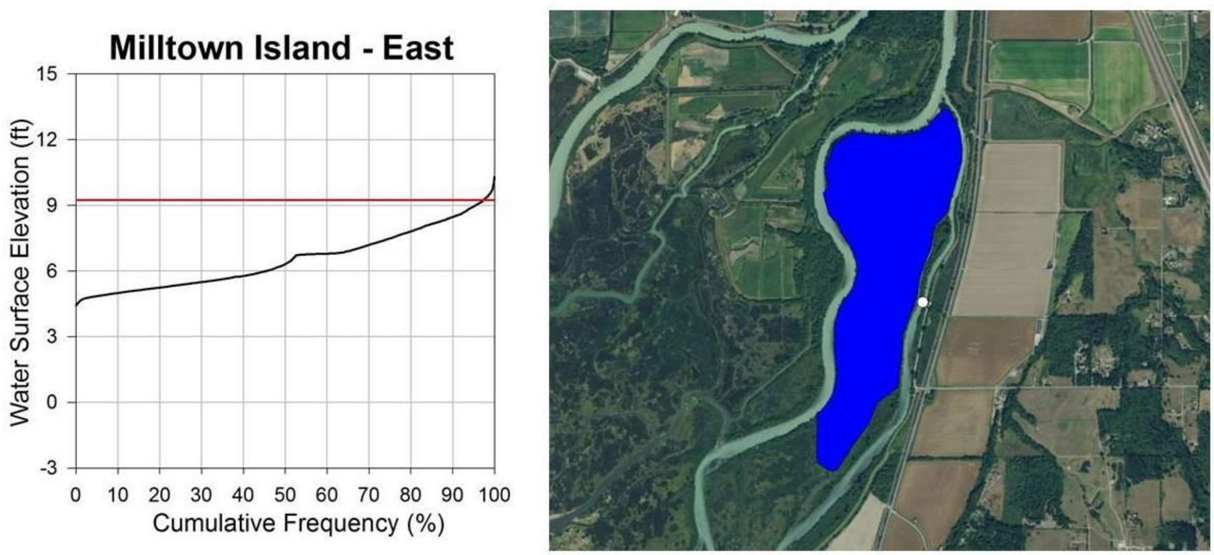


Figure G.6. Cumulative frequency plot and corresponding map for Milltown Island (east) during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

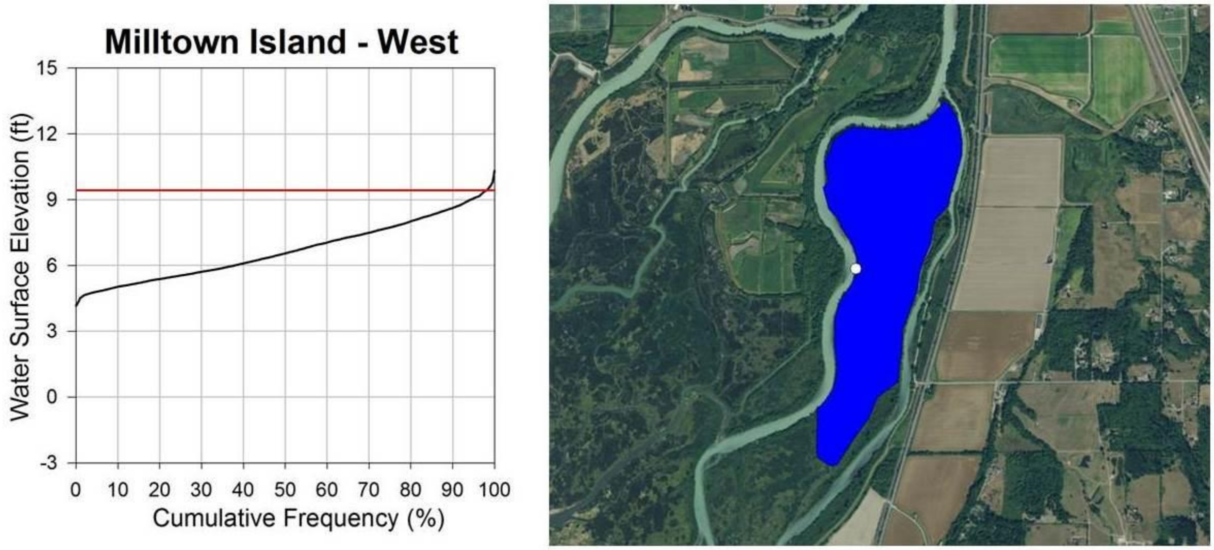


Figure G.7. Cumulative frequency plot and corresponding map for Milltown Island (west) during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

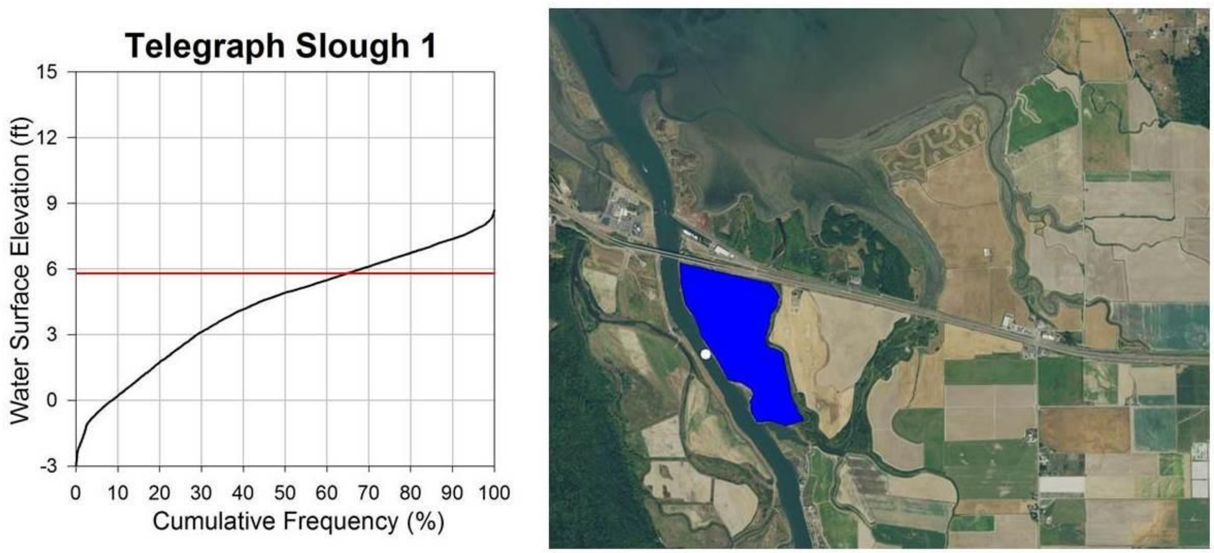


Figure G.8. Cumulative frequency plot and corresponding map for Telegraph Slough 1 during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

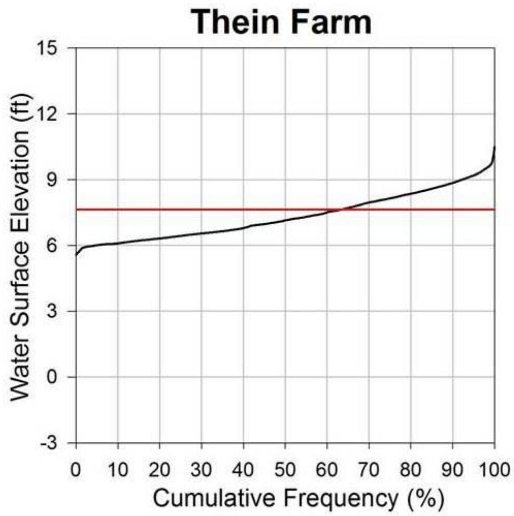


Figure G.9. Cumulative frequency plot and corresponding map for Thein Farm during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

G.4 Moderate Influence Projects Deliverable 4

Deliverable 4 is a set of contour maps showing the depth of inundation during the Moderate Influence Projects simulation (Simulation 6). The plotted condition was the mean river discharge for the month of May (20,400 cfs) and high spring tide (10.8 ft). All depth values are relative to model bathymetry, which uses linear interpolation to the resolution of the grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure G.10 through Figure G.14.

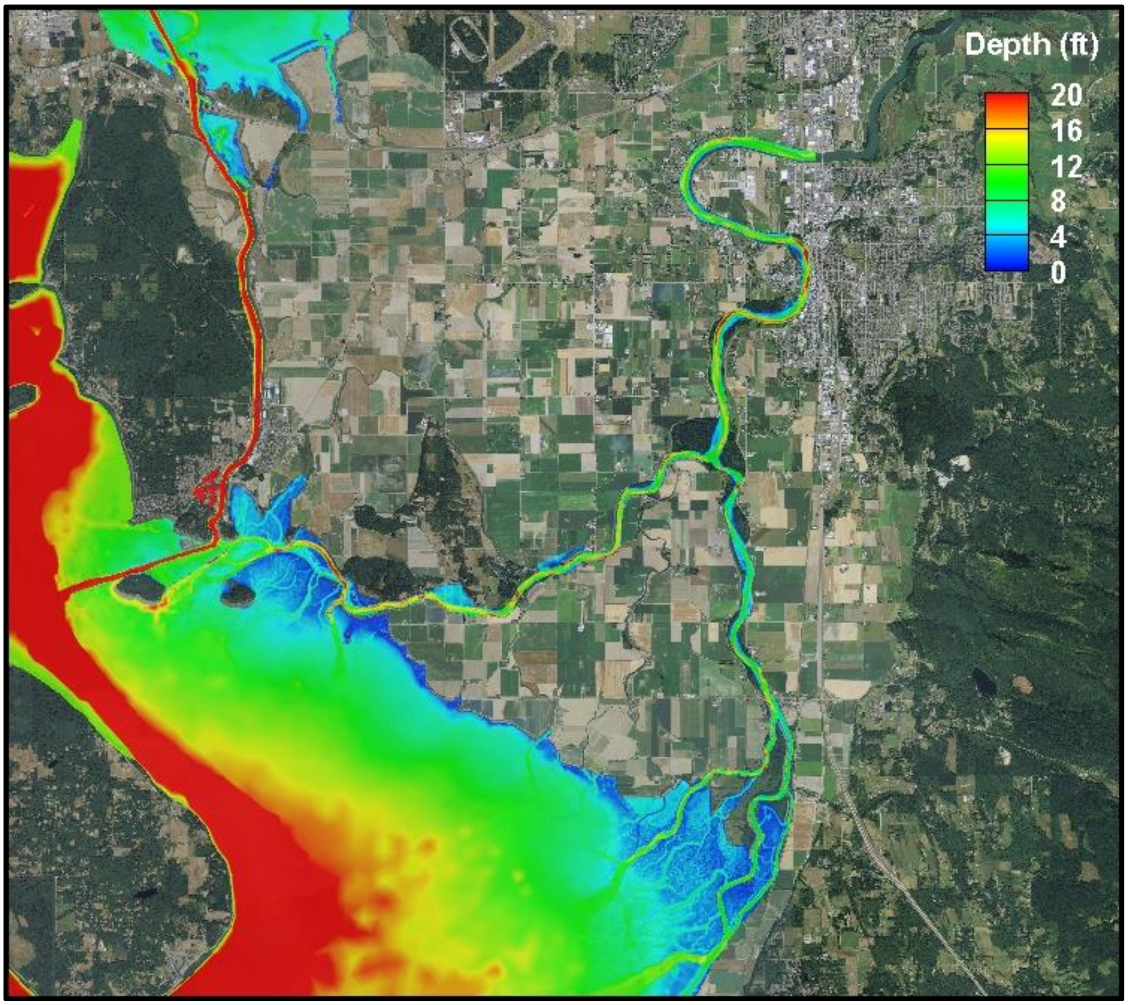


Figure G.10. Contour map of depths for the full domain during the Moderate Influence Projects simulation with May flow and high spring tide.

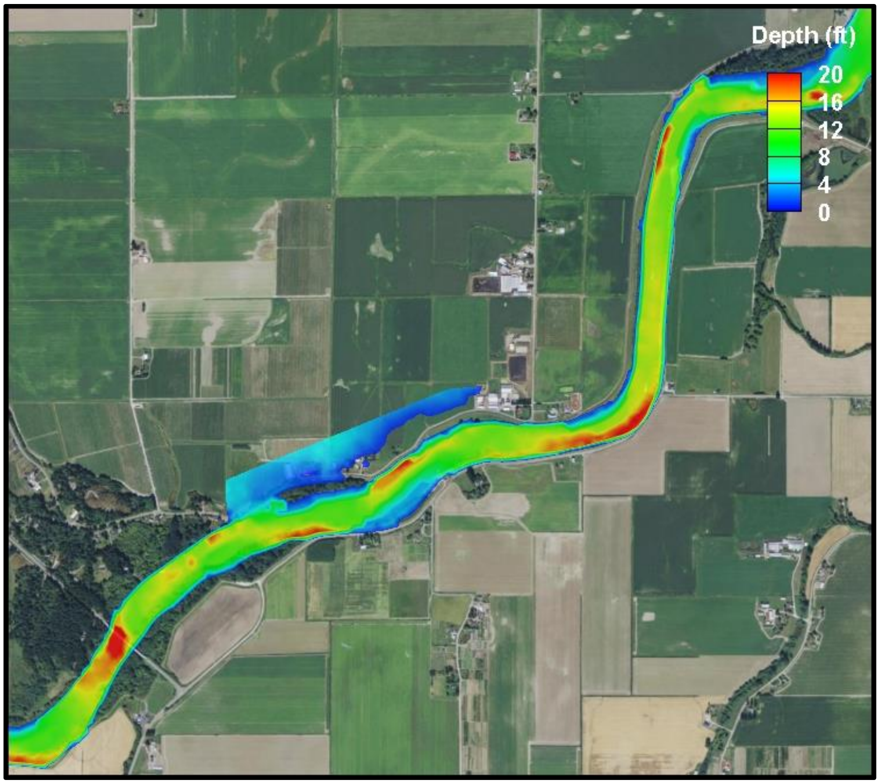


Figure G.11. Contour map of depths for NF Right Bank Levee Setback during the Moderate Influence Projects simulation.

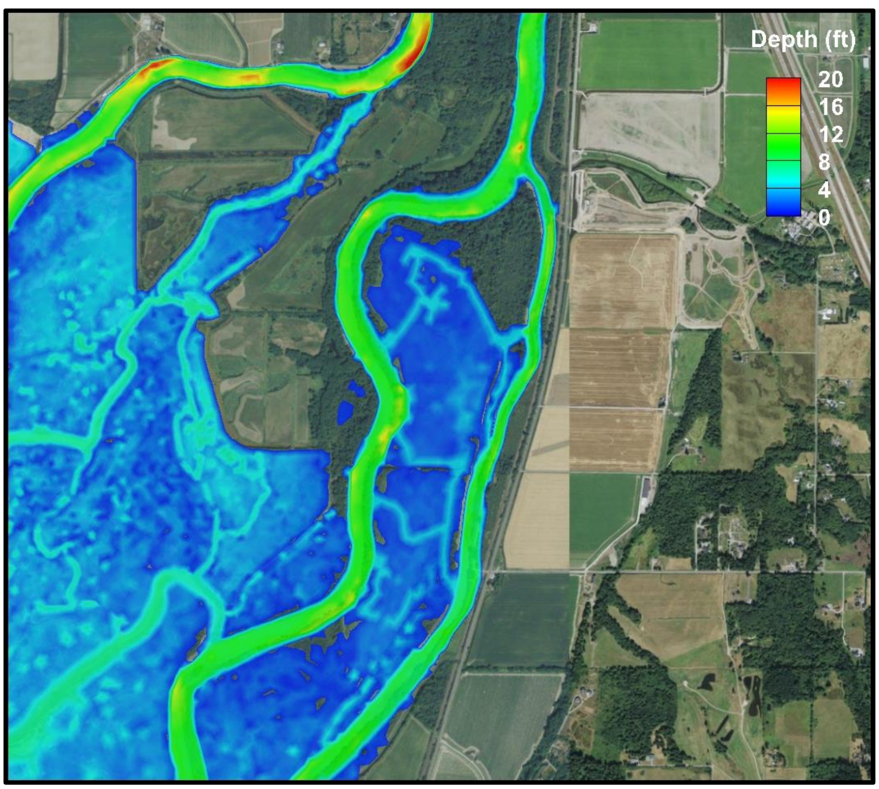


Figure G.12. Contour map of depths for Milltown Island during the Moderate Influence Projects simulation.

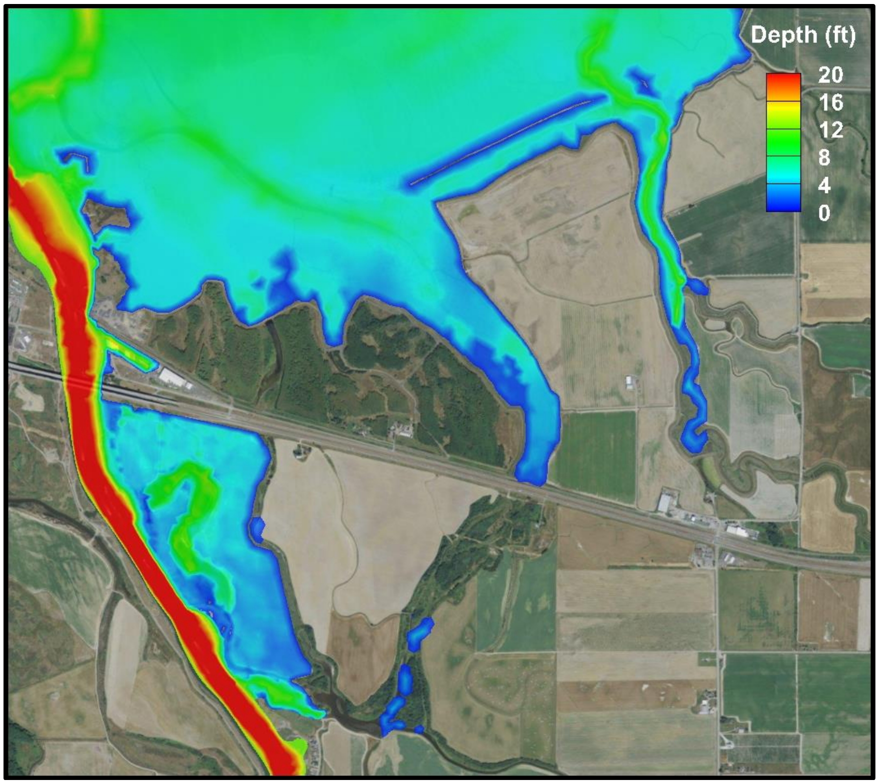


Figure G.13. Contour map of depths for Telegraph Slough 1 during the Moderate Influence Projects simulation.

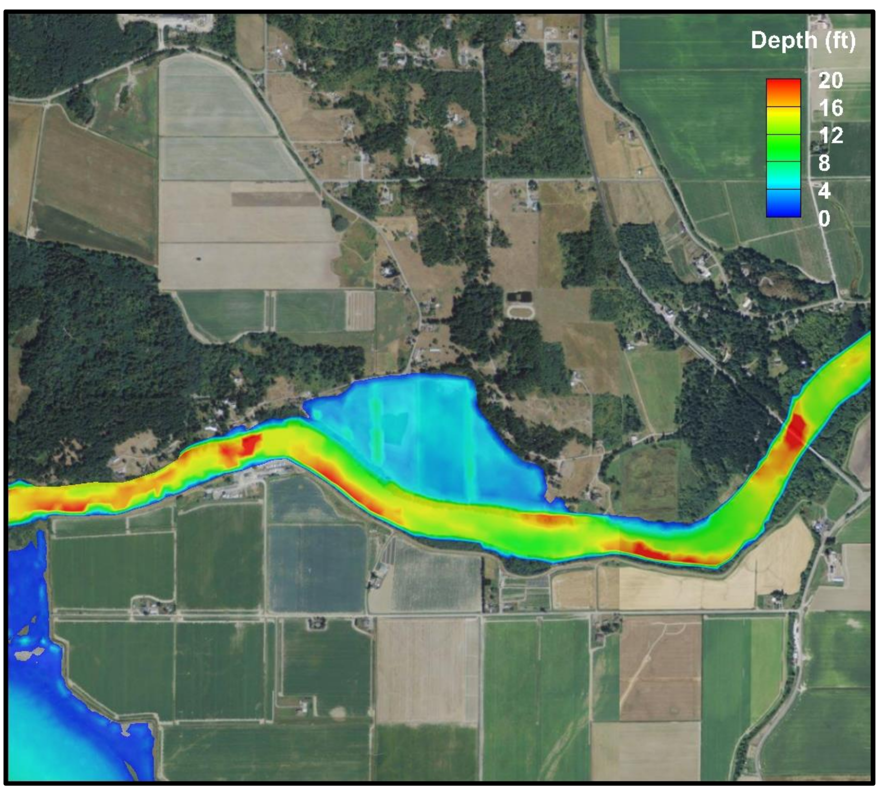


Figure G.14. Contour map of depths for Thein Farm during the Moderate Influence Projects simulation.

G.5 Moderate Influence Projects Deliverable 5

Deliverable 5 is a set of histograms showing the distribution of water depths in 1 ft bins across each project site during a high spring tide (10.8 ft) and mean river discharge for the month of May (20,400 cfs), the same conditions corresponding to the maps of Deliverable 4. All depth values are relative to model bathymetry, which uses linear interpolation to the resolution of the grid. The histograms can be seen in Figure G.15 through Figure G.18.

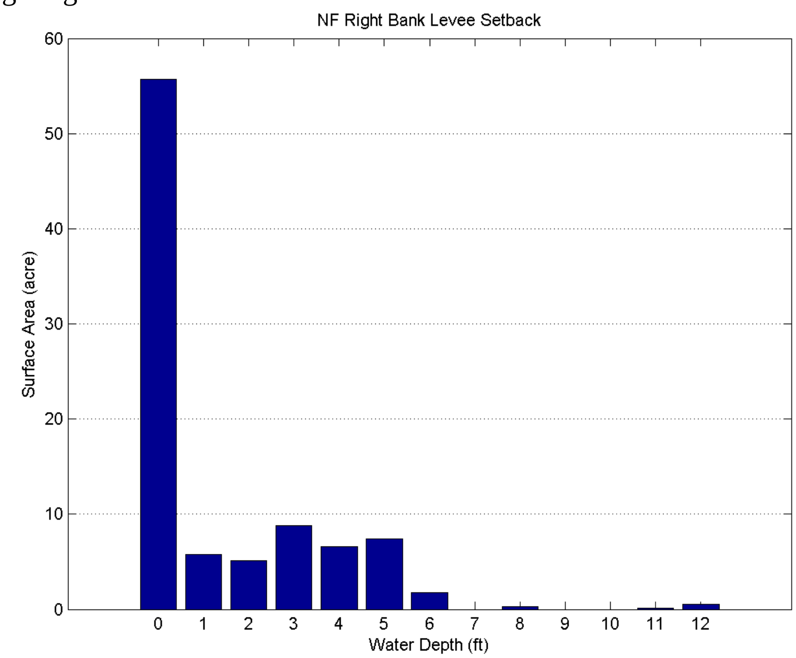


Figure G.15. Histogram of depths for NF Right Bank Levee Setback.

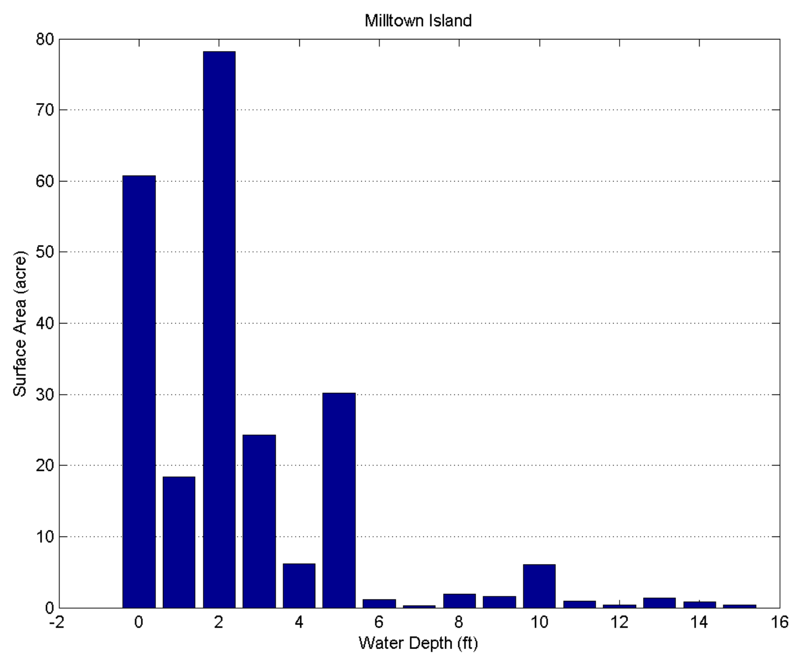


Figure G.16. Histogram of depths for Milltown Island.

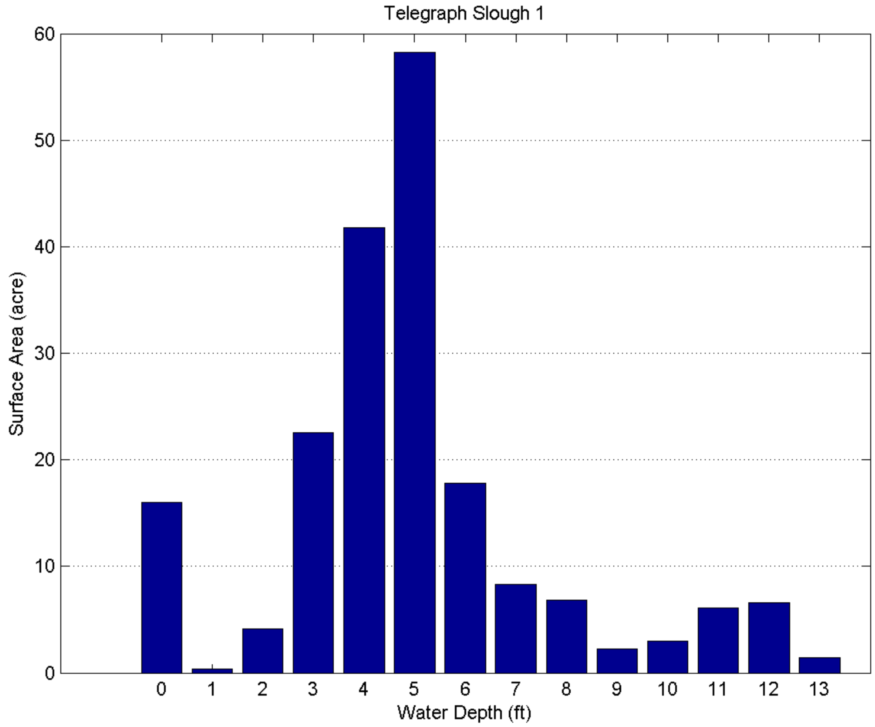


Figure G.17. Histogram of depths for Telegraph Slough 1.

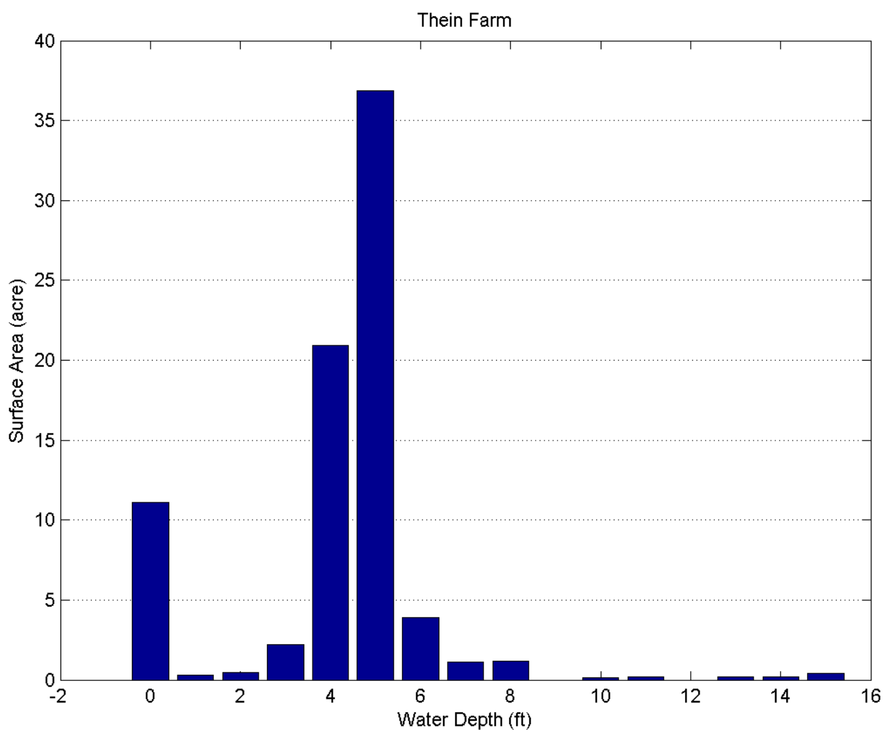


Figure G.18. Histogram of depths for Thein Farm.

G.6 Moderate Influence Projects Deliverable 6

Deliverable 6 is a set of contour maps showing the change in water surface elevation between the Baseline Simulation (Simulation 0) and the Moderate Influence Projects simulation (Simulation 6). Two conditions were compared: (1) a low spring tide (-3.3 ft) and Q2 flow (62,000 cfs) and (2) a high spring tide (10.4 ft) and a flood condition (93,200 cfs), representing the change from baseline to restored conditions. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure G.19 through Figure G.24.

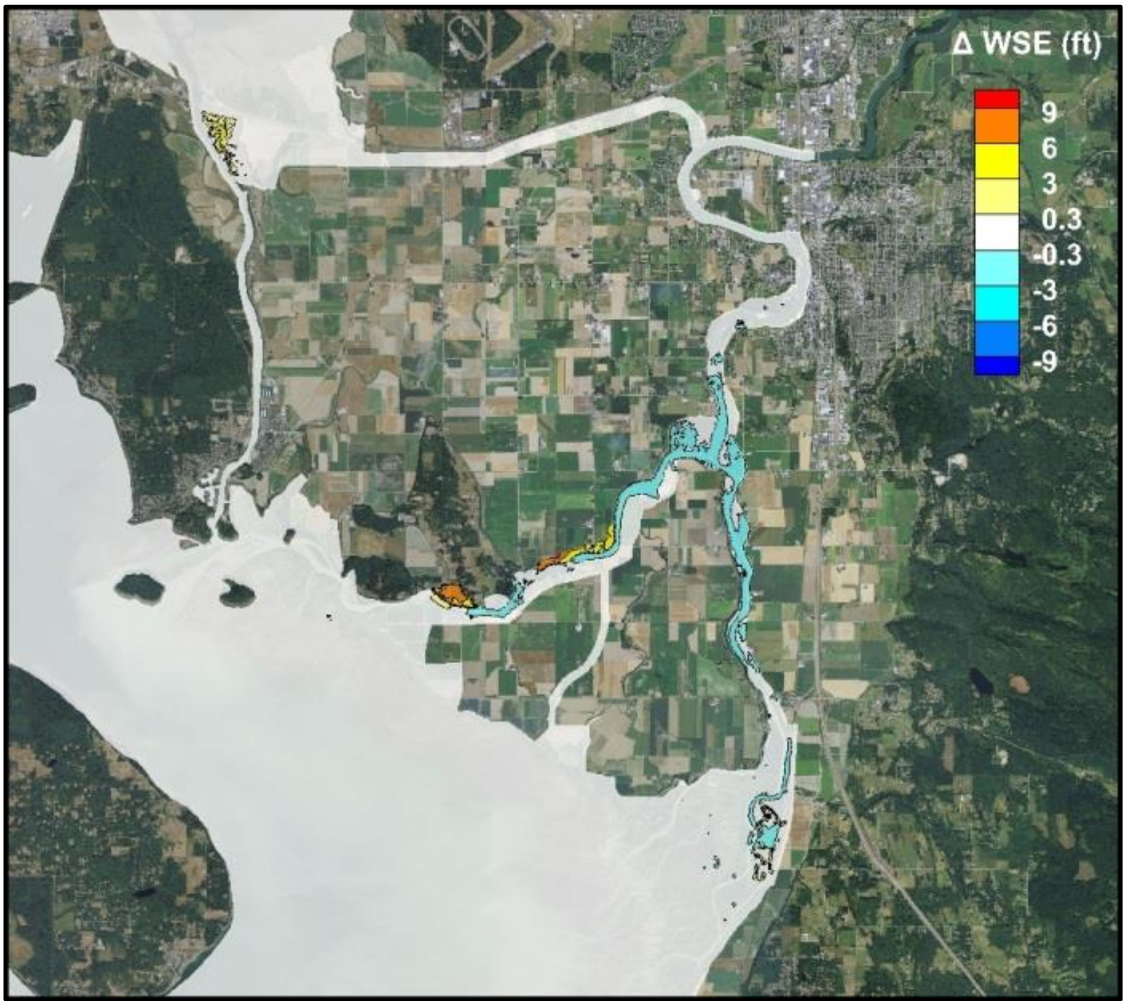


Figure G.19. Contour map of change in WSE from the Baseline to Moderate Influence Projects #1 simulation with Q2 flow and low tide.

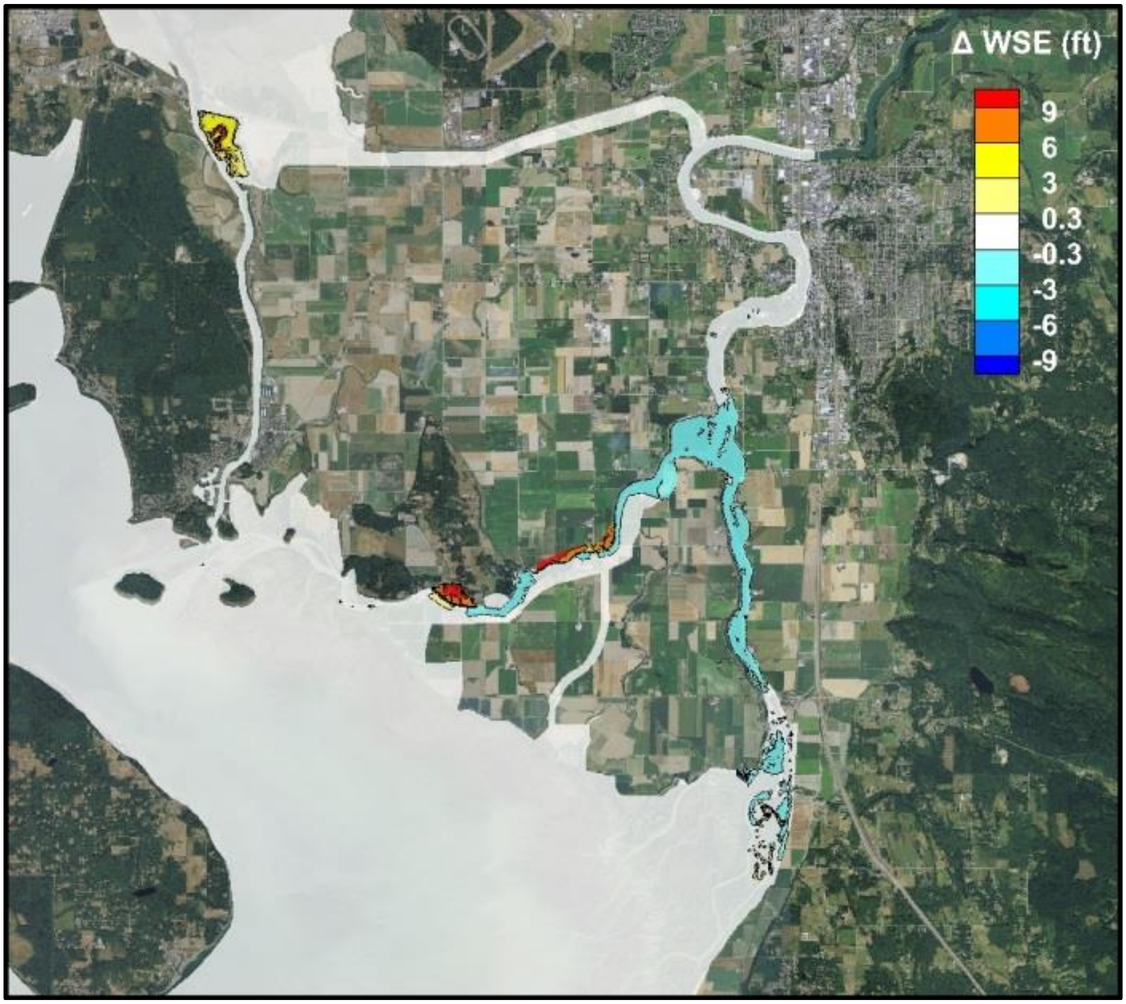


Figure G.20. Contour map of change in WSE from the Baseline to Moderate Influence Projects #1 simulation with flood flow and high tide.

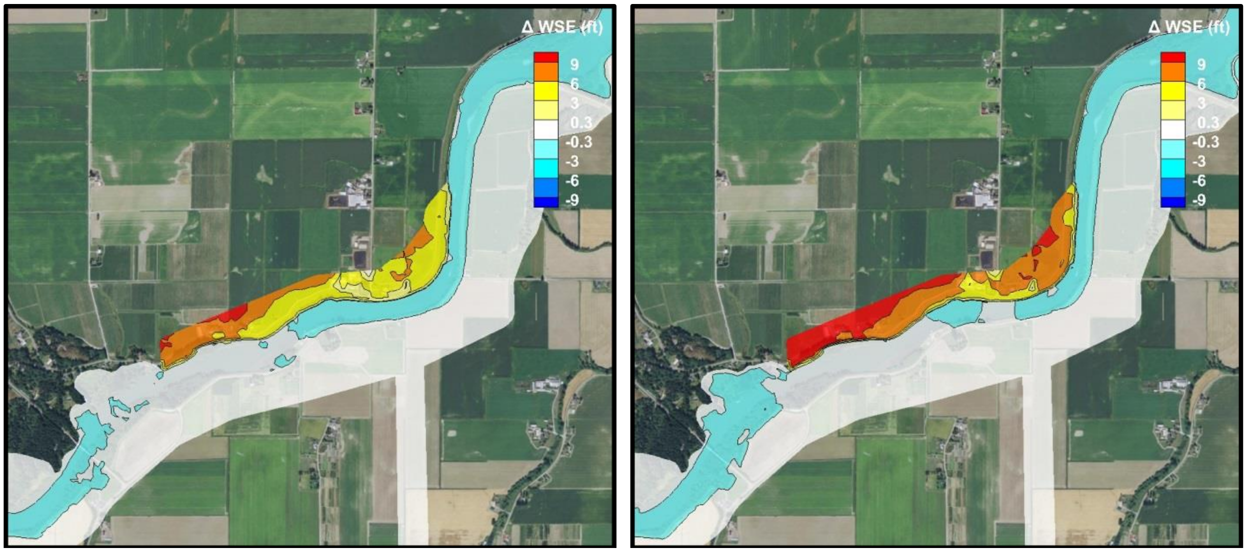


Figure G.21. Contour map of change in WSE from the Baseline simulation for NF Right Bank Levee Setback with Q2 flow and low tide (left) and flood flow and high tide (right).

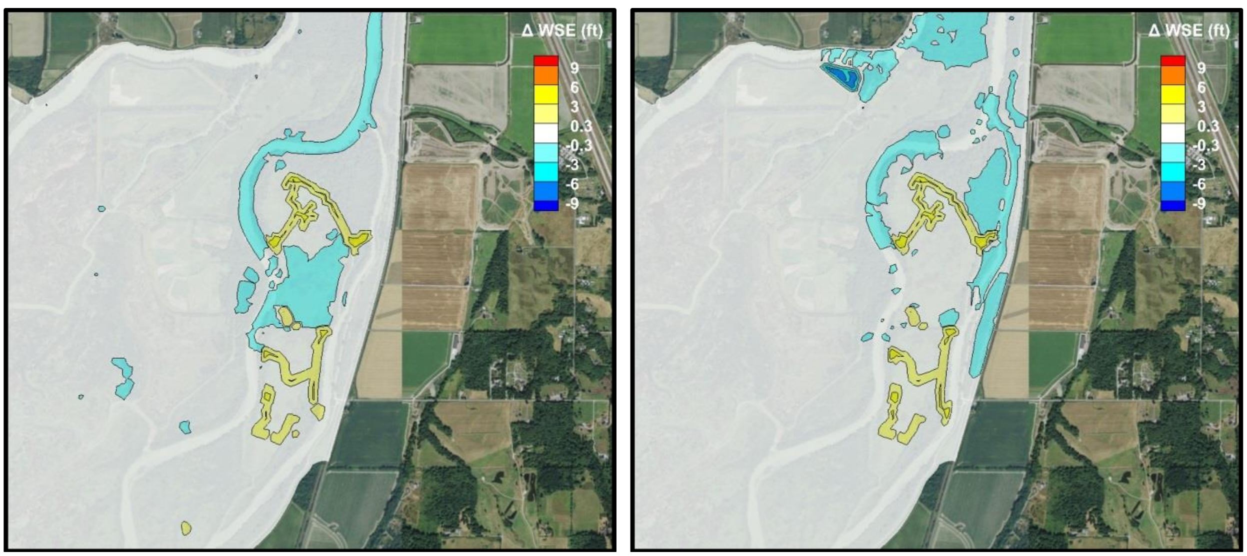


Figure G.22. Contour map of change in WSE from the Baseline simulation for Milltown Island with Q2 flow and low tide (left) and flood flow and high tide (right).

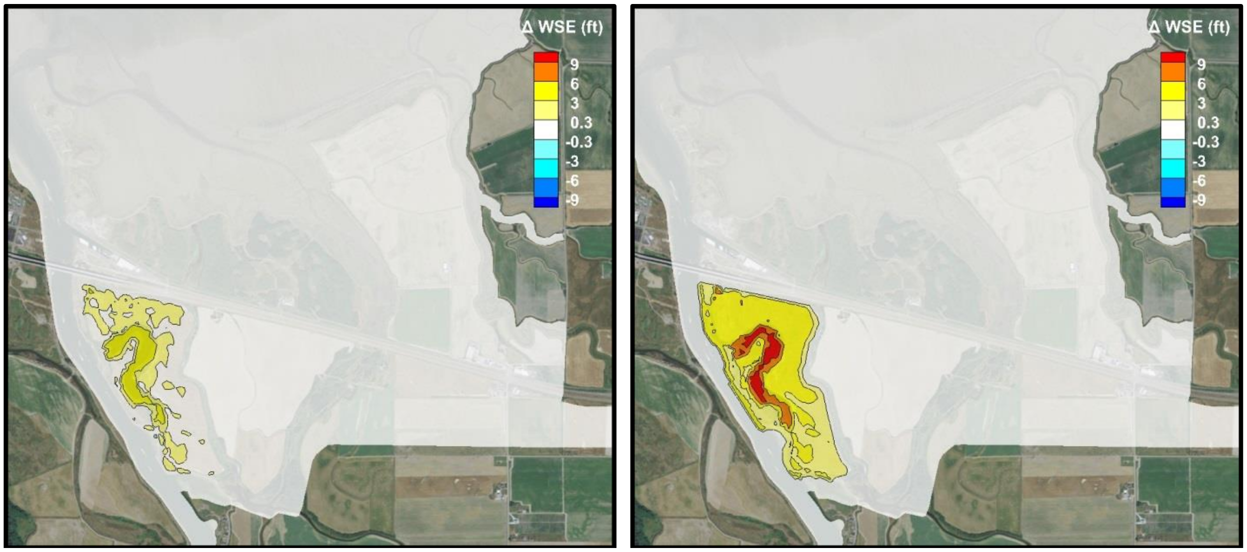


Figure G.23. Contour map of change in WSE from the Baseline simulation for Telegraph Slough 1 with Q2 flow and low tide (left) and flood flow and high tide (right).

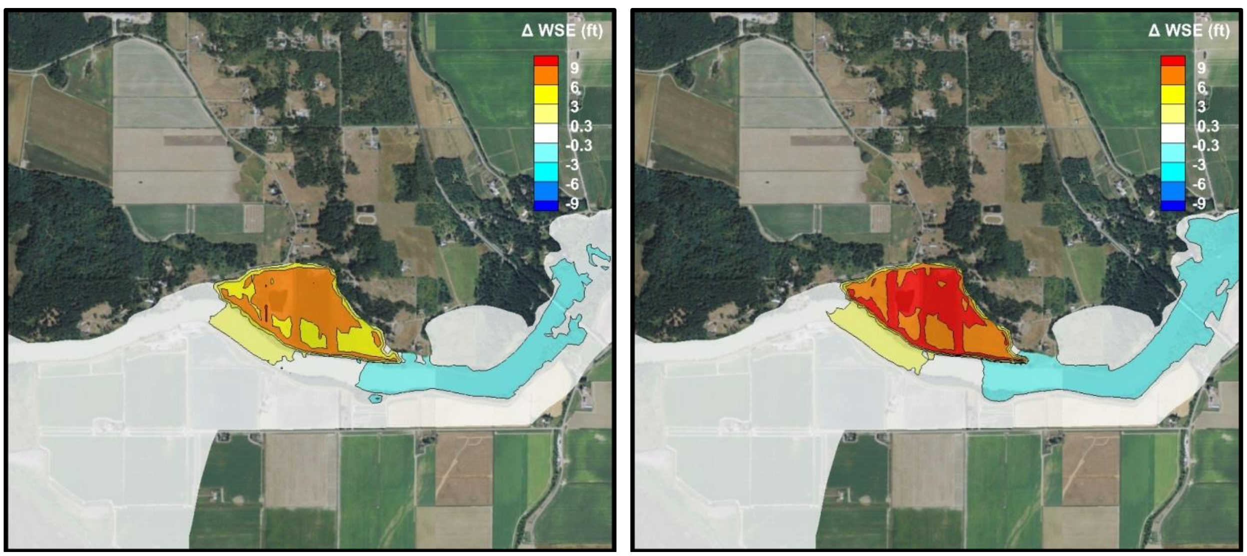


Figure G.24. Contour map of change in WSE from the Baseline simulation for Thein Farm with Q2 flow and low tide (left) and flood flow and high tide (right).

G.7 Moderate Influence Projects Deliverable 7

Deliverable 7 is a set of contour maps showing the change in bed shear stress between the Baseline Simulation (Simulation 0) and the Moderate Influence Projects simulation (Simulation 6). Two conditions were compared: (1) a full spring tidal cycle during a low flow (12,000 cfs) where the peak shear across the map was recorded and (2) a low spring tide (-3.3 ft) and Q2 flow (62,000 cfs), representing the change from baseline to restored conditions. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure G.25 through Figure G.30.

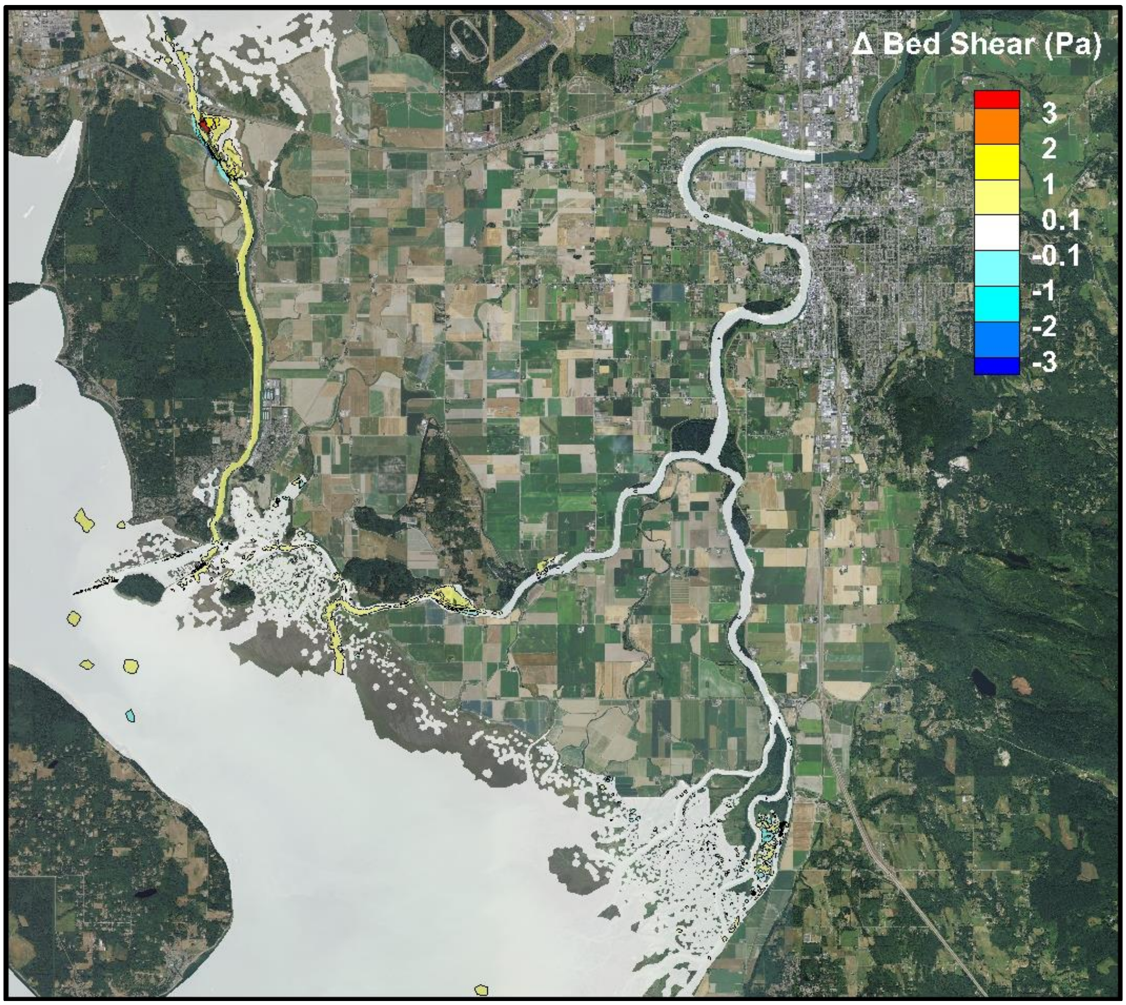


Figure G.25. Contour map of change in shear stress from the Baseline to Moderate Influence Projects #1 simulation with peak shear across a full tidal cycle at low flow.

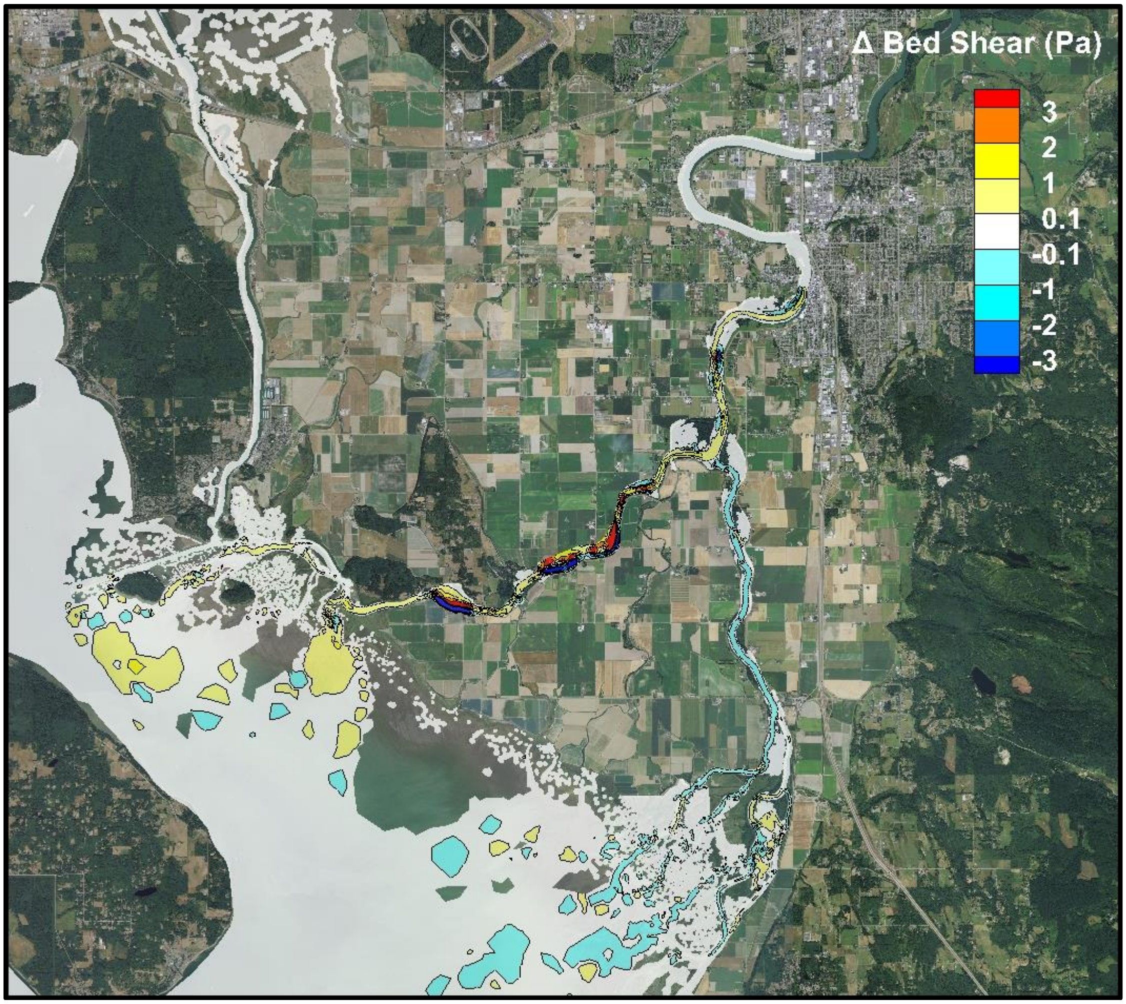


Figure G.26. Contour map of change in shear stress from the Baseline to Moderate Influence Projects #1 simulation with Q2 flow and low tide.

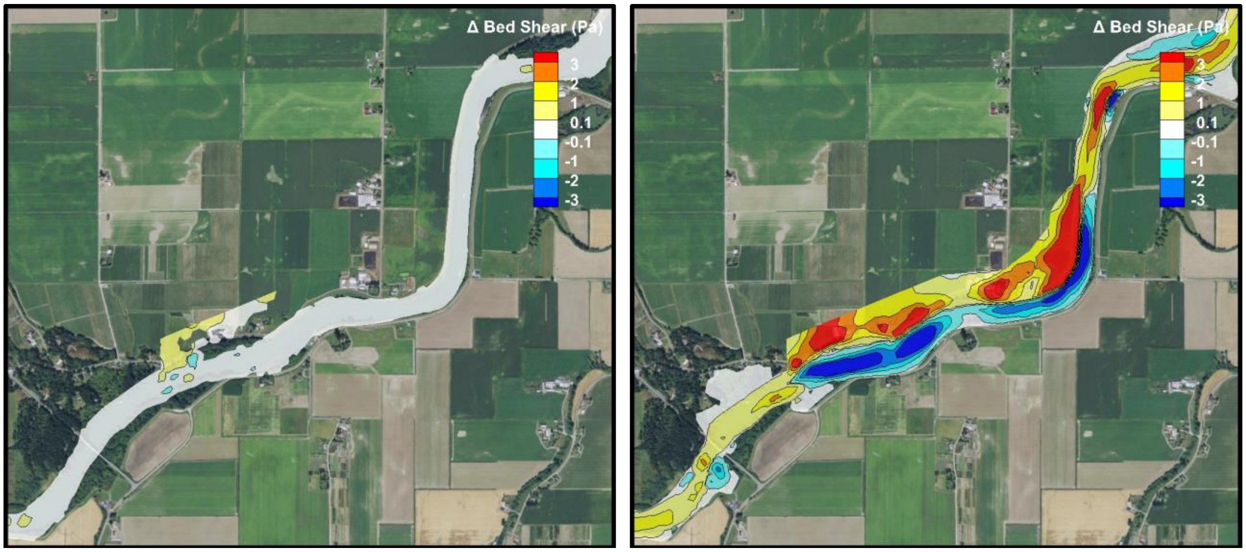


Figure G.27. Contour map of change in shear stress from the Baseline simulation for NF Right Bank Levee Setback with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

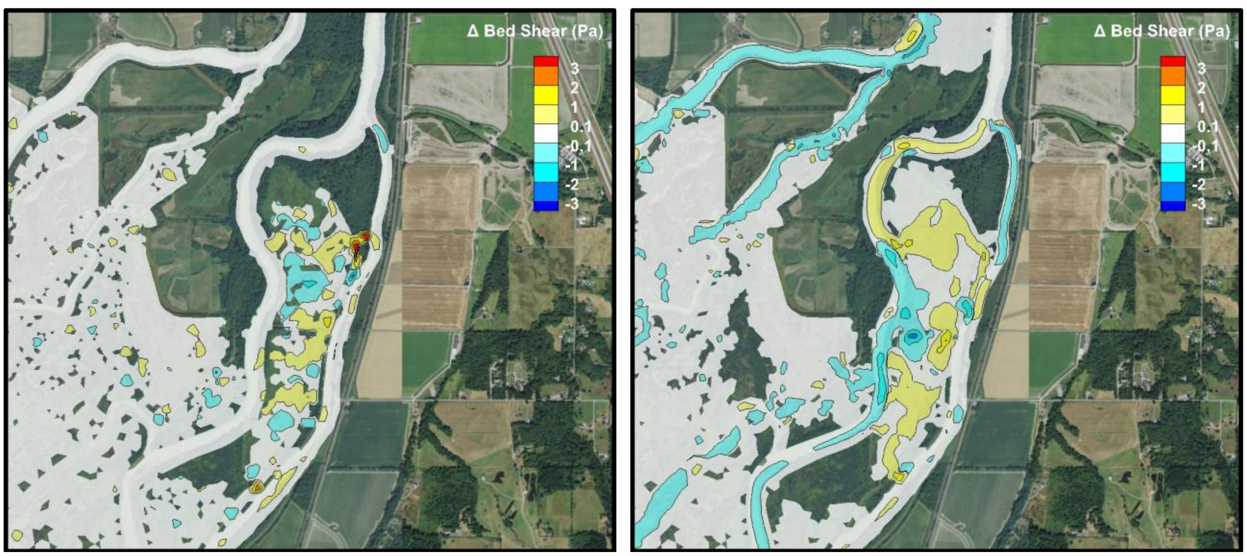


Figure G.28. Contour map of change in shear stress from the Baseline simulation for Milltown Island with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

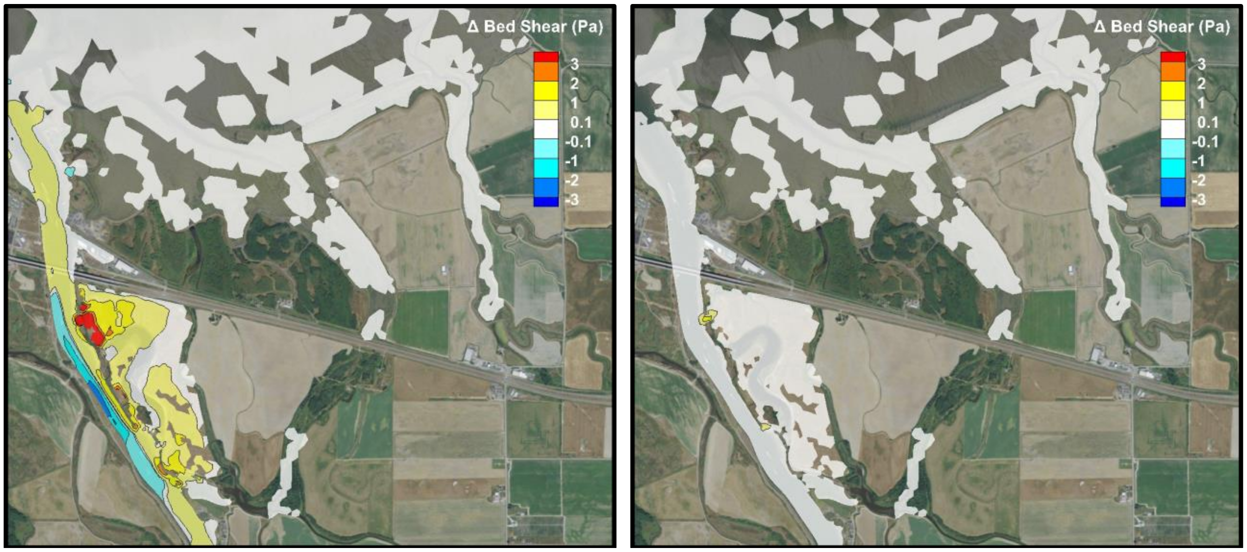


Figure G.29. Contour map of change in shear stress from the Baseline simulation for Telegraph Slough 1 with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

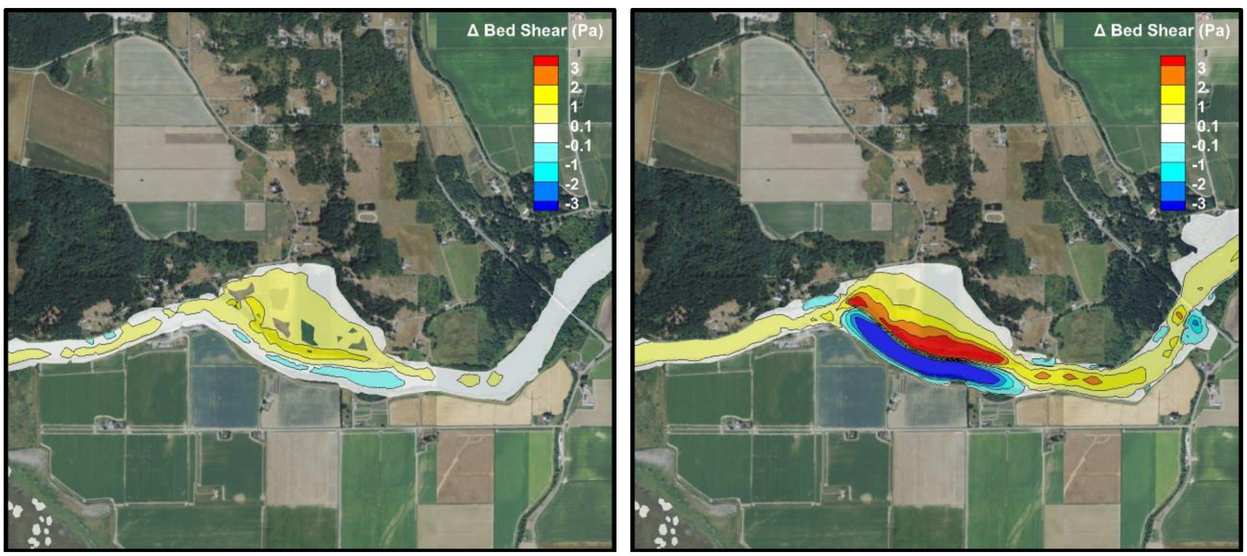


Figure G.30. Contour map of change in shear stress from the Baseline simulation for Thein Farm with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

G.8 Moderate Influence Projects Deliverable 8

Deliverable 8 is a set of contour maps showing the change in salinity between the Baseline Simulation (Simulation 0) and the Moderate Influence Projects simulation (Simulation 6). The compared conditions were a low flow (12,000 cfs) and high spring tide (10.8 ft), representing the change from baseline to restored conditions. The compared salinity values represent an average of the bottom 10% of the water depth to show the furthest extent of the salt wedge. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. Changes in salinity could affect habitat suitability, the distribution of fish, and have potential effects on agriculture. The maps can be seen in Figure G.31 through Figure G.35.

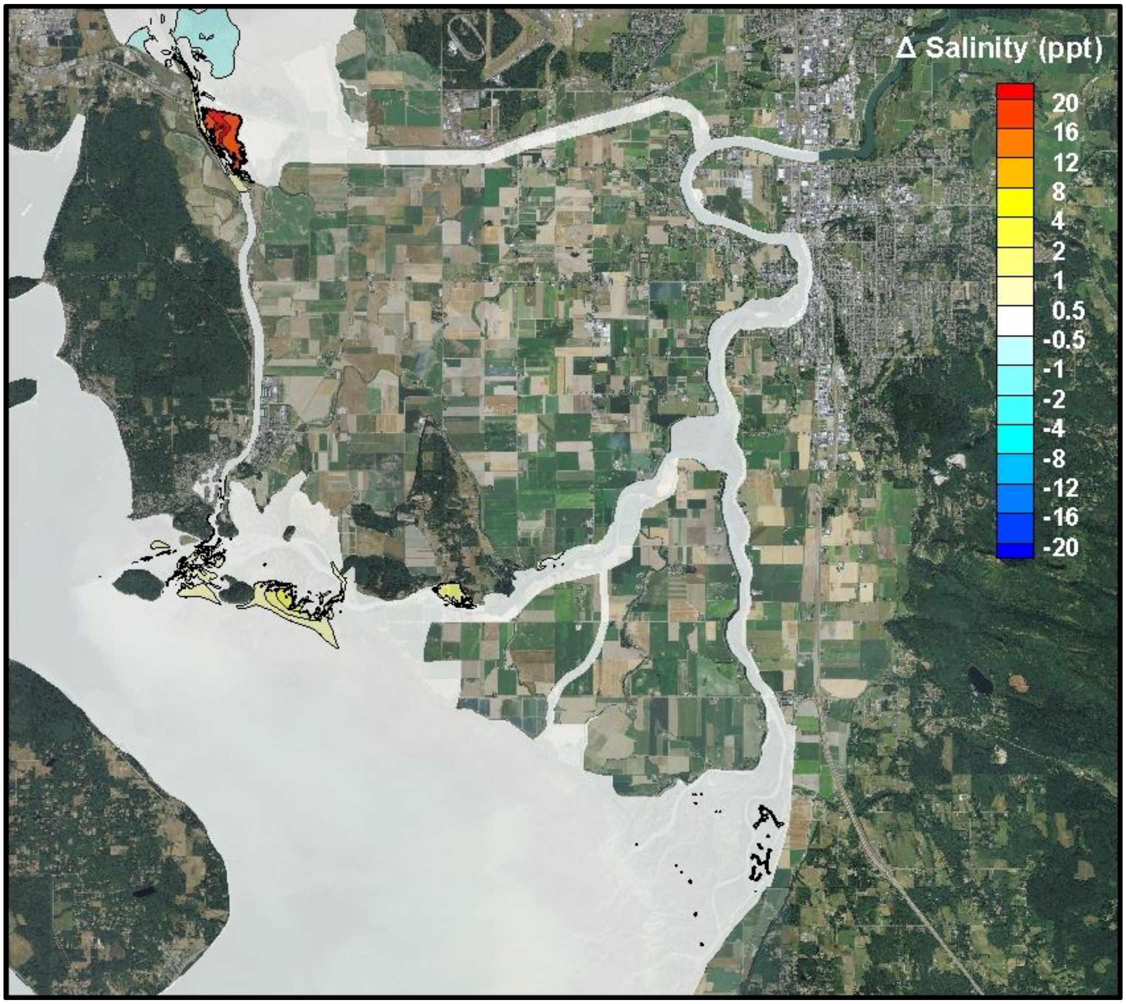


Figure G.31. Contour map of change in salinity from the Baseline to Moderate Influence Projects #1 simulation with low flow and high tide.

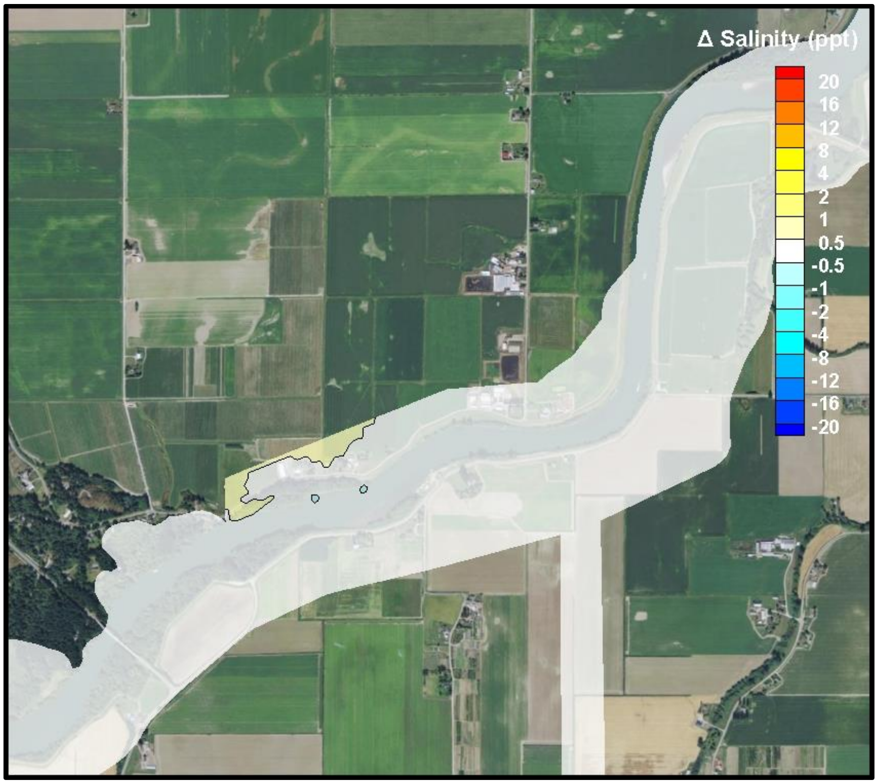


Figure G.32. Contour map of change in salinity from the Baseline simulation for NF Right Bank Levee Setback with low flow and high tide.

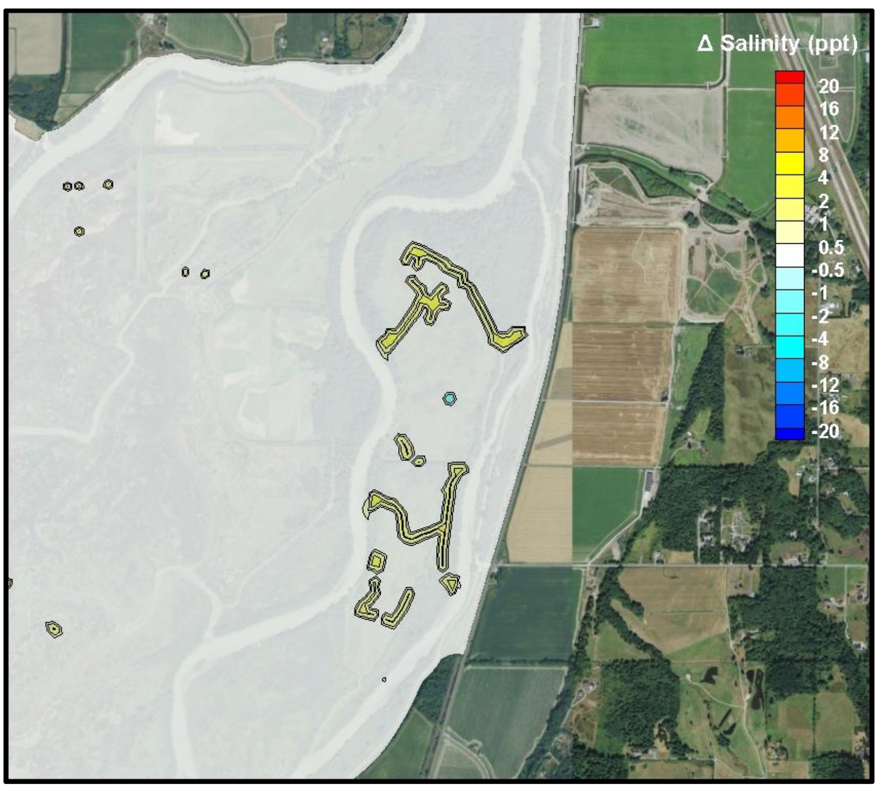


Figure G.33. Contour map of change in salinity from the Baseline simulation for Milltown Island with low flow and high tide.

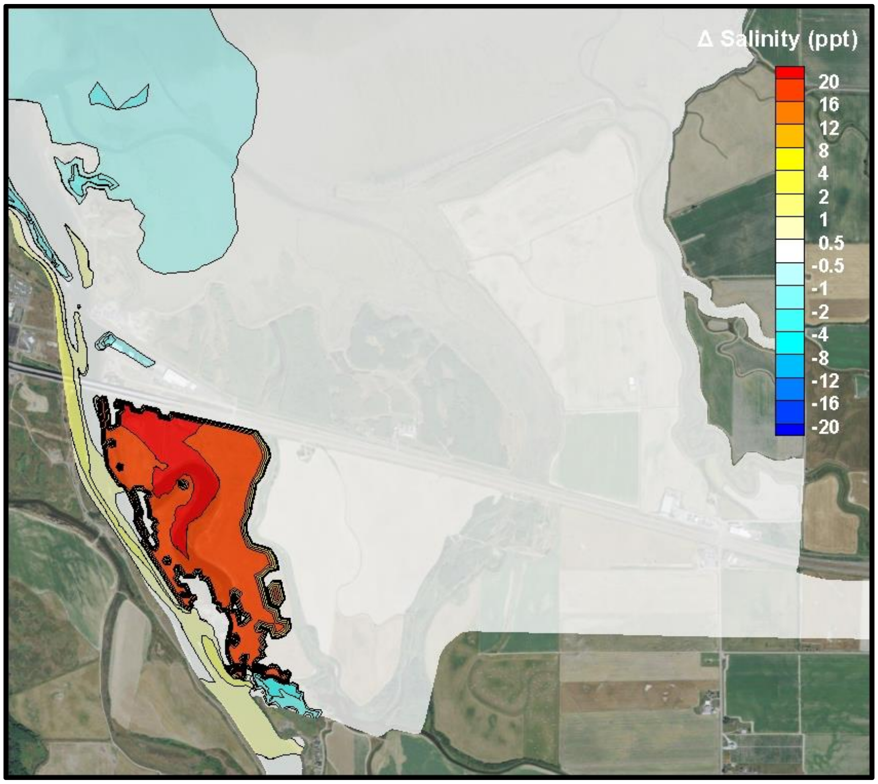


Figure G.34. Contour map of change in salinity from the Baseline simulation for Telegraph Slough 1 with low flow and high tide.

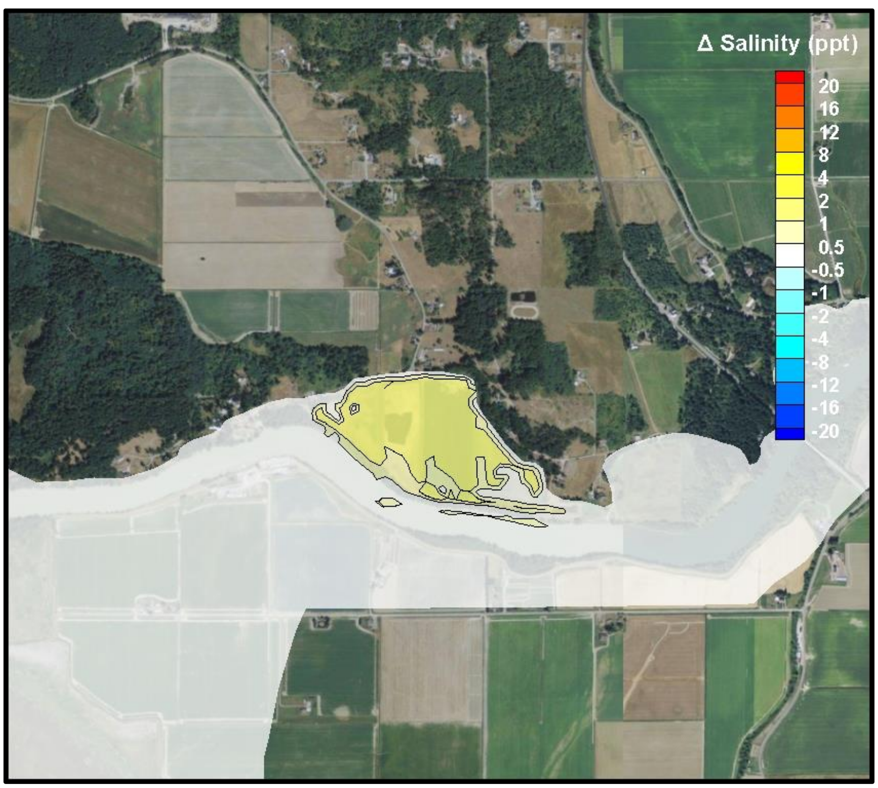


Figure G.35. Contour map of change in salinity from the Baseline simulation for Thein Farm with low flow and high tide.

G.9 Moderate Influence Projects Deliverable 9

Deliverable 9 is a set of plots that compare water surface elevation and flow between the Baseline Simulation and the Moderate Influence Projects simulation, plotting all time steps during the entire 7-month simulation from November 2, 2014 through May 29, 2015. Plots are provided for the North Fork, South Fork, Freshwater Slough, and Steamboat Slough gauge locations. Flow was computed at a cross section bisecting the gauge locations. An Excel file was also generated to provide the WSE and flow information at the gauge locations. The maps can be seen in Figure G.36 through Figure G.39.

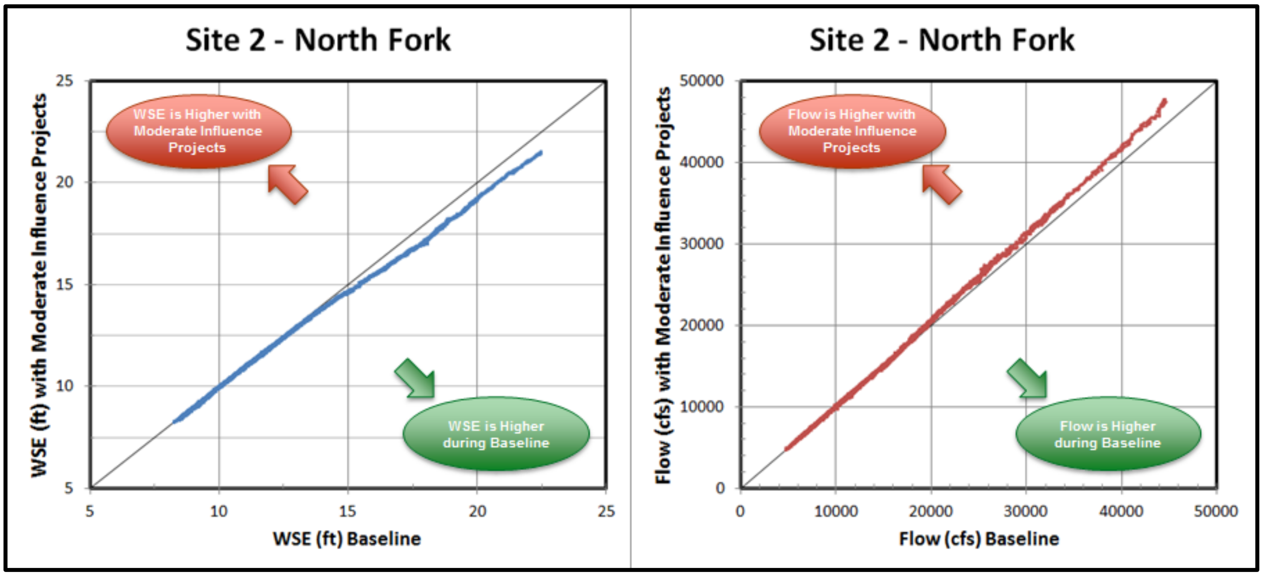


Figure G.36. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Moderate Influence Projects simulation at the North Fork gauge location compared with the same information under baseline conditions.

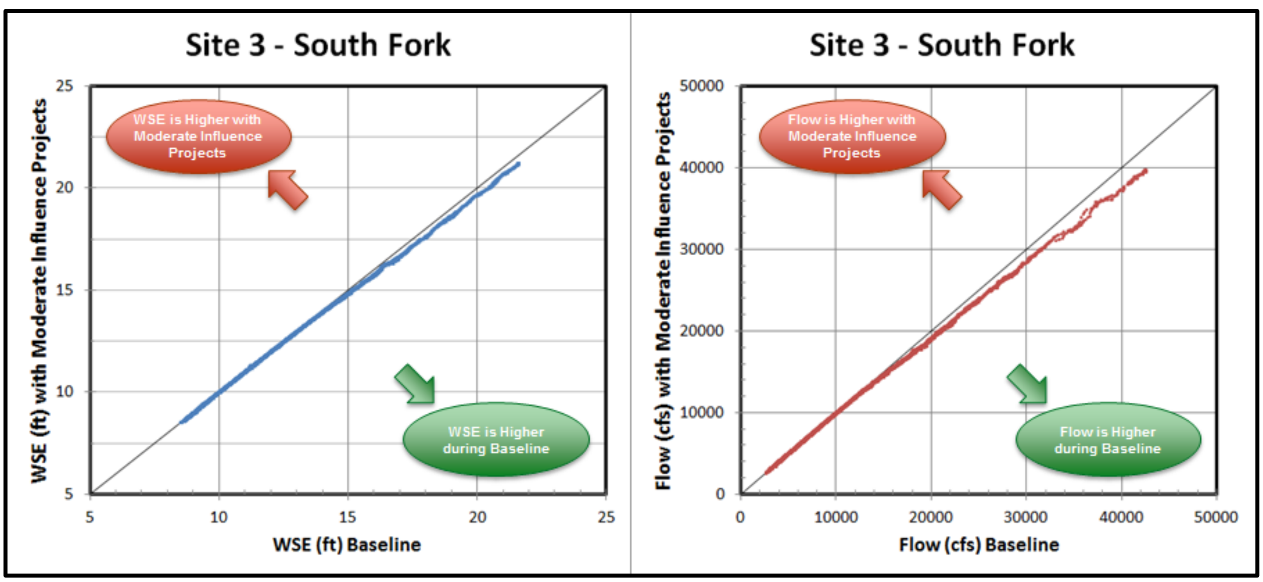


Figure G.37. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Moderate Influence Projects simulation at the South Fork gauge location compared with the same information under baseline conditions.

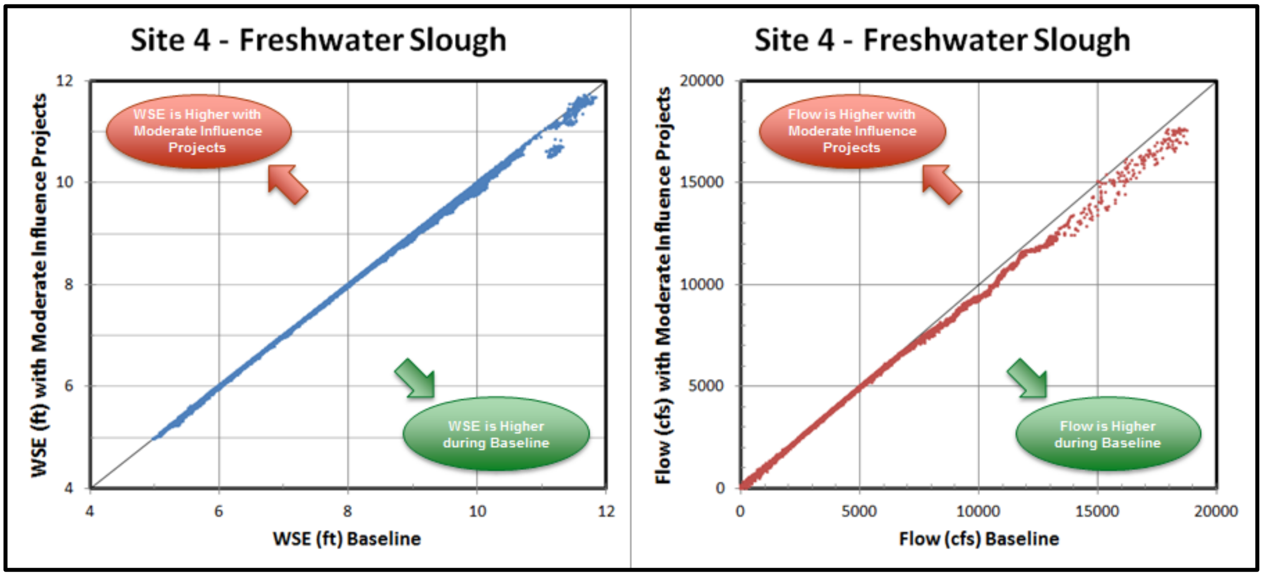


Figure G.38. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Moderate Influence Projects simulation at the Freshwater Slough gauge location compared with the same information under baseline conditions.

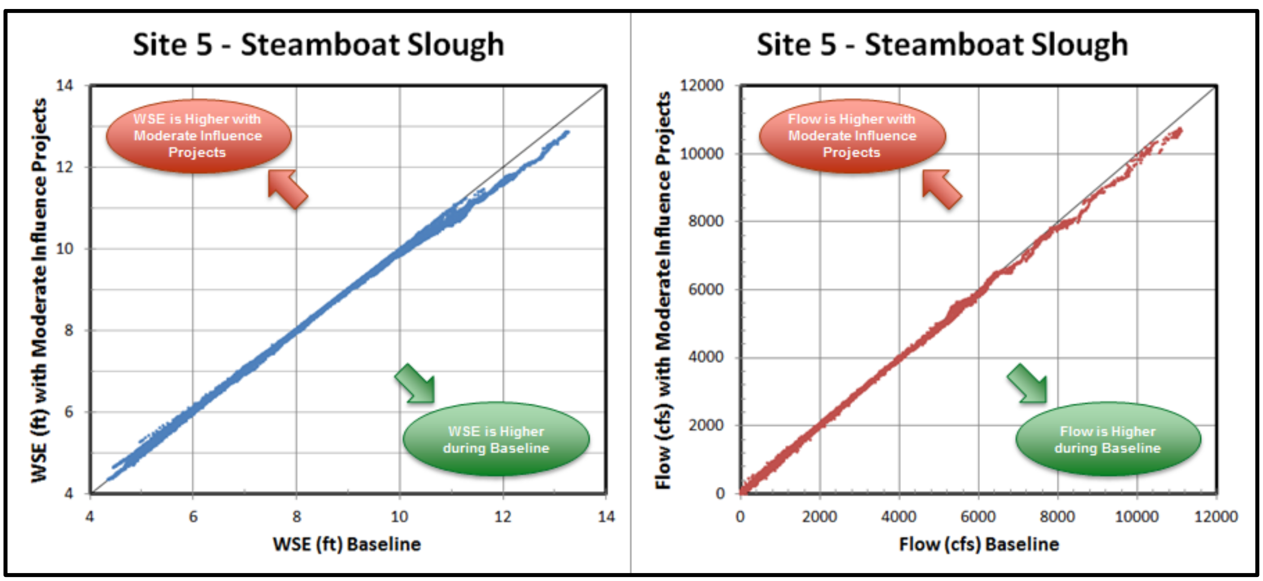


Figure G.39. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Moderate Influence Projects simulation at the Steamboat Slough gauge location compared with the same information under baseline conditions.

Appendix H

Simulation 7: Moderate Influence Projects #2 Deliverables

Appendix H

Simulation 7: Moderate Influence Projects #2 Deliverables

The following list of deliverables is associated with Simulation 7: Deepwater Slough Phase 2, Rawlins Road, Telegraph Slough 1&2 (Figure H.1). These deliverables were created by the SHDM Team to address specific objectives for the alternative analysis (Friebel et al., in preparation).

1. Table entries showing the change in area subject to natural tidal and riverine processes for each sub-basin in the study area during moderate influence projects (Simulation 7).

2. Table entries showing the change in area subject to natural tidal and riverine processes for each moderate influence project (Simulation 7). Because of error with wetted area calculations, high resolution, georeferenced maps showing the depth of inundation under (1) low flow and high tide and (2) Q2 flow and low tide were also provided (not shown).

3. At points in the main channel and bay front selected by the SHDM Team, cumulative frequency of WSE (for the months of March, April, and May). An Excel file of the data associated with the plot data was also provided (not shown).

4. Contour maps showing water depth for moderate influence projects (Simulation 7) during (1) mean river discharge for the month of May and spring high tide. High-resolution, georeferenced map was also provided (not shown).

5. Histograms of water depth with 1 ft bins at each moderate influence project (Simulation 7) during (1) mean river discharge for the month of May and high spring tide.

6. Contour maps showing change in WSE from baseline (Simulation 0) to moderate influence projects (Simulation 7) during (1) Q2 flow and low spring tide and (2) a flood condition and high tide. High-resolution, georeferenced maps were also provided, including (3) low flow and high spring tide and absolute WSE for all three conditions (not shown).

7. Contour maps showing change in bed shear stress from baseline (Simulation 0) to moderate influence projects (Simulation 7) during (1) low flow and the peak shear stress during a full tidal cycle and (2) Q2 flow and low spring tide. High-resolution, georeferenced maps were also provided, including absolute bed shear stress for both conditions (not shown).

8. Contour maps showing change in salinity from baseline (Simulation 0) to moderate influence projects (Simulation 7) during (1) low flow and high spring tide. High-resolution, georeferenced maps were also provided, including absolute salinity for both conditions (not shown).

9. Plots of change in WSE and flow from baseline (Simulation 0) to moderate influence projects (Simulation 7) for the South Fork, North Fork, Freshwater Slough, and Steamboat Slough to determine the basin effects. An Excel file of the data associated with the plots was also provided.

Figure H.1. A map of project area in the Moderate Influence Projects simulation Group #2.

H.1 Moderate Influence Projects Deliverable 1

For this deliverable, the area was divided into sub-basins, as seen in Figure H.2. Deliverable 1 is a table showing the increase in inundation area subject to natural tidal and riverine processes within each sub-basin, as seen in

Table H.1. The accuracy of area calculation is limited by the spatial resolution of the triangular grid, which varies throughout the model domain. A node is considered wet when the model calculated water depth exceeds the minimum wetting and drying criteria of 10 cm (0.3281 ft). For any wetted node included in the project boundary polygon, its associated computational area was counted toward the total inundated area.

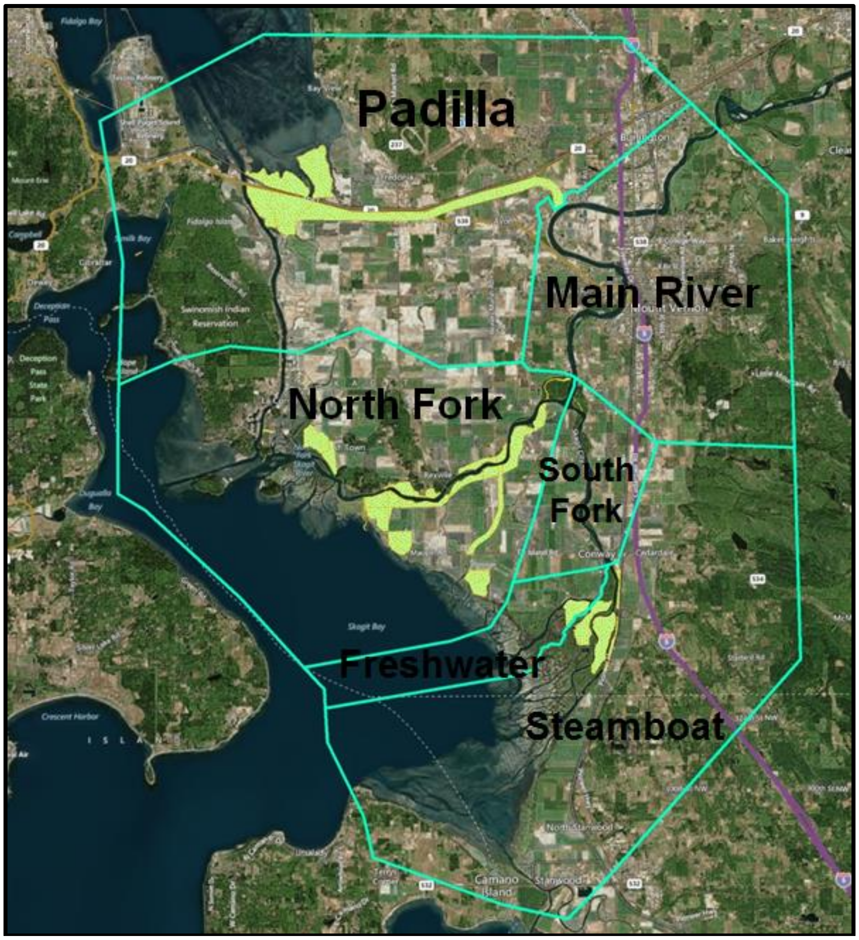


Figure H.2. Sub-basins within the Skagit region used for area calculations.

Table H.1. Table entry showing area increase for each sub-basin under tidal and riverine conditions during the Moderate Influence Projects simulation.

Sub-basin	Baseline (acres)	With Projects (acres)	Increase in Area (acres)
Tidal Influence: High Spring Tide (10.8 ft) + Low Flow (12,000 cfs)			
Sum	20,256.9	21,223.5	**966.6**
Main River	7.8	7.1	**-0.8**
North Fork	8,330.6	8,524.2	**193.6**
South Fork	30.0	30.0	**0.0**
Freshwater	1,944.6	2,057.8	**113.2**
Steamboat	5,827.3	6,038.0	**210.8**
Padilla	4,116.8	4,566.6	**449.8**

Riverine Influence: Low Spring Tide (-3.3 ft) + Q2 Flow (62,000 cfs)			
Sum	7,921.4	8,772.4	**851.1**
Main River	159.0	156.0	**-3.0**
North Fork	2,998.2	3,373.6	**375.4**
South Fork	171.8	146.3	**-25.5**
Freshwater	1,065.1	1,153.1	**88.0**
Steamboat	2,640.2	2,737.0	**96.8**
Padilla	887.0	1,206.5	**319.5**

H.2 Moderate Influence Projects Deliverable 2

Deliverable 2 is a table showing the increase in inundation area subject to natural tidal and riverine processes within each project area, as seen in Table H.2. Inundation area is counted only within the project footprint. The same limitations and definition of an inundated cell that applied for Deliverable 1 apply here.

Table H.2. Table entry showing area increase for each project under tidal and riverine conditions during the Moderate Influence Projects simulation. Measurements correspond to a measured area that differs from the true project footprint because of grid resolution.

Project (measured area)	Baseline (acres)	With Projects (acres)	Increase in Area (acres)
Tidal Influence: High Spring Tide (10.8 ft) + Low Flow (12,000 cfs)			
Sum (**974.6 acres**)	24.2	935.1	**910.9**
Deepwater Slough Phase 2 (**271.3 acres**)	0.0	270.8	**270.8**
Rawlins Road (**202.6 acres**)	0.7	194.6	**193.9**
Telegraph Slough 1&2 (**500.7 acres**)	23.5	469.7	**446.2**
Riverine Influence: Low Spring Tide (-3.3 ft) + Q2 Flow (62,000 cfs)			
Sum (**974.6 acres**)	24.5	786.9	**762.4**
Deepwater Slough Phase 2 (**271.3 acres**)	0.3	268.4	**268.1**
Rawlins Road (**202.6 acres**)	0.7	194.6	**193.9**
Telegraph Slough 1&2 (**500.7 acres**)	23.5	323.9	**300.4**

H.3 Moderate Influence Projects Deliverable 3

Deliverable 3 is a set of cumulative frequency plots showing water surface elevation at a point in the main channel or Bayfront near each project site. These are from the spring months of the Moderate Influence Projects simulation (Simulation 7), representing March 1 – May 22, 2015, a time period chosen to coincide with the primary fish outmigration. A red mark line was provided with every point to represent an approximation of the average elevation of the project area bed. All WSE values are relative to the NAVD88 datum. An Excel file was also generated with WSE at each node location. The plots can be seen in Figure H.3 through Figure H.7.

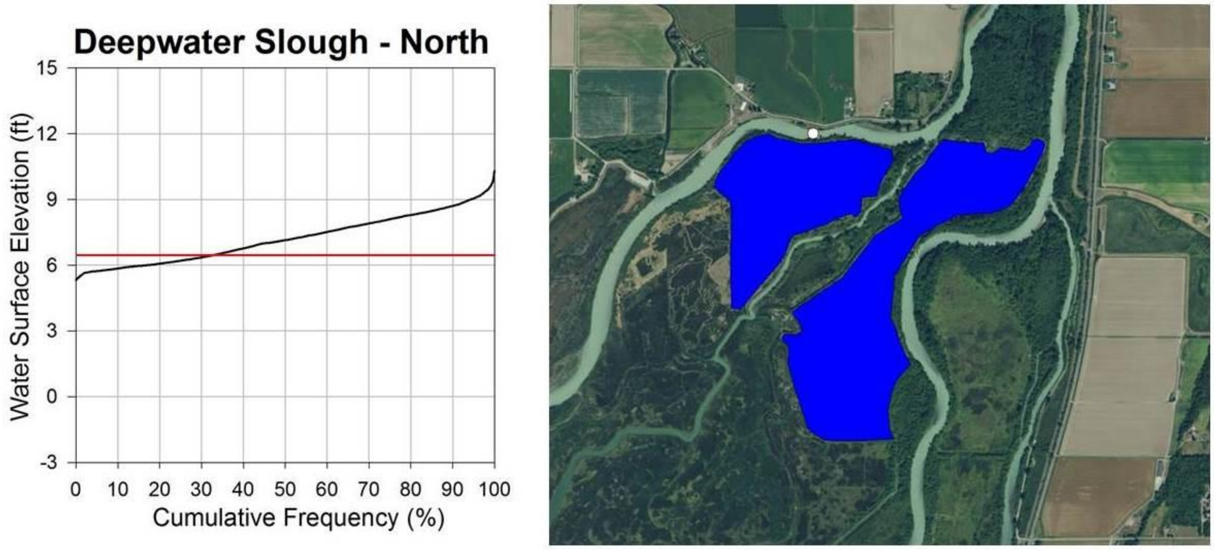


Figure H.3. Cumulative frequency plot and corresponding map for Deepwater Slough Phase 2 (north) during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

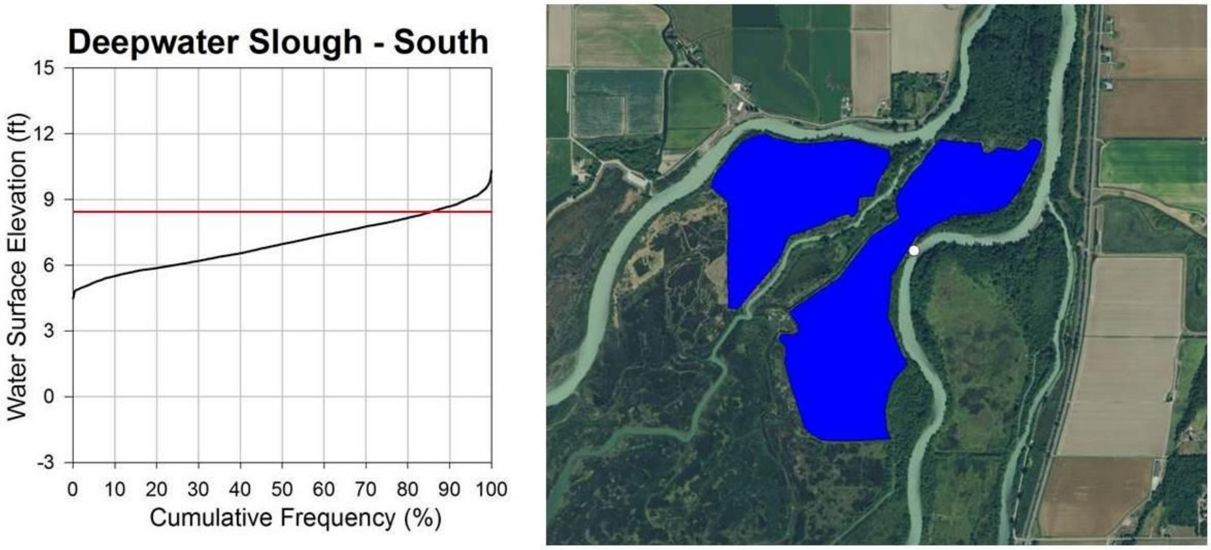


Figure H.4. Cumulative frequency plot and corresponding map for Deepwater Slough Phase 2 (south) during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

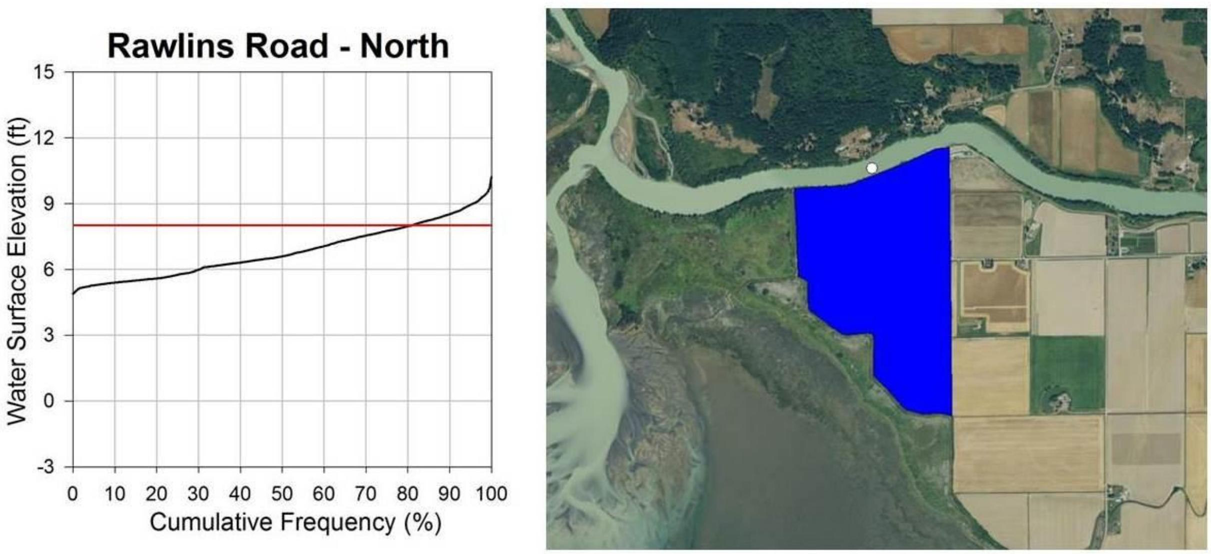


Figure H.5. Cumulative frequency plot and corresponding map for Rawlins Road (north) during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

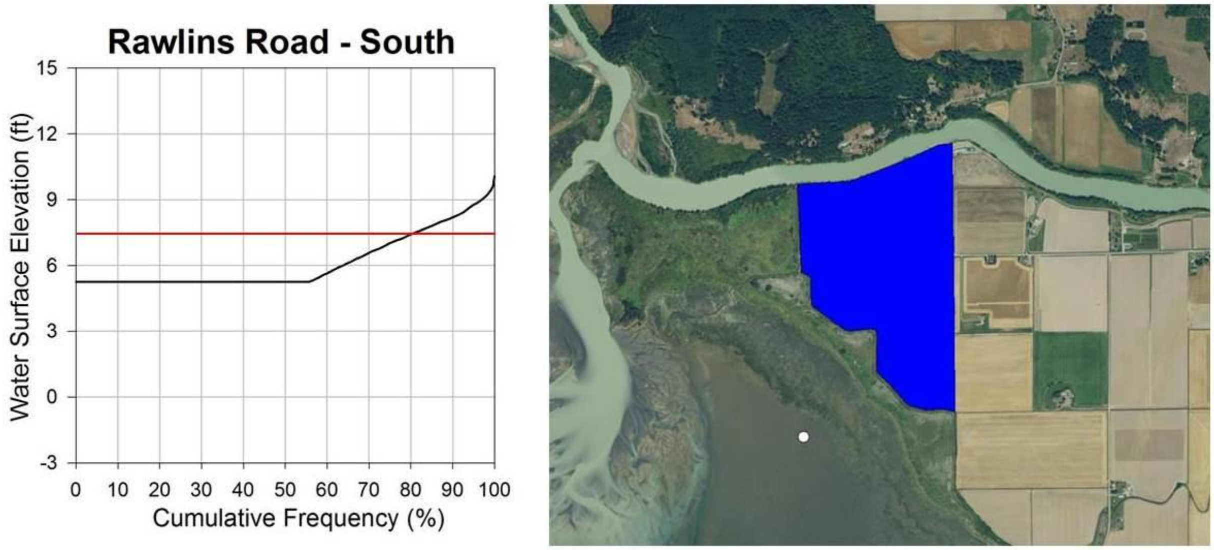


Figure H.6. Cumulative frequency plot and corresponding map for Rawlins Road (south) during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

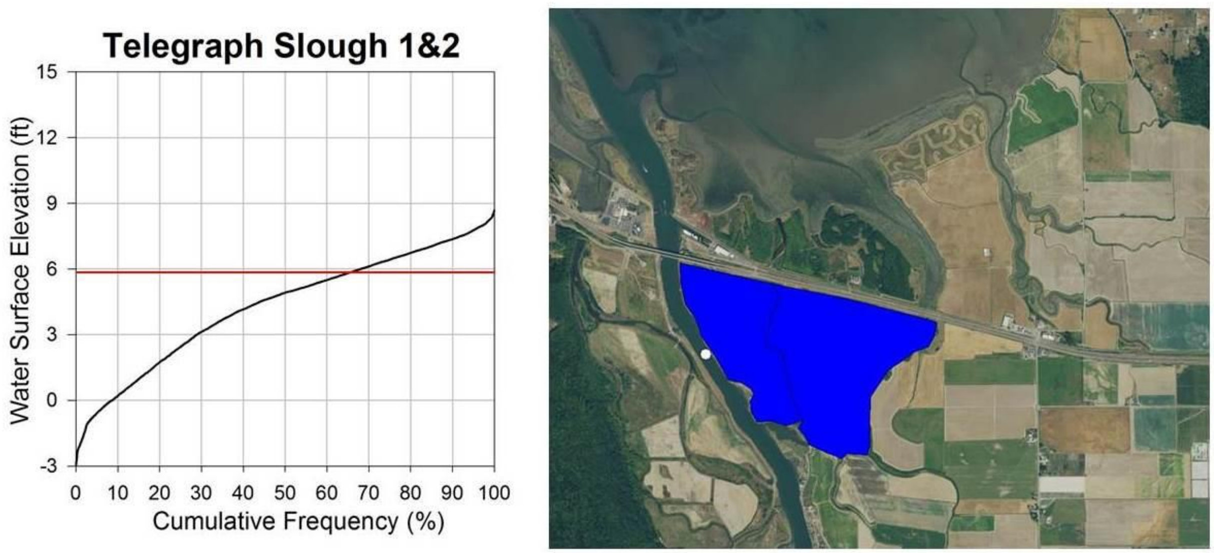


Figure H.7. Cumulative frequency plot and corresponding map for Telegraph Slough 1&2 during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

H.4 Moderate Influence Projects Deliverable 4

Deliverable 4 is a set of contour maps showing the depth of inundation during the Moderate Influence Projects simulation (Simulation 7). The plotted condition was the mean river discharge for the month of May (20,400 cfs) and high spring tide (10.8 ft). All depth values are relative to model bathymetry, which uses linear interpolation to the resolution of the grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure H.8 through Figure H.11.

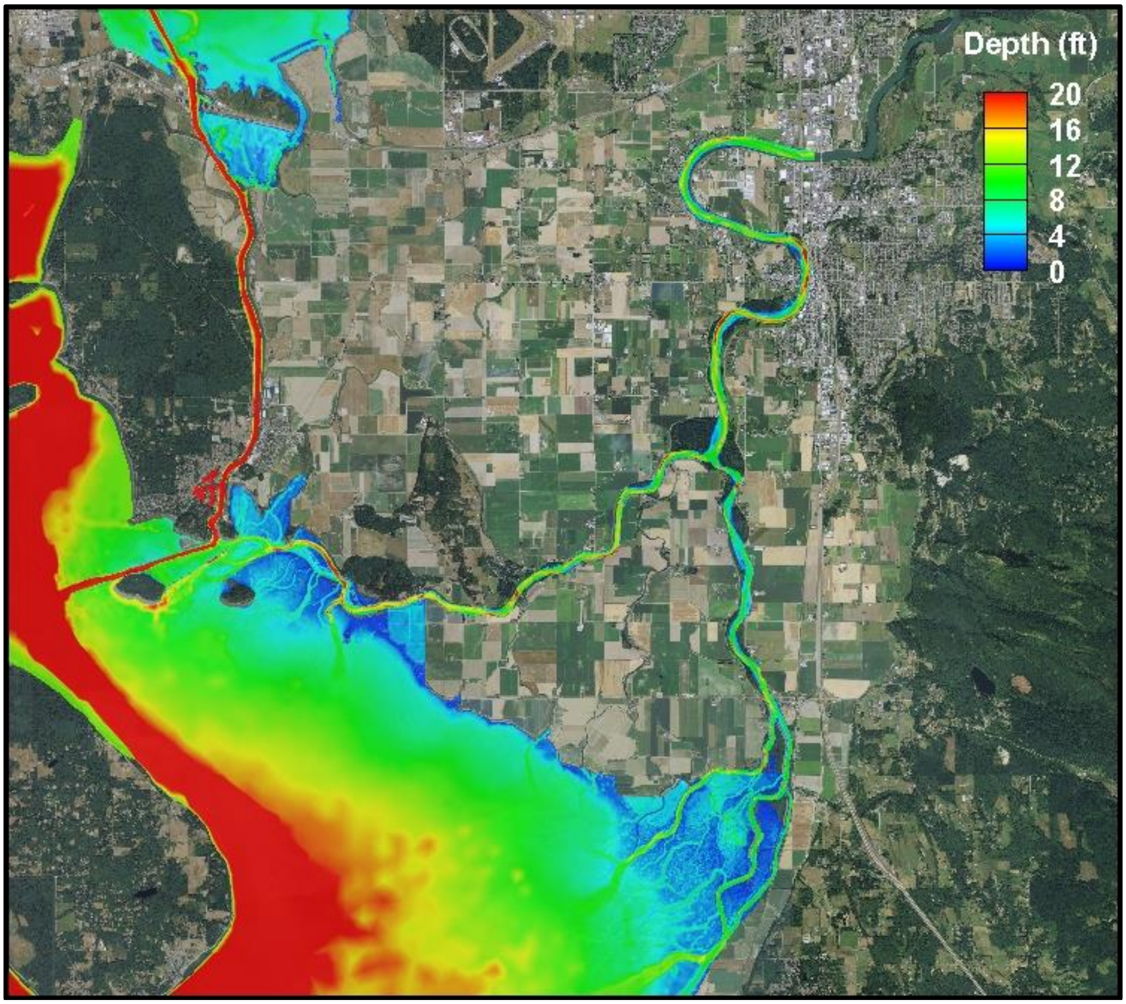


Figure H.8. Contour map of depths for the full domain during the Moderate Influence Projects simulation with May flow and high spring tide.

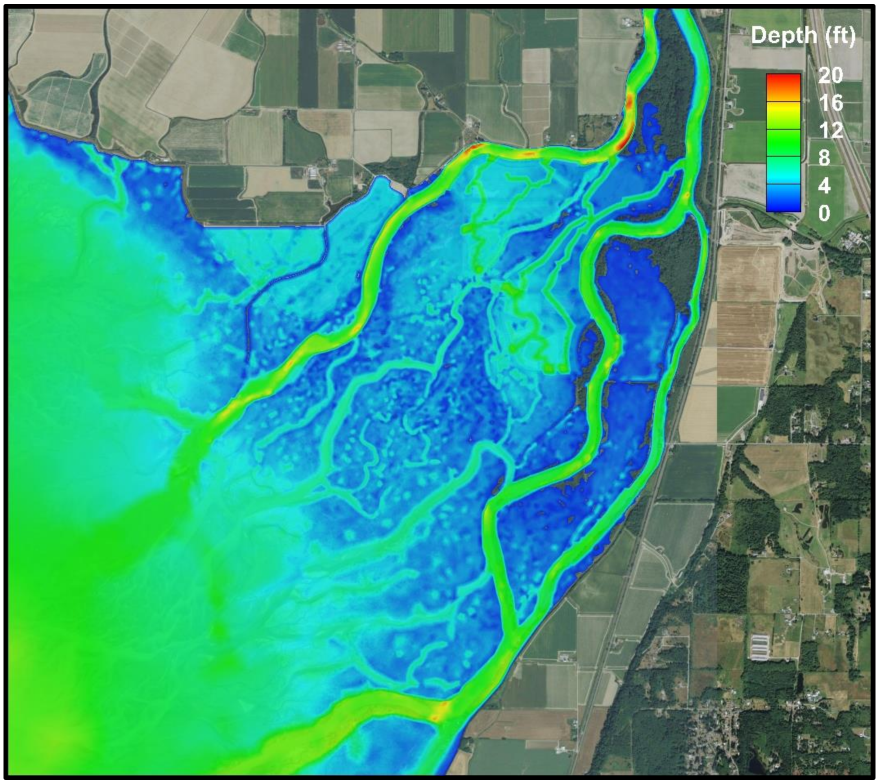


Figure H.9. Contour map of depths for Deepwater Slough Phase 2 during the Moderate Influence Projects simulation.

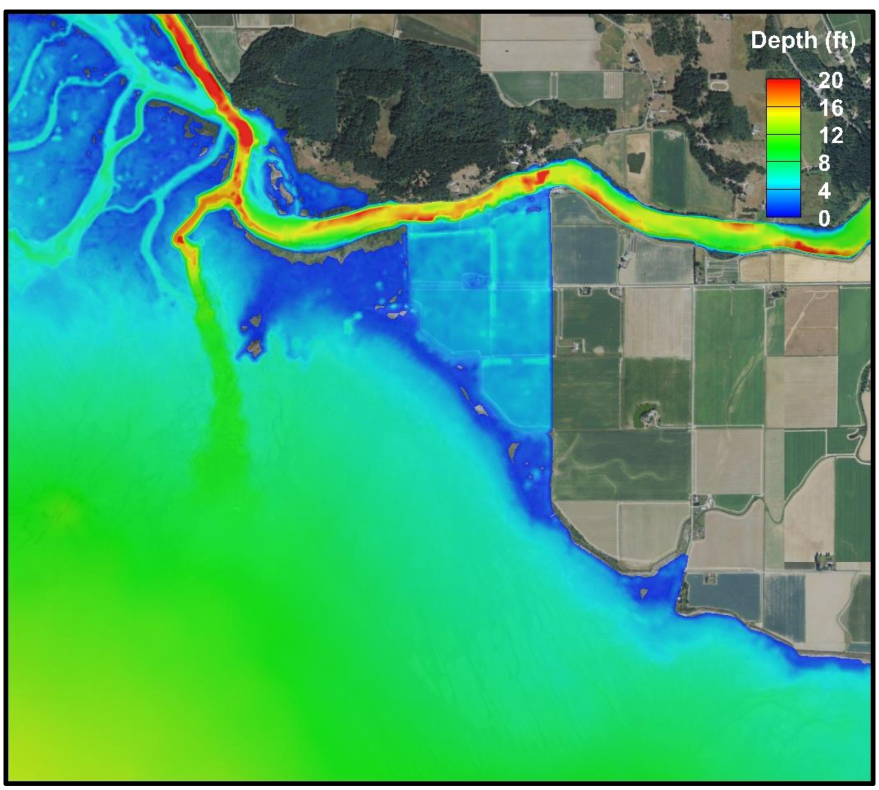


Figure H.10. Contour map of depths for Rawlins Road during the Moderate Influence Projects simulation.

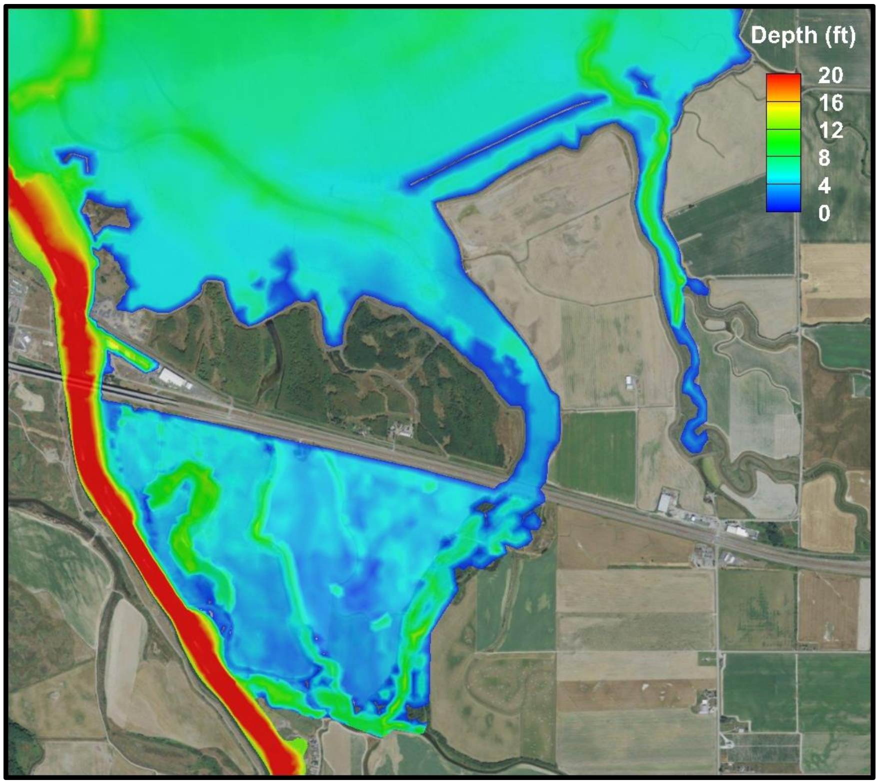


Figure H.11. Contour map of depths for Telegraph Slough 1&2 during the Moderate Influence Projects simulation.

H.5 Moderate Influence Projects Deliverable 5

Deliverable 5 is a set of histograms showing the distribution of water depths in 1 ft bins across each project site during a high spring tide (10.8 ft) and mean river discharge for the month of May (20,400 cfs), the same conditions corresponding to the maps of Deliverable 4. All depth values are relative to model bathymetry, which uses linear interpolation to the resolution of the grid. The histogram can be seen in Figure H.12 through Figure H.14.

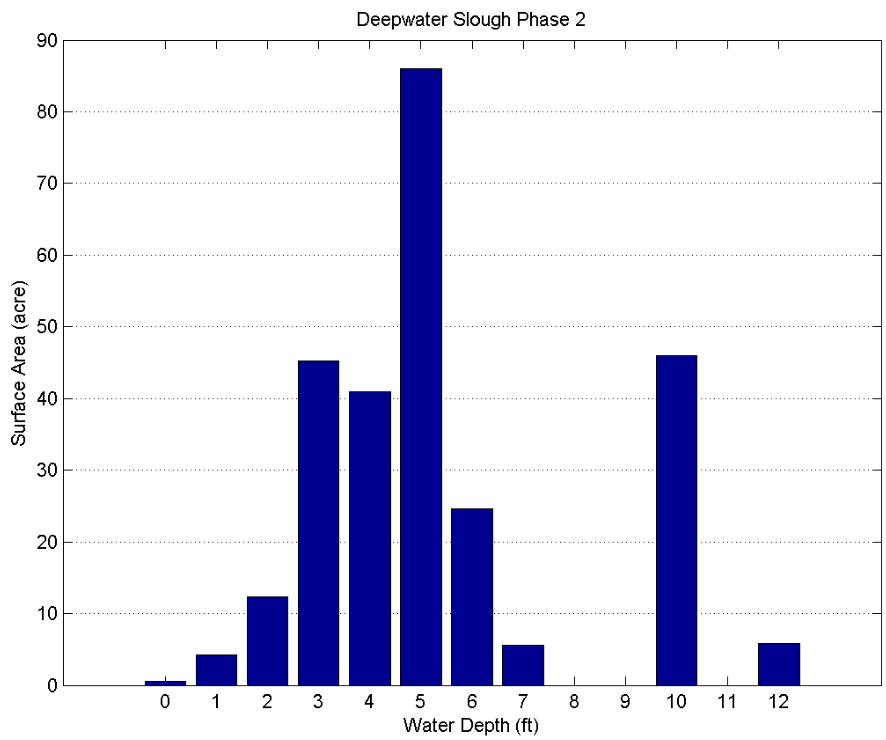


Figure H.12. Histogram of depths for Deepwater Slough Phase 2.

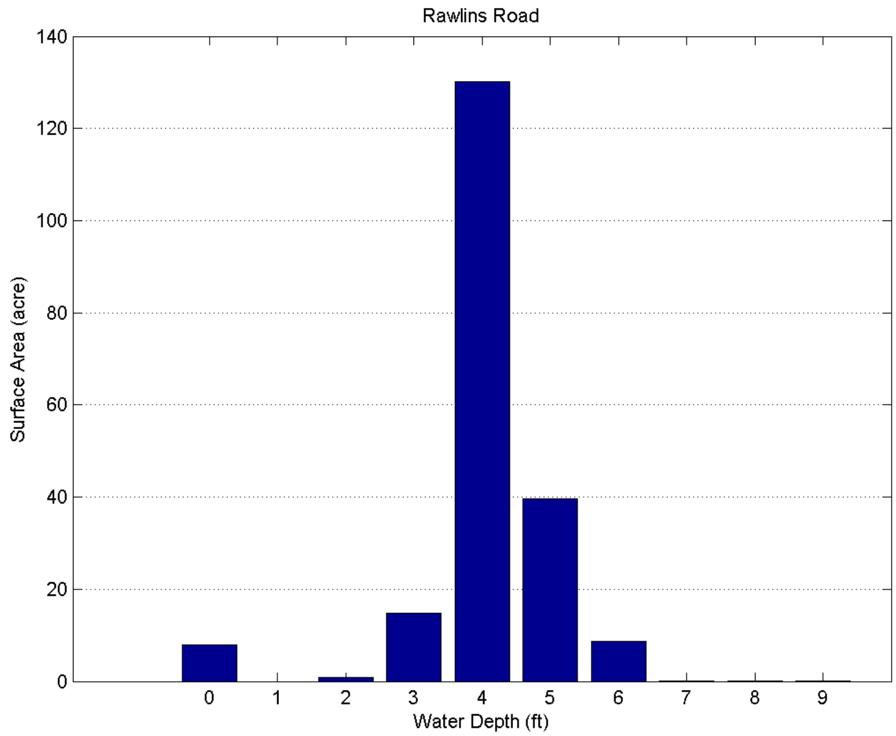


Figure H.13. Histogram of depths for Rawlins Road.

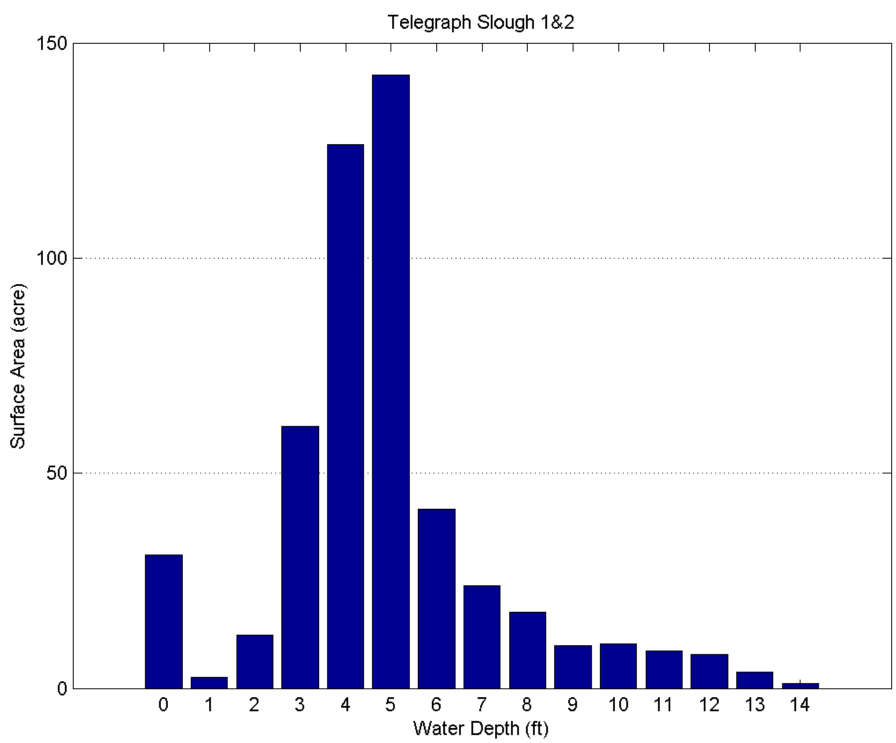


Figure H.14. Histogram of depths for Telegraph Sloughs 1 & 2.

H.6 Moderate Influence Projects Deliverable 6

Deliverable 6 is a set of contour maps showing the change in water surface elevation between the Baseline Simulation (Simulation 0) and the Moderate Influence Projects simulation (Simulation 7). Two conditions were compared: (1) a low spring tide (-3.3 ft) and Q2 flow (62,000 cfs) and (2) a high spring tide (10.4 ft) and a flood condition (93,200 cfs), representing the change from baseline to restored conditions. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure H.15 through Figure H.19.

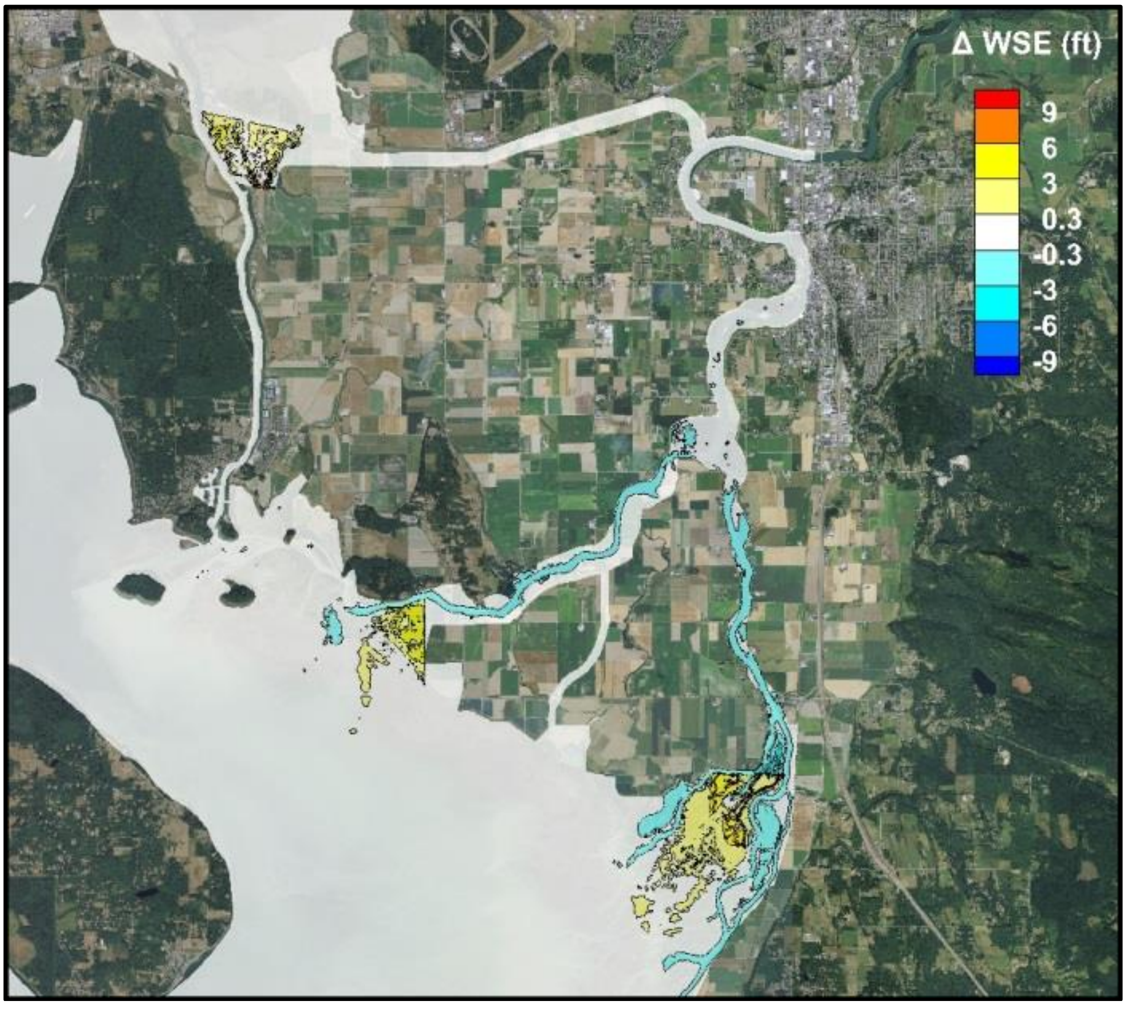


Figure H.15. Contour map of change in WSE from the Baseline to Moderate Influence Projects #2 simulation with Q2 flow and low tide.

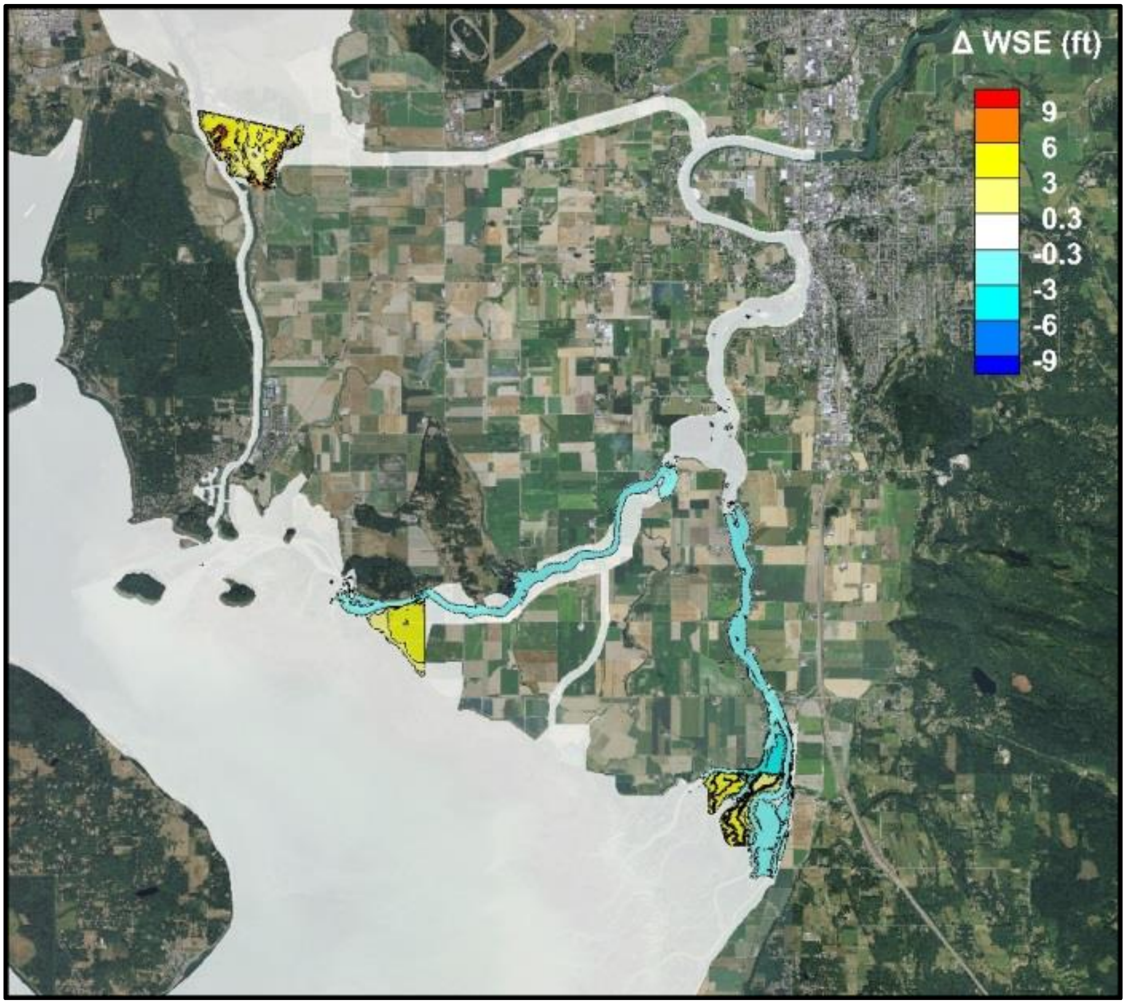


Figure H.16. Contour map of change in WSE from the Baseline to Moderate Influence Projects #2 simulation with flood flow and high tide.

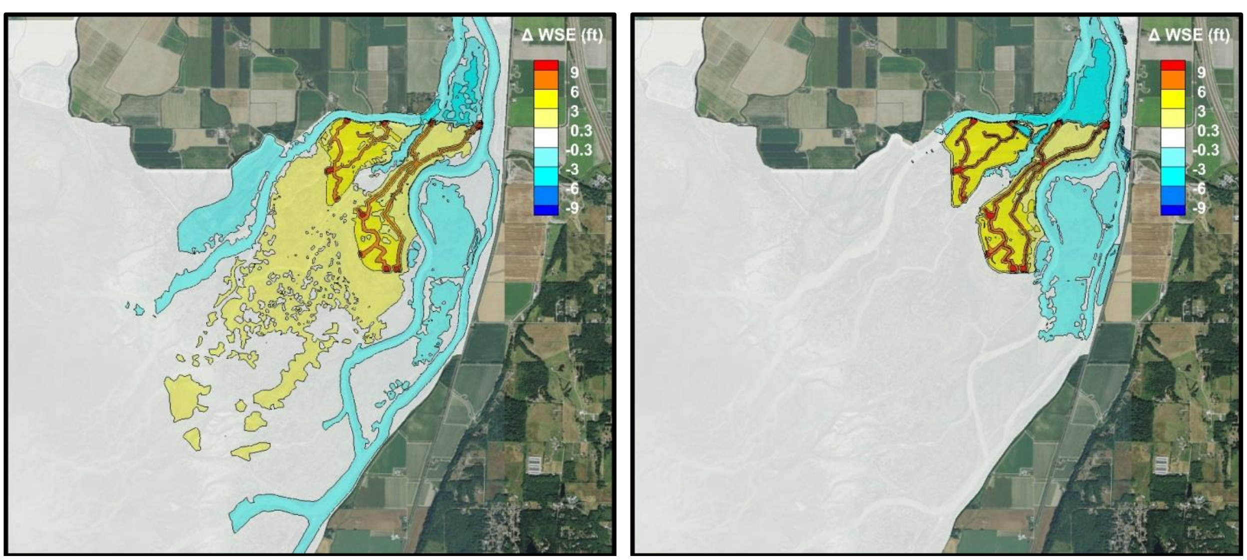


Figure H.17. Contour map of change in WSE from the Baseline simulation for Deepwater Slough Phase 2 with Q2 flow and low tide (left) and flood flow and high tide (right).

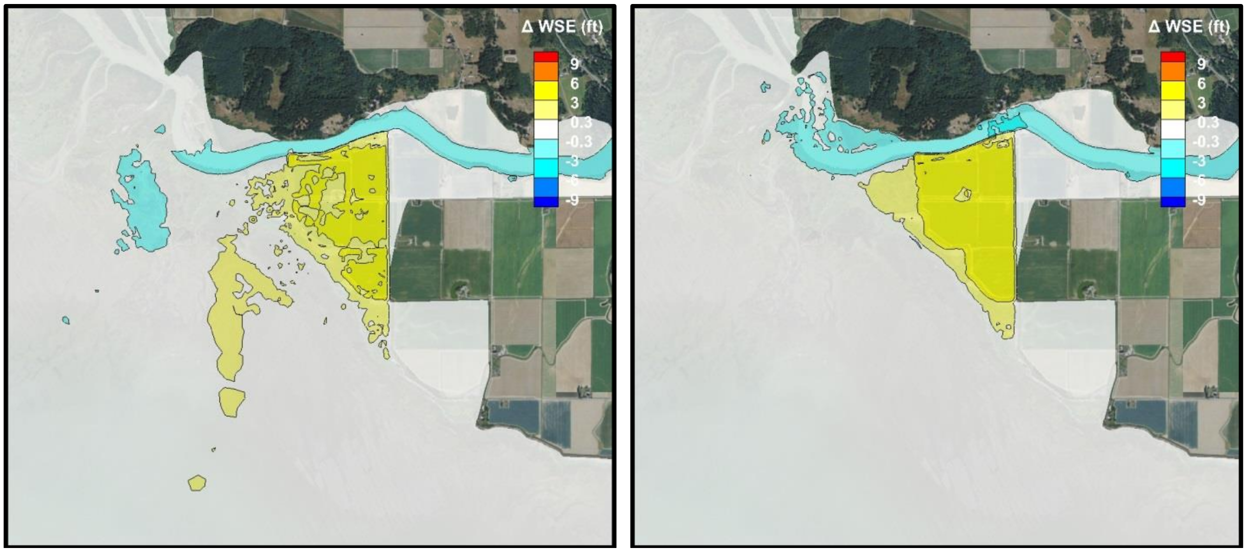


Figure H.18. Contour map of change in WSE from the Baseline simulation for Rawlins Road with Q2 flow and low tide (left) and flood flow and high tide (right).

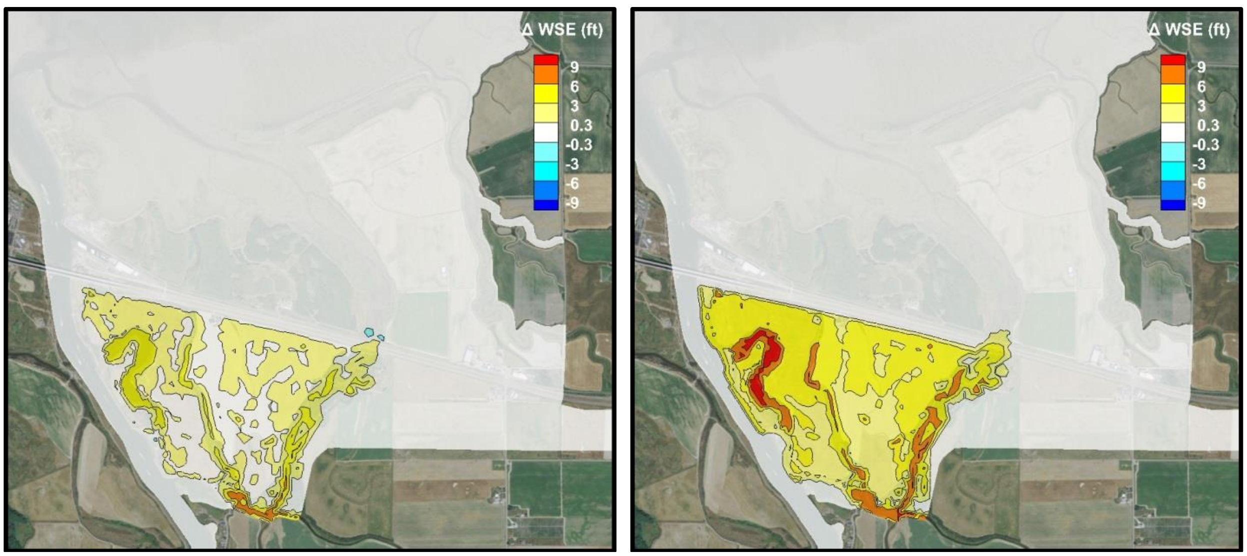


Figure H.19. Contour map of change in WSE from the Baseline simulation for Telegraph Slough 1&2 with Q2 flow and low tide (left) and flood flow and high tide (right).

H.7 Moderate Influence Projects Deliverable 7

Deliverable 7 is a set of contour maps showing the change in bed shear stress between the Baseline Simulation (Simulation 0) and the Moderate Influence Projects simulation (Simulation 7). Two conditions were compared: (1) a full spring tidal cycle during a low flow (12,000 cfs) where the peak shear across the map was recorded and (2) a low spring tide (-3.3 ft) and Q2 flow (62,000 cfs), representing the change from baseline to restored conditions. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure H.20 through Figure H.24.

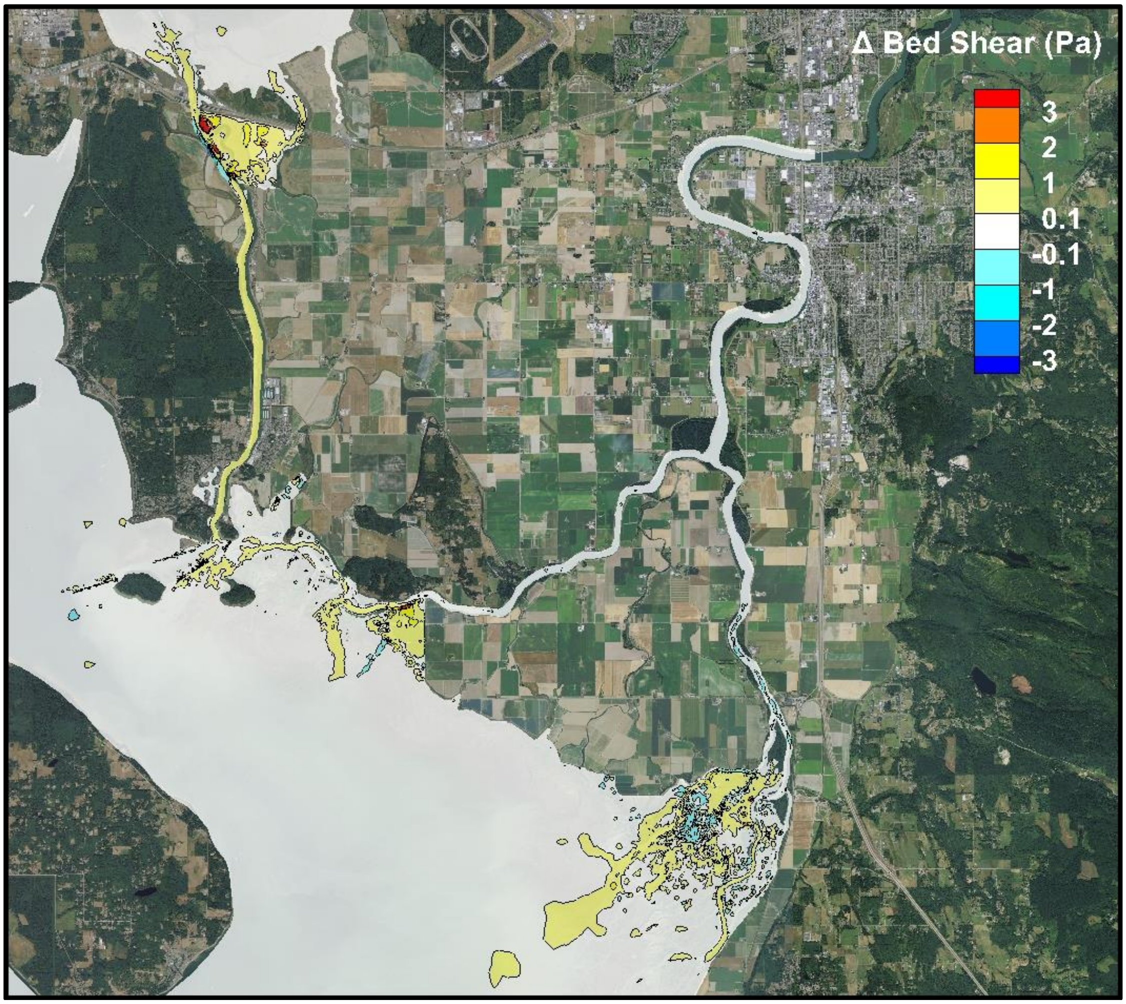


Figure H.20. Contour map of change in shear stress from the Baseline to Moderate Influence Projects #2 simulation with peak shear across a full tidal cycle at low flow.

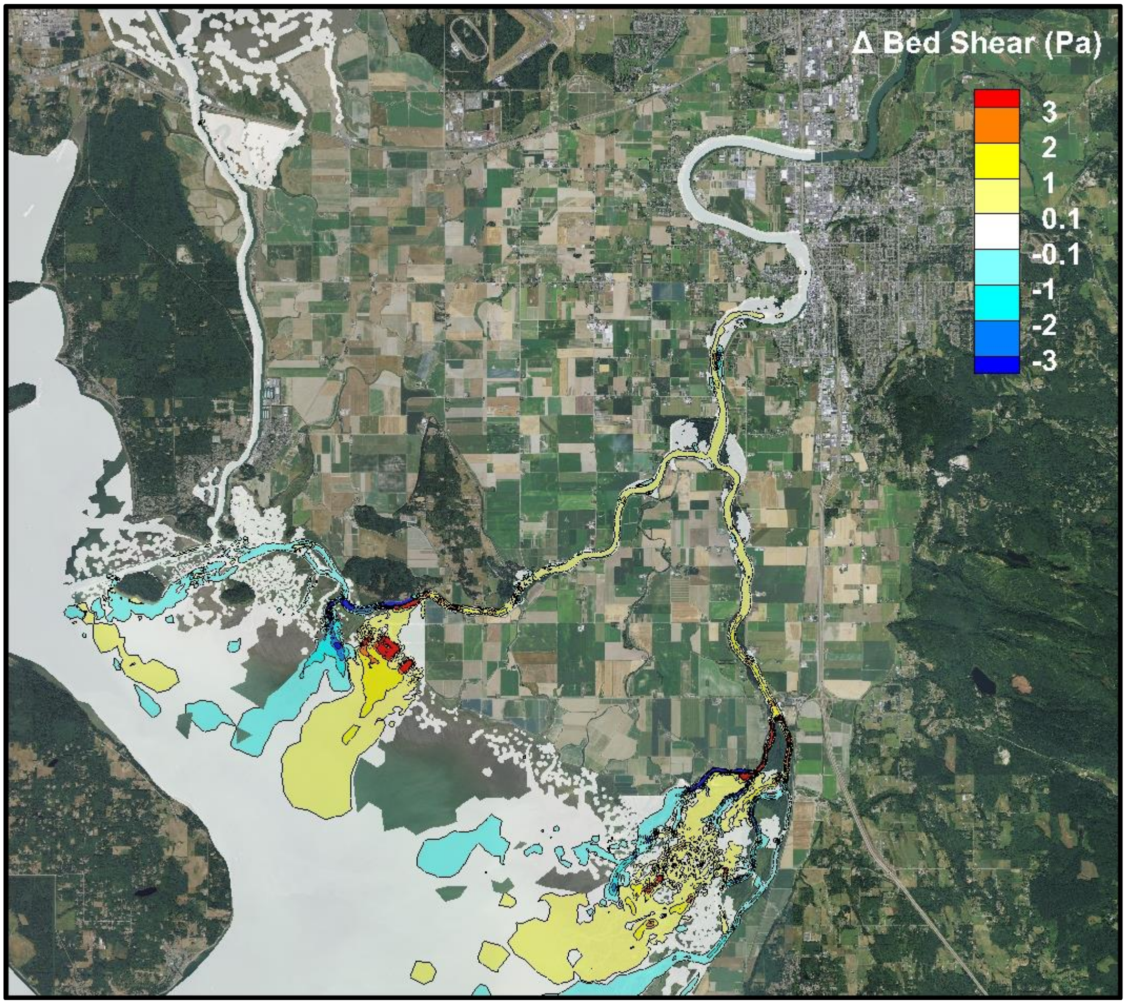


Figure H.21. Contour map of change in shear stress from the Baseline to Moderate Influence Projects #2 simulation with Q2 flow and low tide.

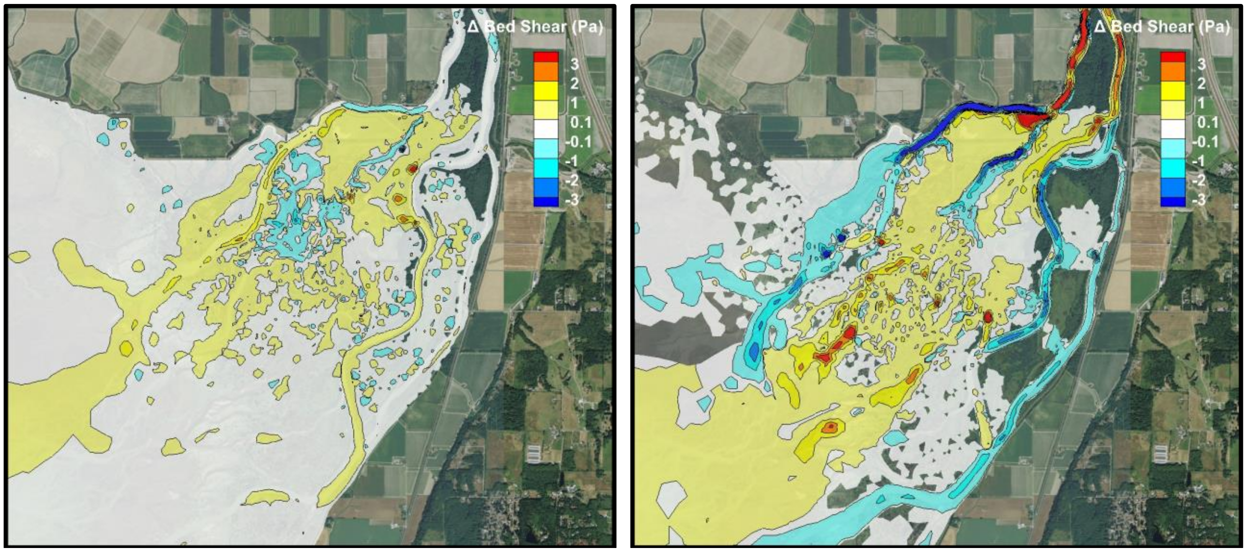


Figure H.22. Contour map of change in shear stress from Baseline for Deepwater Slough Phase 2 with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

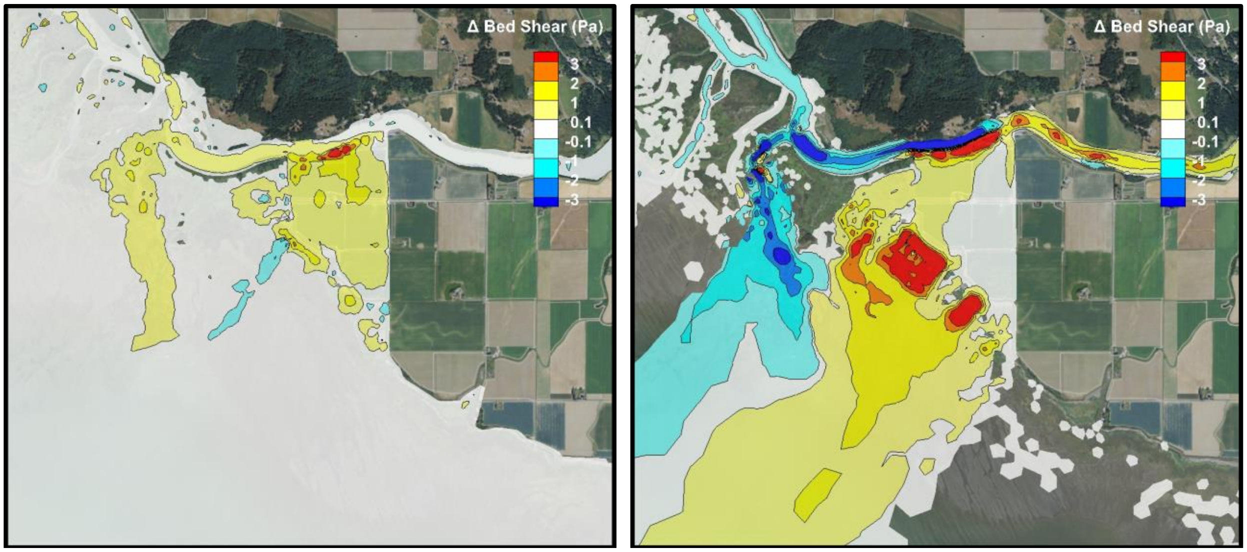


Figure H.23. Contour map of change in shear stress from the Baseline simulation for Rawlins Road with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

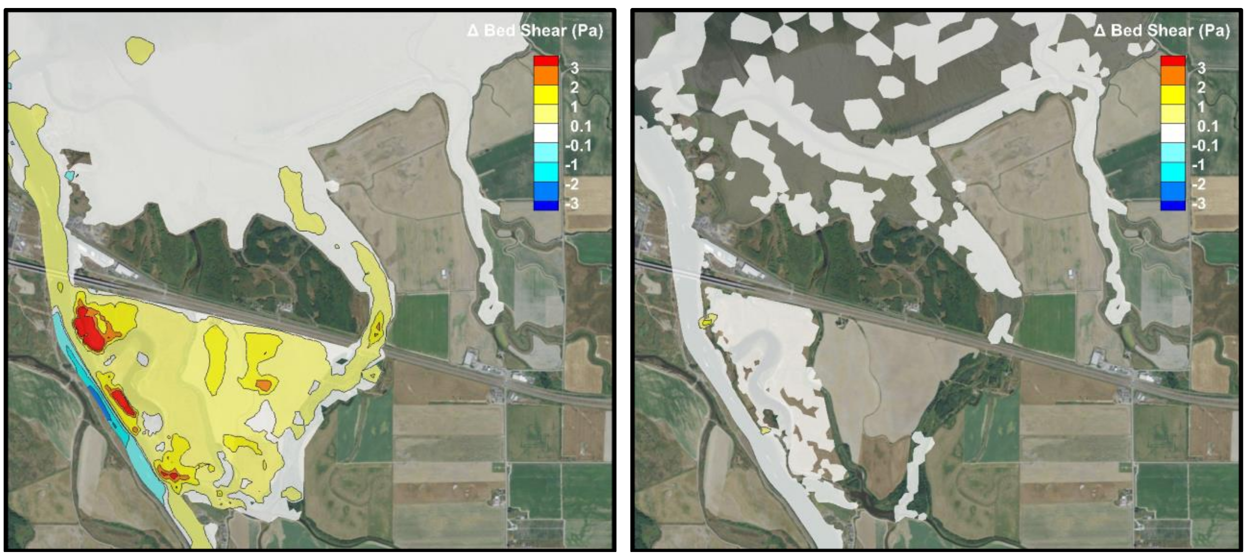


Figure H.24. Contour map of change in shear stress from the Baseline simulation for Telegraph Slough 1&2 with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

H.8 Moderate Influence Projects Deliverable 8

Deliverable 8 is a set of contour maps showing the change in salinity between the Baseline Simulation (Simulation 0) and the Moderate Influence Projects simulation (Simulation 7). The compared conditions were a low flow (12,000 cfs) and high spring tide (10.8 ft), representing the change from baseline to restored conditions. The compared salinity values represent an average of the bottom 10% of the water depth to show the furthest extent of the salt wedge. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. Changes in salinity could affect habitat suitability, the distribution of fish, and have potential effects on agriculture. The maps can be seen in Figure H.25 through Figure H.28.

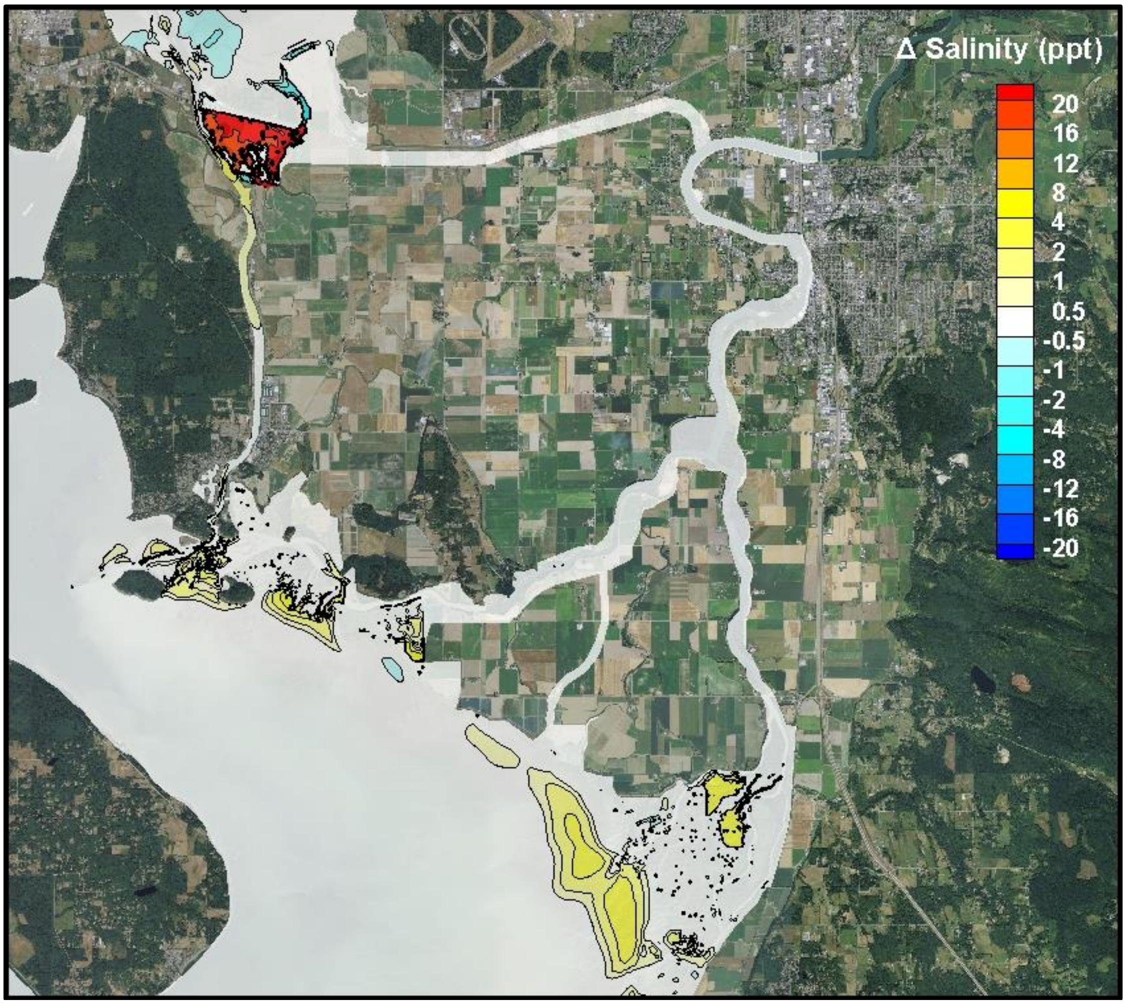


Figure H.25. Contour map of change in salinity from the Baseline to Moderate Influence Projects #2 simulation with low flow and high tide.

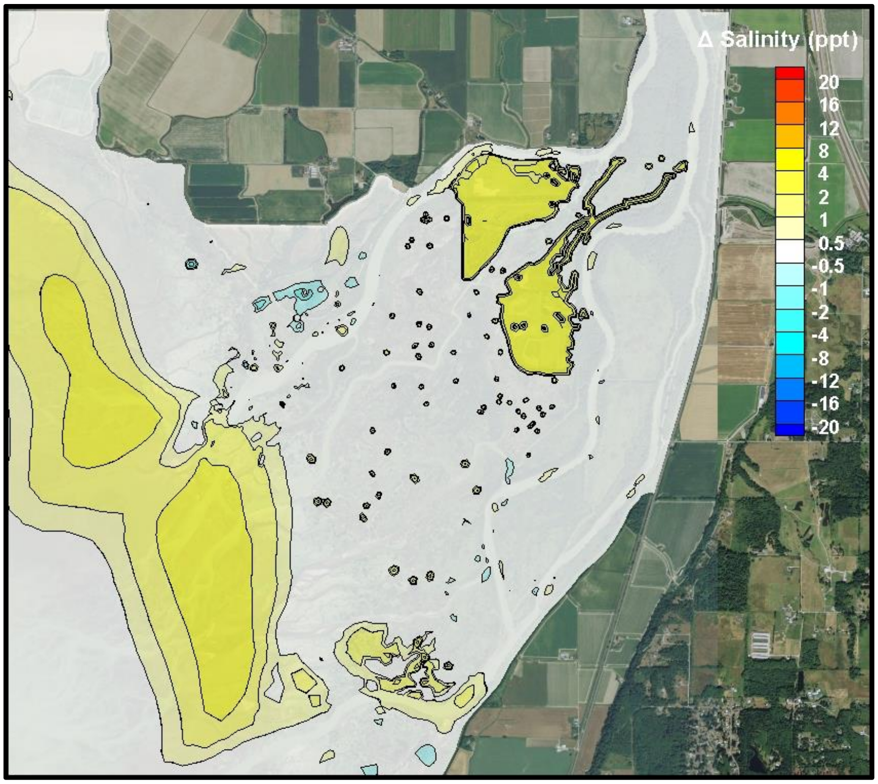


Figure H.26. Contour map of change in salinity from the Baseline simulation for Deepwater Slough Phase 2 with low flow and high tide.

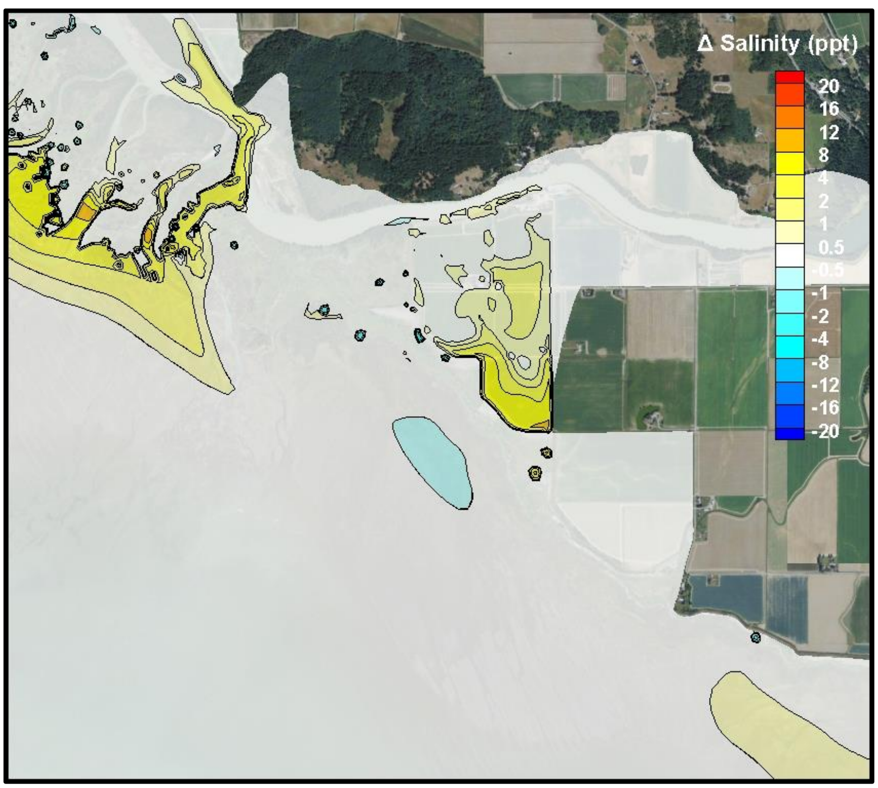


Figure H.27. Contour map of change in salinity from the Baseline simulation for Rawlins Road with low flow and high tide.

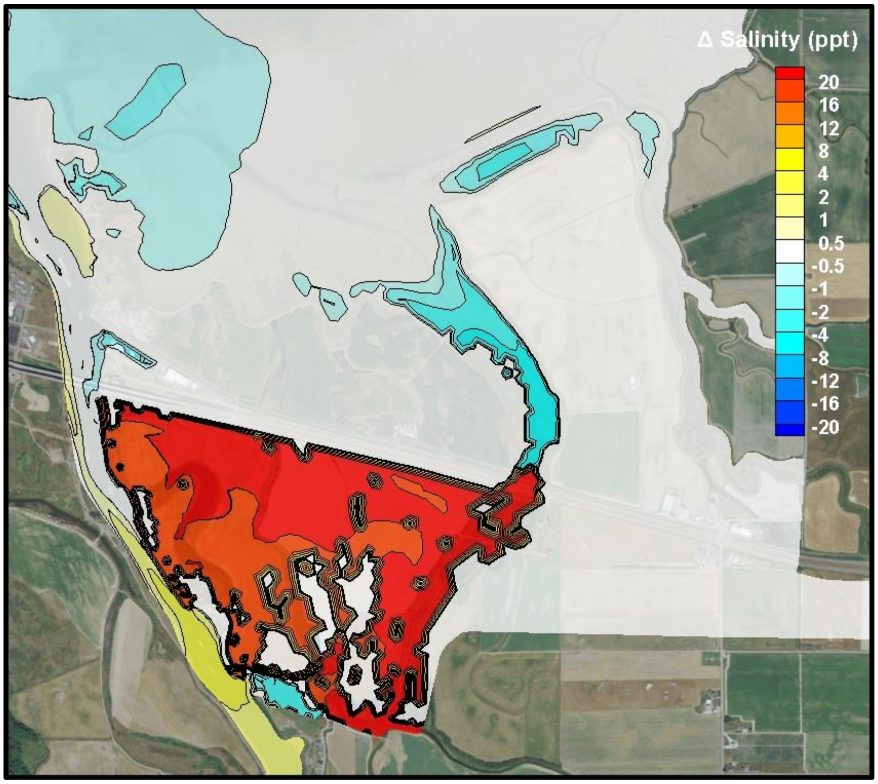


Figure H.28. Contour map of change in salinity from the Baseline simulation for Telegraph Slough 1&2 with low flow and high tide.

H.9 Moderate Influence Projects Deliverable 9

Deliverable 9 is a set of plots that compare water surface elevation and flow between the Baseline Simulation and the Moderate Influence Projects simulation, plotting all time steps during the entire 7-month simulation from November 2, 2014 through May 29, 2015. Plots are provided for the North Fork, South Fork, Freshwater Slough, and Steamboat Slough gauge locations. Results in Freshwater and Steamboat are non-linear because higher flows move across the Deepwater Slough Phase 2 project concept. Flow was computed at a cross section bisecting the gauge locations. An Excel file was also generated to provide the WSE and flow information at the gauge locations. The maps can be seen in Figure H.29 through Figure H.32.

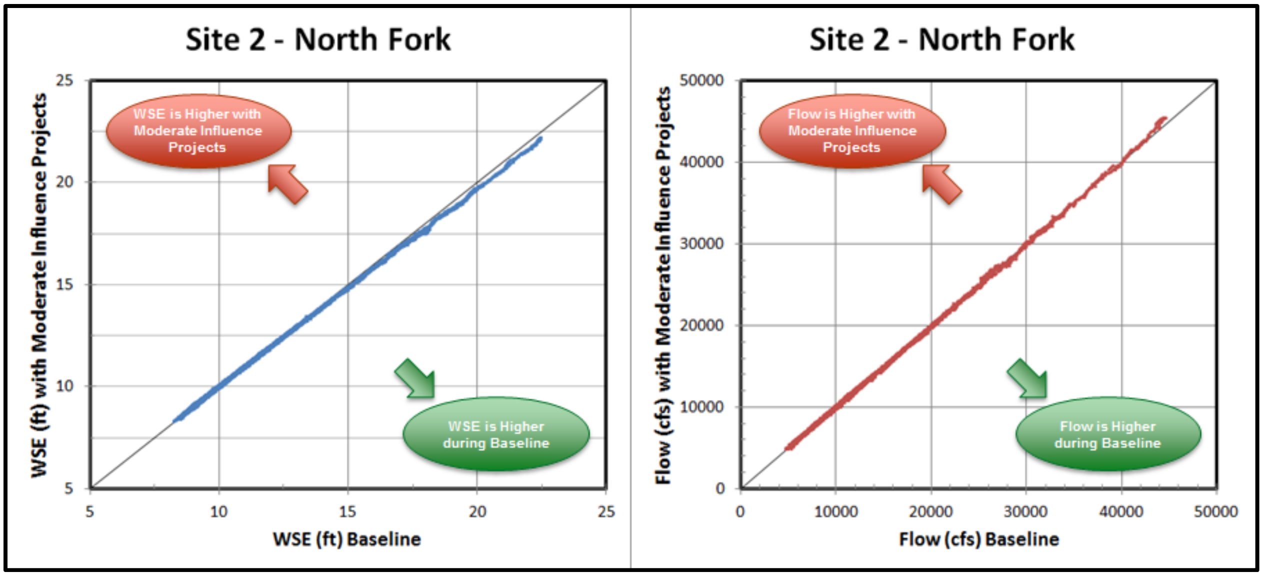


Figure H.29. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Moderate Influence Projects simulation at the North Fork gauge location compared with the same information under baseline conditions.

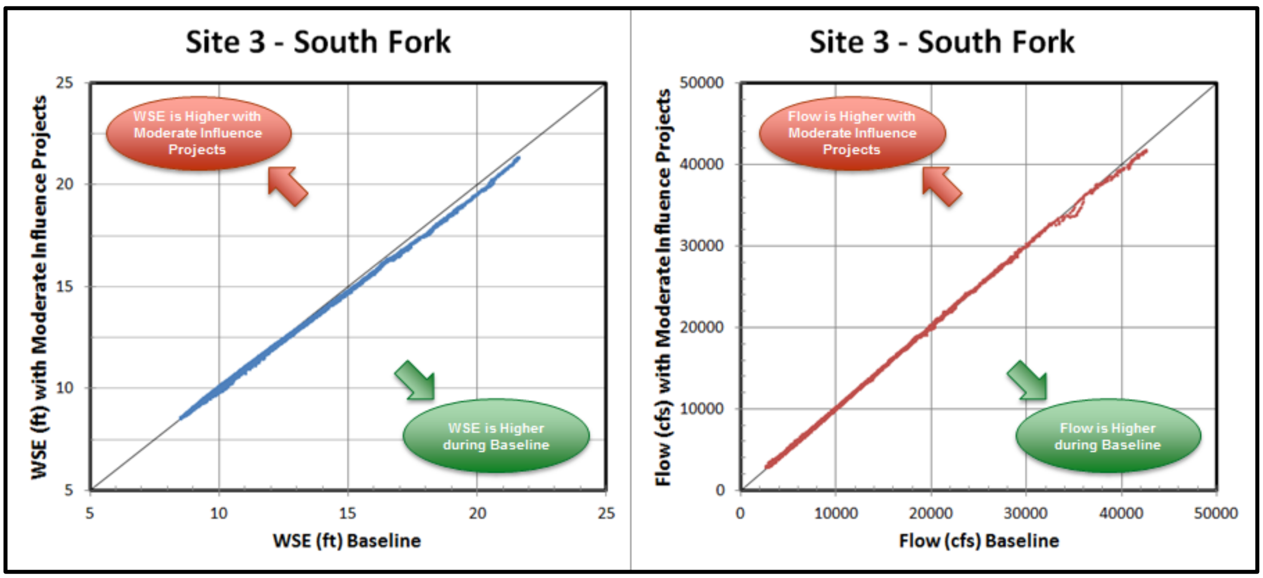


Figure H.30. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Moderate Influence Projects simulation at the South Fork gauge location compared with the same information under baseline conditions.

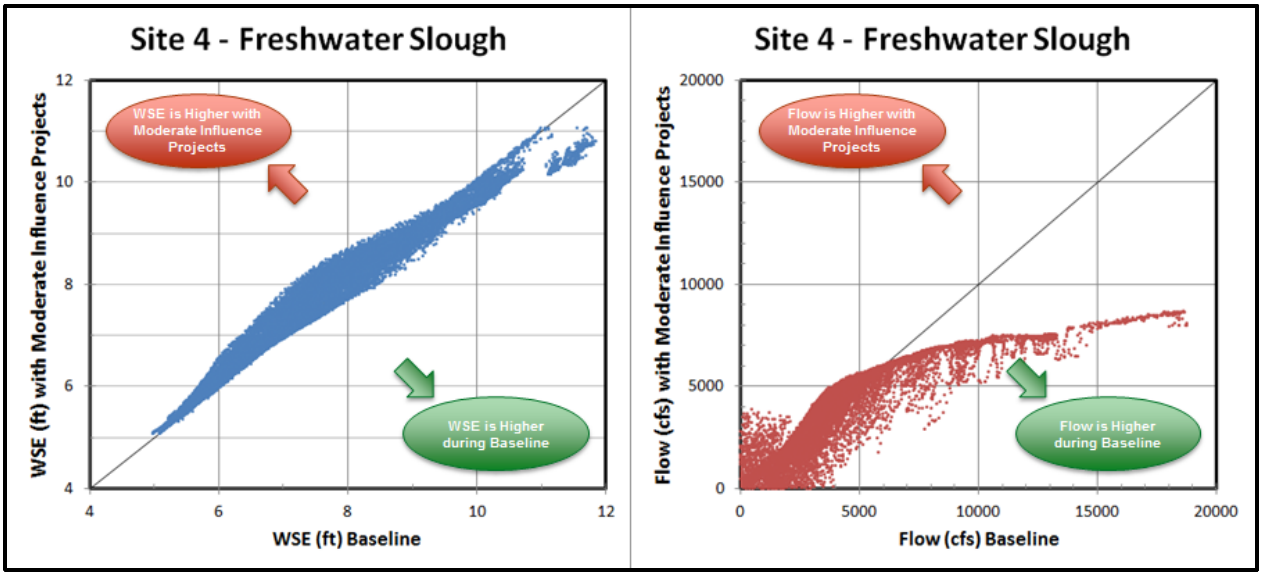


Figure H.31. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Moderate Influence Projects simulation at the Freshwater Slough gauge location compared with the same information under baseline conditions.

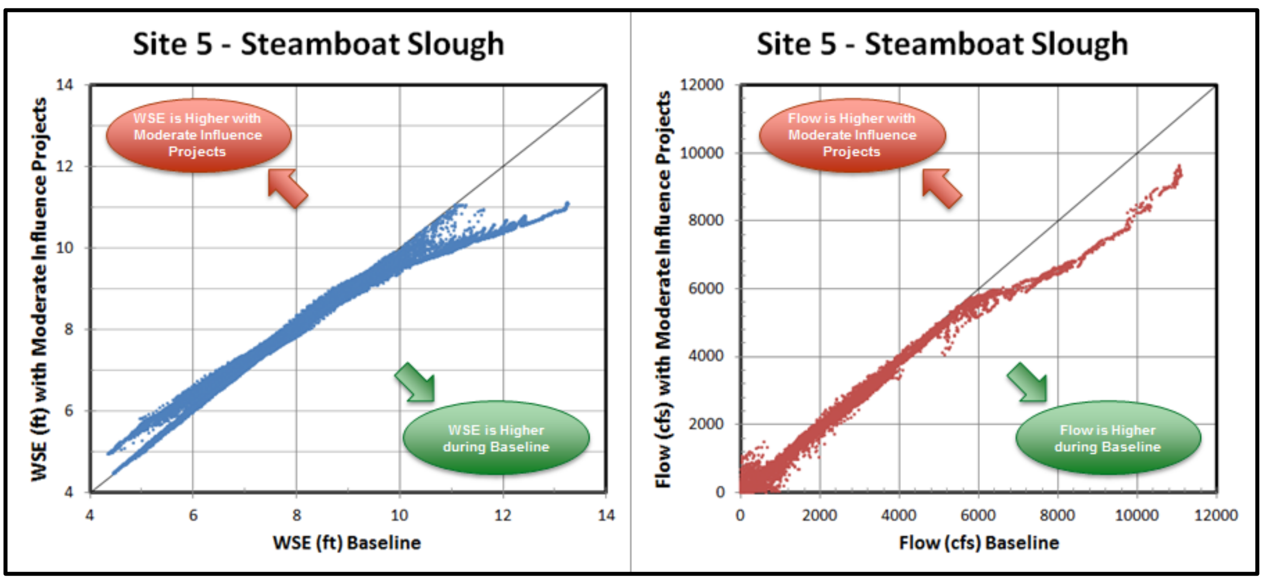


Figure H.32. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Moderate Influence Projects simulation at the Steamboat Slough gauge location compared with the same information under baseline conditions.

Appendix I

Simulation 8: Selected Projects Deliverables

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Simulation 8: Selected Projects Deliverables

The following list of deliverables is associated with Simulation 8: SF Levee Setbacks 2, 3, and 4, McGlinn Causeway, TNC South Fork, Cottonwood Island, East Cottonwood, Pleasant Ridge South, Hall Slough, Fir Island Farm, Telegraph Slough Full, Sullivan Hacienda, Rawlins Distributary, Cross Island Connector, NF Levee Setback C, NF Right Bank Levee Setback, Milltown Island, Thein Farm, Deepwater Slough Phase 2, Rawlins Road (Figure I.1). These deliverables were created by the SHDM Team to address specific objectives for the alternative analysis (Friebel et al., in preparation).

1. Table entries showing the change in area subject to natural tidal and riverine processes for each sub-basin in the study area during selected projects (Simulation 8).

2. Table entries showing the change in area subject to natural tidal and riverine processes for each selected project (Simulation 8). Because of error with wetted area calculations, high resolution, georeferenced maps showing the depth of inundation under (1) low flow and high tide and (2) Q2 flow and low tide were also provided (not shown).

3. At points in the main channel and bay front selected by the SHDM Team, cumulative frequency of WSE (for the months of March, April, and May). An Excel file of the data associated with the plot data was also provided (not shown).

4. Contour maps showing water depth for selected projects (Simulation 8) during (1) mean river discharge for the month of May and spring high tide. High-resolution, georeferenced map was also provided (not shown).

5. Contour maps showing change in WSE from baseline (Simulation 0) to selected projects (Simulation 8) during (1) Q2 flow and low spring tide and (2) a flood condition and high tide. High-resolution, georeferenced maps were also provided, including (3) low flow and high spring tide and absolute WSE for all three conditions (not shown).

6. Contour maps showing change in salinity from baseline (Simulation 0) to selected projects (Simulation 8) during (1) low flow and high spring tide. High-resolution, georeferenced maps were also provided, including absolute salinity for both conditions (not shown).

7. Plots of change in WSE and flow from baseline (Simulation 0) to selected projects (Simulation 8) for the South Fork, North Fork, Freshwater Slough, and Steamboat Slough to determine the basin effects. An Excel file of the data associated with the plots was also provided.

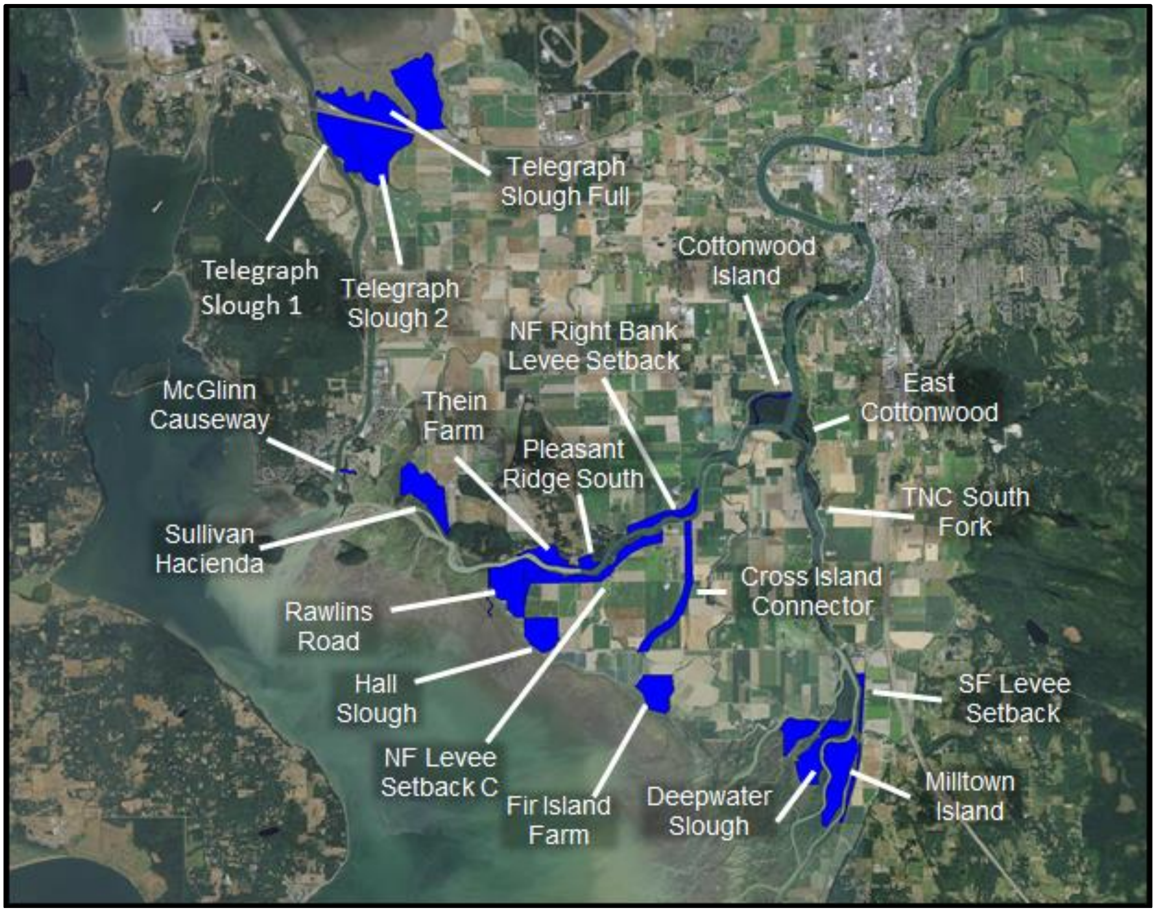

Figure I.1. A map of project area in the Selected Projects simulation.

I.1 Selected Projects Deliverable 1

For this deliverable, the area was divided into sub-basins, as seen in Figure I.2. Deliverable 1 is a table showing the increase in inundation area subject to natural tidal and riverine processes within each sub-basin, as seen in Table I.1. The accuracy of area calculation is limited by the spatial resolution of the triangular grid, which varies throughout the model domain. A node is considered wet when the model calculated water depth exceeds the minimum wetting and drying criteria of 10 cm (0.3281 ft). For any wetted node included in the project boundary polygon, its associated computational area was counted toward the total inundated area.

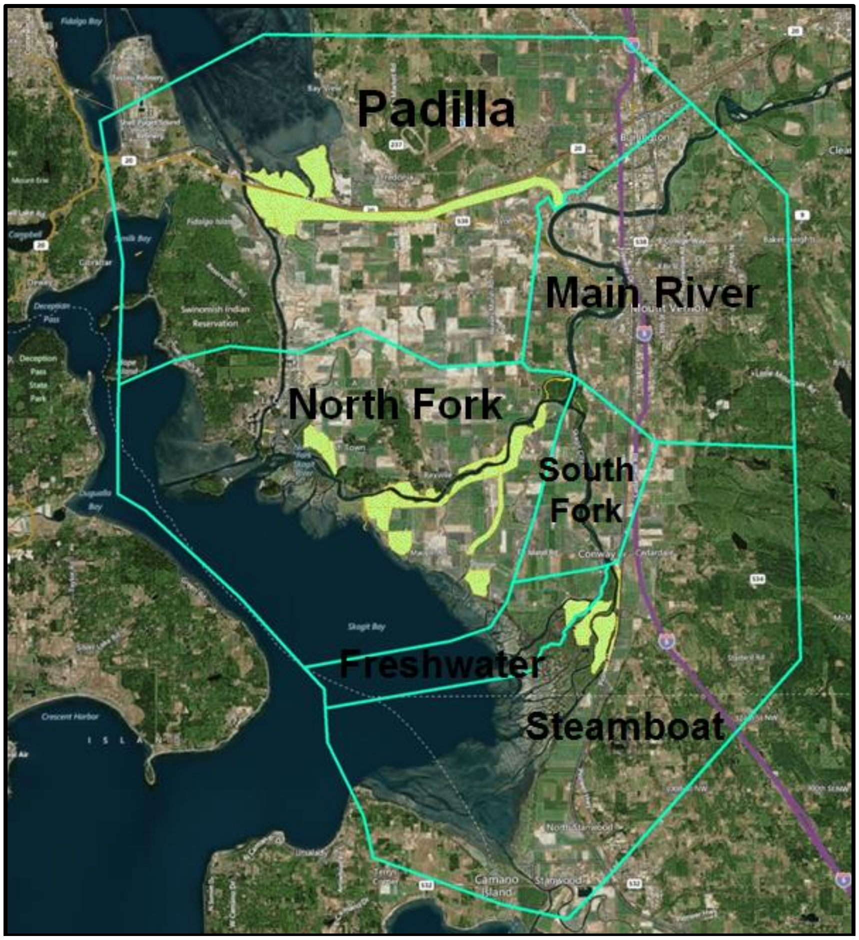

Figure I.2. Sub-basins within the Skagit region used for area calculations.

Table I.1. Table entry showing area increase for each sub-basin under tidal and riverine conditions during the Selected Projects simulation.

Sub-basin	Baseline (acres)	With Projects (acres)	Increase in Area (acres)
Tidal Influence: High Spring Tide (10.8 ft) + Low Flow (12,000 cfs)			
Sum	20,256.9	25,665.8	**5,408.9**
Main River	7.8	413.5	**405.7**
North Fork	8,330.6	10,234.9	**1,904.3**
South Fork	30.0	324.8	**294.8**
Freshwater	1,944.6	2,087.8	**143.2**
Steamboat	5,827.3	6,337.3	**510.0**
Padilla	4,116.8	6,267.5	**2,150.7**

Riverine Influence: Low Spring Tide (-3.3 ft) + Q2 Flow (62,000 cfs)			
Sum	7,921.4	10,981.2	**3,059.8**
Main River	159.0	144.3	**-14.7**
North Fork	2,998.2	5,042.3	**2,044.1**
South Fork	171.8	128.8	**-43.0**
Freshwater	1,065.1	1,139.6	**74.5**
Steamboat	2,640.2	2,889.6	**249.4**
Padilla	887.0	1,636.6	**749.6**

I.2 Selected Projects Deliverable 2

Deliverable 2 is a table showing the increase in inundation area subject to natural tidal and riverine processes within each project area, as seen in Table I.2. Inundation area is counted only within the project footprint. The same limitations and definition of an inundated cell that applied for Deliverable 1 apply here.

Table I.2. Table entry showing area increase for each project under tidal and riverine conditions during the Selected Projects simulation. Measurements correspond to a measured area that differs from the true project footprint because of grid resolution.

Project (measured area)	Baseline (acres)	With Projects (acres)	Increase in Area (acres)
Tidal Influence: High Spring Tide (10.8 ft) + Low Flow (12,000 cfs)			
Sum (**3,093.7 acres**)	254.7	3,442.7	**3,188.0**
SF Levee Setbacks 2, 3, 4 (**62.2 acres**)	0.0	50.1	**50.1**
McGlinn Causeway (**7.4 acres**)	5.9	7.4	**1.5**
TNC South Fork (**2.1 acres**)	0.0	2.1	**2.1**
Cottonwood Island (**24.7 acres**)	0.2	24.7	**24.5**
East Cottonwood (**4.5 acres**)	0.1	1.5	**1.4**
Pleasant Ridge South (**30.5 acres**)	0.0	22.3	**22.3**
Hall Slough (**139.6 acres**)	0.0	132.7	**132.7**
Fir Island Farm (**148.0 acres**)	0.1	139.4	**139.3**
Telegraph Slough Full (**1,123.3 acres**)	24.1	1,047.0	**1,022.9**
Sullivan Hacienda (**214.7 acres**)	0.0	212.1	**212.1**
Rawlins Distributary (**13.9 acres**)	13.2	13.9	**0.7**
Cross Island Connector (**152.3 acres**)	0.3	115.1	**114.8**
NF Levee Setback C (**292.5 acres**)	0.0	274.5	**274.5**
NF Right Levee Setback (**92.0 acres**)	2.4	26.8	**24.4**
Milltown Island (**232.9 acres**)	165.1	173.6	**8.5**

Project (measured area)	Baseline (acres)	With Projects (acres)	Increase in Area (acres)
Telegraph Slough 1 (**195.4 acres**)	15.2	193.4	**178.2**
Thein Farm (**79.2 acres**)	3.9	68.0	**64.1**
Deepwater Slough Phase 2 (**271.3 acres**)	0.0	270.8	**270.8**
Rawlins Road (**202.6 acres**)	0.7	197.5	**196.8**
Telegraph Slough 1&2 (**500.7 acres**)	23.5	469.7	**446.2**
Riverine Influence: Low Spring Tide (-3.3 ft) + Q2 Flow (62,000 cfs)			
Sum (**3,093.7 acres**)	255.1	2,773.4	**2,518.3**
SF Levee Setbacks 2, 3, 4 (**62.2 acres**)	0.1	38.7	**38.6**
McGlinn Causeway (**7.4 acres**)	2.5	0.5	**-2.0**
TNC South Fork (**2.1 acres**)	2.1	2.1	**0.0**
Cottonwood Island (**24.7 acres**)	11.8	24.7	**12.9**
East Cottonwood (**4.5 acres**)	3.2	4.5	**1.3**
Pleasant Ridge South (**30.5 acres**)	0.4	22.3	**21.9**
Hall Slough (**139.6 acres**)	0.0	122.0	**122.0**
Fir Island Farm (**148.0 acres**)	0.0	138.5	**138.5**
Telegraph Slough Full (**1,123.3 acres**)	24.1	673.0	**648.9**
Sullivan Hacienda (**214.7 acres**)	0.0	191.2	**191.2**
Rawlins Distributary (**13.9 acres**)	0.7	13.9	**13.2**
Cross Island Connector (**152.3 acres**)	0.3	116.9	**116.6**
NF Levee Setback C (**292.5 acres**)	0.0	285.3	**285.3**
NF Right Levee Setback (**92.0 acres**)	8.5	85.7	**77.2**
Milltown Island (**232.9 acres**)	156.1	75.1	**-81.0**
Telegraph Slough 1 (**195.4 acres**)	15.2	125.2	**110.0**
Thein Farm (**79.2 acres**)	5.6	67.8	**62.2**
Deepwater Slough Phase 2 (**271.3 acres**)	0.3	266.8	**266.5**
Rawlins Road (**202.6 acres**)	0.7	197.5	**196.8**
Telegraph Slough 1&2 (**500.7 acres**)	23.5	321.5	**298.0**

I.3 Selected Projects Deliverable 3

Deliverable 3 is a set of cumulative frequency plots showing water surface elevation at a point in the main channel or Bayfront near each project site. These are from the spring months of the Selected Projects simulation (Simulation 8), representing March 1 – May 22, 2015, a time period chosen to coincide with the primary fish outmigration. A red mark line was provided with every point to represent an approximation of the average elevation of the project area bed. All WSE values are relative to the NAVD88 datum. An Excel file was also generated with WSE at each node location. The plots can be seen in Figure I.3 through Figure I.28.

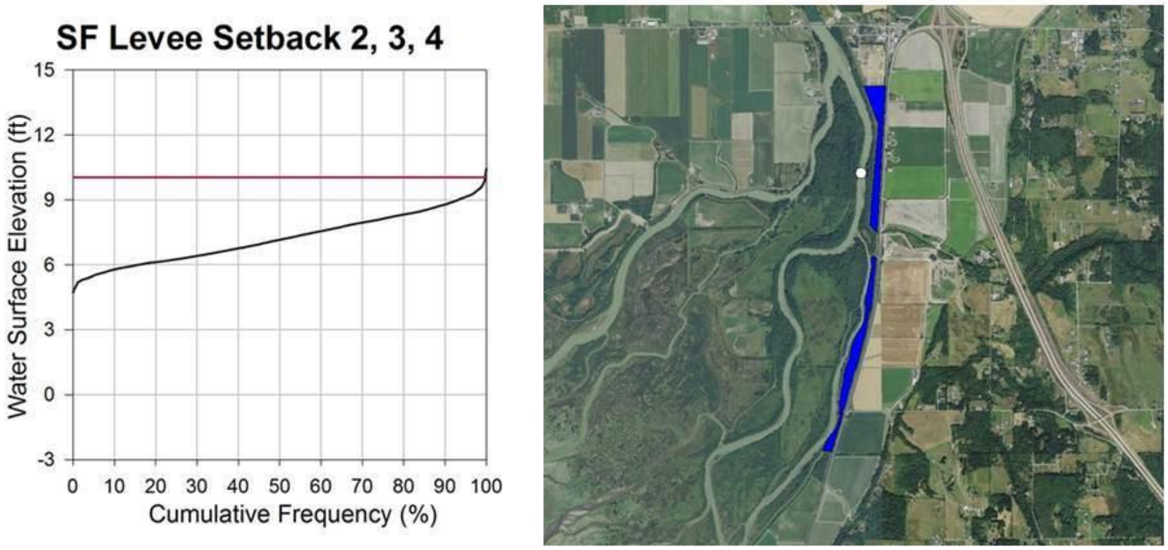

Figure I.3. Cumulative frequency plot and corresponding map for SF Levee Setbacks 2, 3, and 4 during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

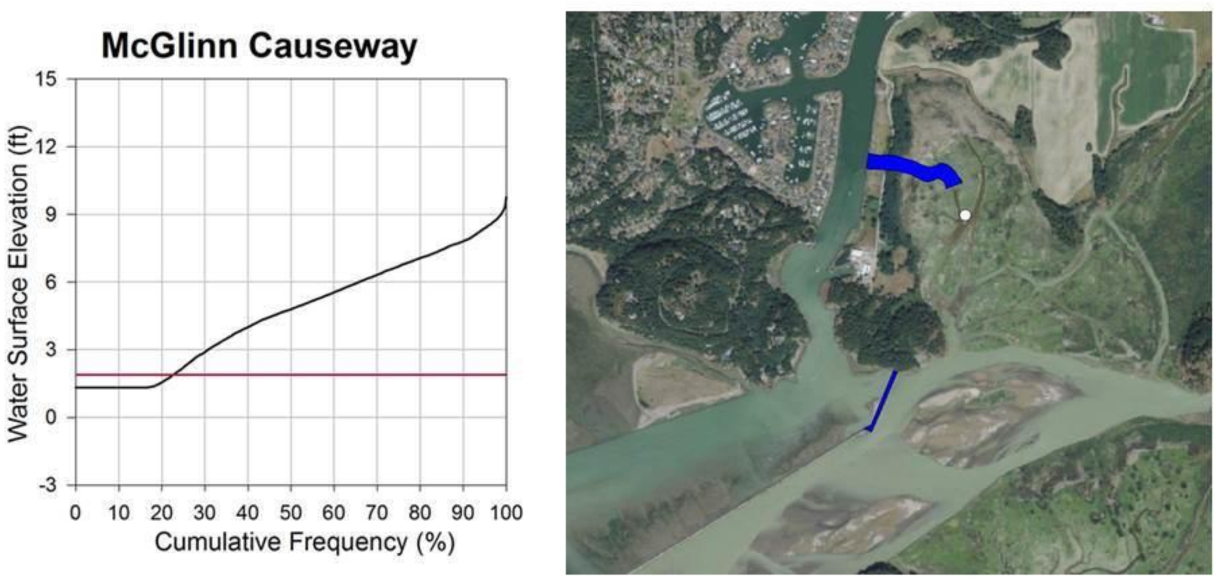

Figure I.4. Cumulative frequency plot and corresponding map for McGlinn Causeway during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

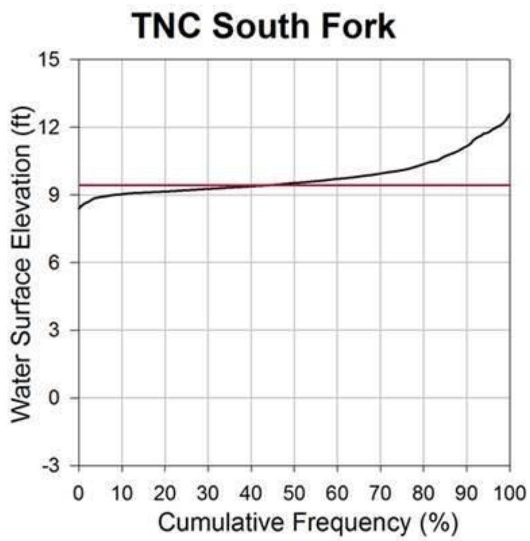

Figure I.5. Cumulative frequency plot and corresponding map for TNC South Fork during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

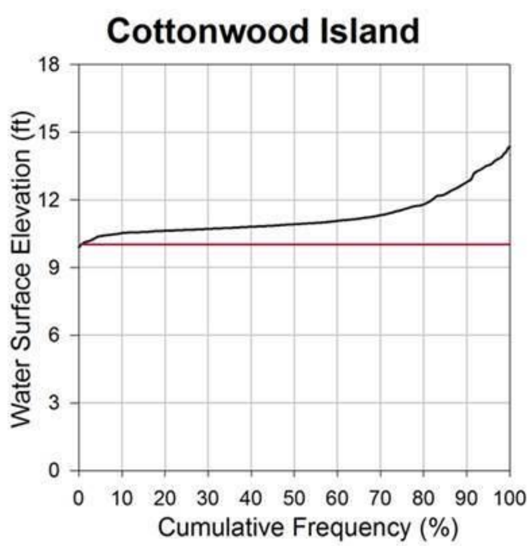

Figure I.6. Cumulative frequency plot and corresponding map for Cottonwood Island during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

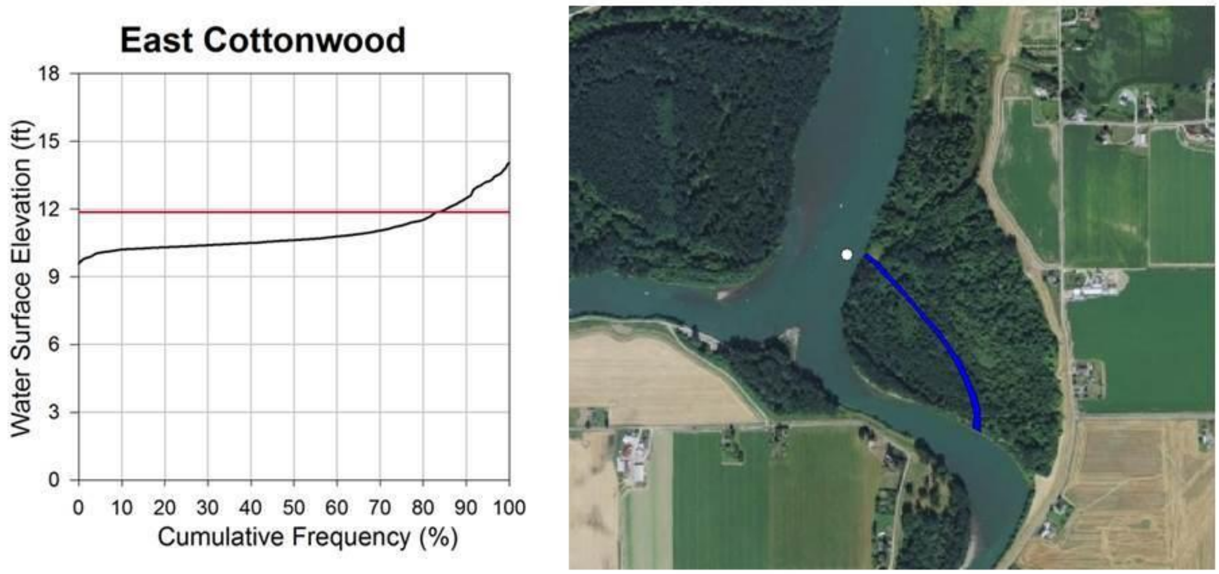

Figure I.7. Cumulative frequency plot and corresponding map for East Cottonwood during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

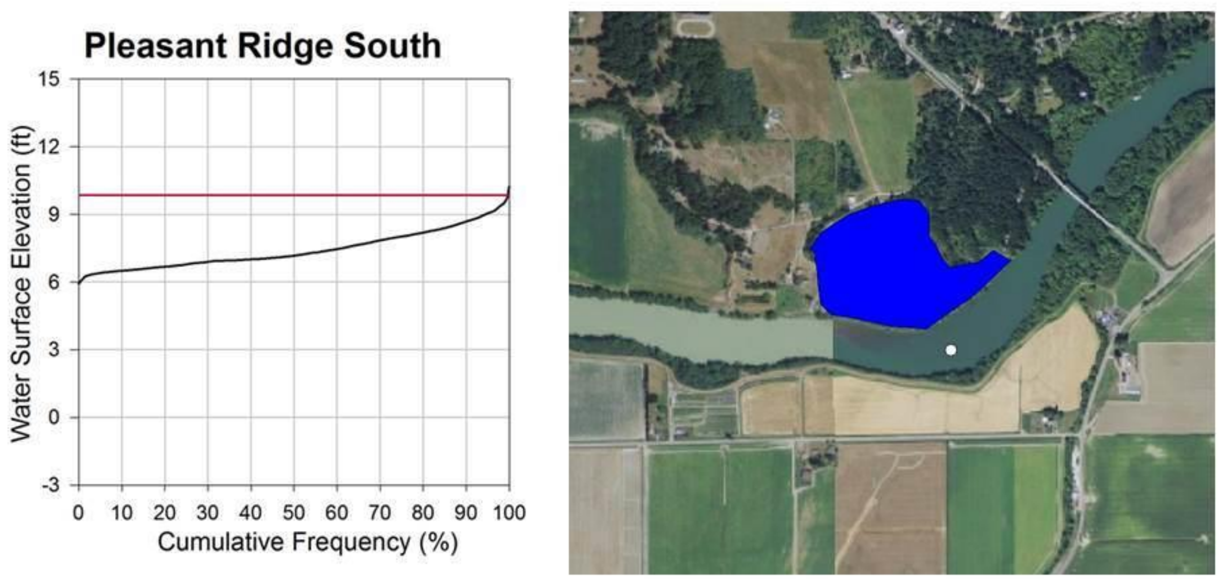

Figure I.8. Cumulative frequency plot and corresponding map for Pleasant Ridge South during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

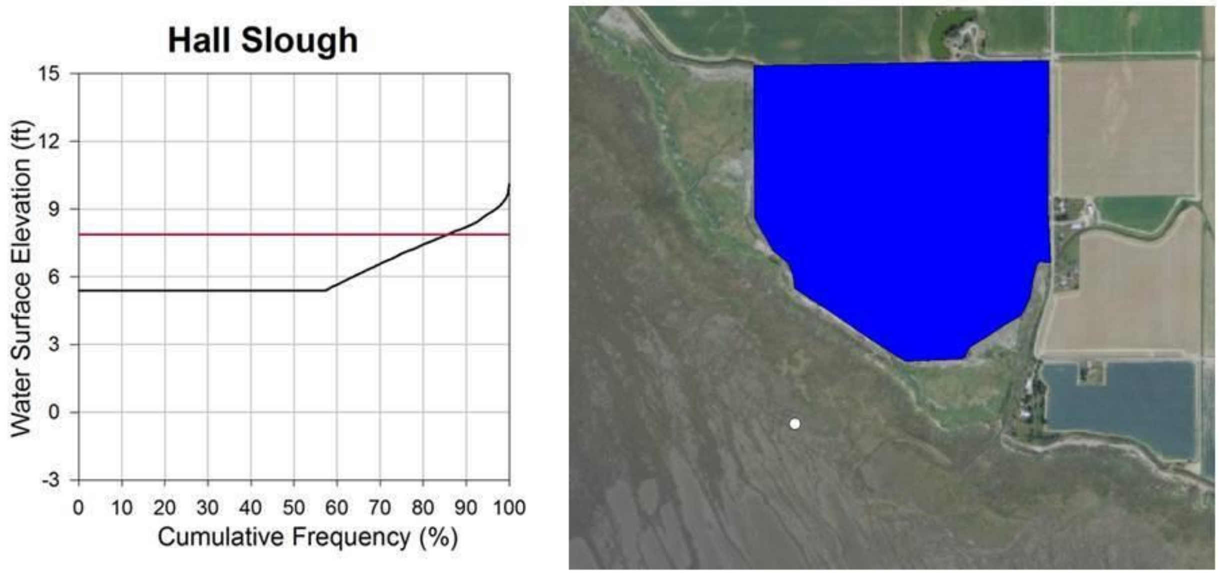

Figure I.9. Cumulative frequency plot and corresponding map for Hall Slough during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

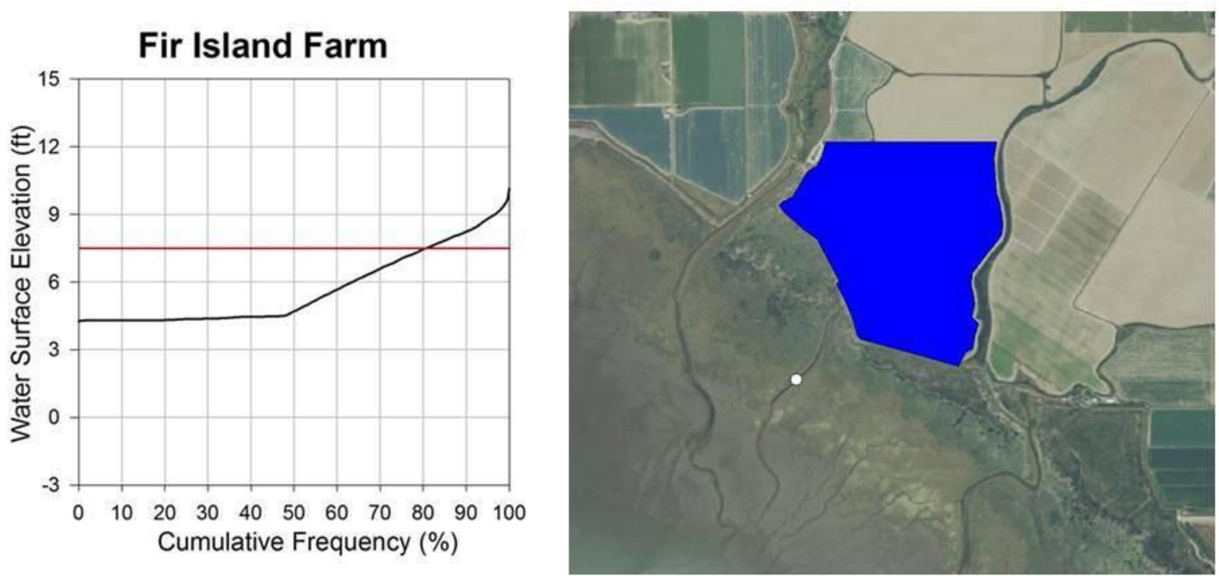

Figure I.10. Cumulative frequency plot and corresponding map for Fir Island Farm during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

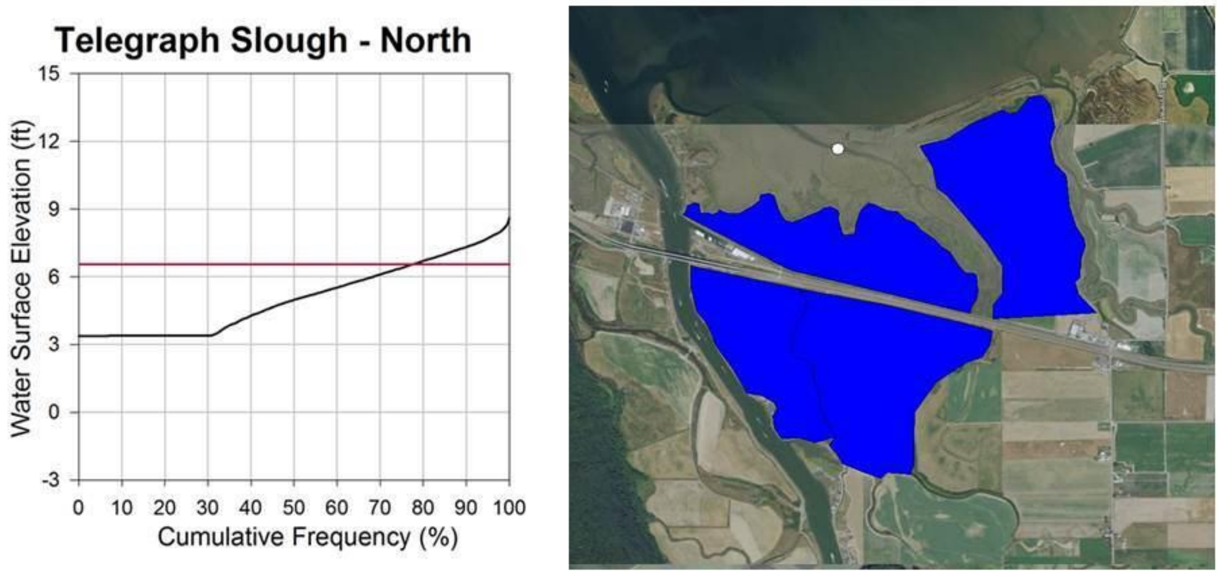

Figure I.11. Cumulative frequency plot and corresponding map for Telegraph Slough (North) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

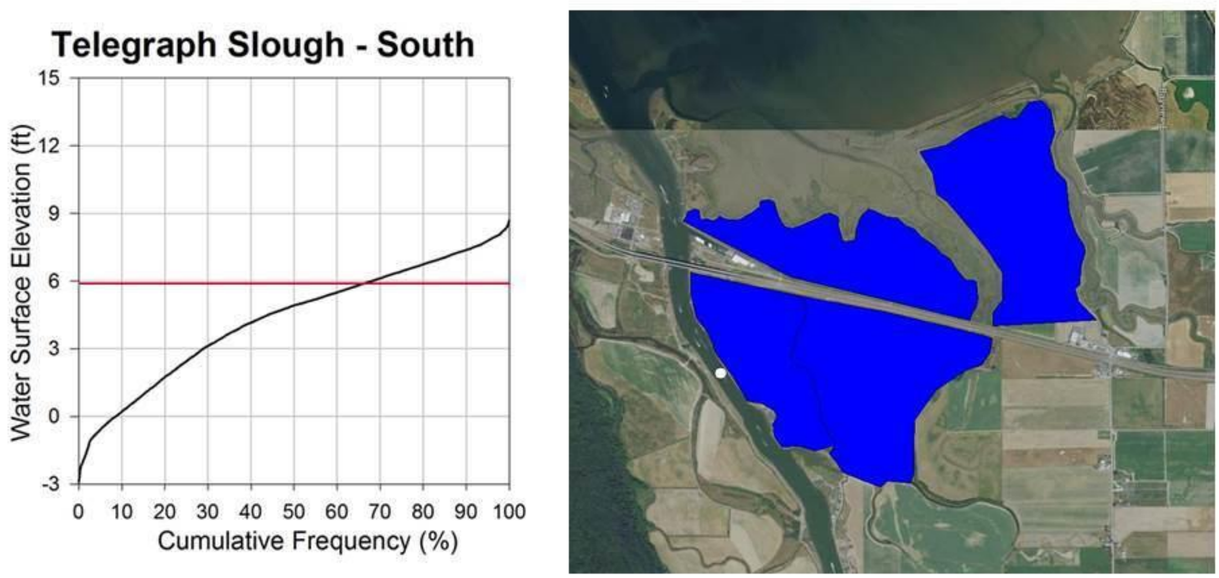

Figure I.12. Cumulative frequency plot and corresponding map for Telegraph Slough (South) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

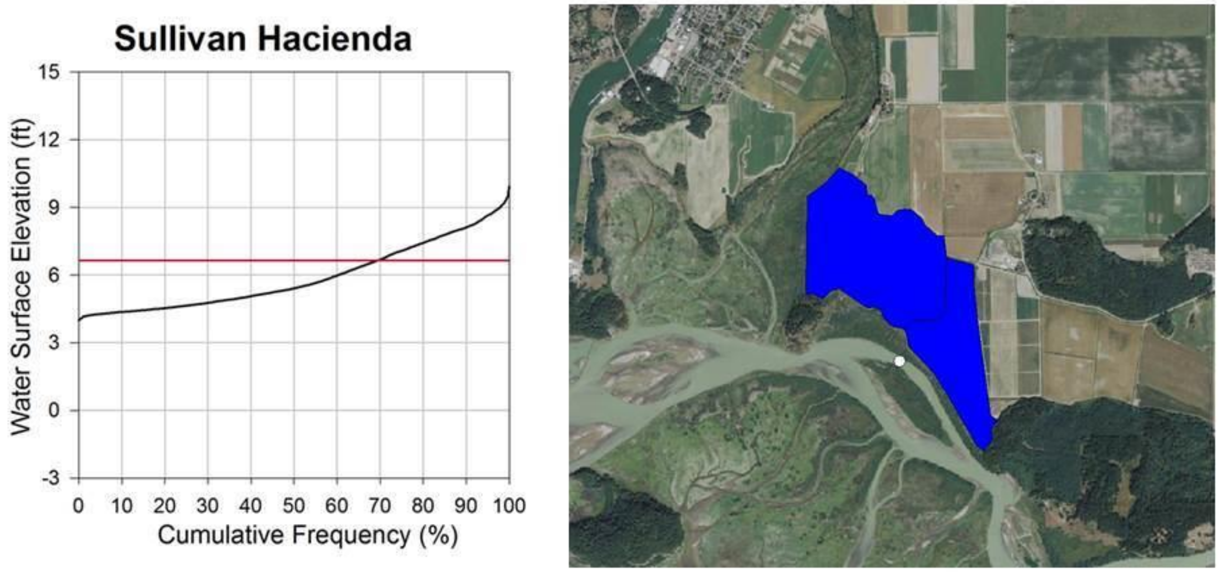

Figure I.13. Cumulative frequency plot and corresponding map for Sullivan Hacienda during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

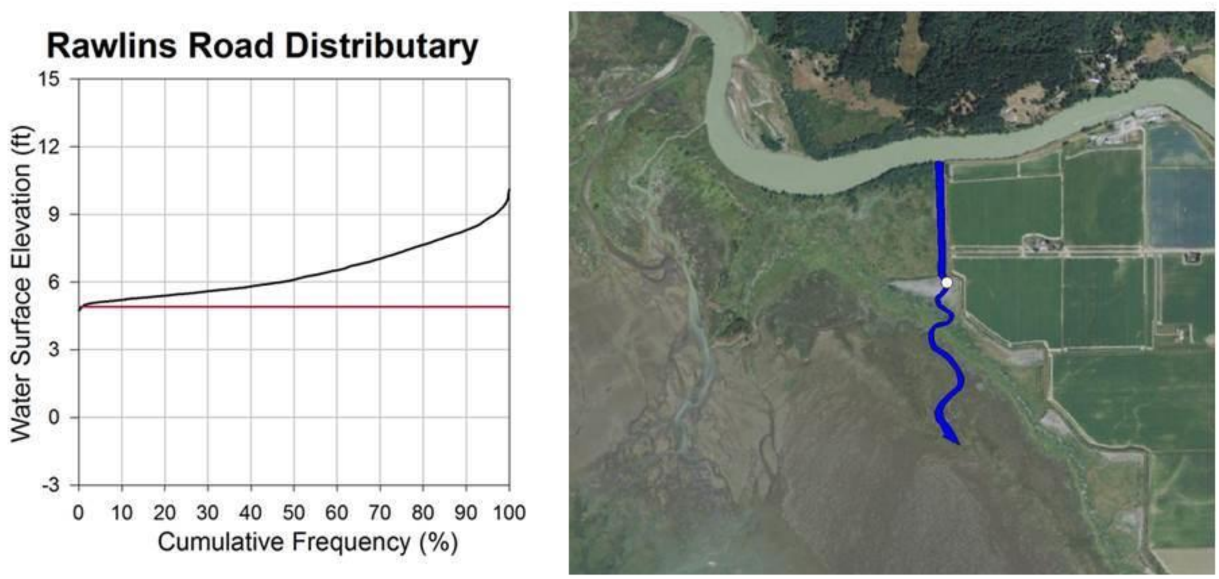

Figure I.14. Cumulative frequency plot and corresponding map for Rawlins Road Distributary during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

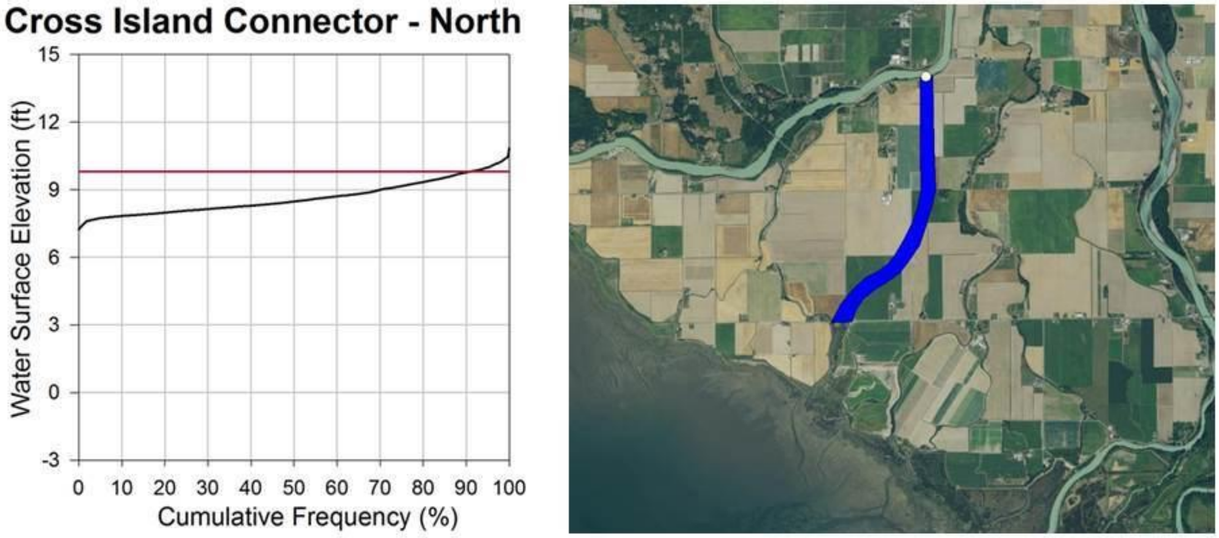

Figure I.15. Cumulative frequency plot and corresponding map for Cross Island Connector (north) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

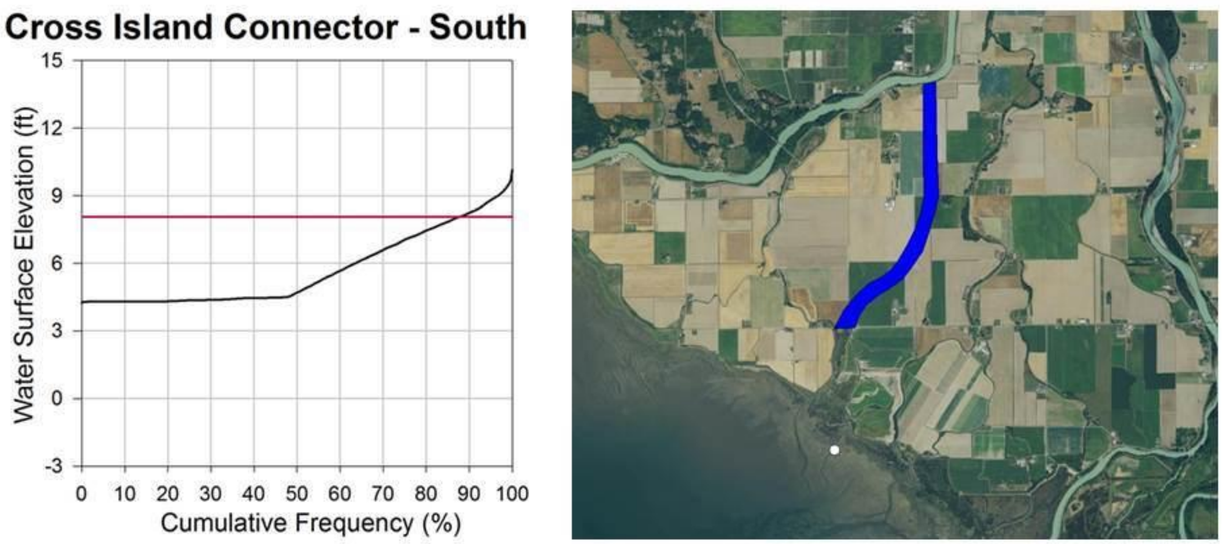

Figure I.16. Cumulative frequency plot and corresponding map for Cross Island Connector (south) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

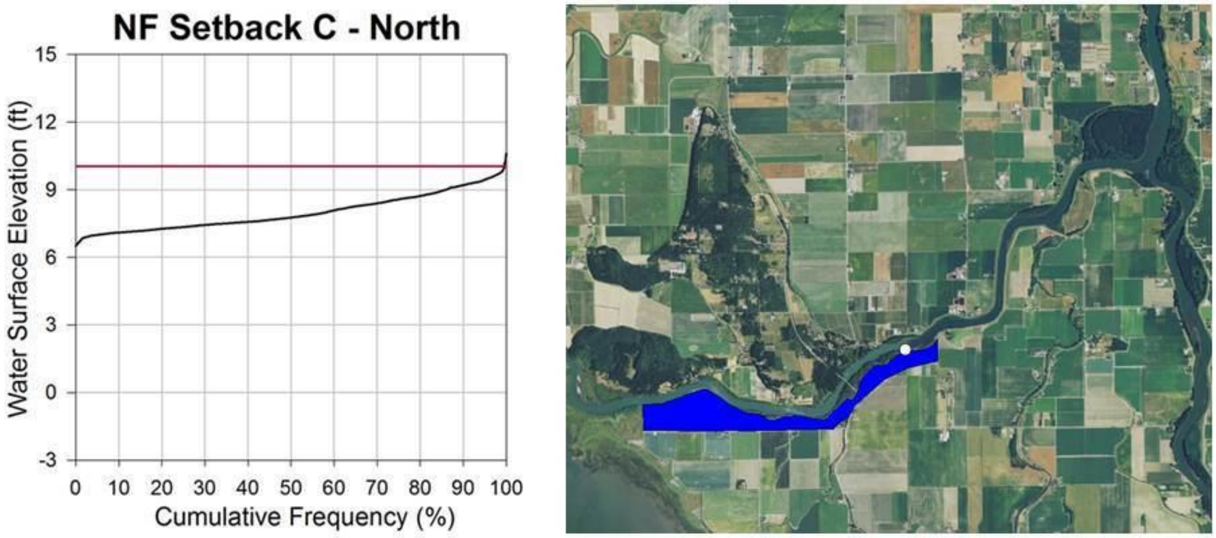

Figure I.17. Cumulative frequency plot and corresponding map for NF Levee Setback C (north) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

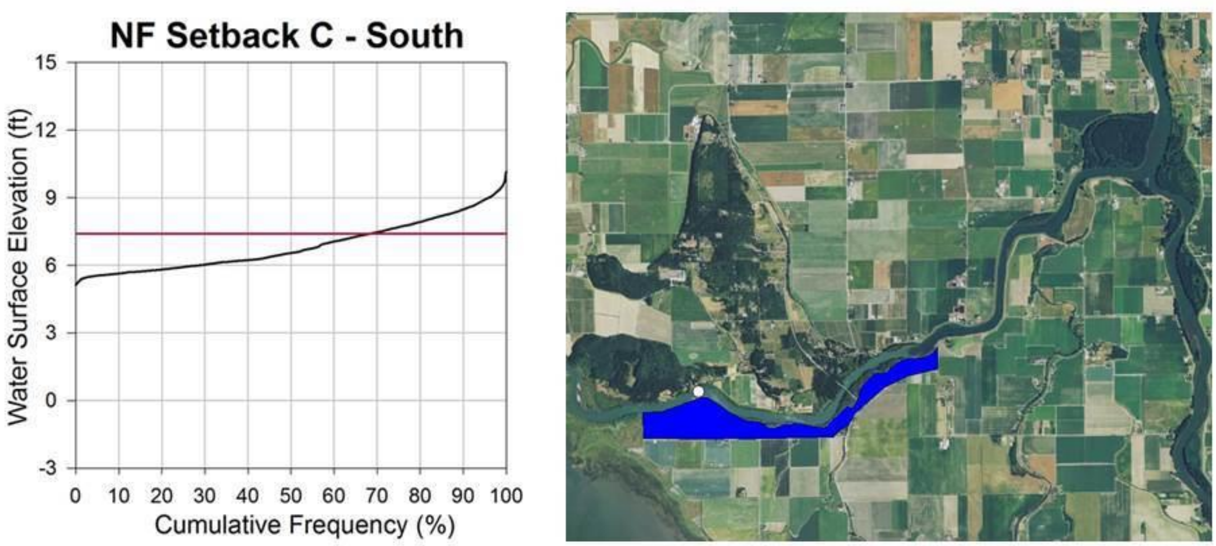

Figure I.18. Cumulative frequency plot and corresponding map for NF Levee Setback C (south) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

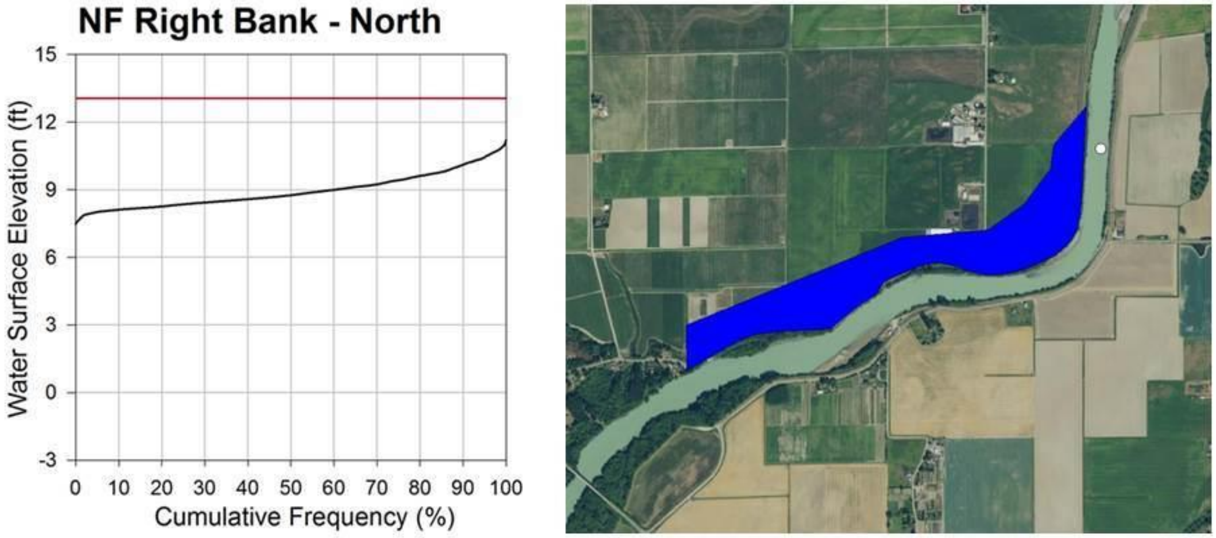

Figure I.19. Cumulative frequency plot and corresponding map for NF Right Bank (north) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

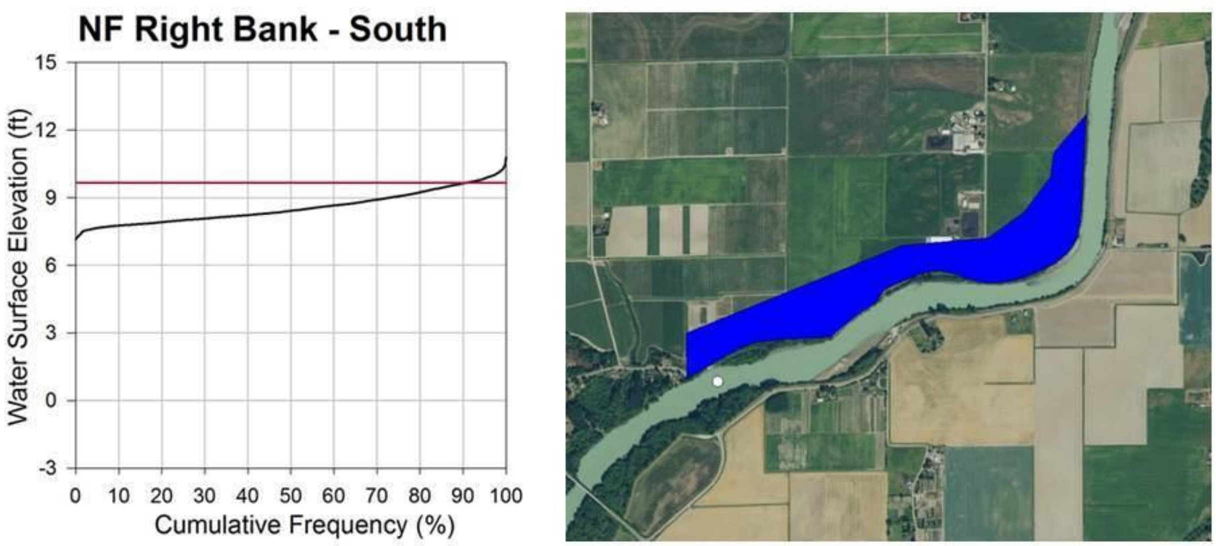

Figure I.20. Cumulative frequency plot and corresponding map for NF Right Bank (south) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

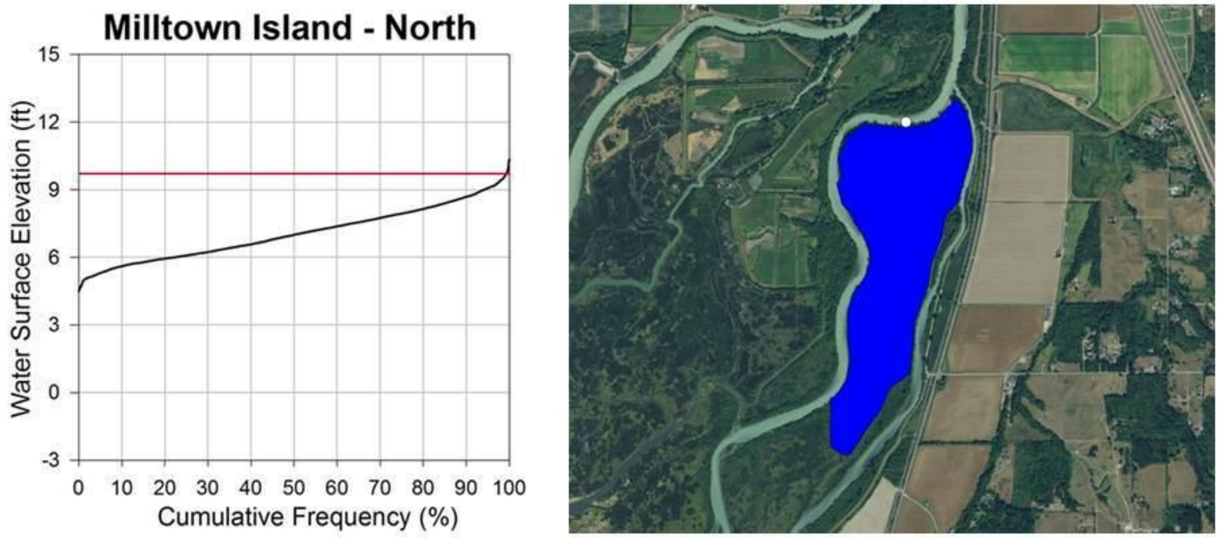

Figure I.21. Cumulative frequency plot and corresponding map for Milltown Island (north) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

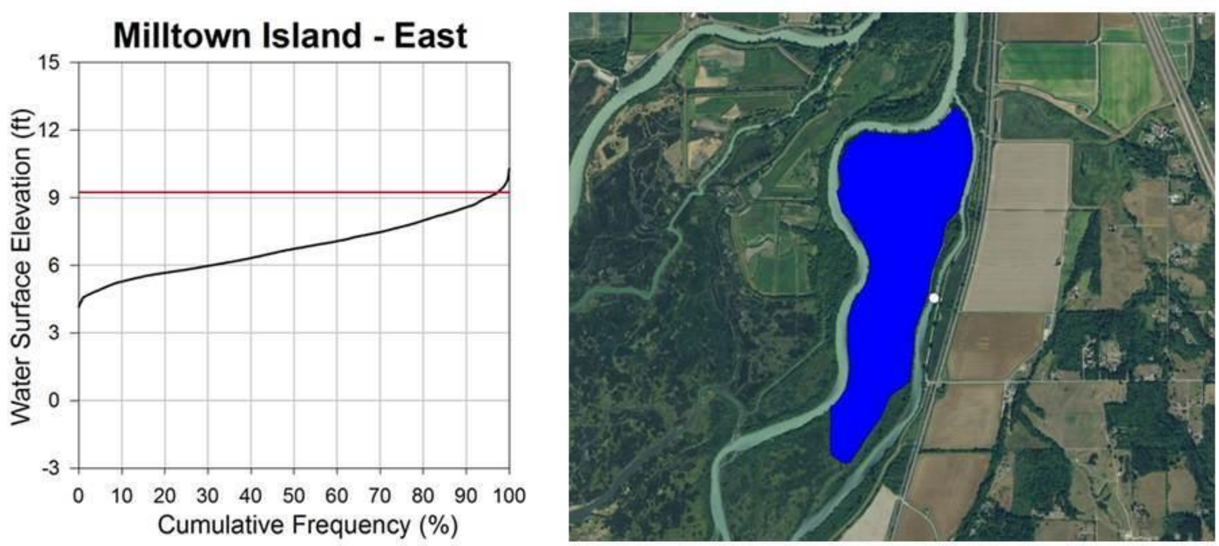

Figure I.22. Cumulative frequency plot and corresponding map for Milltown Island (east) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

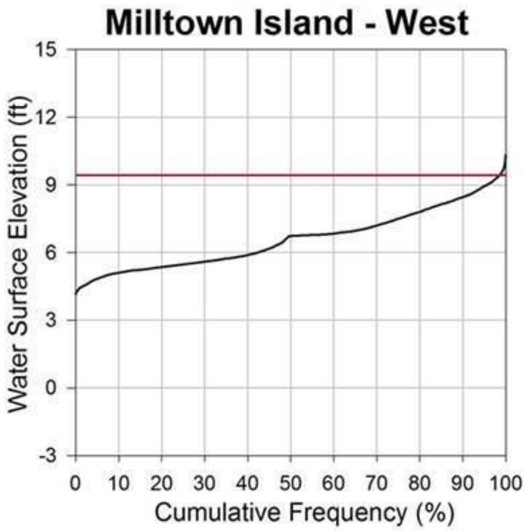

Figure I.23. Cumulative frequency plot and corresponding map for Milltown Island (west) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

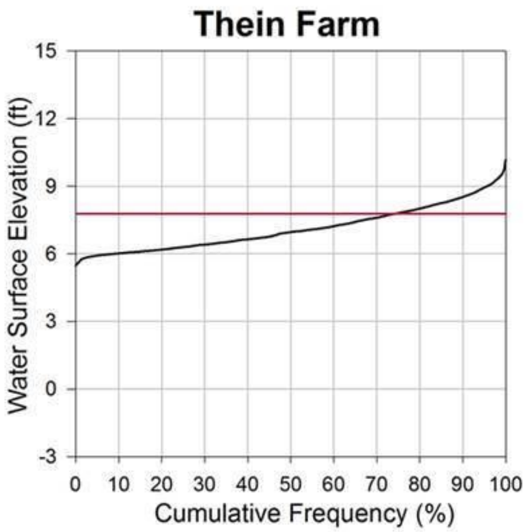

Figure I.24. Cumulative frequency plot and corresponding map for Thein Farm during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

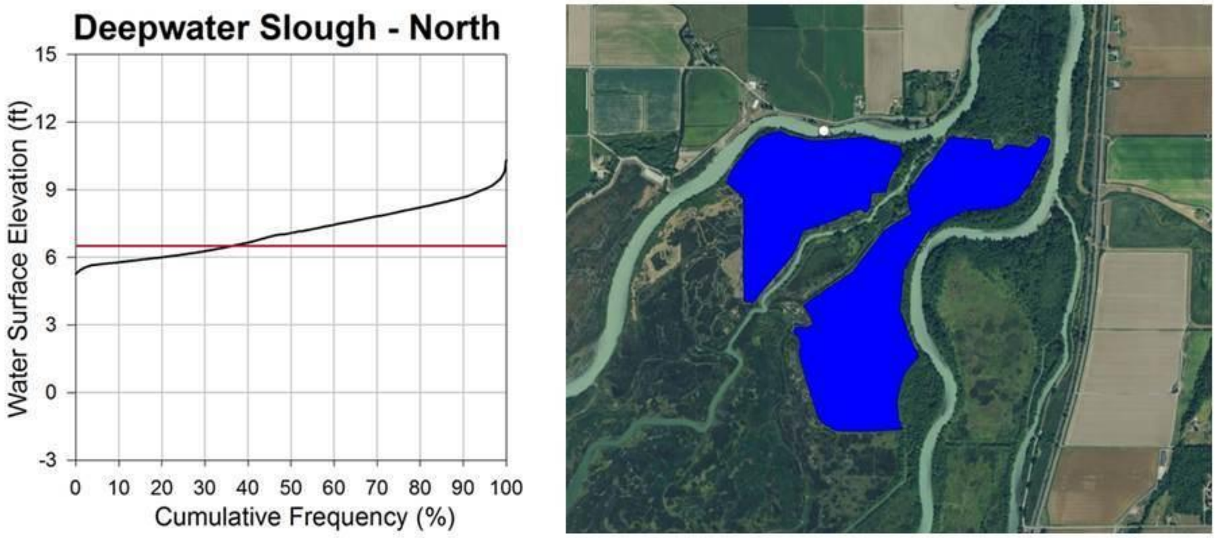

Figure I.25. Cumulative frequency plot and corresponding map for Deepwater Slough (north) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

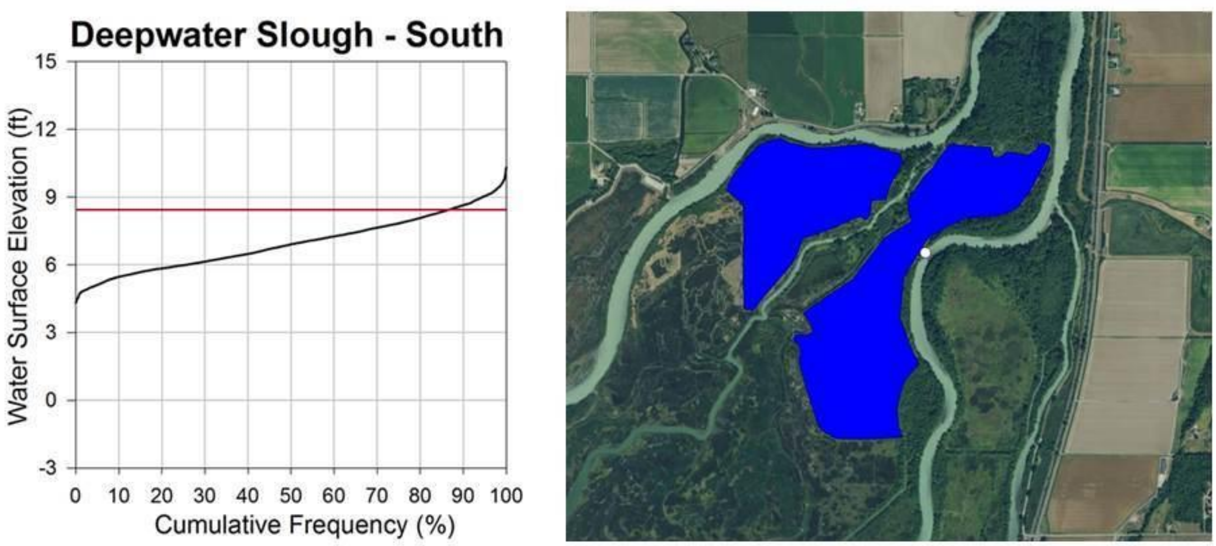

Figure I.26. Cumulative frequency plot and corresponding map for Deepwater Slough (south) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

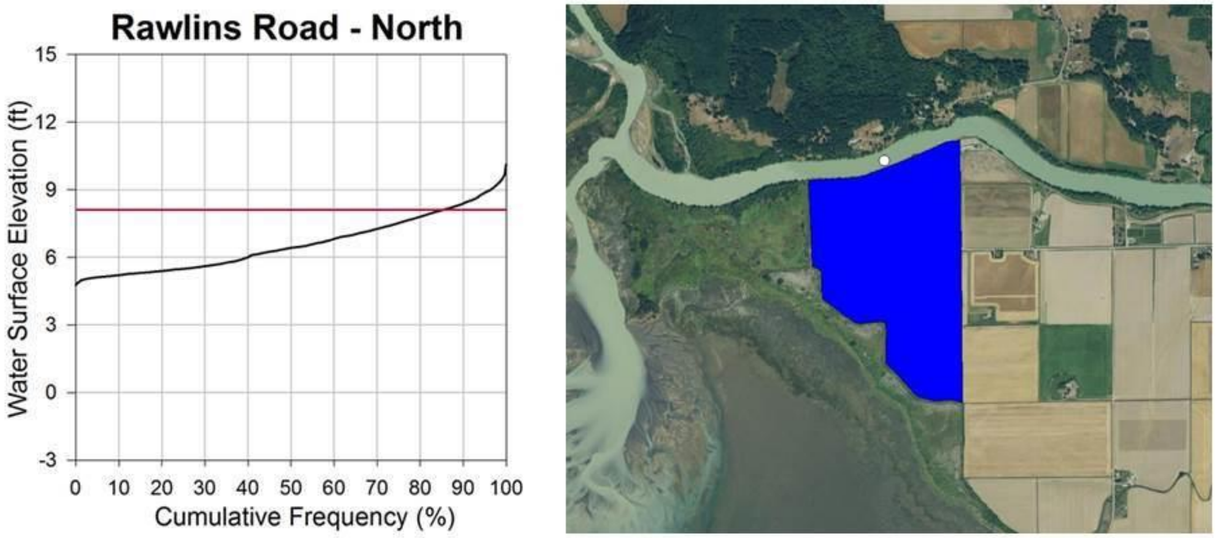

Figure I.27. Cumulative frequency plot and corresponding map for Rawlins Road (north) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

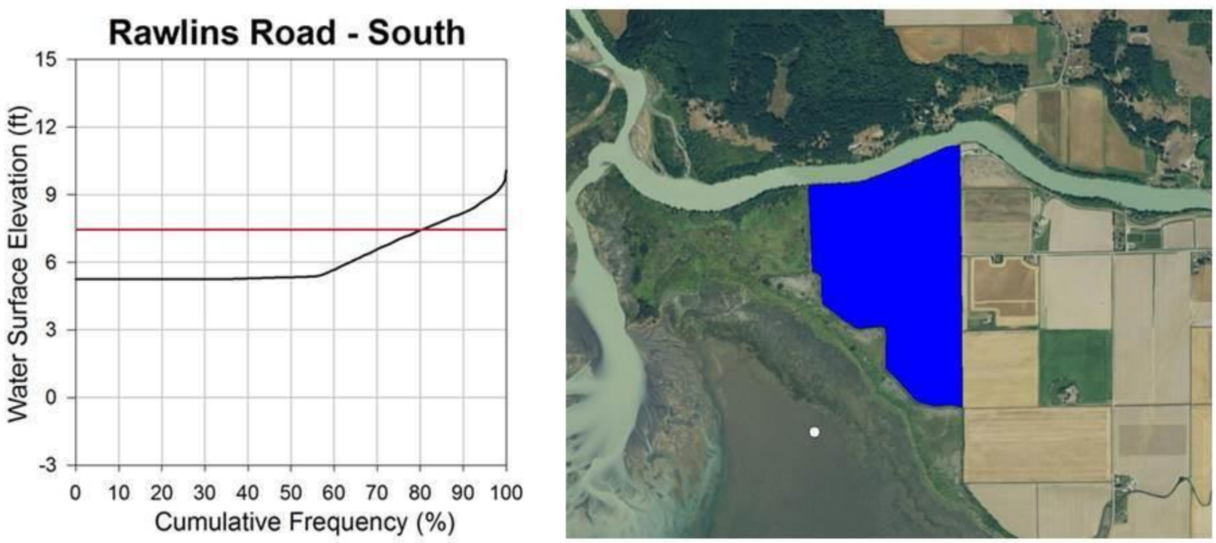

Figure I.28. Cumulative frequency plot and corresponding map for Rawlins Road (south) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

I.4 Selected Projects Deliverable 4

Deliverable 4 is a set of contour maps showing the depth of inundation during the Selected Projects simulation (Simulation 8). The plotted condition was the mean river discharge for the month of May (20,400 cfs) and high spring tide (10.8 ft). All depth values are relative to model bathymetry, which uses linear interpolation to the resolution of the grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure I.29 through Figure I.47.

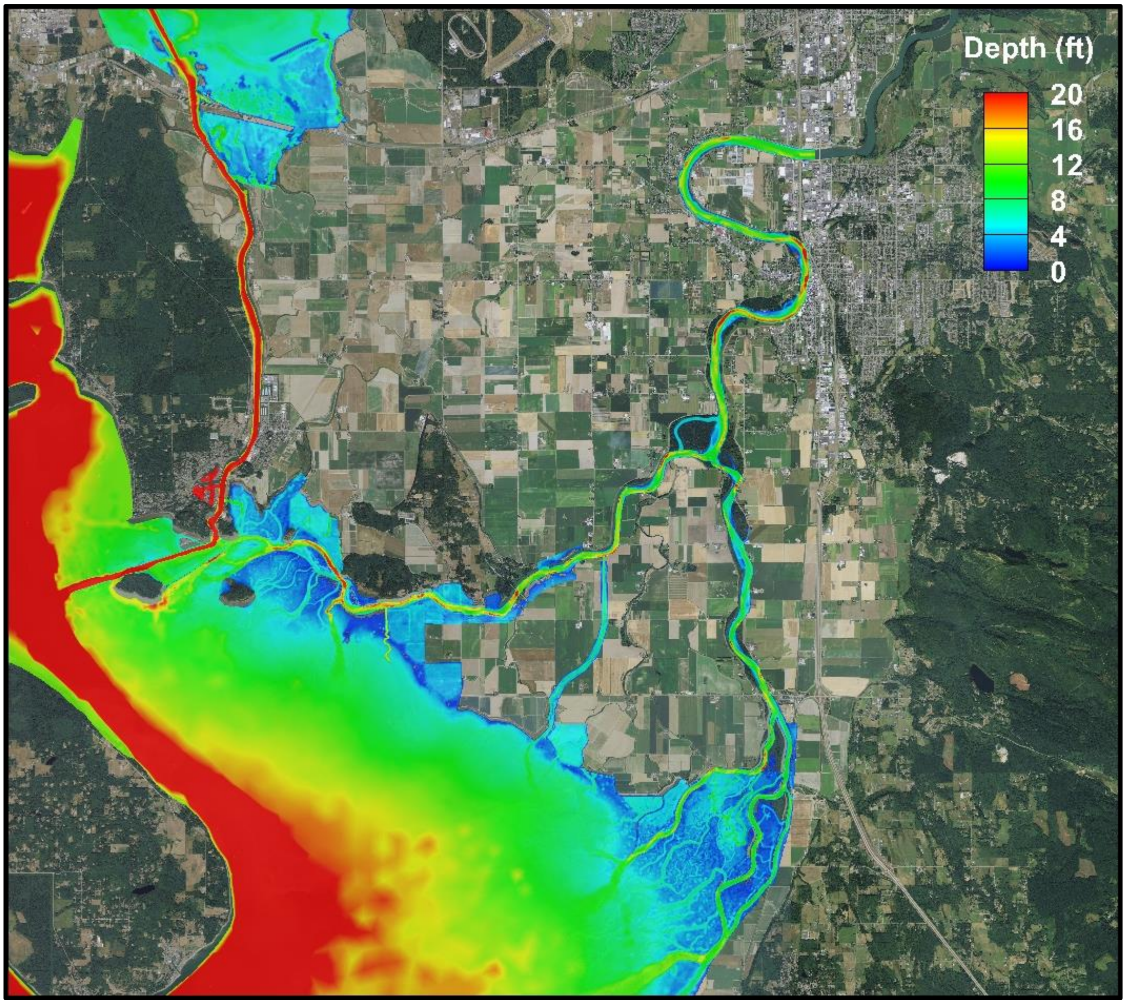

Figure I.29. Contour map of depths for the full domain during the Selected Projects simulation with May flow and high spring tide.

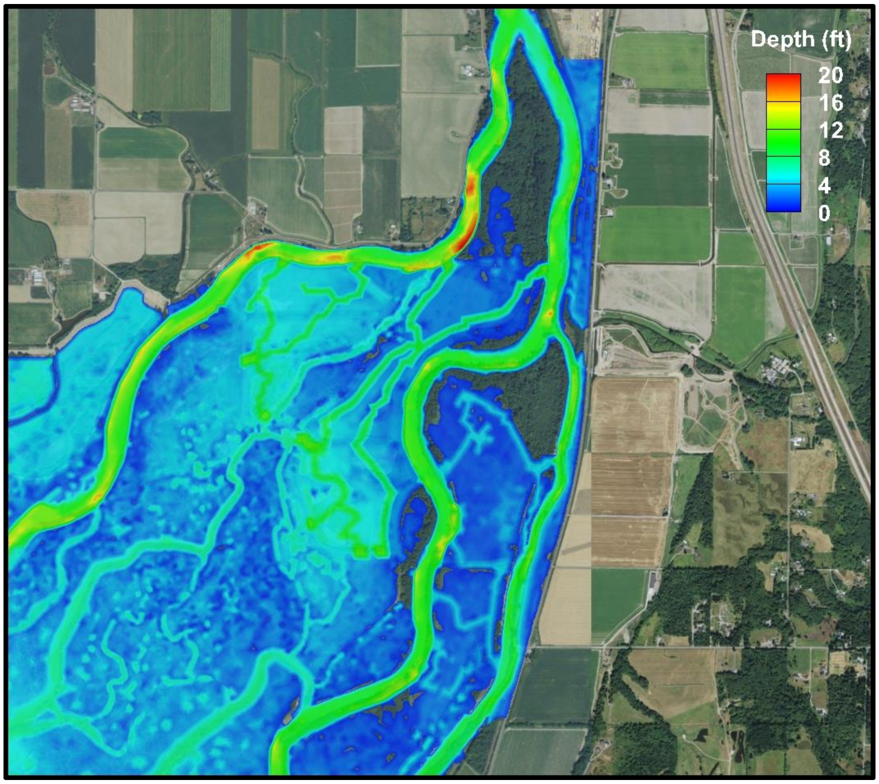

Figure I.30. Contour map of depths for SF Levee Setbacks 2, 3, and 4 during the Selected Projects simulation.

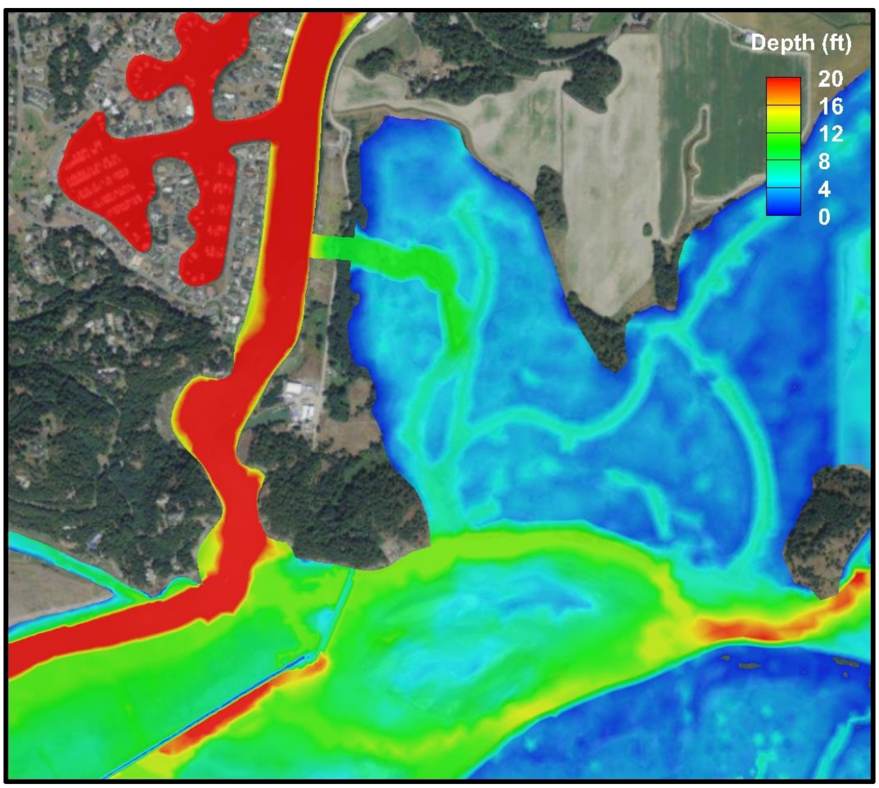

Figure I.31. Contour map of depths for McGlinn Causeway during the Selected Projects simulation.

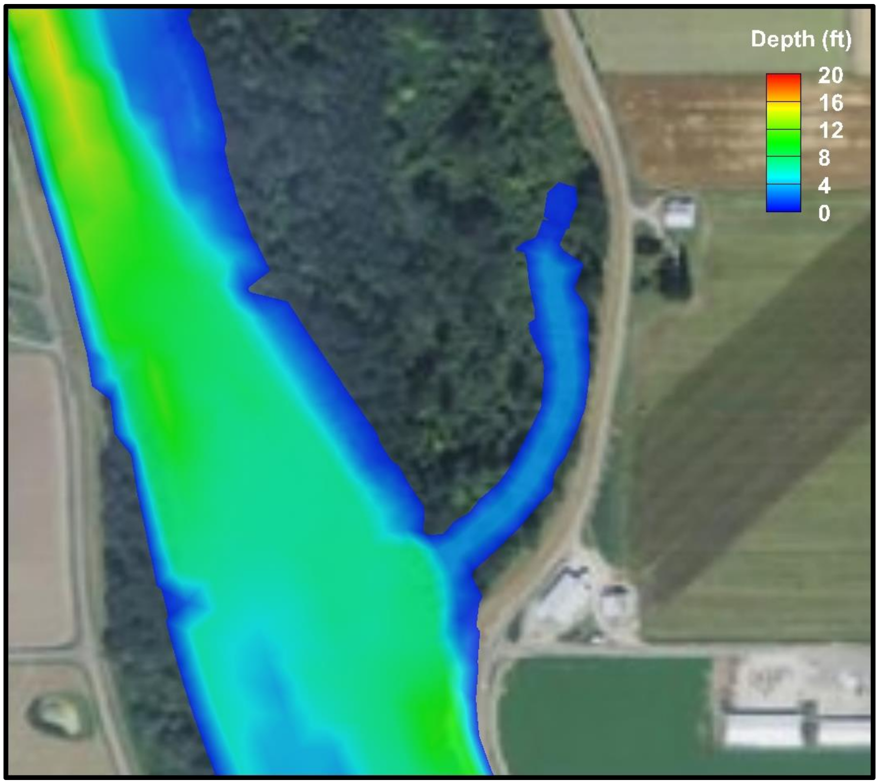

Figure I.32. Contour map of depths for TNC South Fork during the Selected Projects simulation.

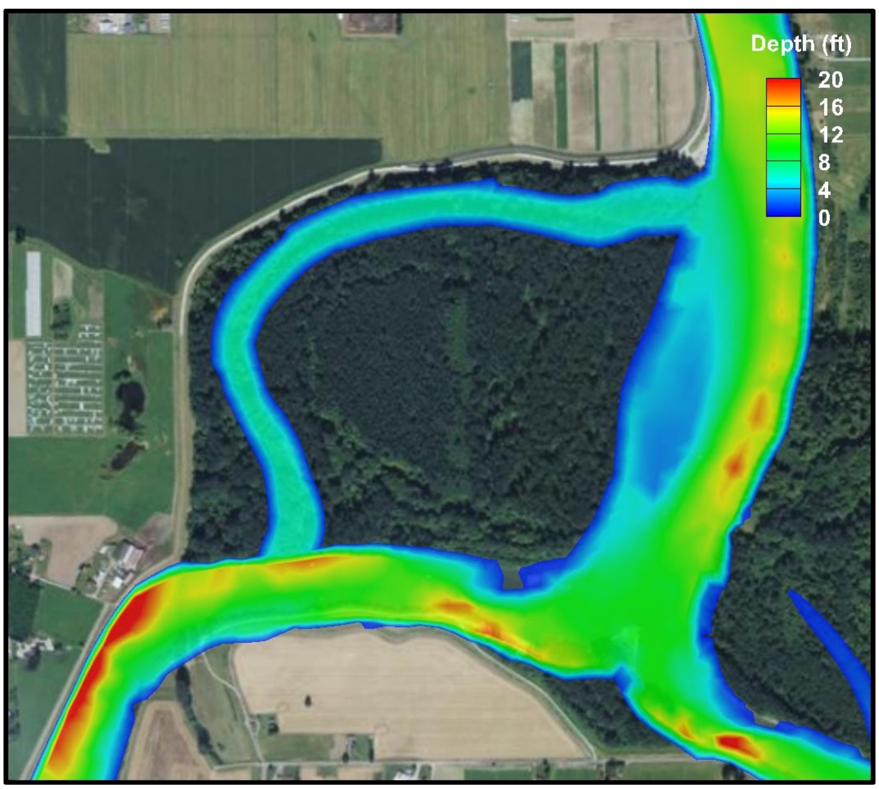

Figure I.33. Contour map of depths for Cottonwood Island during the Selected Projects simulation.

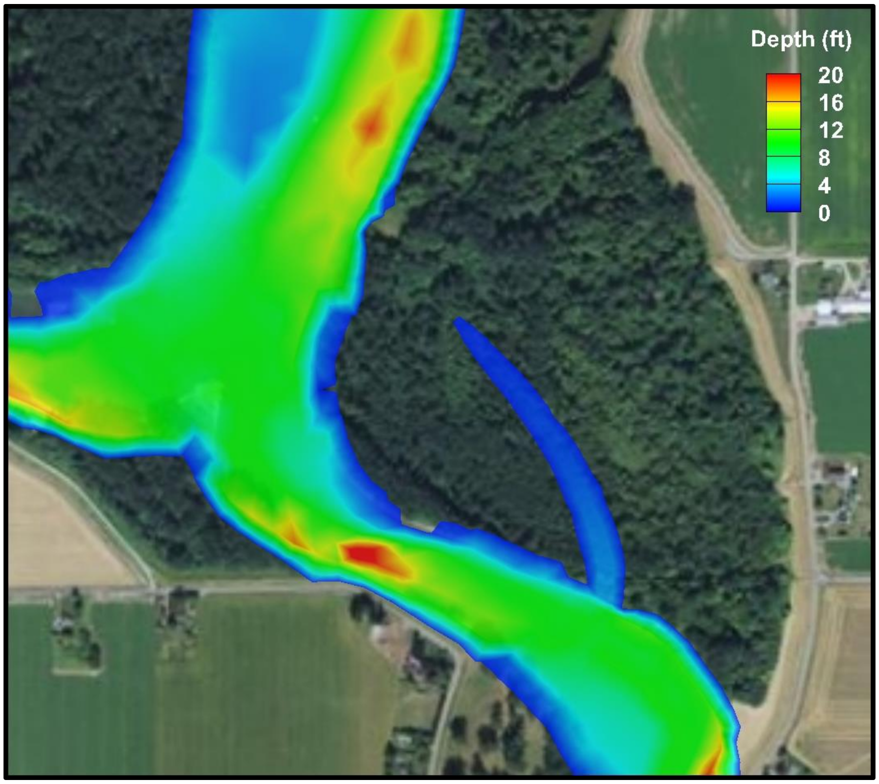

Figure I.34. Contour map of depths for East Cottonwood during the Selected Projects simulation.

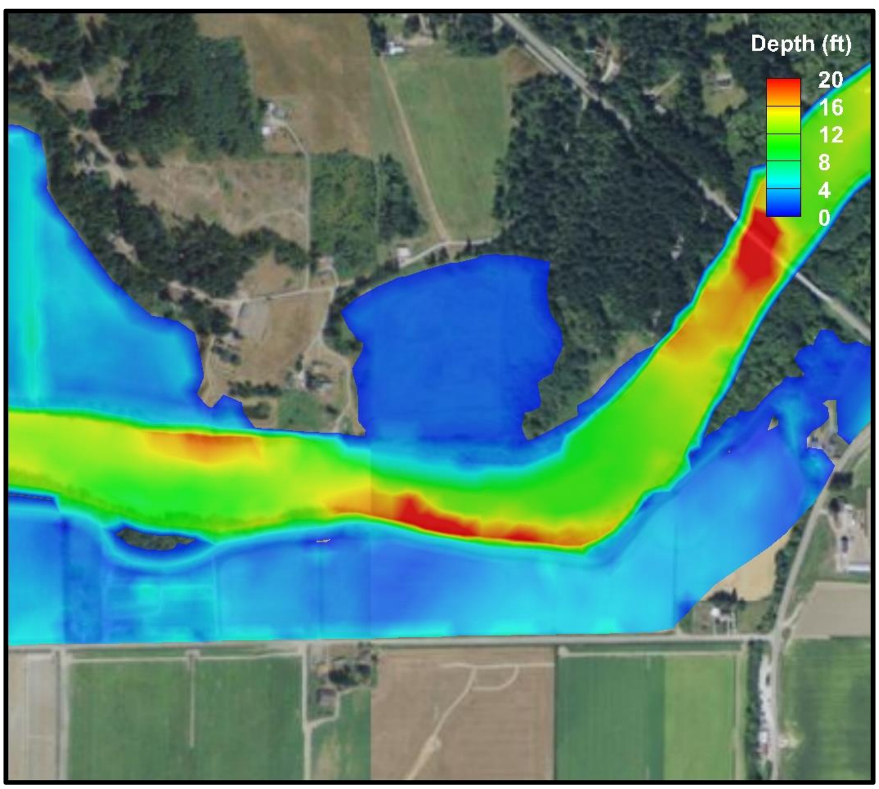

Figure I.35 Contour map of depths for Pleasant Ridge South during the Selected Projects simulation.

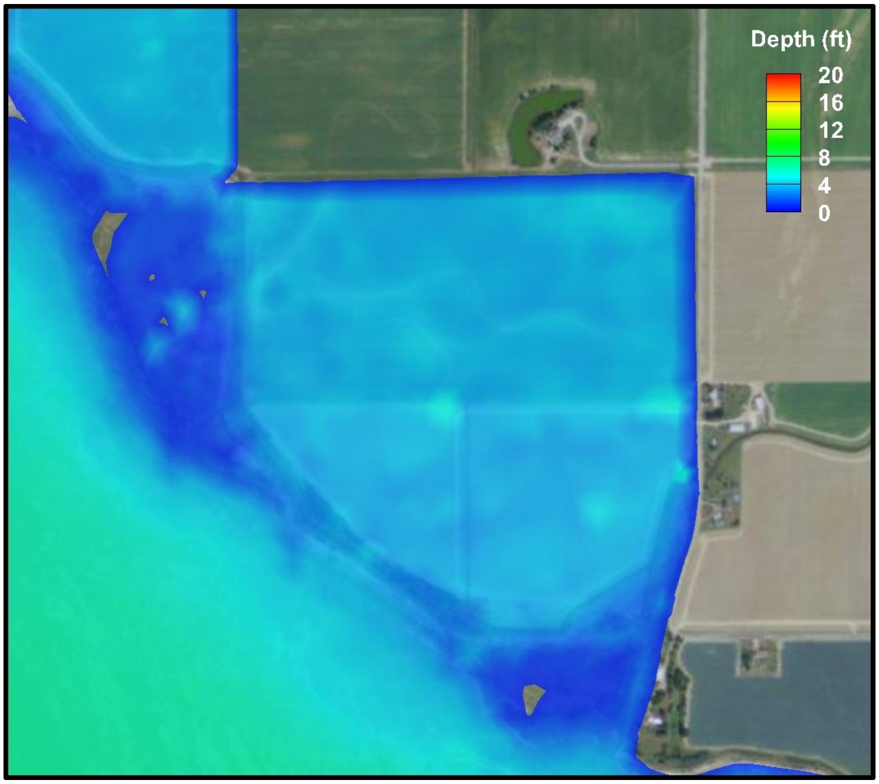

Figure I.36. Contour map of depths for Hall Slough during the Selected Projects simulation.

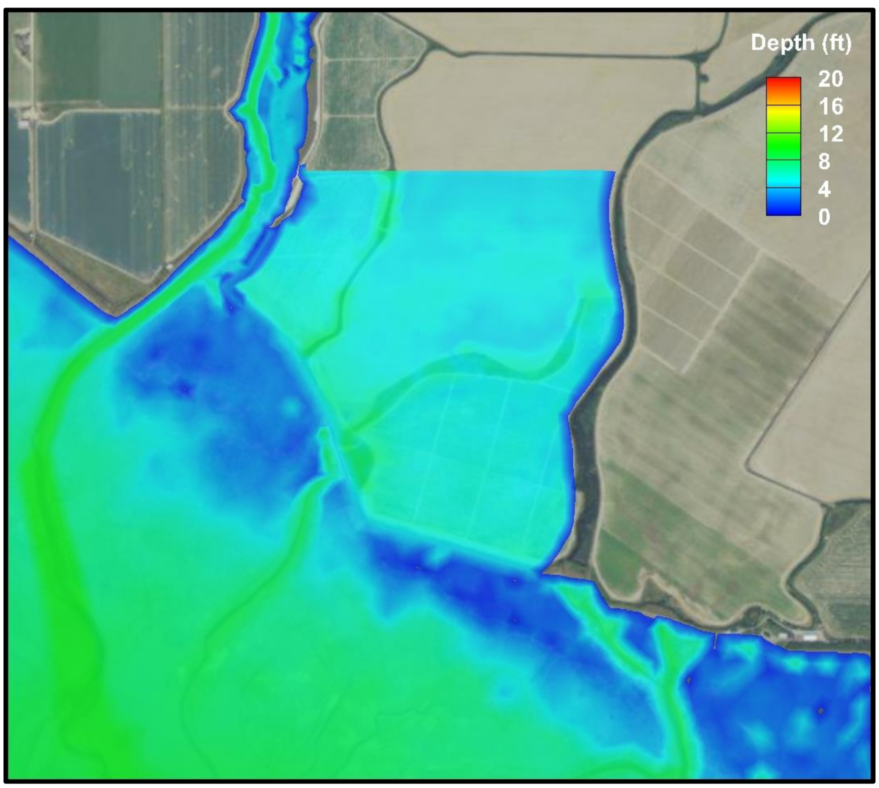

Figure I.37. Contour map of depths for Fir Island Farm during the Selected Projects simulation.

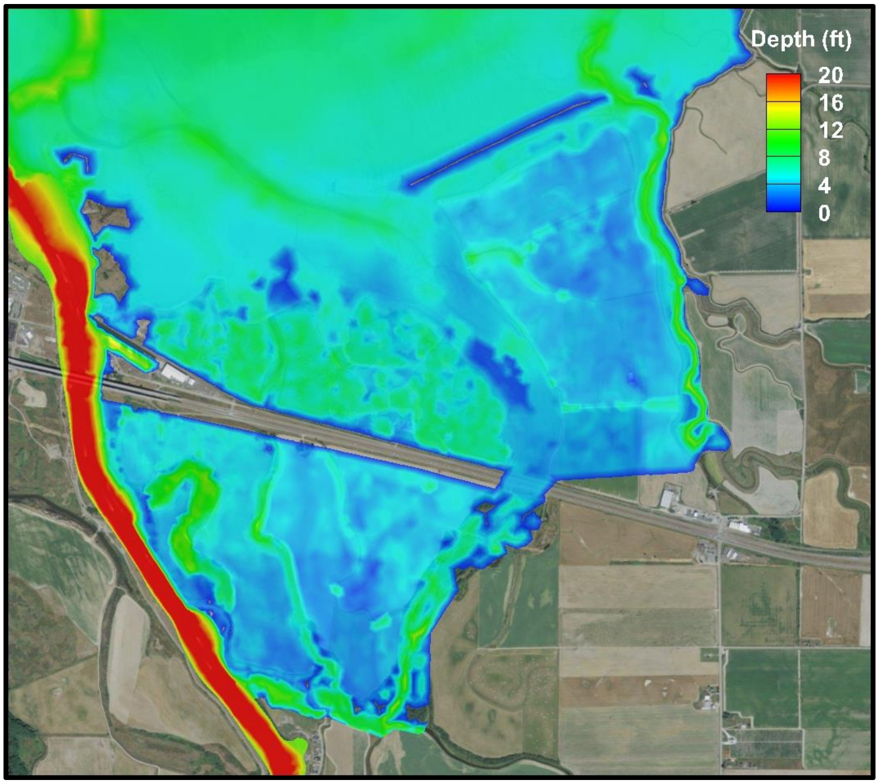

Figure I.38. Contour map of depths for Telegraph Slough Full during the Selected Projects simulation.

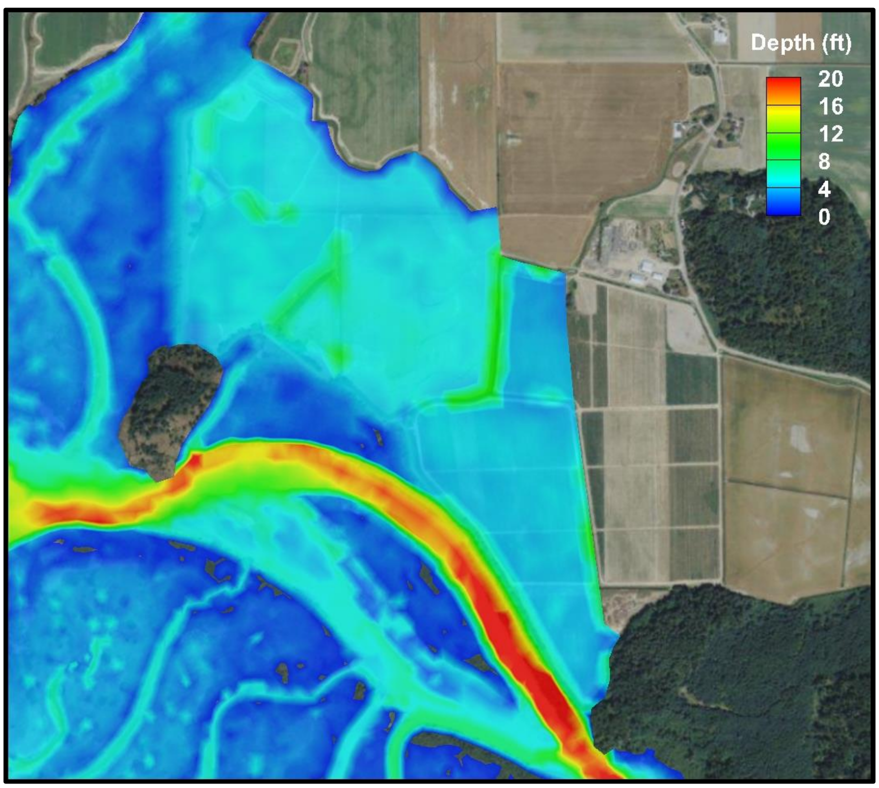

Figure I.39. Contour map of depths for Sullivan Hacienda during the Selected Projects simulation.

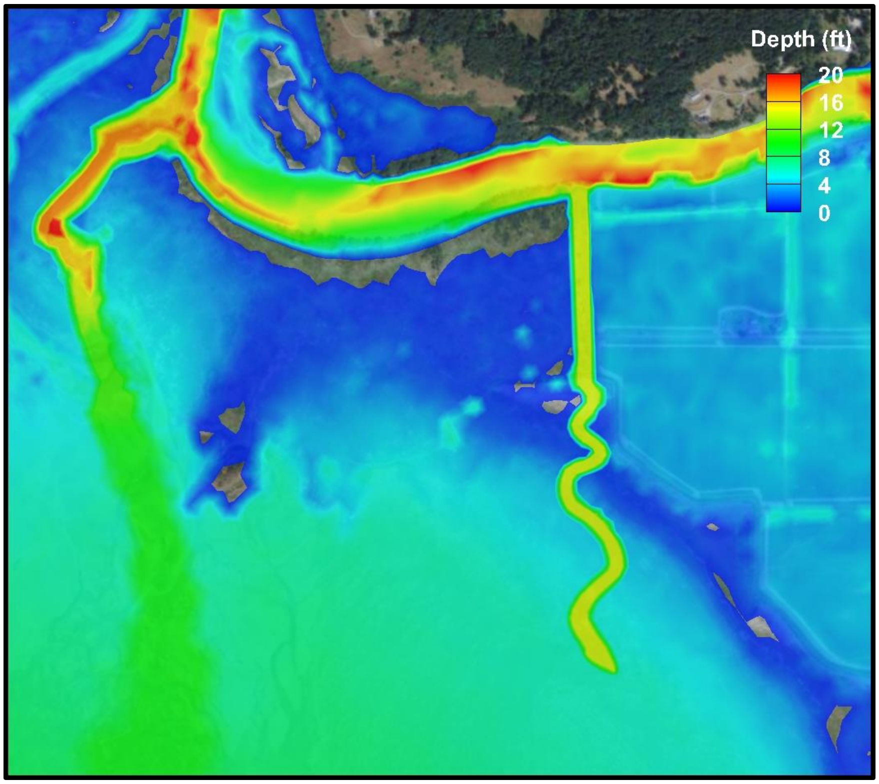

Figure I.40. Contour map of depths for Rawlins Road Distributary during the Selected Projects simulation.

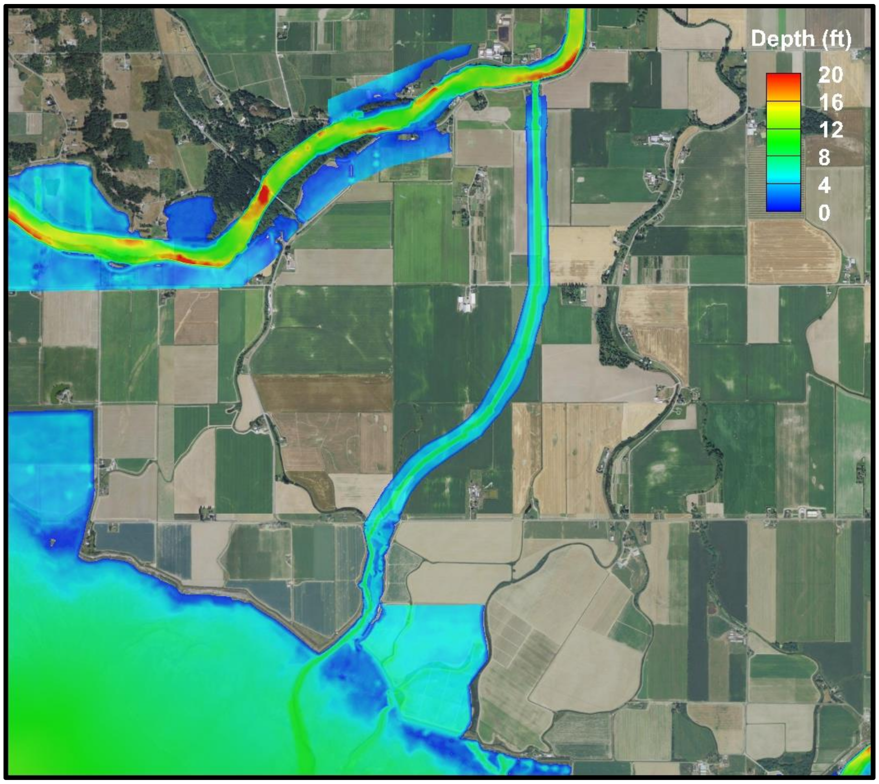

Figure I.41. Contour map of depths for Cross Island Connector during the Selected Projects simulation.

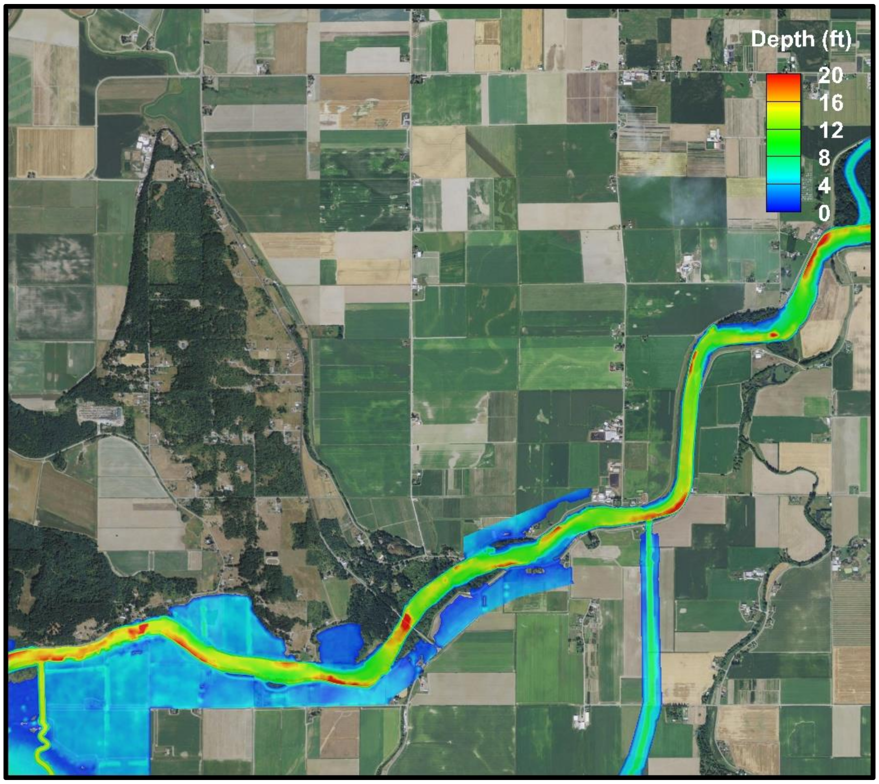

Figure I.42. Contour map of depths for NF Levee Setback C during the Selected Projects simulation.

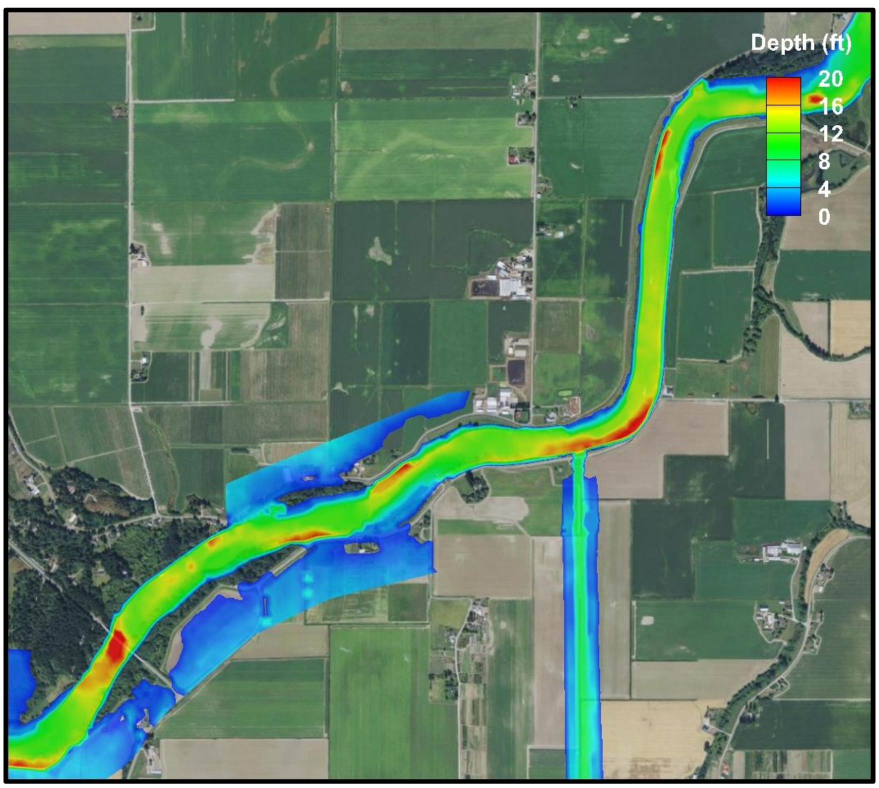

Figure I.43. Contour map of depths for NF Right Bank Levee Setback during the Selected Projects simulation.

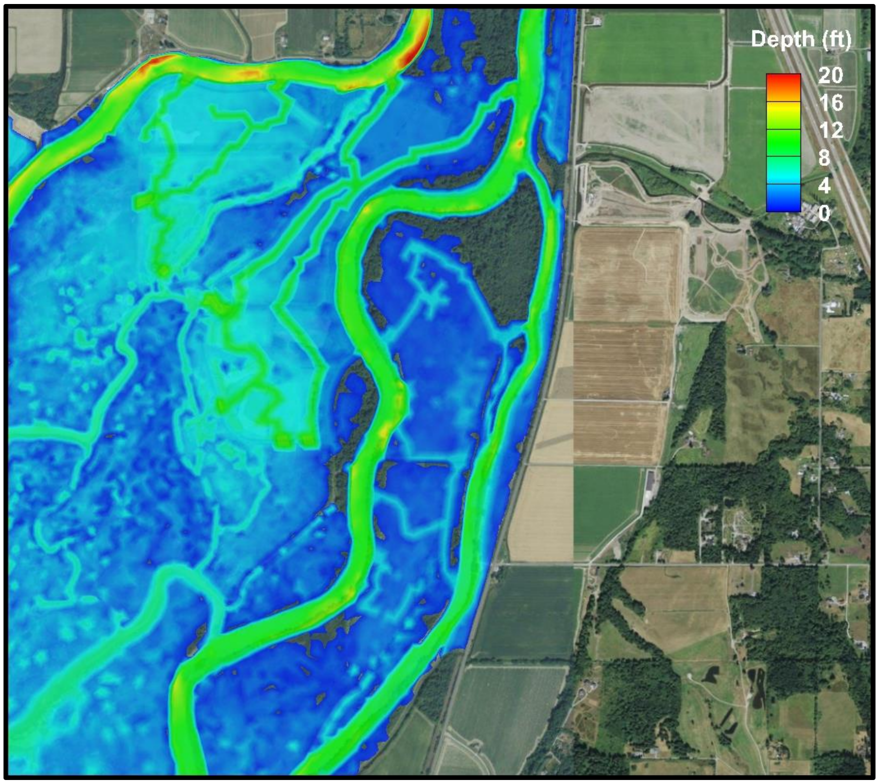

Figure I.44. Contour map of depths for Milltown Island during the Selected Projects simulation.

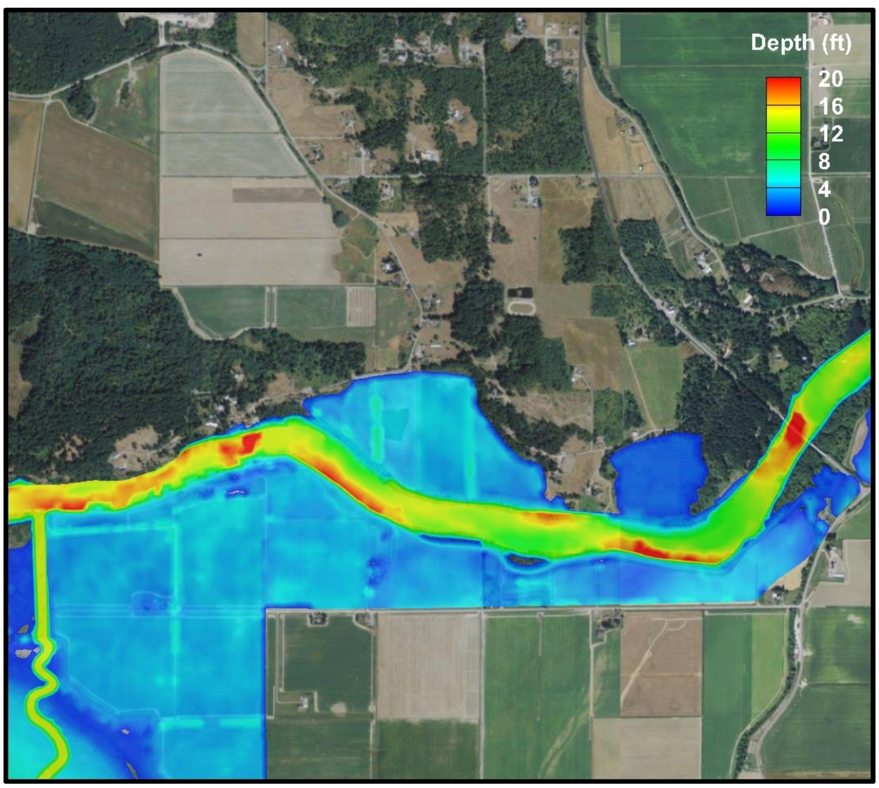

Figure I.45. Contour map of depths for Thein Farm during the Selected Projects simulation.

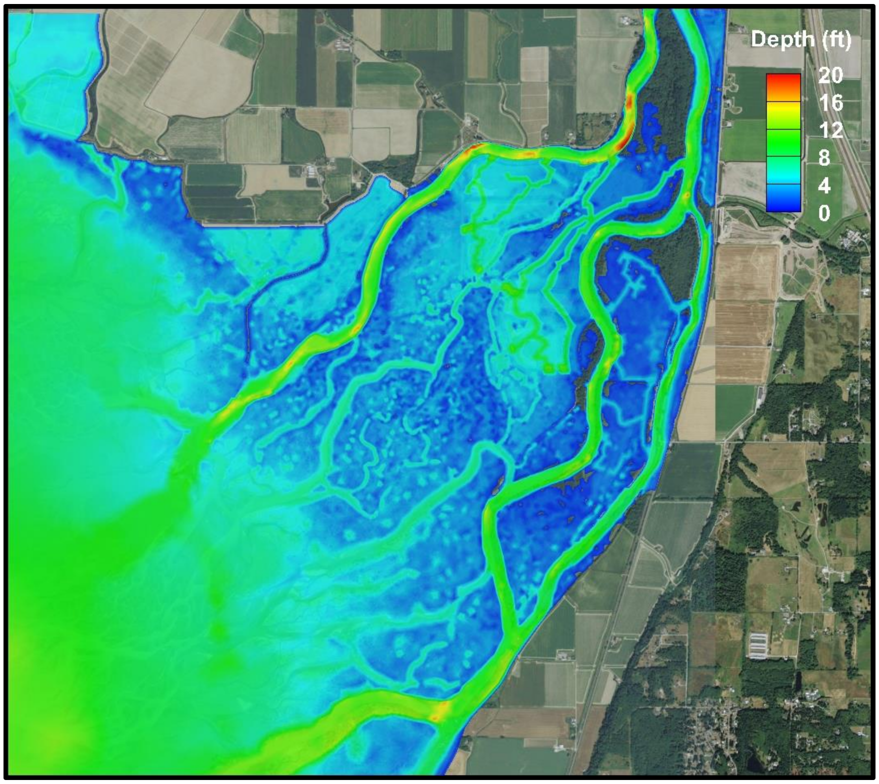

Figure I.46. Contour map of depths for Deepwater Slough Phase 2 during the Selected Projects simulation.

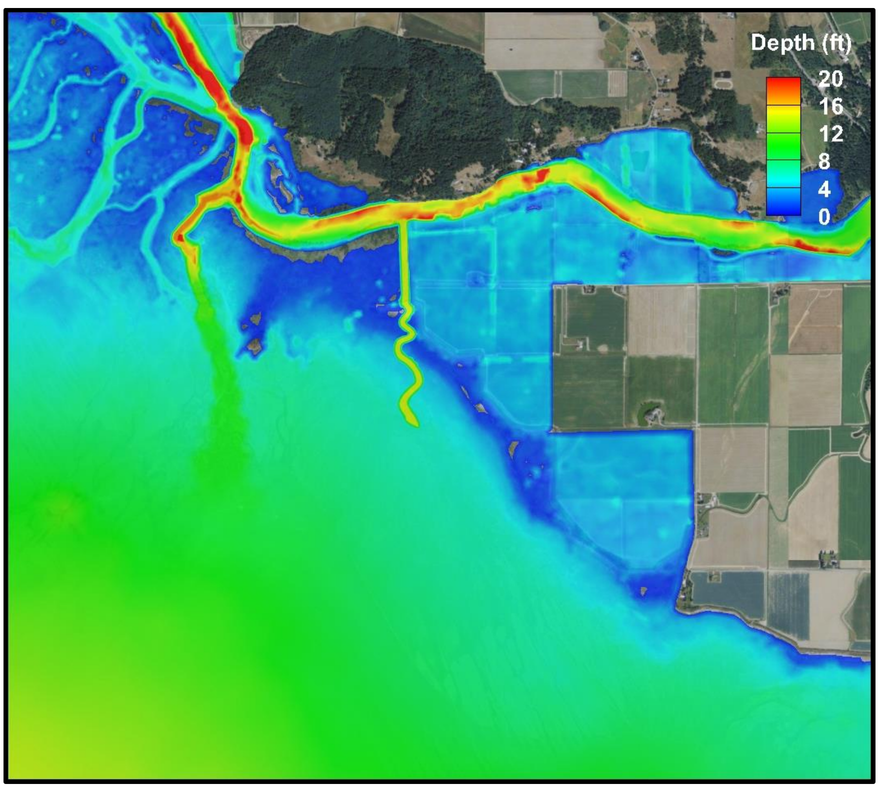

Figure I.47. Contour map of depths for Rawlins Road during the Selected Projects simulation.

I.5 Selected Projects Deliverable 5

Deliverable 5 is a set of contour maps showing the change in water surface elevation between the Baseline Simulation (Simulation 0) and the Selected Projects simulation (Simulation 8). Two conditions were compared: (1) a low spring tide (-3.3 ft) and Q2 flow (62,000 cfs) and (2) a high spring tide (10.4 ft) and a flood condition (93,200 cfs), representing the change from baseline to restored conditions. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure I.48 through Figure I.67.

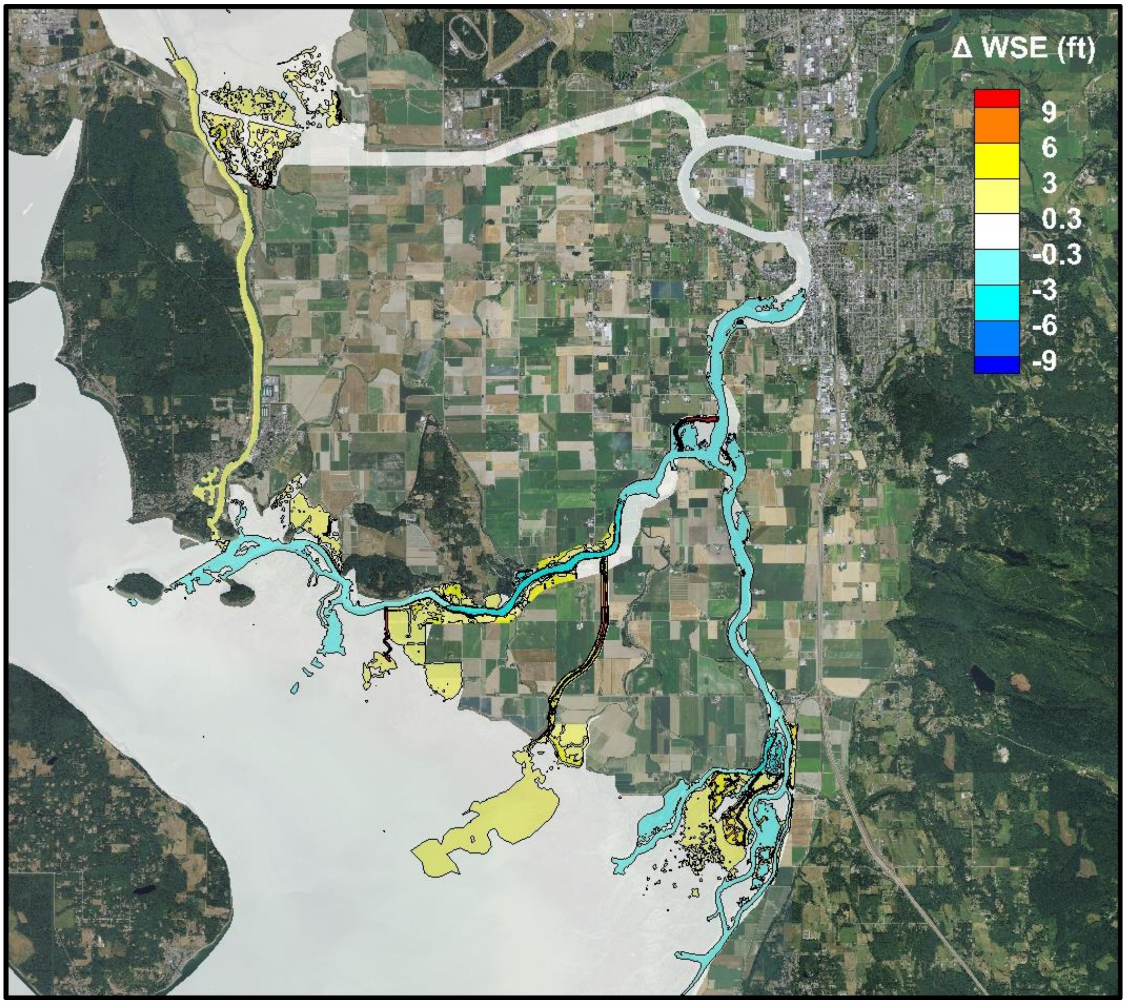

Figure I.48. Contour map of change in WSE from the Baseline to Selected Projects simulation with Q2 flow and low tide.

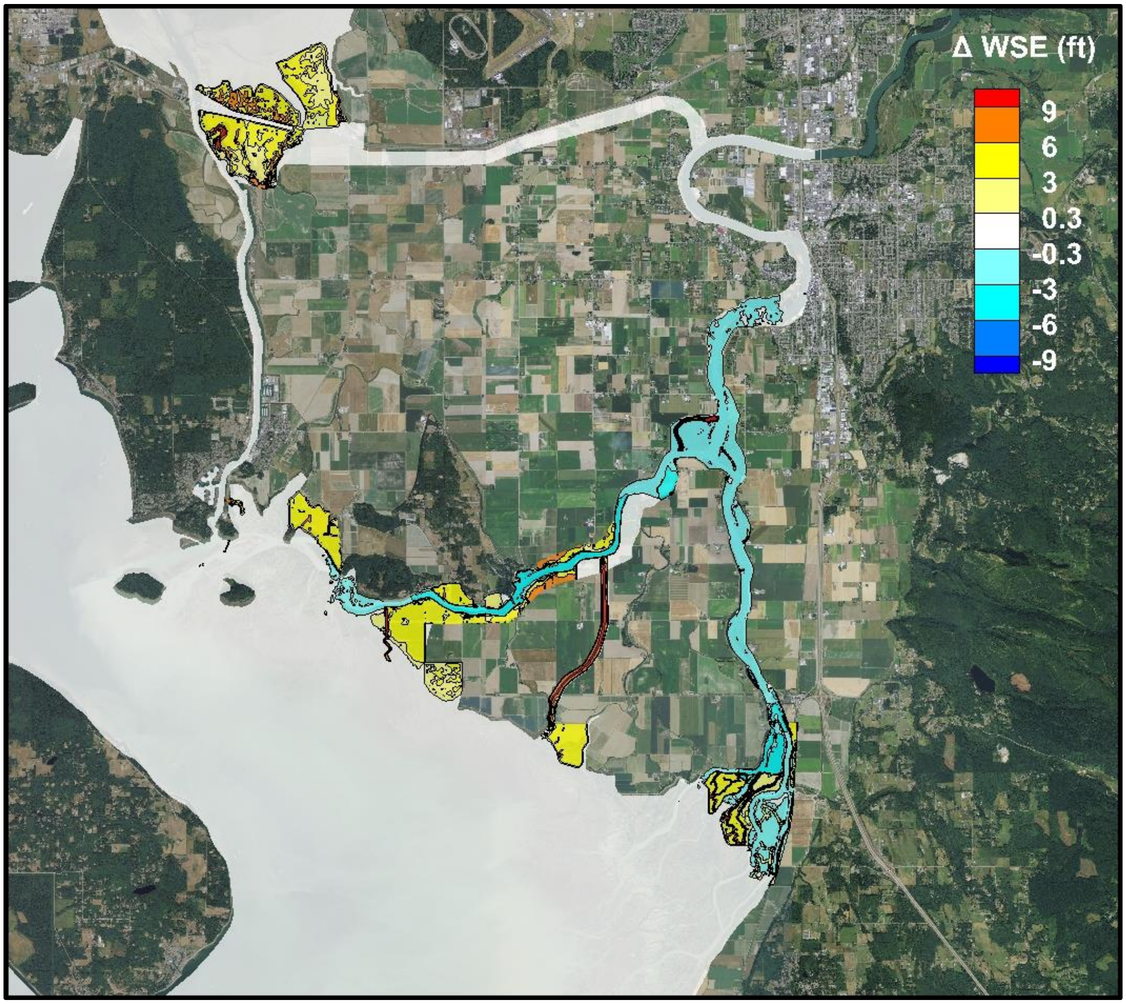

Figure I.49. Contour map of change in WSE from the Baseline to Selected Projects simulation with flood flow and high tide.

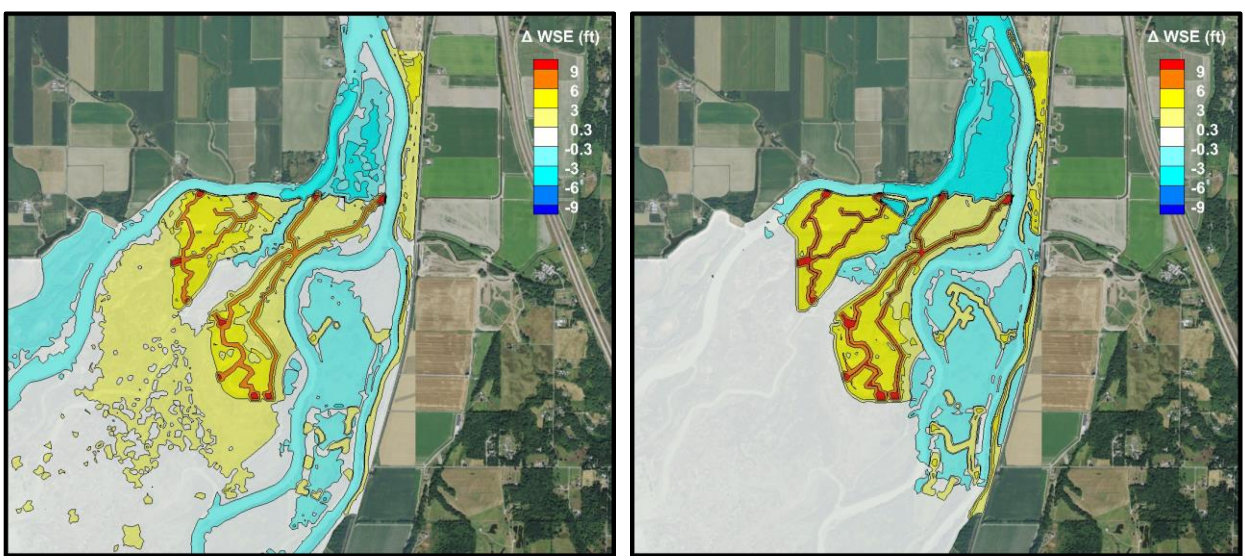

Figure I.50. Contour map of change in WSE from the Baseline simulation for SF Levee Setbacks 2, 3, and 4 with Q2 flow and low tide (left) and flood flow and high tide (right).

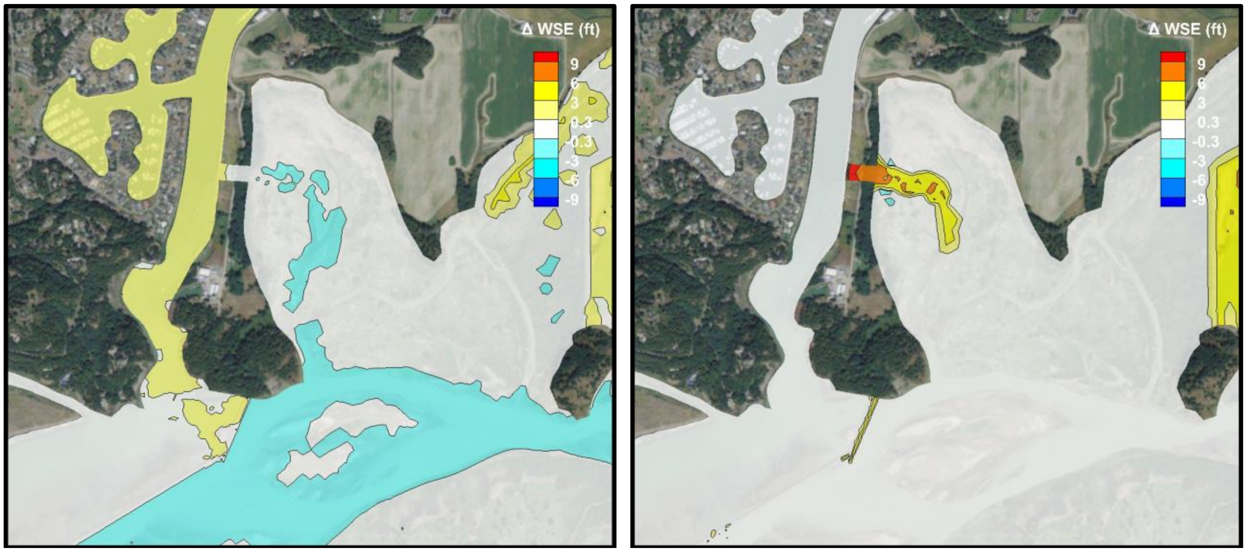

Figure I.51. Contour map of change in WSE from the Baseline simulation for McGlinn Causeway with Q2 flow and low tide (left) and flood flow and high tide (right).

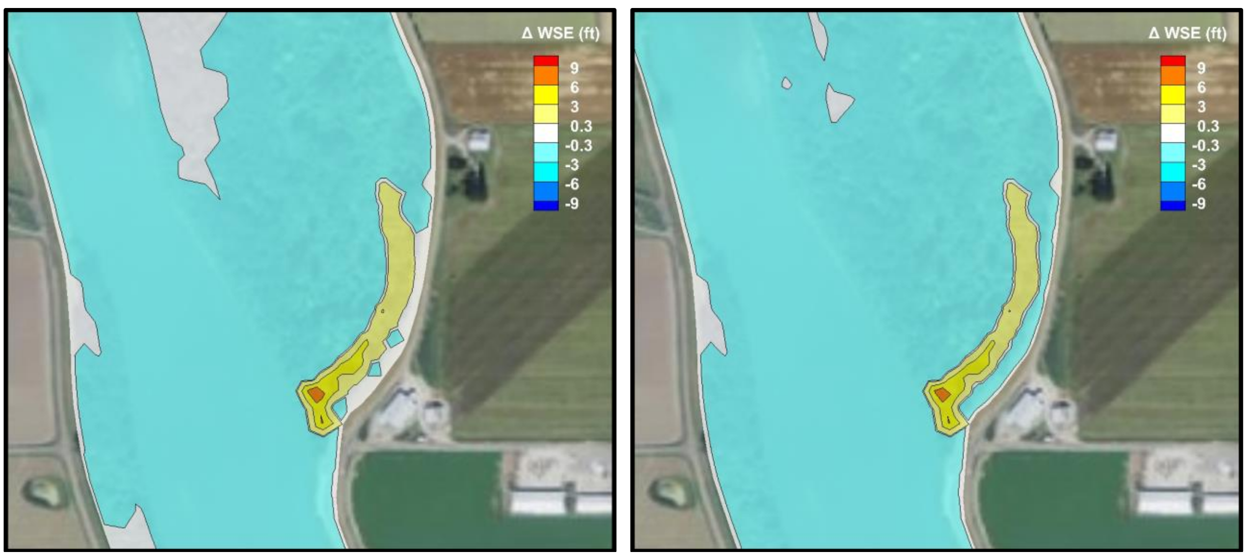

Figure I.52. Contour map of change in WSE from the Baseline simulation for TNC South Fork with Q2 flow and low tide (left) and flood flow and high tide (right).

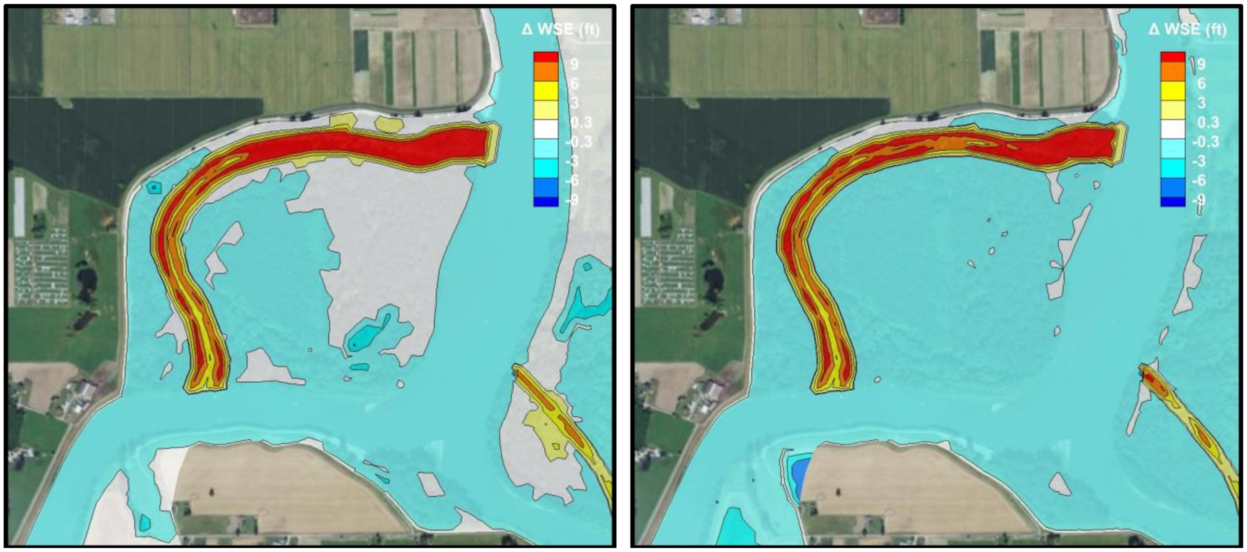

Figure I.53. Contour map of change in WSE from the Baseline simulation for Cottonwood Island with Q2 flow and low tide (left) and flood flow and high tide (right).

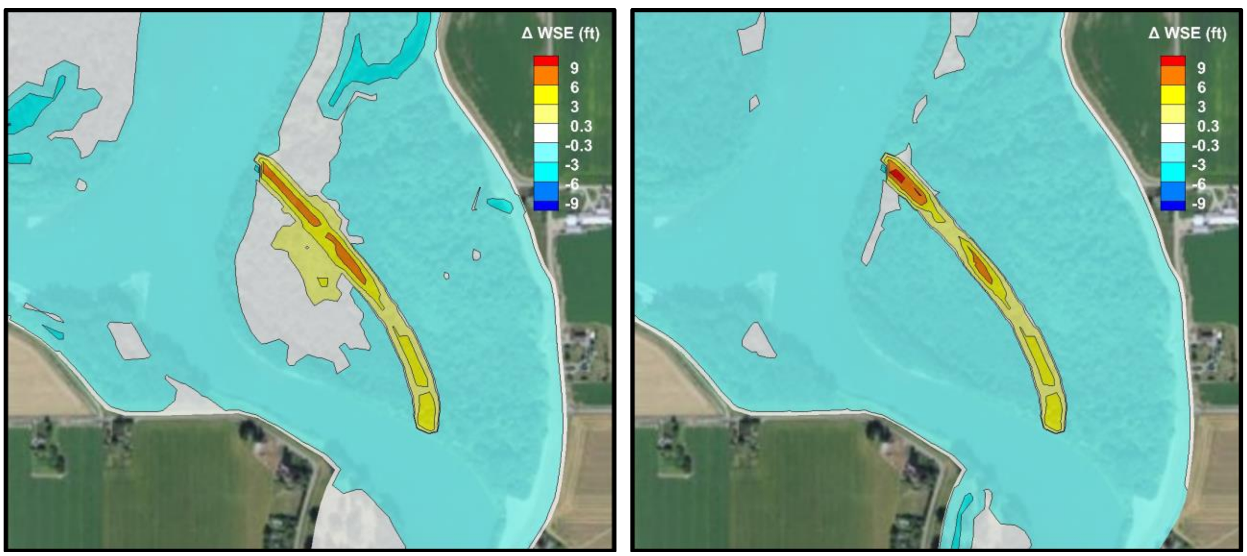

Figure I.54. Contour map of change in WSE from the Baseline simulation for East Cottonwood with Q2 flow and low tide (left) and flood flow and high tide (right).

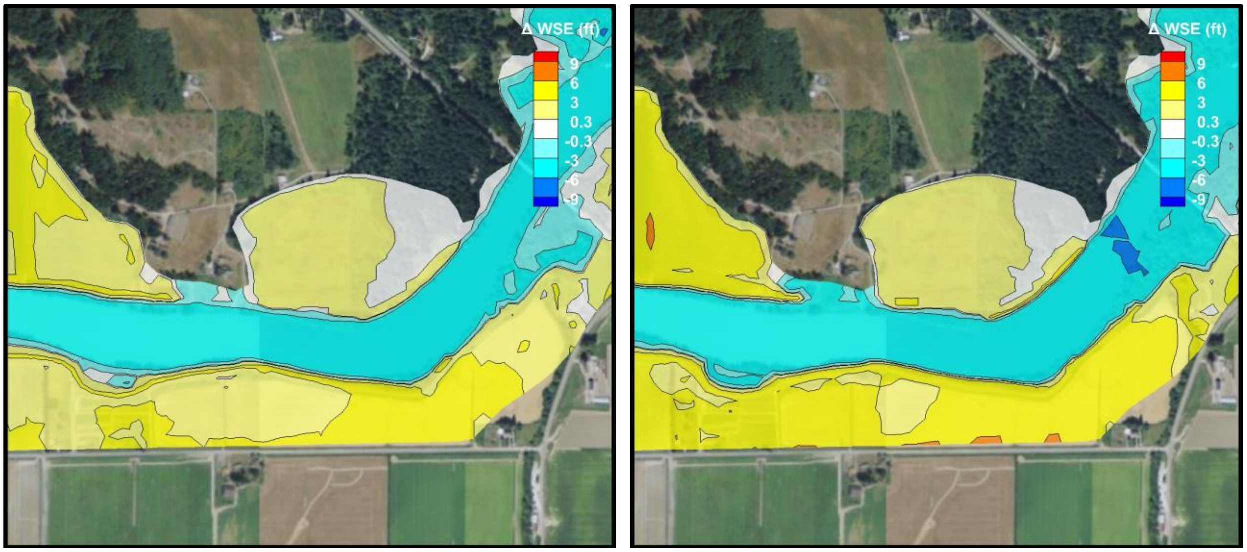

Figure I.55. Contour map of change in WSE from the Baseline simulation for Pleasant Ridge South with Q2 flow and low tide (left) and flood flow and high tide (right).

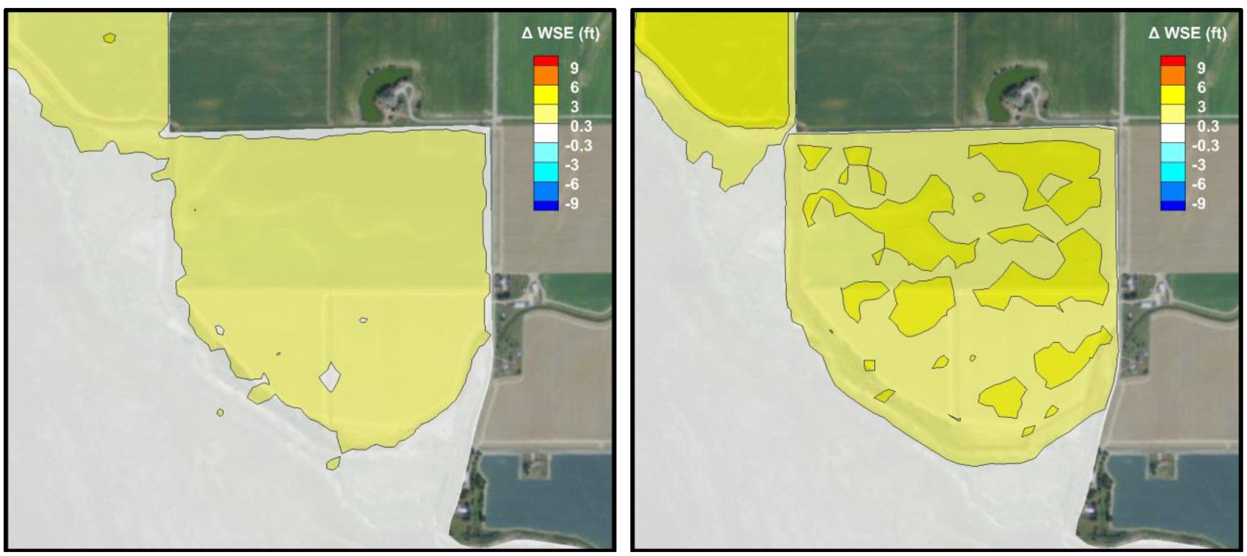

Figure I.56. Contour map of change in WSE from the Baseline simulation for Hall Slough with Q2 flow and low tide (left) and flood flow and high tide (right).

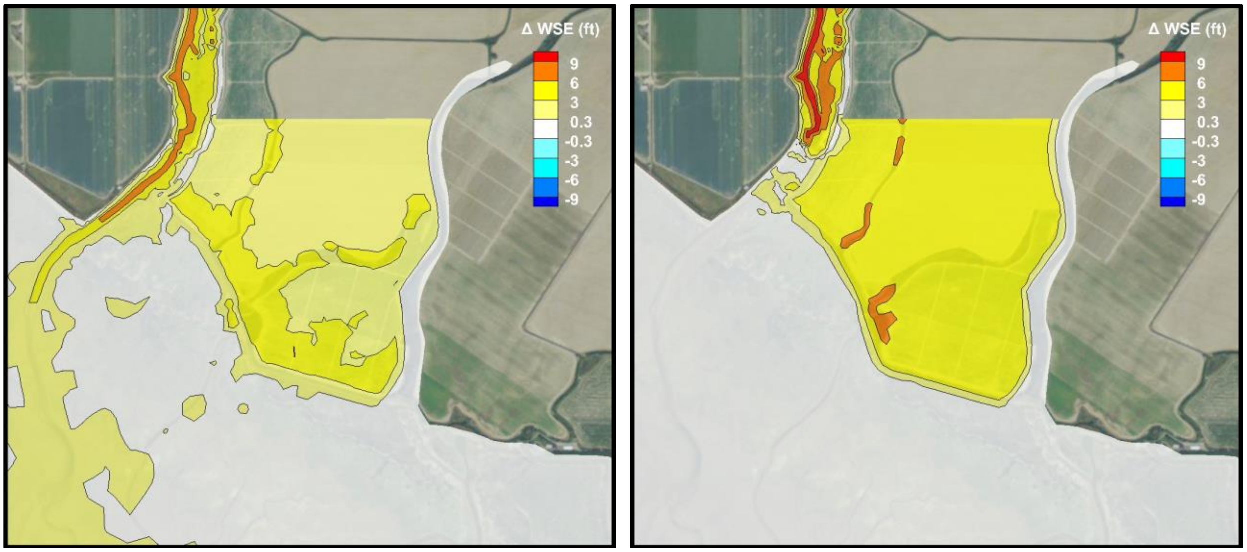

Figure I.57. Contour map of change in WSE from the Baseline simulation for Fir Island Farm with Q2 flow and low tide (left) and flood flow and high tide (right).

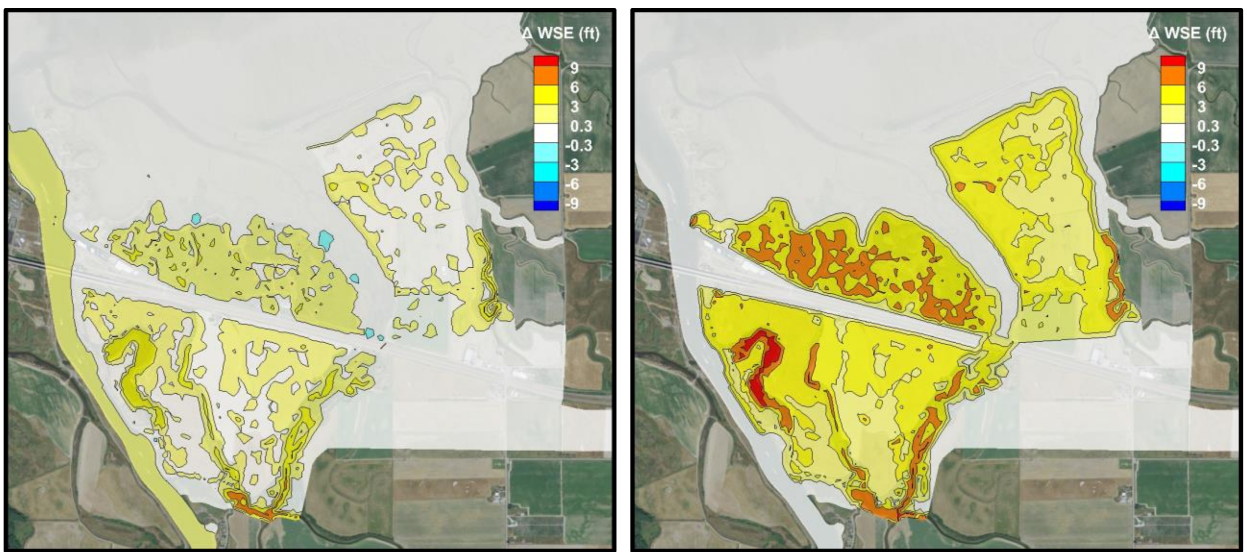

Figure I.58. Contour map of change in WSE from the Baseline simulation for Telegraph Slough Full with Q2 flow and low tide (left) and flood flow and high tide (right).

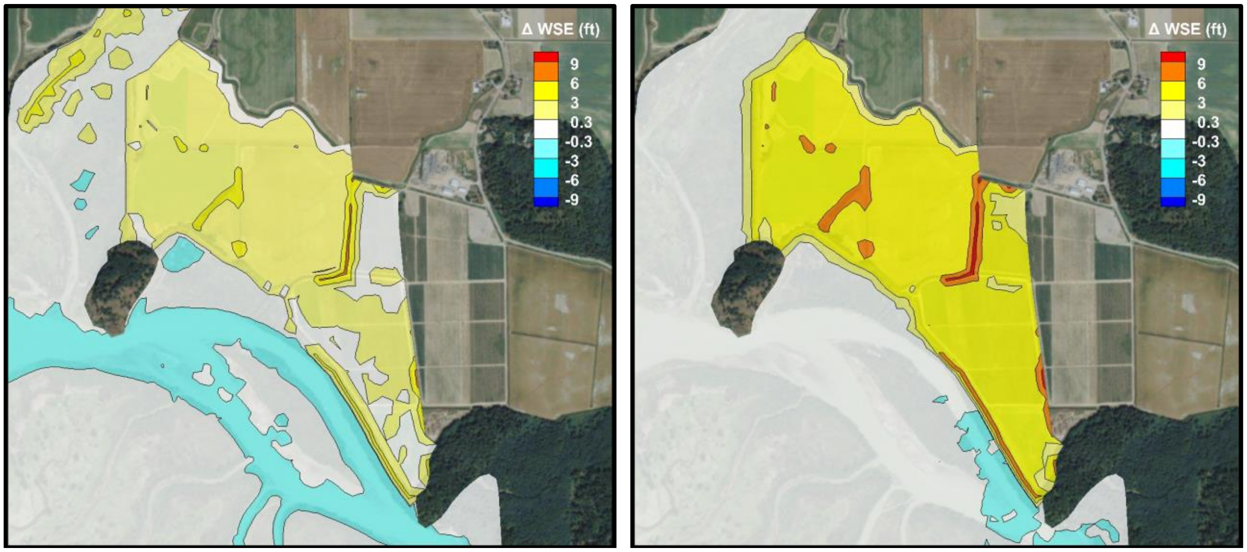

Figure I.59. Contour map of change in WSE from the Baseline simulation for Sullivan Hacienda with Q2 flow and low tide (left) and flood flow and high tide (right).

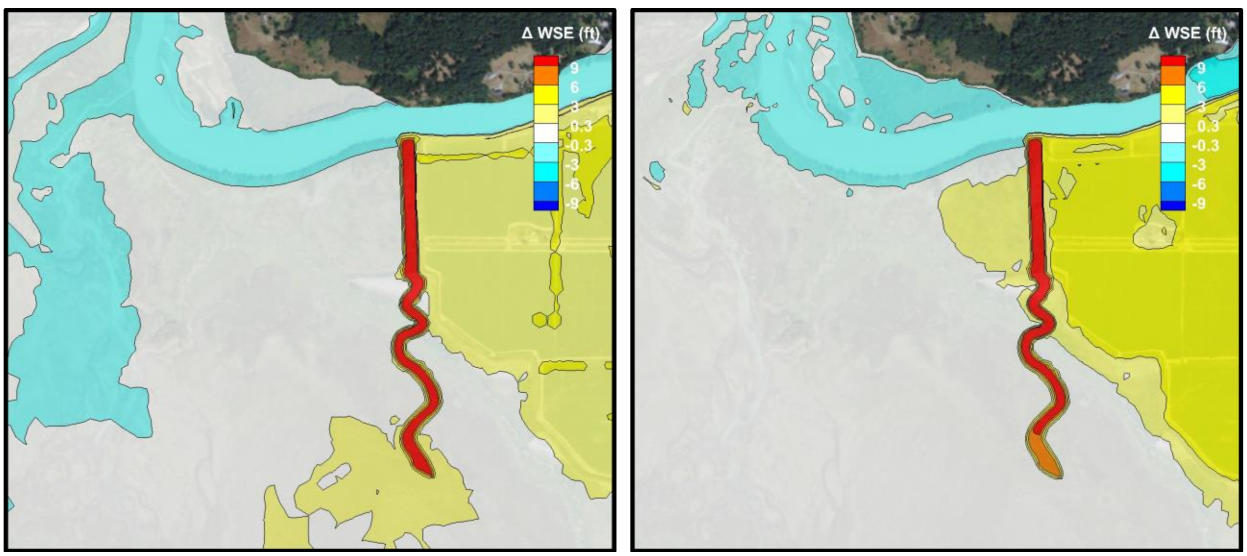

Figure I.60. Contour map of change in WSE from the Baseline simulation for Rawlins Road Distributary with Q2 flow and low tide (left) and flood flow and high tide (right).

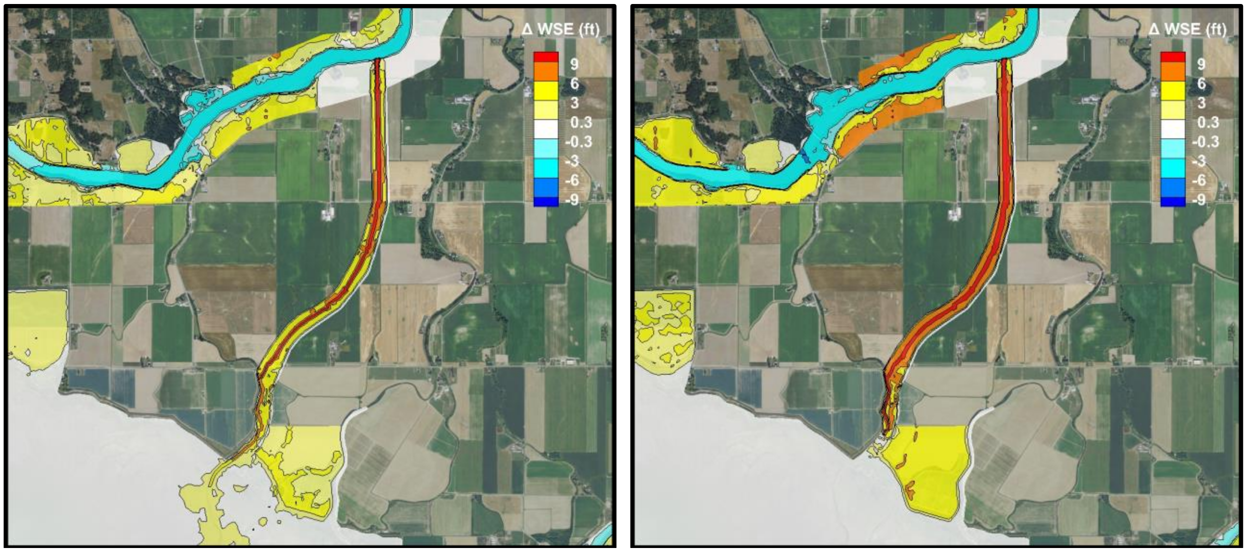

Figure I.61. Contour map of change in WSE from the Baseline simulation for Cross Island Connector with Q2 flow and low tide (left) and flood flow and high tide (right).

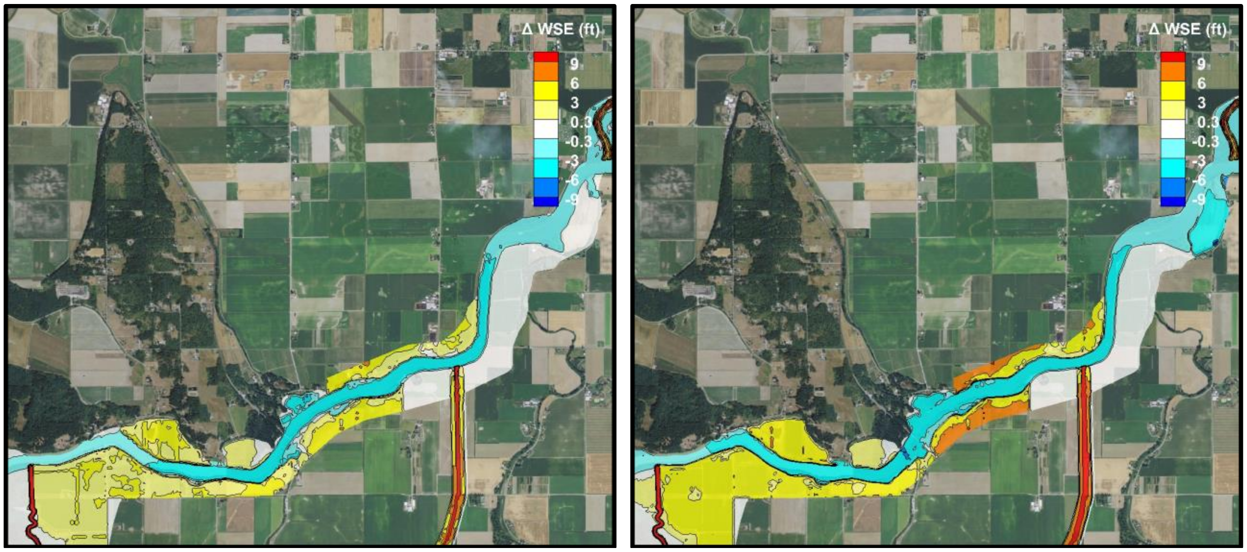

Figure I.62. Contour map of change in WSE from the Baseline simulation for NF Levee Setback C with Q2 flow and low tide (left) and flood flow and high tide (right).

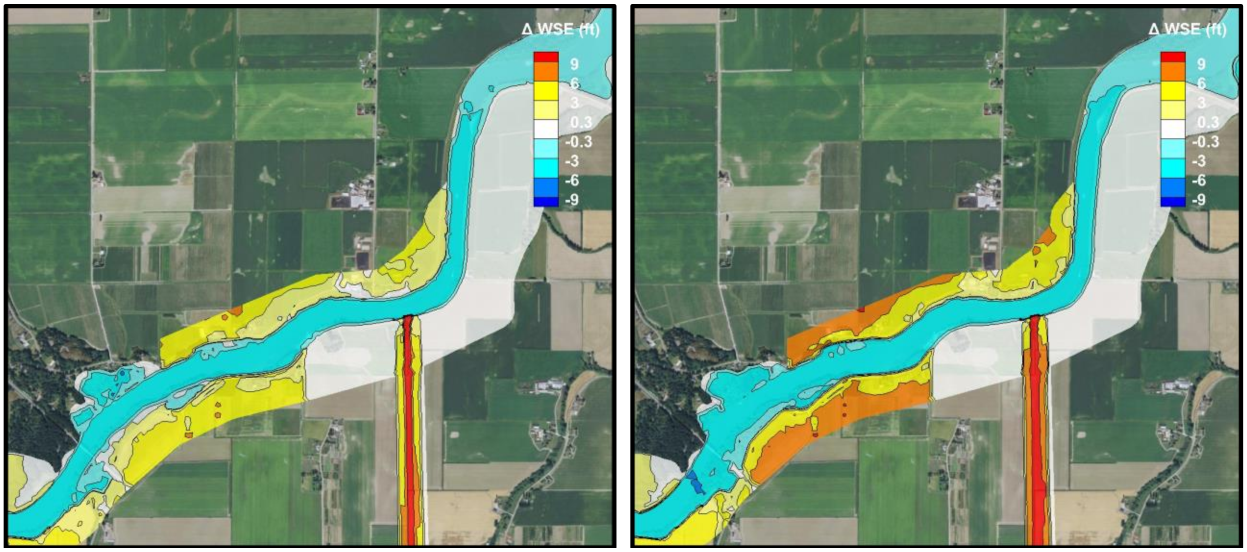

Figure I.63. Contour map of change in WSE from the Baseline simulation for NF Right Bank Levee Setback with Q2 flow and low tide (left) and flood flow and high tide (right).

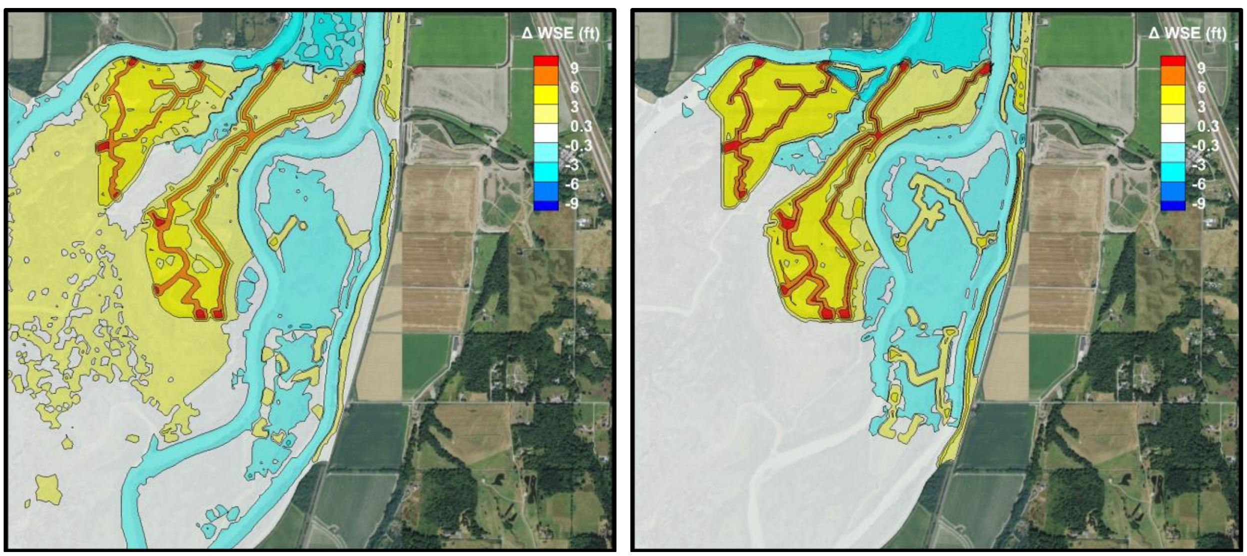

Figure I.64. Contour map of change in WSE from the Baseline simulation for Milltown Island with Q2 flow and low tide (left) and flood flow and high tide (right).

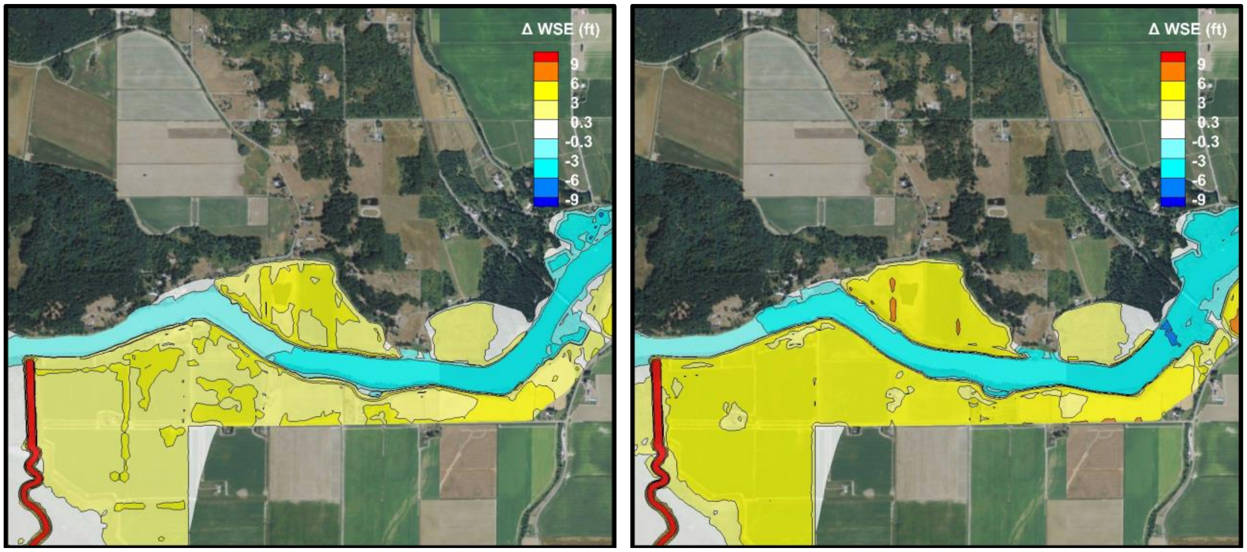

Figure I.65. Contour map of change in WSE from the Baseline simulation for Thein Farm with Q2 flow and low tide (left) and flood flow and high tide (right).

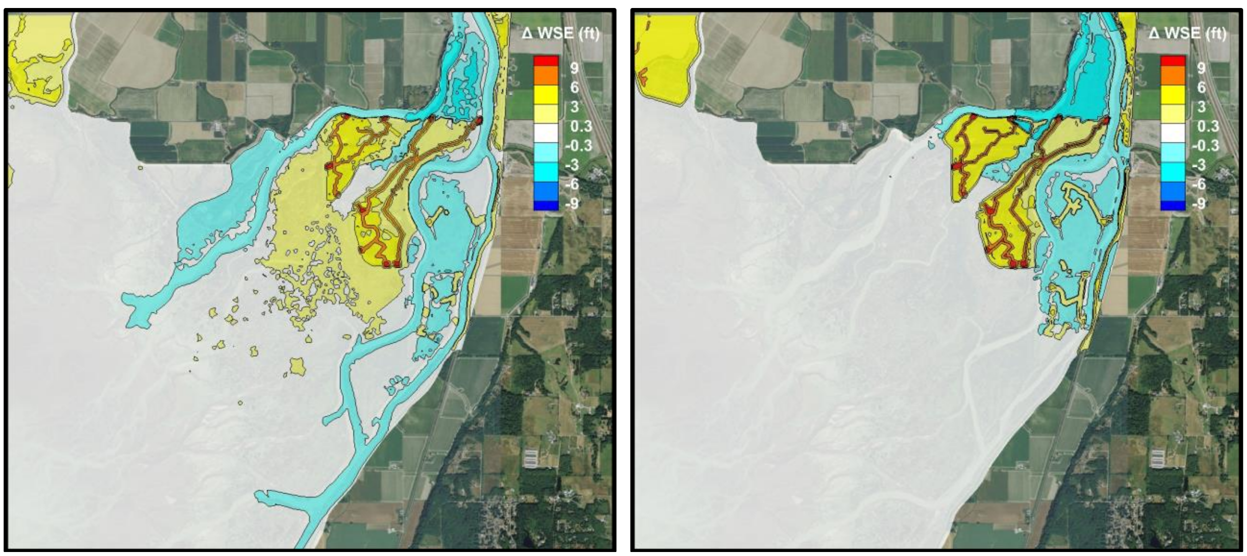

Figure I.66. Contour map of change in WSE from the Baseline simulation for Deepwater Slough Phase 2 with Q2 flow and low tide (left) and flood flow and high tide (right).

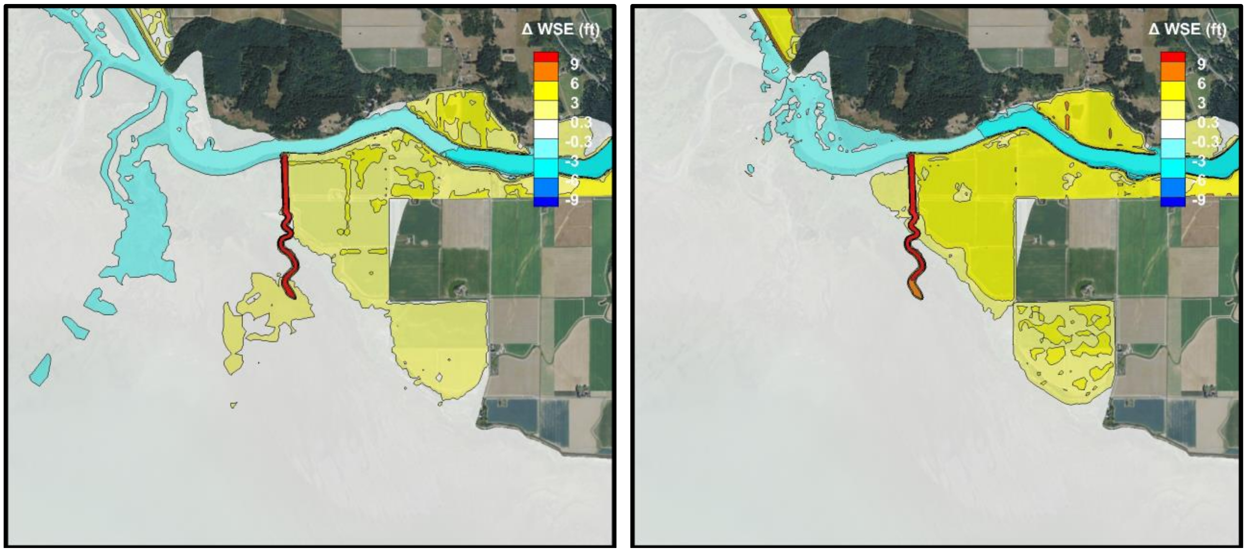

Figure I.67. Contour map of change in WSE from the Baseline simulation for Rawlins Road with Q2 flow and low tide (left) and flood flow and high tide (right).

I.6 Selected Projects Deliverable 6

Deliverable 6 is a set of contour maps showing the change in salinity between the Baseline Simulation (Simulation 0) and the Selected Projects simulation (Simulation 8). The compared conditions were a low flow (12,000 cfs) and high spring tide (10.8 ft), representing the change from baseline to restored conditions. The compared salinity values represent an average of the bottom 10% of the water depth to show the furthest extent of the salt wedge. No change is represented as white across the extent of the model grid. Projects TNC South Fork, Cottonwood Island, East Cottonwood, and NF Right Bank Levee Setback were omitted because no change was seen. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. Changes in salinity could affect habitat suitability, the distribution of fish, and have potential effects on agriculture. The maps can be seen in Figure I.68 through Figure I.83.

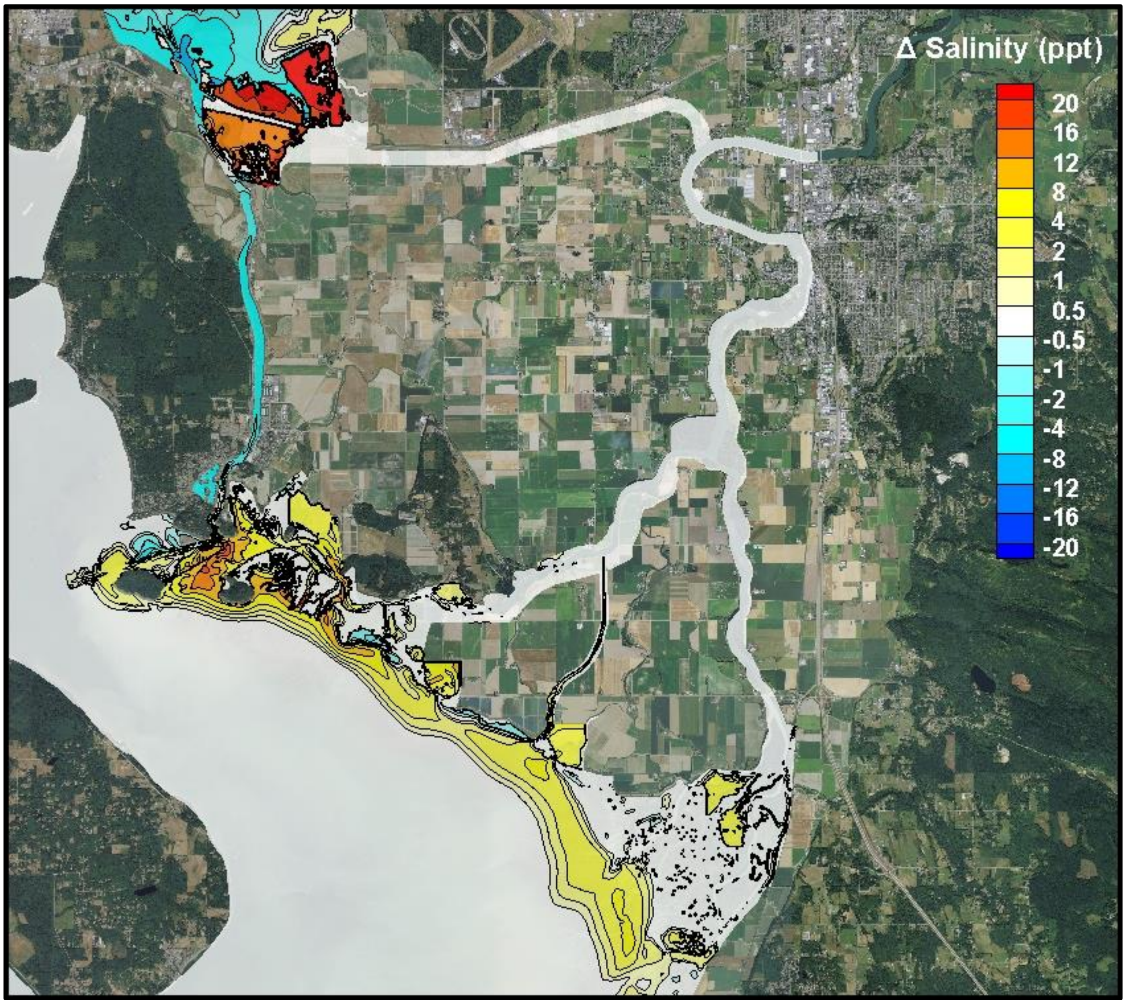

Figure I.68. Contour map of change in salinity from the Baseline to Selected Projects simulation with low flow and high tide.

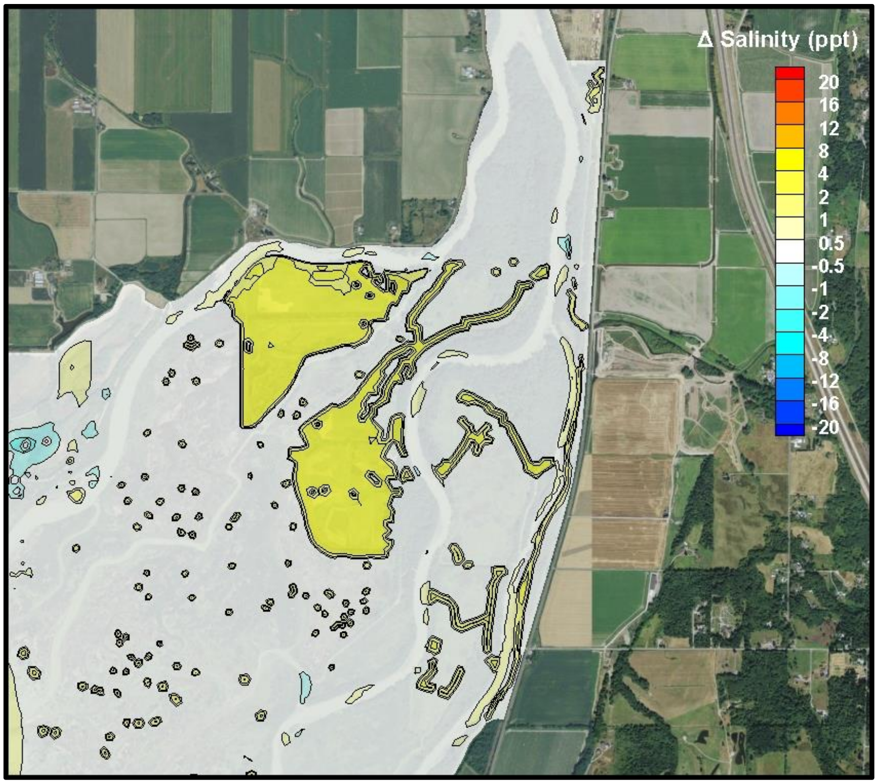

Figure I.69. Contour map of change in salinity from the Baseline simulation for SF Levee Setback 2, 3, 4 with low flow and high tide.

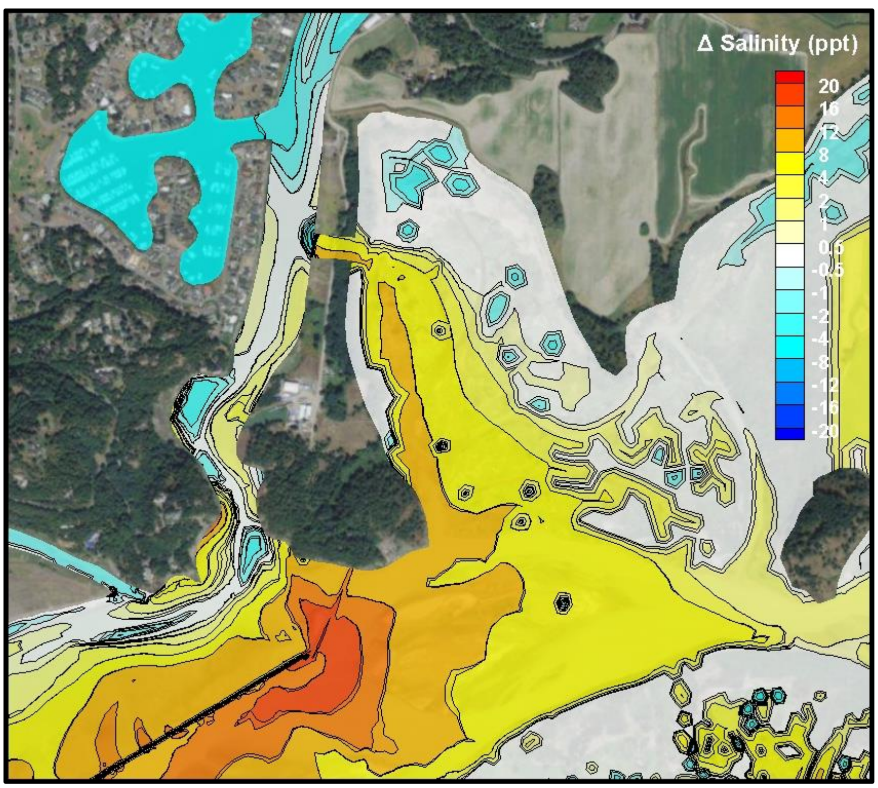

Figure I.70. Contour map of change in salinity from the Baseline simulation for McGlinn Causeway with low flow and high tide.

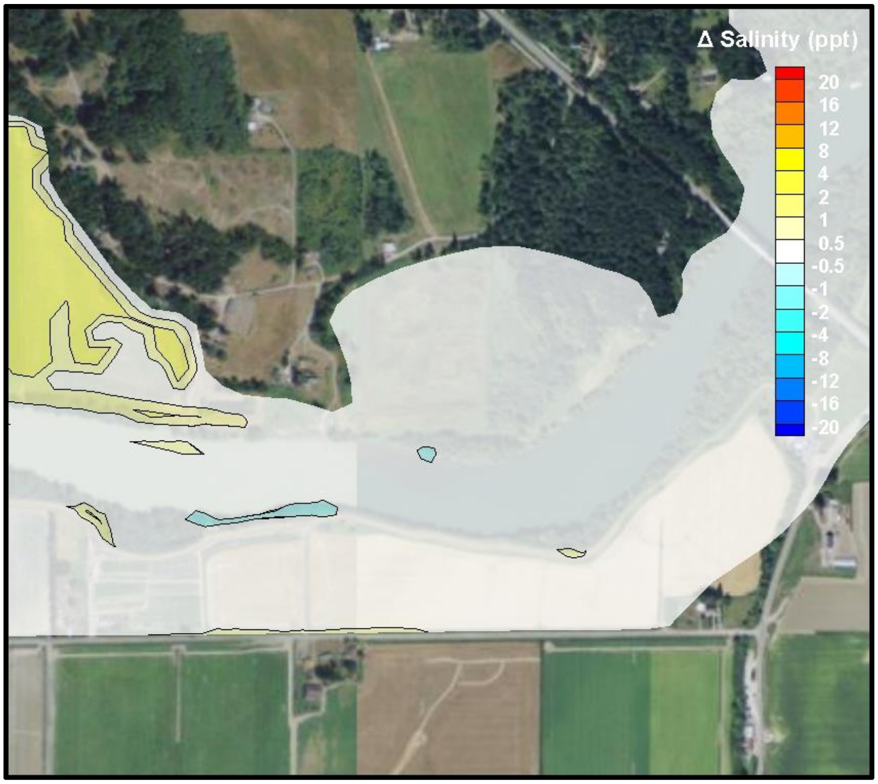

Figure I.71. Contour map of change in salinity from the Baseline simulation for Pleasant Ridge South with low flow and high tide.

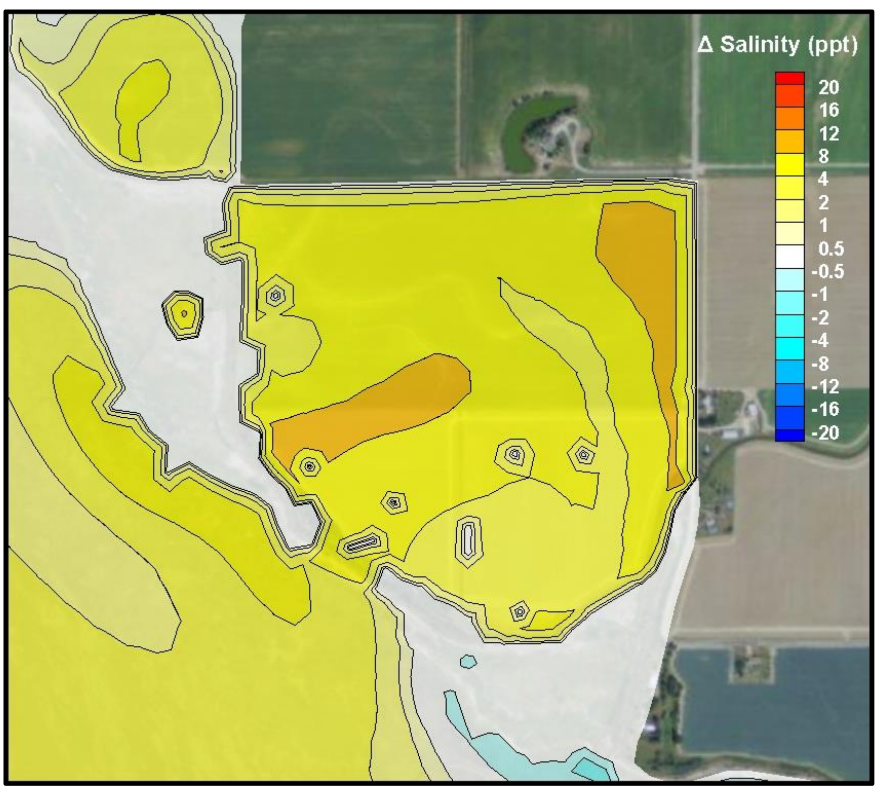

Figure I.72. Contour map of change in salinity from the Baseline simulation for Hall Slough with low flow and high tide.

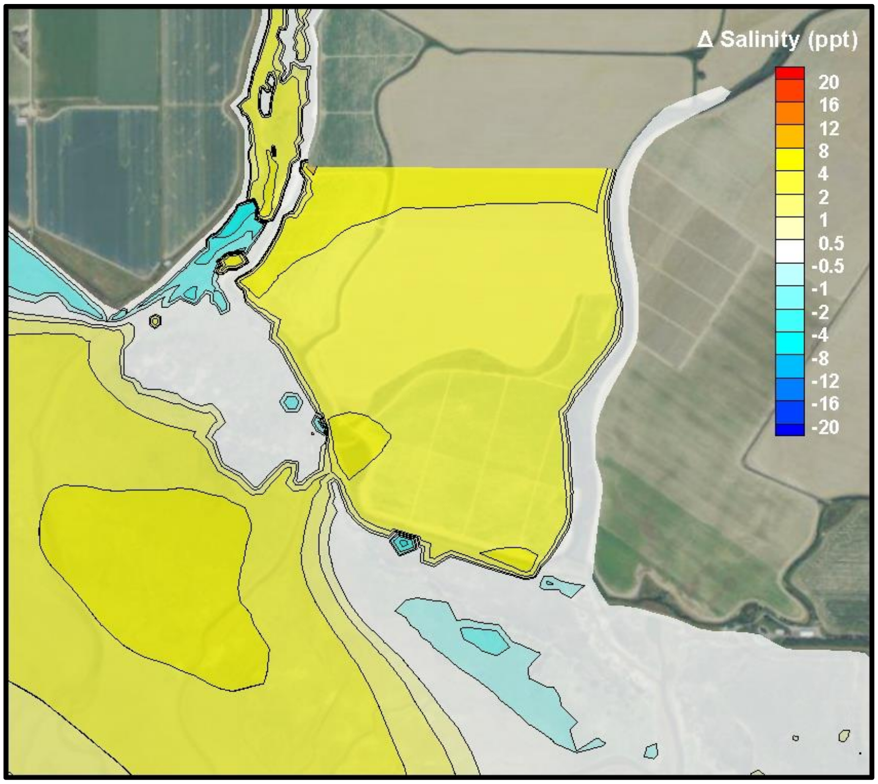

Figure I.73. Contour map of change in salinity from the Baseline simulation for Fir Island Farm with low flow and high tide.

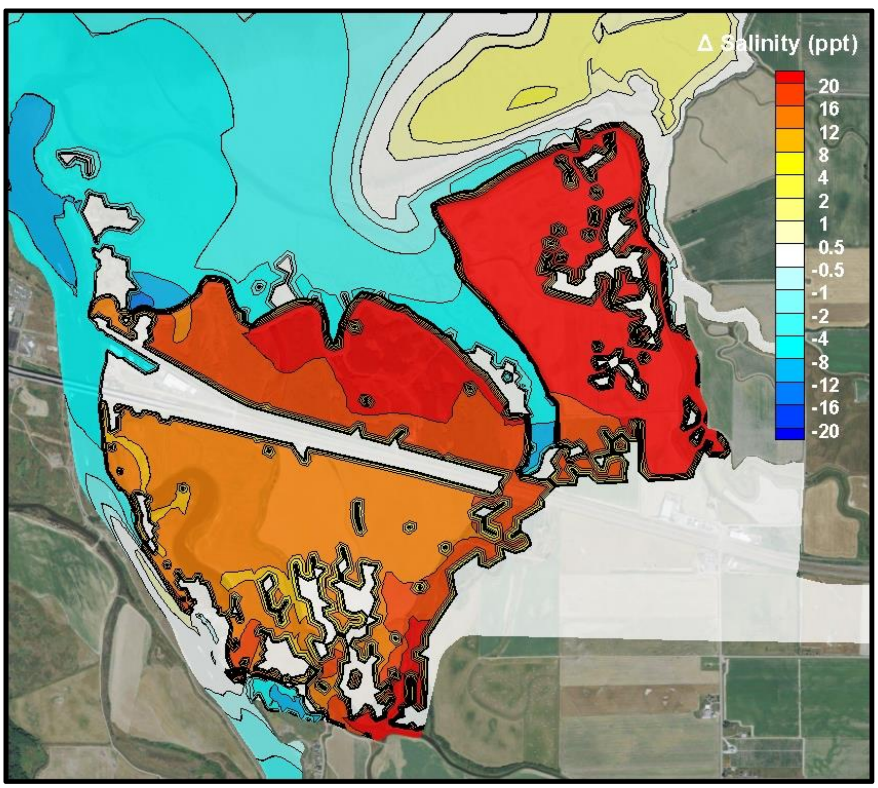

Figure I.74. Contour map of change in salinity from the Baseline simulation for Telegraph Slough Full with low flow and high tide.

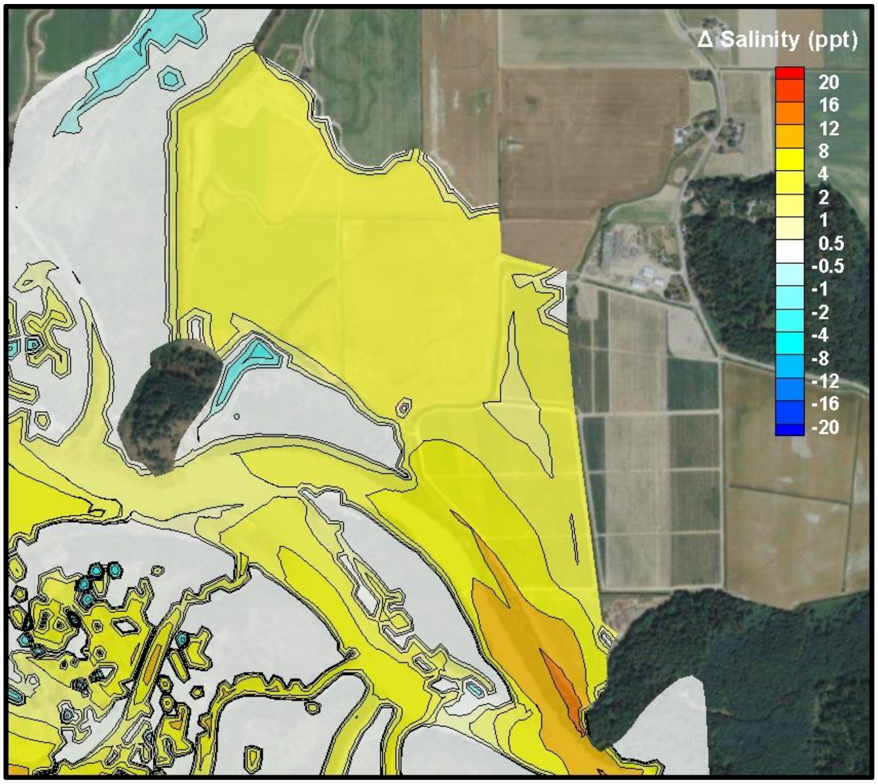

Figure I.75. Contour map of change in salinity from the Baseline simulation for Sullivan Hacienda with low flow and high tide.

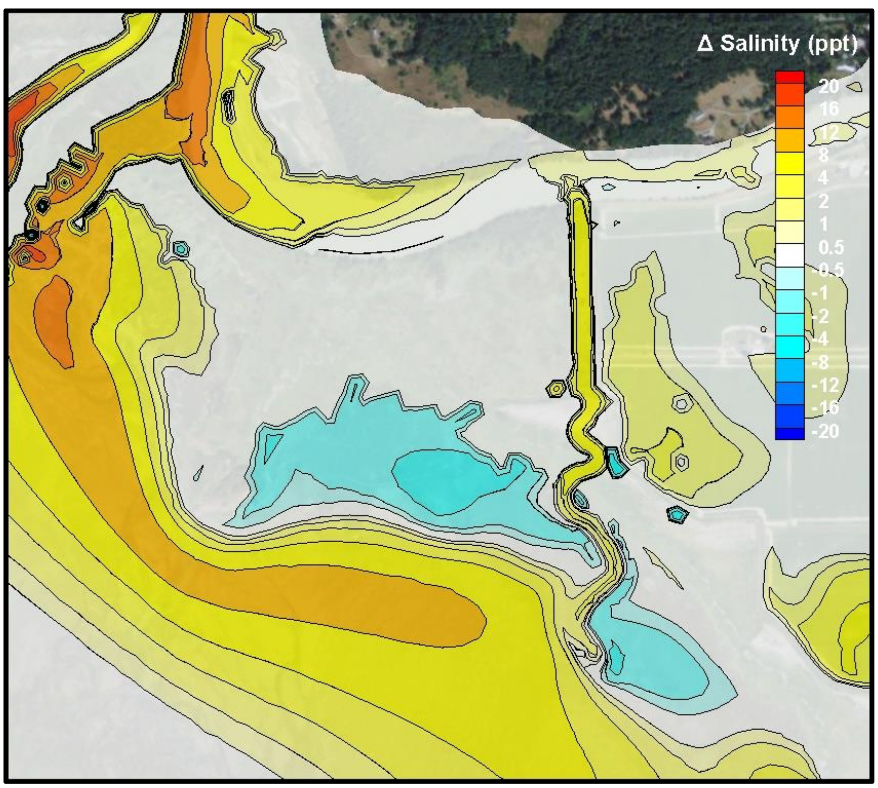

Figure I.76. Contour map of change in salinity from the Baseline simulation for Rawlins Distributary with low flow and high tide.

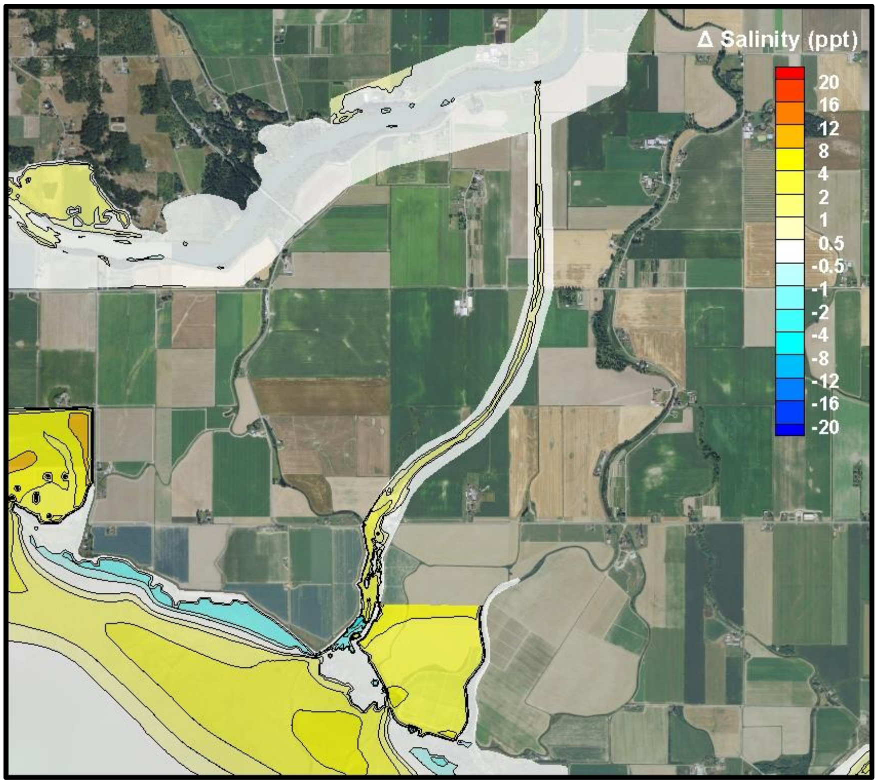

Figure I.77. Contour map of change in salinity from the Baseline simulation for Cross Island Connector with low flow and high tide.

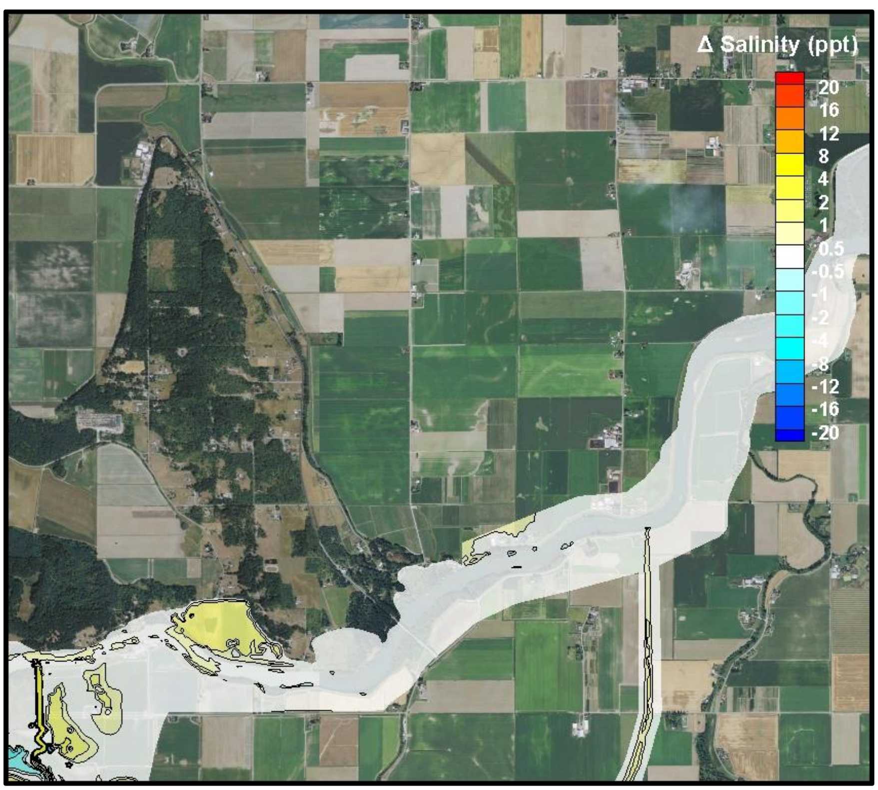

Figure I.78. Contour map of change in salinity from the Baseline simulation for NF Levee Setback C with low flow and high tide.

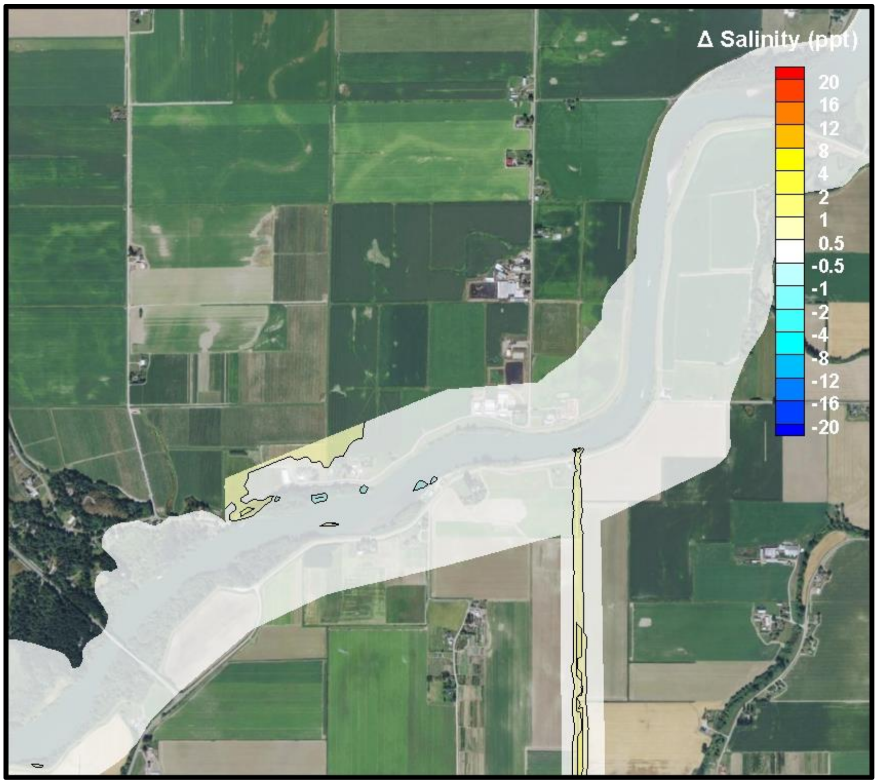

Figure I.79. Contour map of change in salinity from the Baseline simulation for NF Right Bank Levee Setback with low flow and high tide.

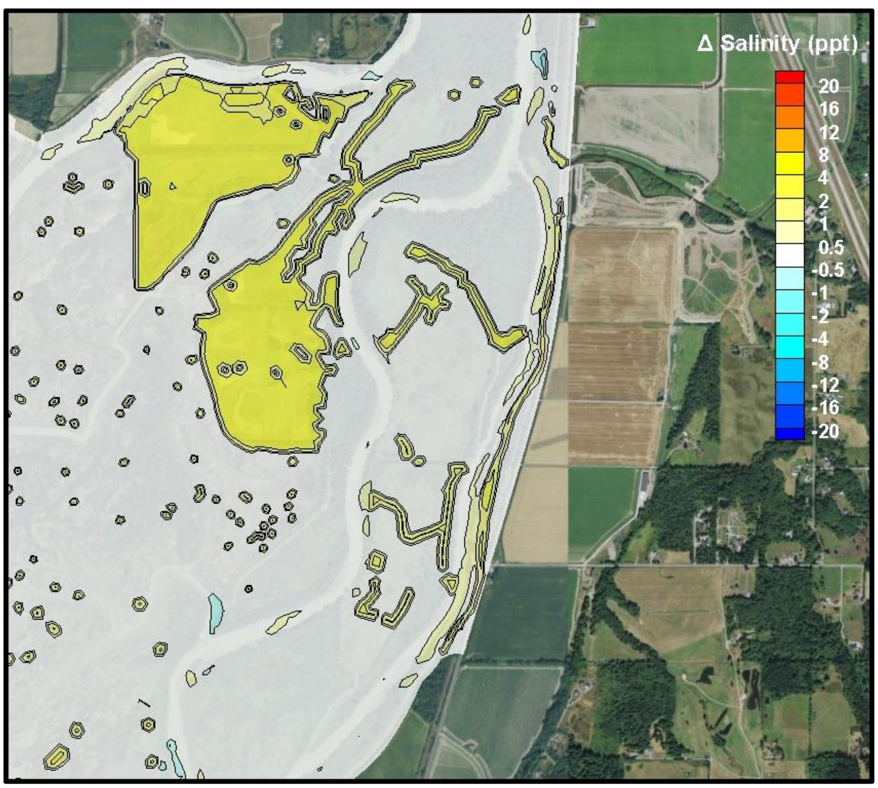

Figure I.80. Contour map of change in salinity from the Baseline simulation for Milltown Island with low flow and high tide.

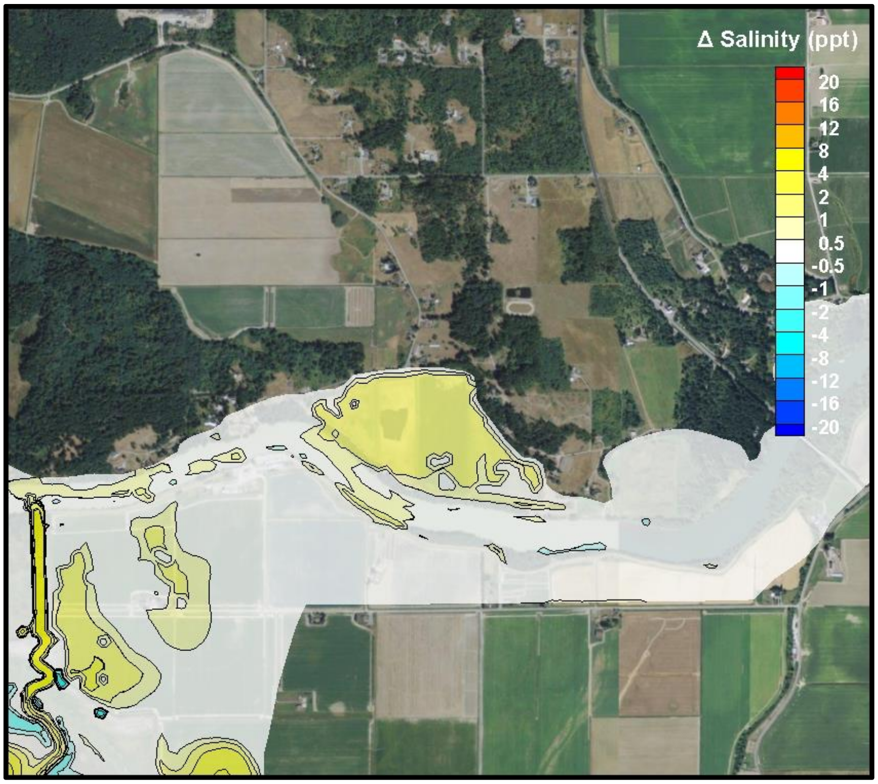

Figure I.81. Contour map of change in salinity from the Baseline simulation for Thein Farm with low flow and high tide.

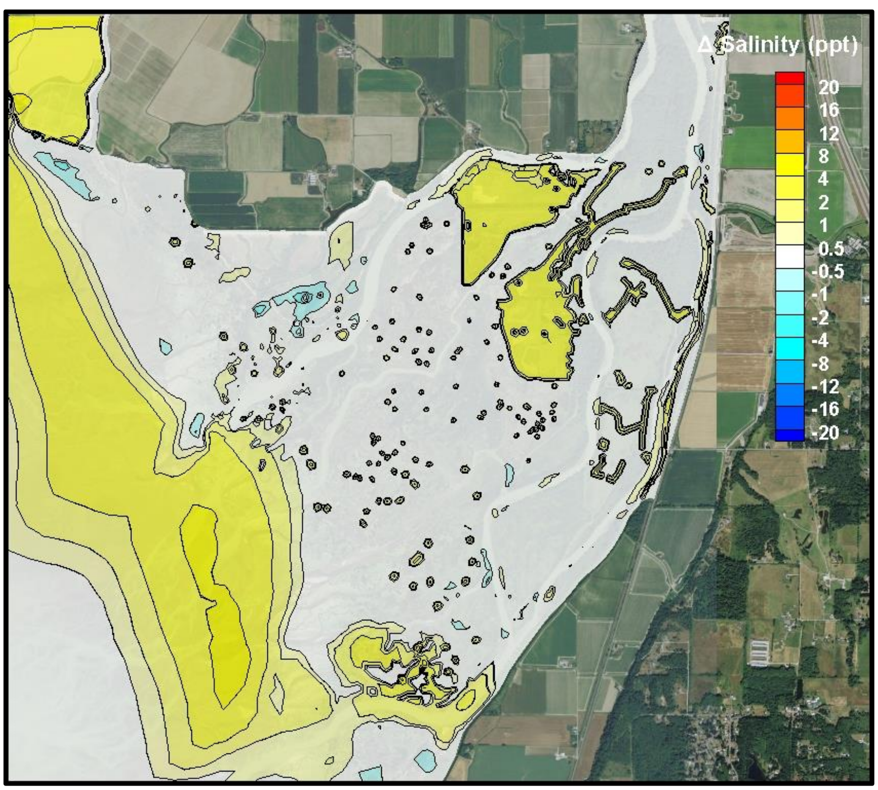

Figure I.82. Contour map of change in salinity from the Baseline simulation for Deepwater Slough Phase 2 with low flow and high tide.

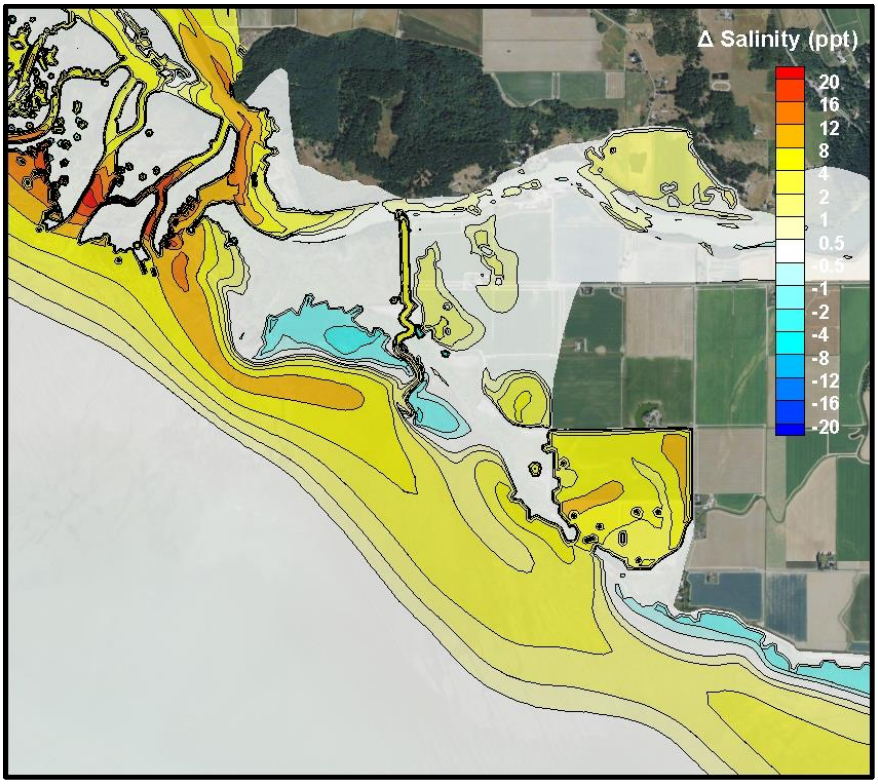

Figure I.83. Contour map of change in salinity from the Baseline simulation for Rawlins Road with low flow and high tide.

I.7 Selected Projects Deliverable 7

Deliverable 7 is a set of plots that compare water surface elevation and flow between the Baseline Simulation and the Selected Projects simulation, plotting all time steps during the entire 7-month simulation from November 2, 2014 through May 29, 2015. Plots are provided for the North Fork, South Fork, Freshwater Slough, and Steamboat Slough gauge locations. Results in Freshwater and Steamboat are non-linear because higher flows move across the Deepwater Slough Phase 2 project concept. Flow was computed at a cross section bisecting the gauge locations. An Excel file was also generated to provide the WSE and flow information at the gauge locations. The maps can be seen in Figure I.84 through Figure I.87.

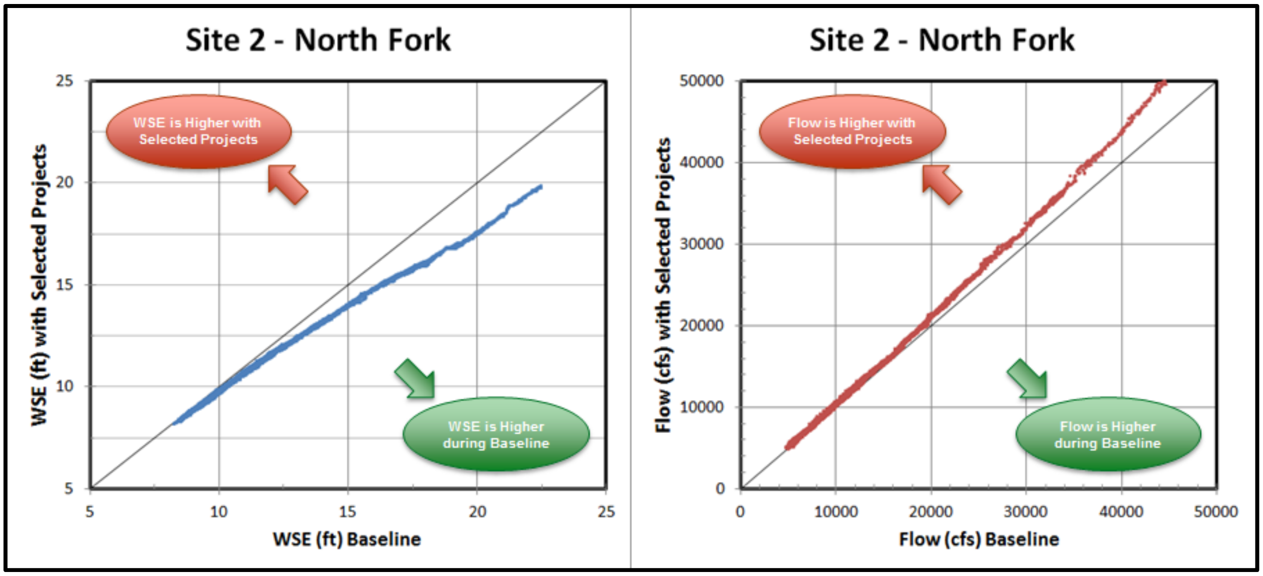

Figure I.84. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Selected Projects simulation at the North Fork gauge location compared with the same information under baseline conditions.

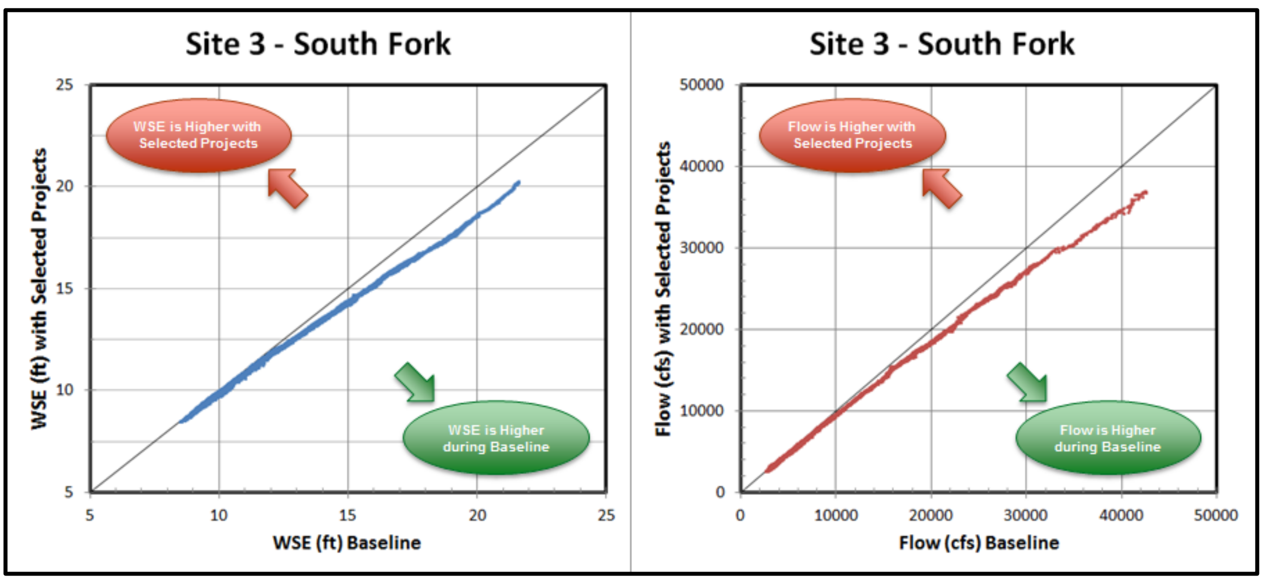

Figure I.85. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Selected Projects simulation at the South Fork gauge location compared with the same information under baseline conditions.

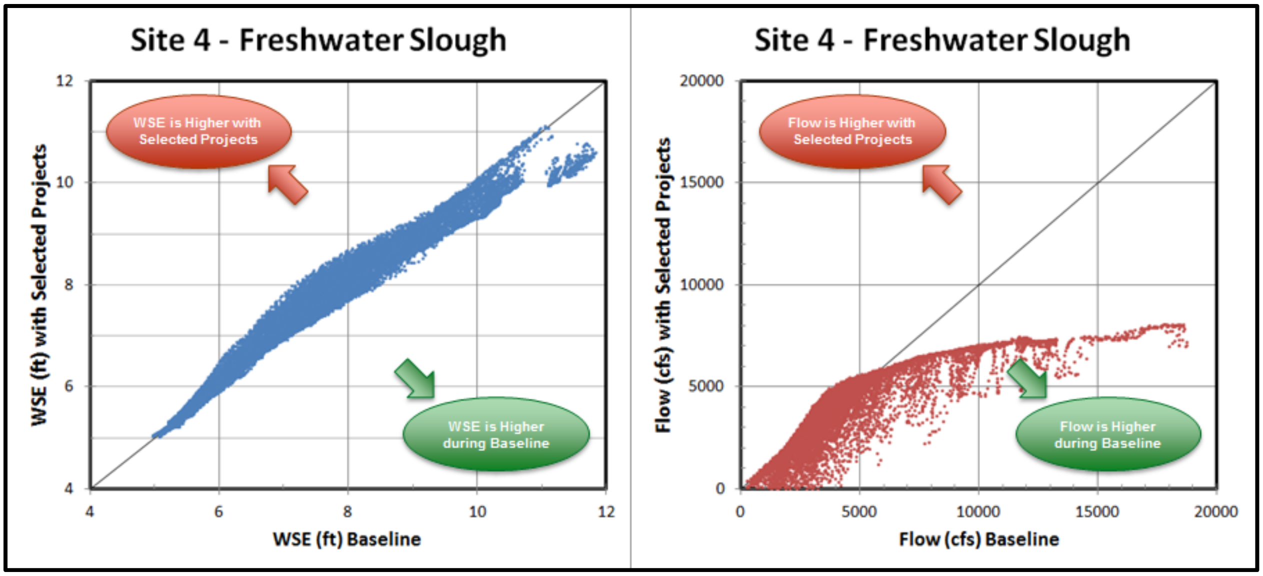

Figure I.86. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Selected Projects simulation at the Freshwater Slough gauge location compared with the same information under baseline conditions.

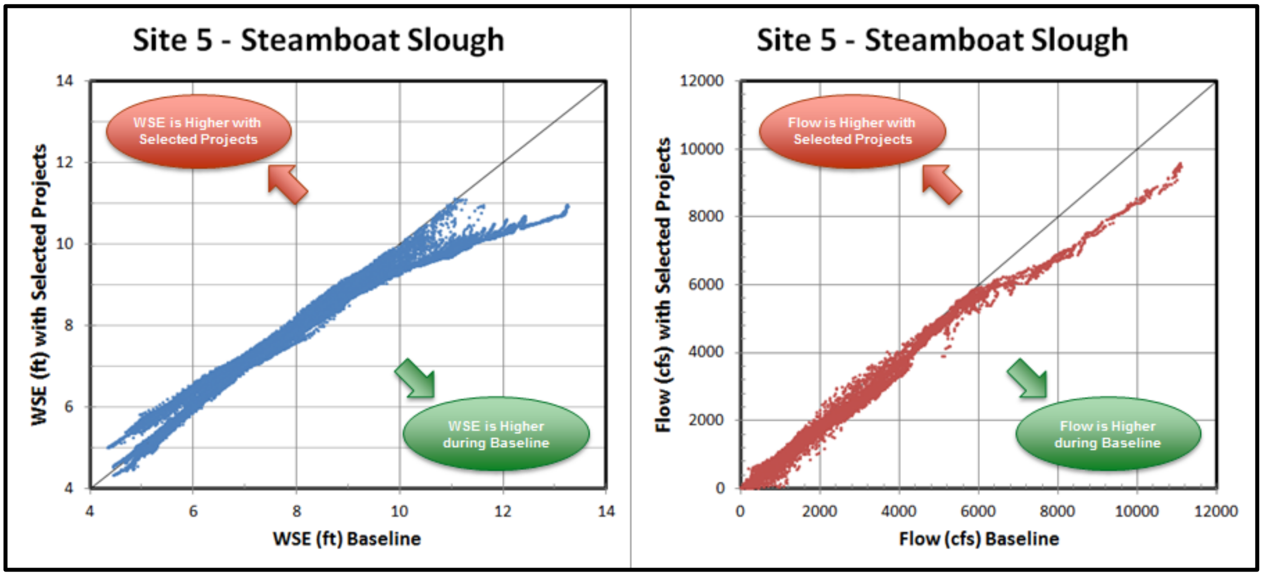

Figure I.87. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Selected Projects simulation at the Steamboat Slough gauge location compared with the same information under baseline conditions.

Appendix J

Simulation 9: Climate Change Baseline Deliverables

Appendix J

Simulation 9: Climate Change Baseline Deliverables

The following list of deliverables is associated with Simulation 9. These deliverables were created by the SHDM Team to address specific objectives for the alternative analysis (Friebel et al., in preparation).

1. A contour map showing change in WSE from baseline (Simulation 0) to climate change baseline (Simulation 9) during (1) Q2 flow and low spring tide. A high-resolution, georeferenced map was also provided (not shown).
2. Contour maps showing WSE for climate change baseline (Simulation 9) during (1) future Q2 flow and future low spring tide and (2) future Q2 flow and future high spring tide. High-resolution, georeferenced maps were also provided (not shown).
3. A contour map showing change in WSE from baseline (Simulation 0) to climate change baseline (Simulation 9) during (1) low flow and future high spring tide. A high-resolution, georeferenced map was also provided (not shown).
4. A contour map showing WSE for climate change baseline (Simulation 9) during (1) low flow and high spring tide. A high-resolution, georeferenced map was also provided (not shown).
5. At points in the main channel and bay front selected by the SHDM Team, cumulative frequency of WSE (for the months of March, April, and May). An Excel file of the data associated with the plot data was also provided.
6. Contour maps showing change in salinity from baseline (Simulation 0) to climate change baseline (Simulation 9) during (1) low flow and high spring tide. High-resolution, georeferenced maps were also provided, including absolute salinity for both conditions (not shown).

J.1 Climate Change Baseline Deliverable 1

Deliverable 1 is contour map showing the change in water surface elevation between the Baseline Simulation (Simulation 0) and the 2080 Climate Change Baseline Simulation (Simulation 9). The compared conditions were a future Q2 flow (103,237 cfs) and future low spring tide (-1.43 ft) versus a Q2 flow (62,000 cfs) and low spring tide (-3.3 ft), representing the change from existing conditions to estimated 2080 conditions with no restoration action by increasing the sea level by 0.57 cm. No change is represented as white across the extent of the model grid. Several restored areas appear to be inundated even during this baseline; this represents overtopping of the levee at those locations. The caveat is that the model only shows overtopping at restoration sites because grid exists there, while grid boundaries appear as an impassable wall. In reality, overtopping may occur elsewhere and spread through the subsided area. Yet these model results may show areas at higher risk for flooding under future conditions, but only within the gridded area. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The map can be seen in Figure J.1.

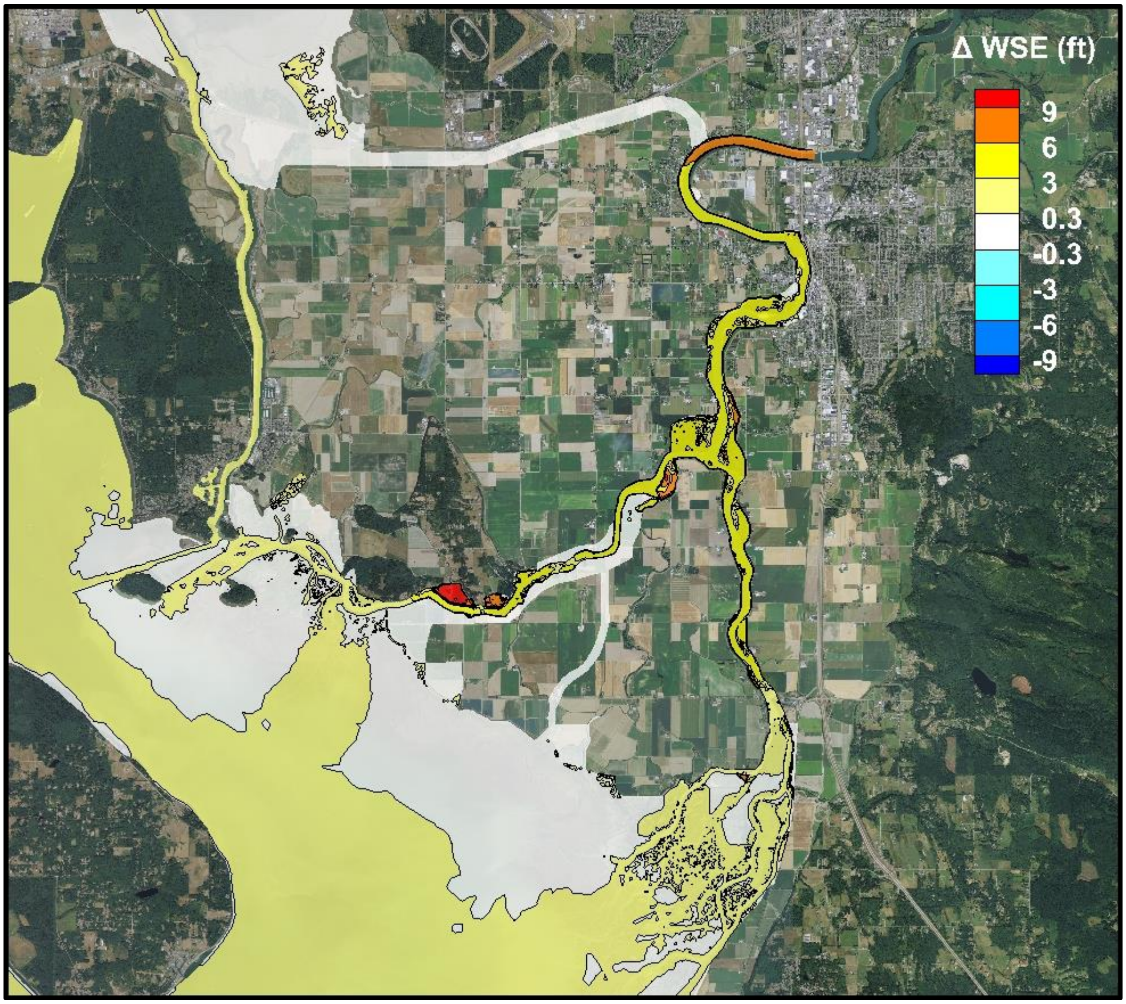

Figure J.1. Contour map of change in WSE for Q2 and low tide for the full basin, comparing Baseline and Climate Change Baseline simulations.

J.2 Climate Change Baseline Deliverable 2

Deliverable 2 is a set of contour maps showing the water surface elevation during the 2080 Climate Change Baseline Simulation (Simulation 9). Two conditions were plotted: (1) a future low spring tide (-1.43 ft) and future Q2 flow (103,237 cfs) and (2) a future high spring tide (12.67 ft) and a future Q2 flow (103,237 cfs). All WSE values are relative to the NAVD88 datum. Areas that are not inundated are blanked out. The small polygons seen in some Bayfront maps are artifacts of a previous high tide caused by small pooling that does not dissipate because the model does not calculate evaporation or seepage of water into the ground. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure J.2 and Figure J.3.

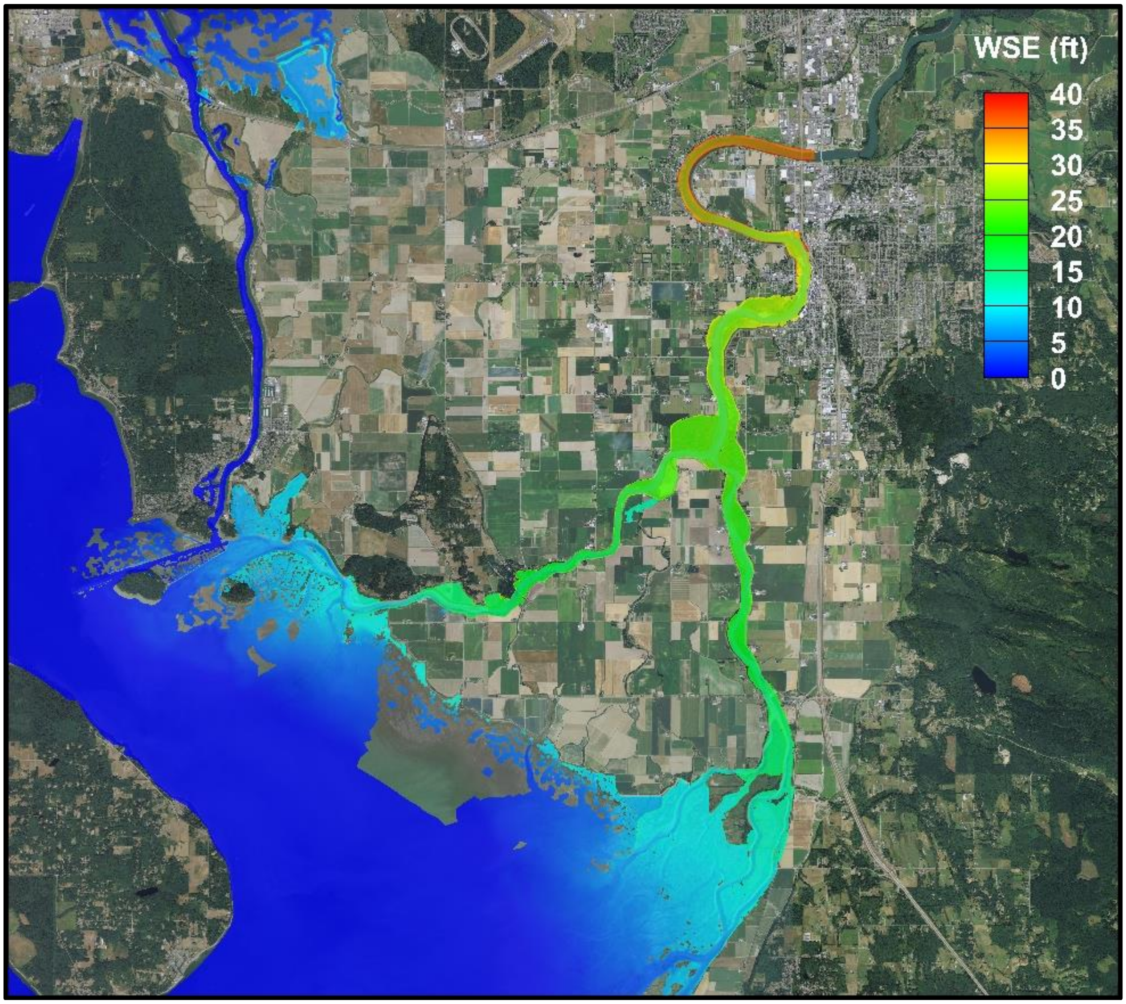

Figure J.2. Contour map of water surface elevation for the full domain during the 2080 Climate Change Baseline Simulation with future Q2 flow and future low spring tide.

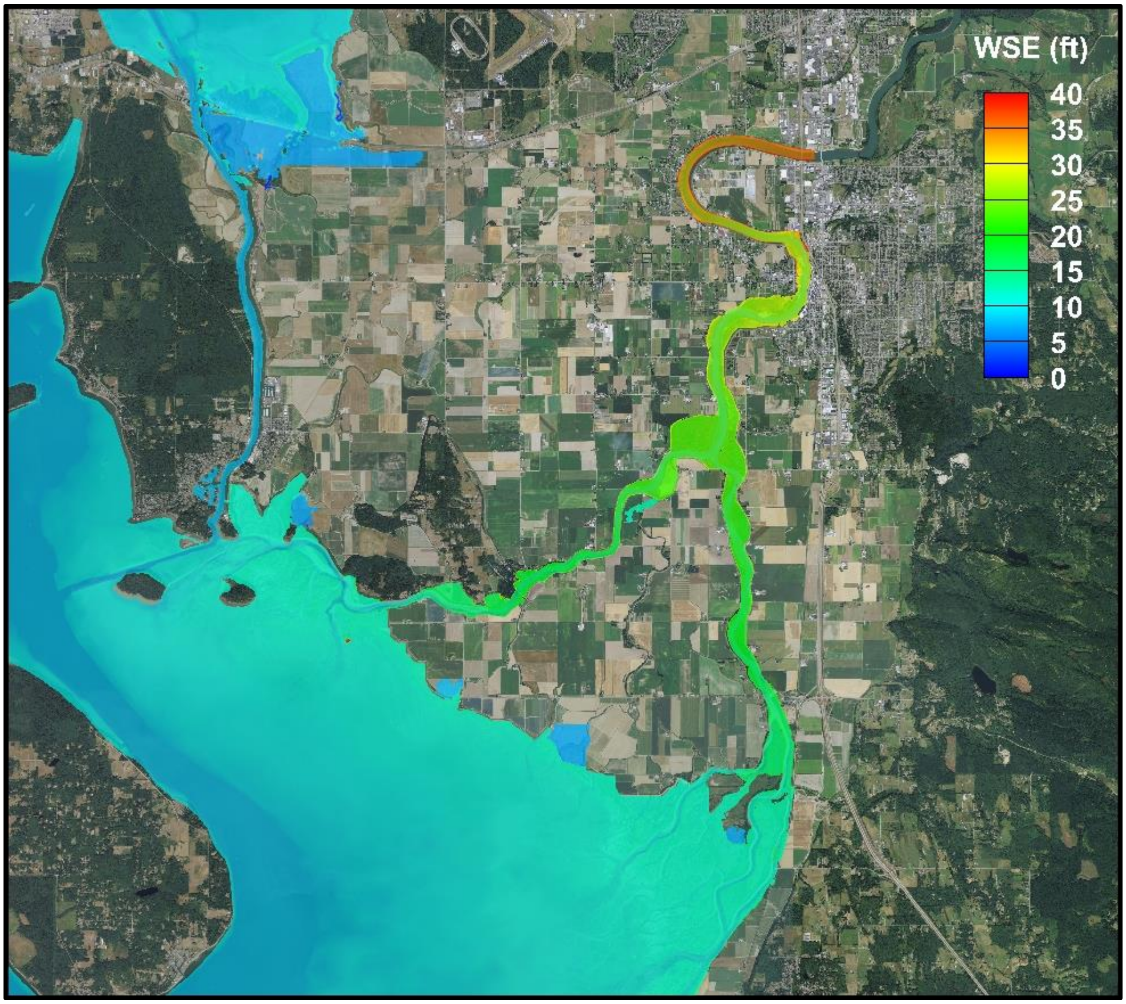

Figure J.3. Contour map of water surface elevation for the full domain during the 2080 Climate Change Baseline Simulation with future Q2 flow and future high spring tide.

J.3 Climate Change Baseline Deliverable 3

Deliverable 3 is contour maps showing the change in water surface elevation between the Baseline Simulation (Simulation 0) and the 2080 Climate Change Baseline Simulation (Simulation 9). The compared conditions were a low flow (12,000 cfs) and future high spring tide (12.67 ft) versus a high spring tide (10.8 ft), representing the change from existing conditions to estimated 2080 conditions with no restoration action by increasing the sea level by 0.57 cm. No change is represented as white across the extent of the model grid. Several restored areas appear to be inundated even during this baseline; this represents overtopping of the levee at those locations. The caveat is that the model only shows overtopping at restoration sites because grid exists there, while grid boundaries appear as an impassable wall. In reality, overtopping may occur elsewhere and spread through the subsided area. Yet these model results may show areas at higher risk for flooding under future conditions. A high-resolution, georeferenced map with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The map can be seen in Figure J.4.

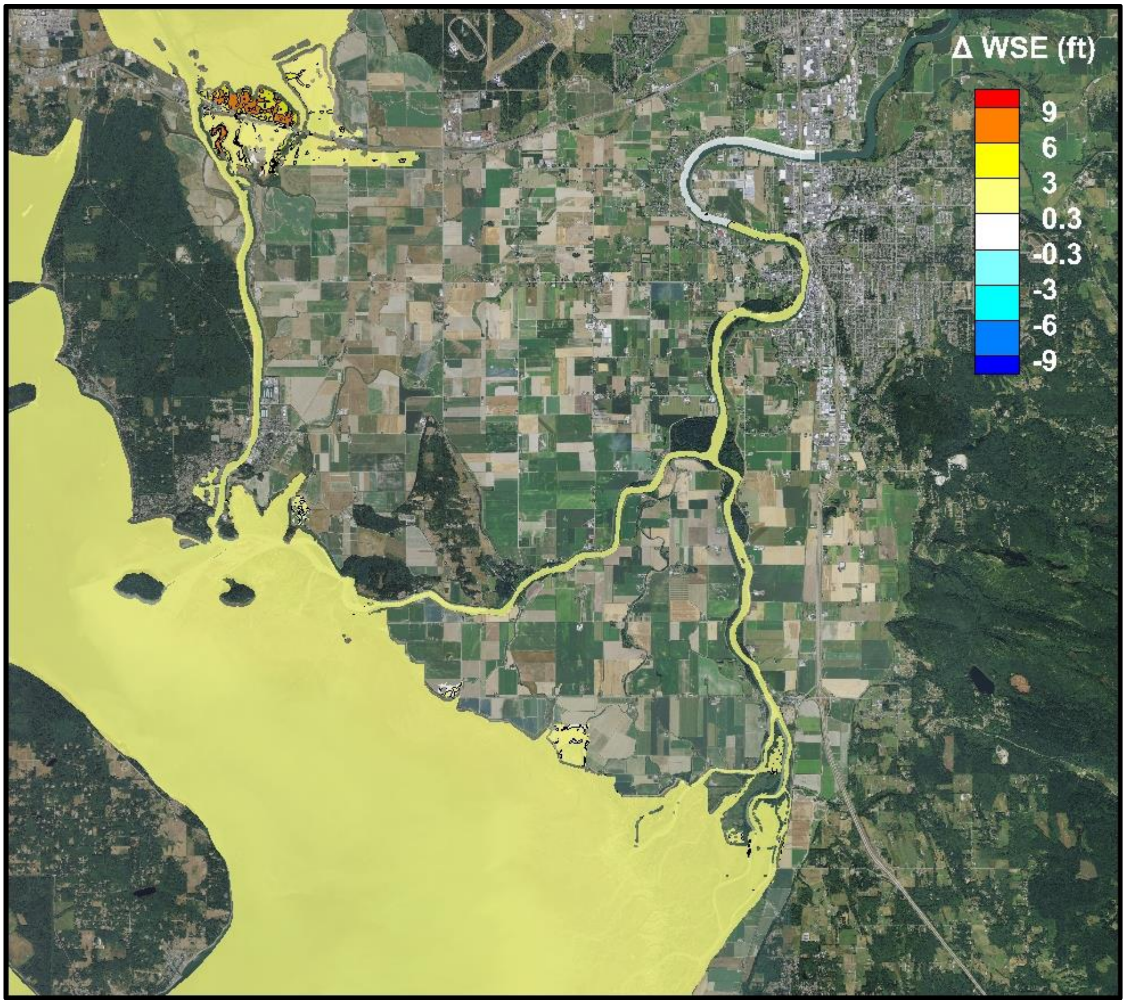

Figure J.4. Contour map of change in WSE for low flow and high tide for the full basin, comparing Baseline and Climate Change Baseline simulations.

J.4 Climate Change Baseline Deliverable 4

Deliverable 4 is a set of contour maps showing the water surface elevation during the 2080 Climate Change Baseline Simulation (Simulation 9). The plotted condition was a low flow (12,000 cfs) and future high spring tide (12.67 ft). All WSE values are relative to the NAVD88 datum. Areas that are not inundated are blanked out. A high-resolution, georeferenced map with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The map can be seen in Figure J.5.

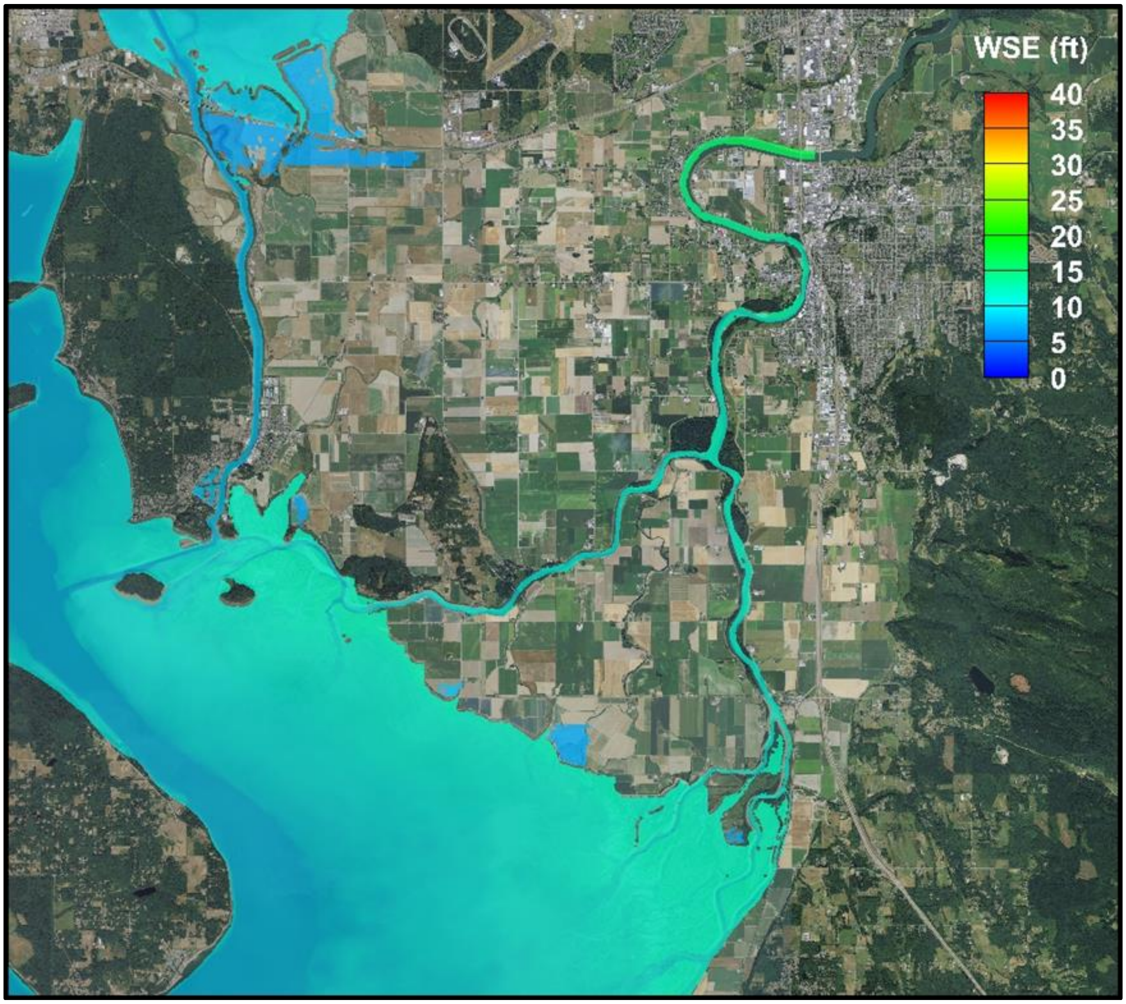

Figure J.5. Contour map of water surface elevation for the full domain during the 2080 Climate Change Baseline Simulation with low flow and future high spring tide.

J.5 Climate Change Baseline Deliverable 5

Deliverable 5 is a set of cumulative frequency plots showing water surface elevation at a point in the main channel or Bayfront near each project site. These are from the spring months of the 2080 Climate Change Baseline Simulation (Simulation 9), representing March 1 – May 22, 2015, a time period chosen to coincide with the primary fish outmigration. It should be noted that the 2080 Climate Change Baseline Simulation (Simulation 9) had no restoration action, so these locations act as a comparable reference point to see the hydrodynamics of the system under future conditions. A red mark line was provided with every point to represent an approximation of the average elevation of the project area bed. All WSE values are relative to the NAVD88 datum. An Excel file was also generated with WSE at each node location. The plots can be seen in Figure J.6 through Figure J.31.

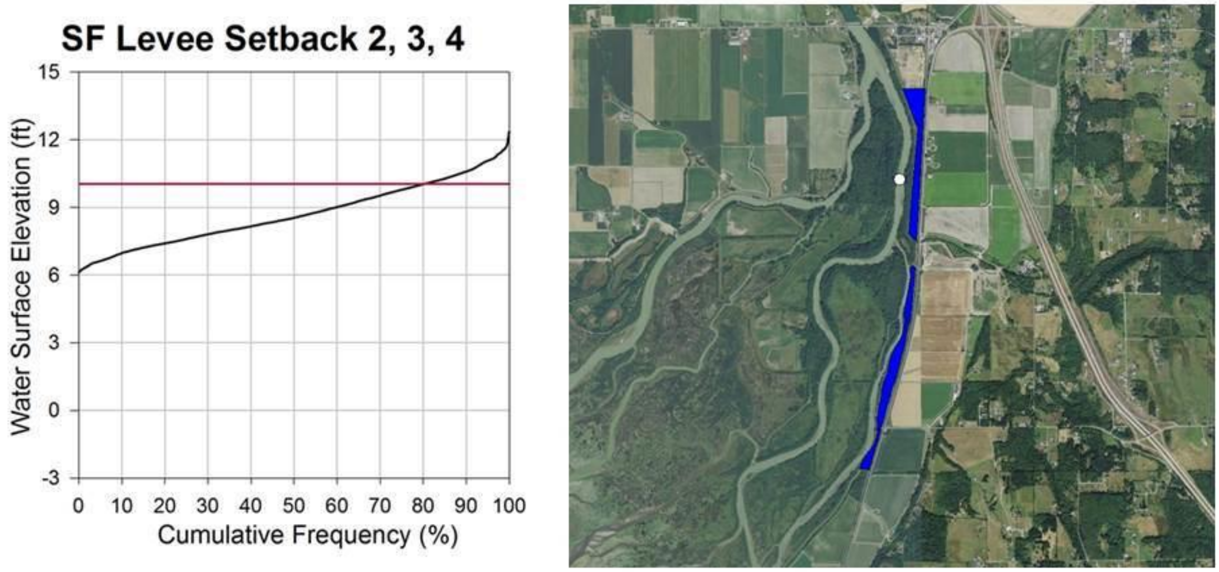

Figure J.6. Cumulative frequency plot and corresponding map for SF Levee Setbacks 2, 3, and 4 during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

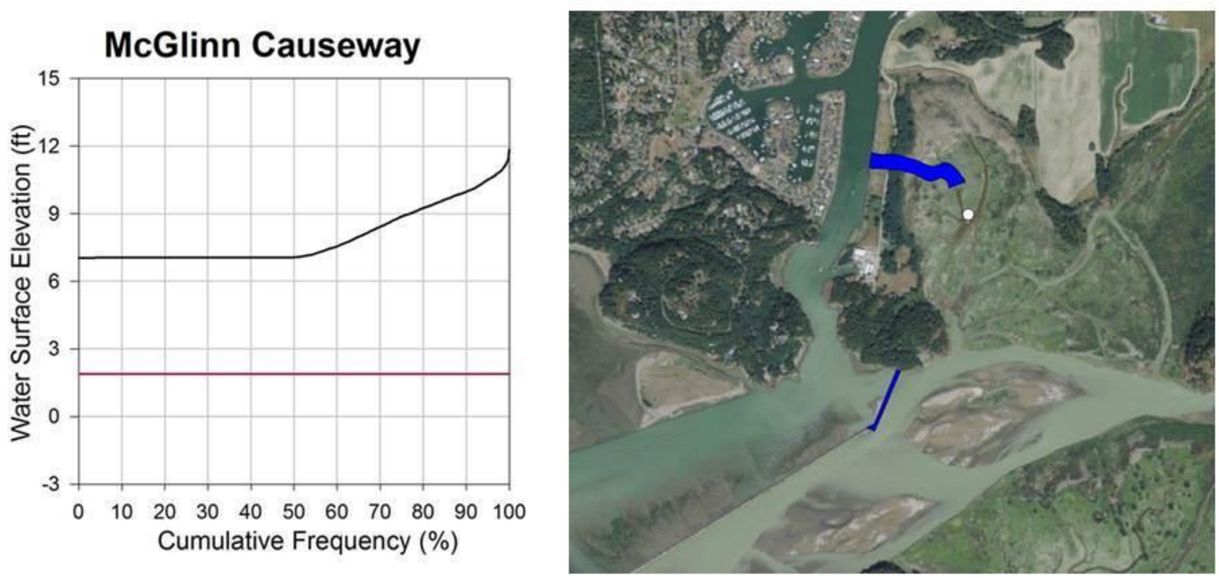

Figure J.7. Cumulative frequency plot and corresponding map for McGlinn Causeway during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

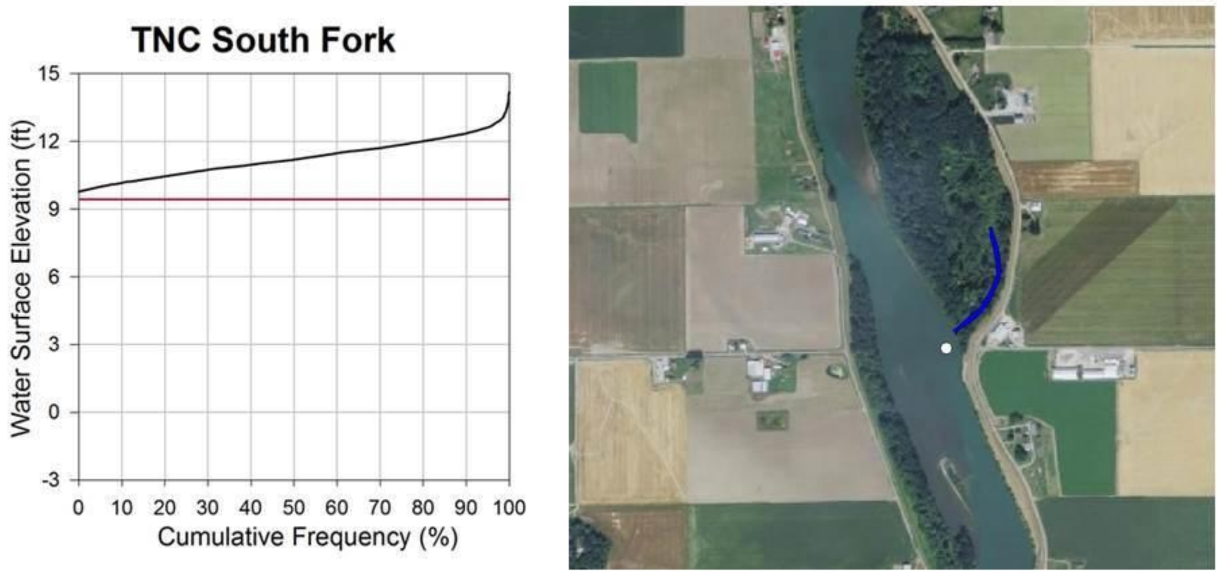

Figure J.8. Cumulative frequency plot and corresponding map for TNC South Fork during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

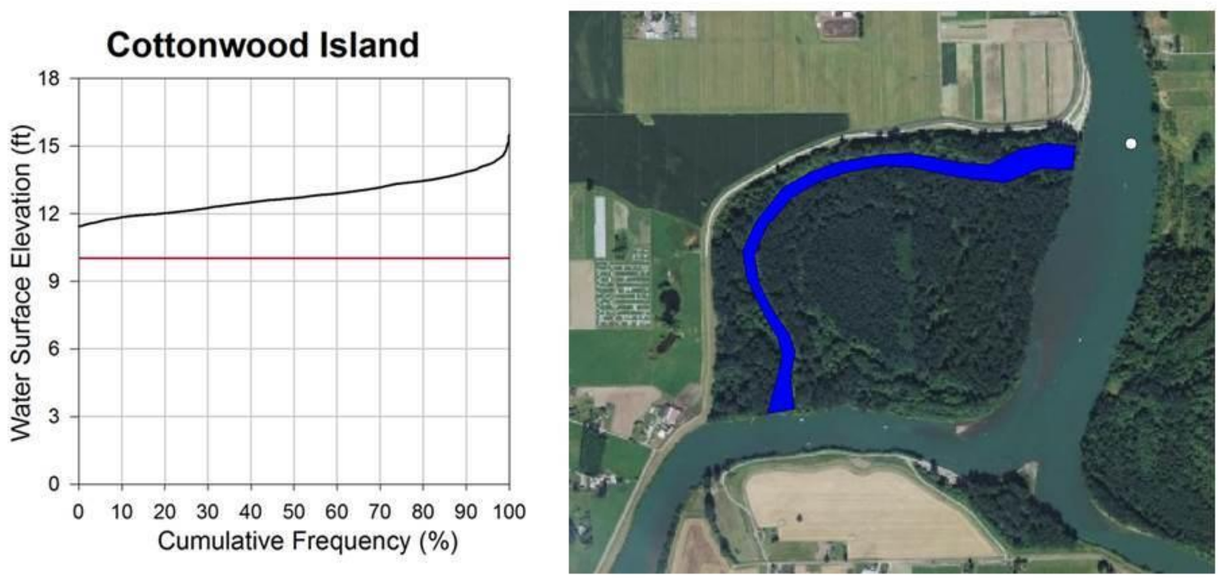

Figure J.9. Cumulative frequency plot and corresponding map for Cottonwood Island during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

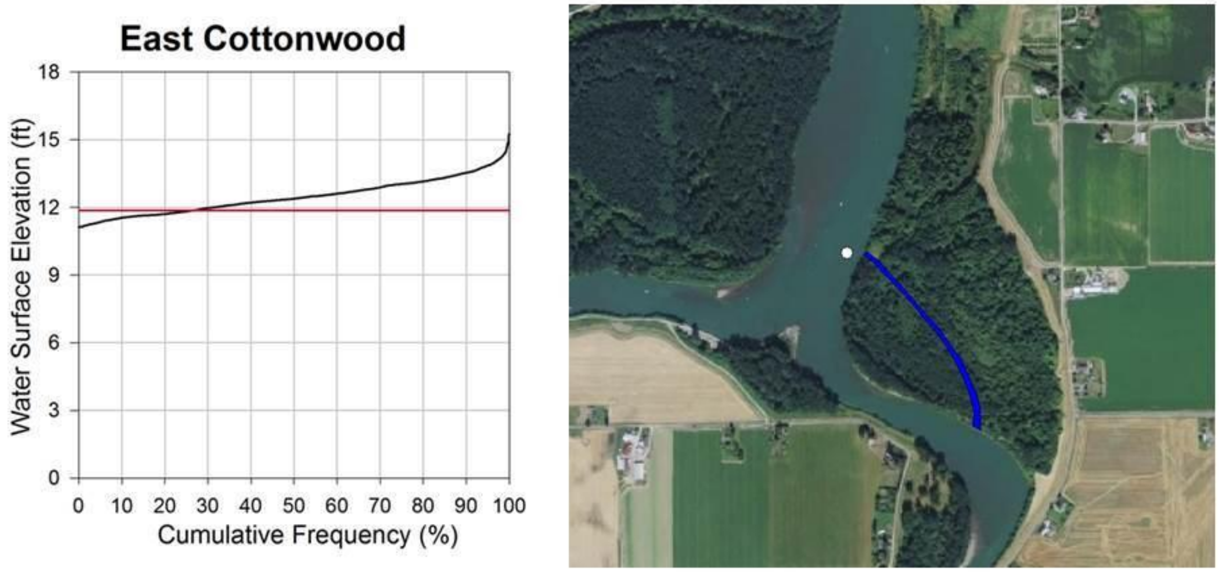

Figure J.10. Cumulative frequency plot and corresponding map for East Cottonwood during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

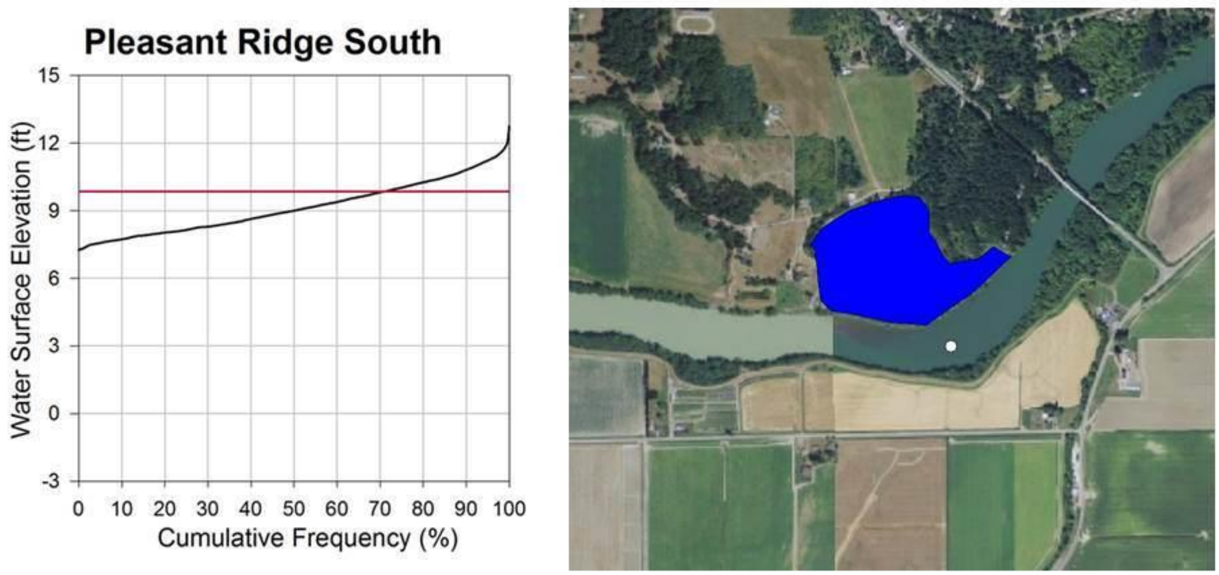

Figure J.11. Cumulative frequency plot and corresponding map for Pleasant Ridge South during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

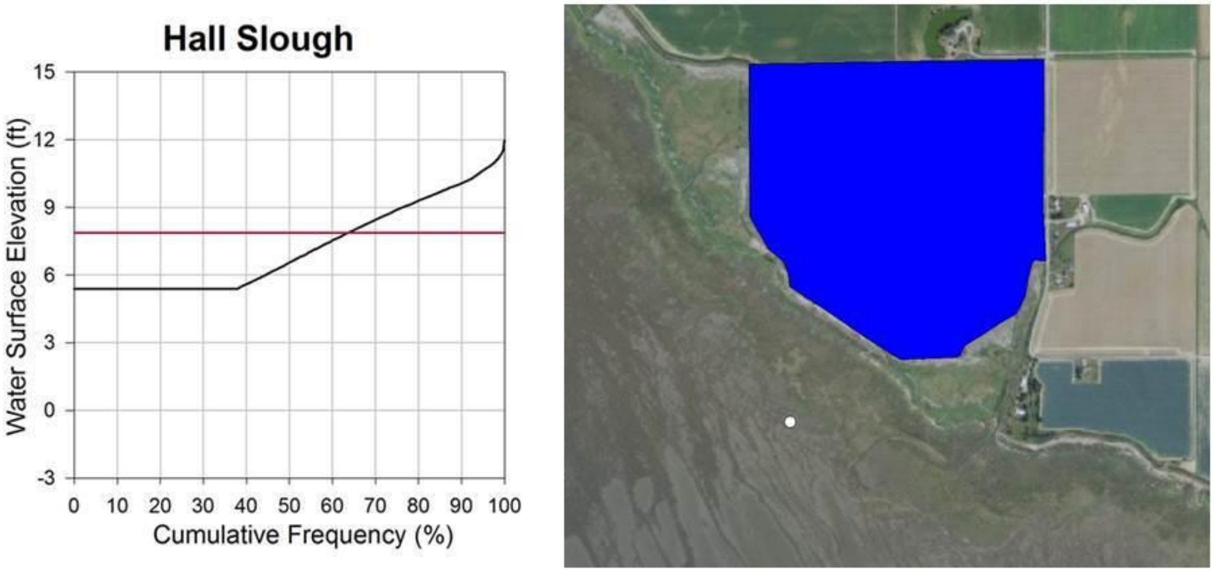

Figure J.12. Cumulative frequency plot and corresponding map for Hall Slough during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

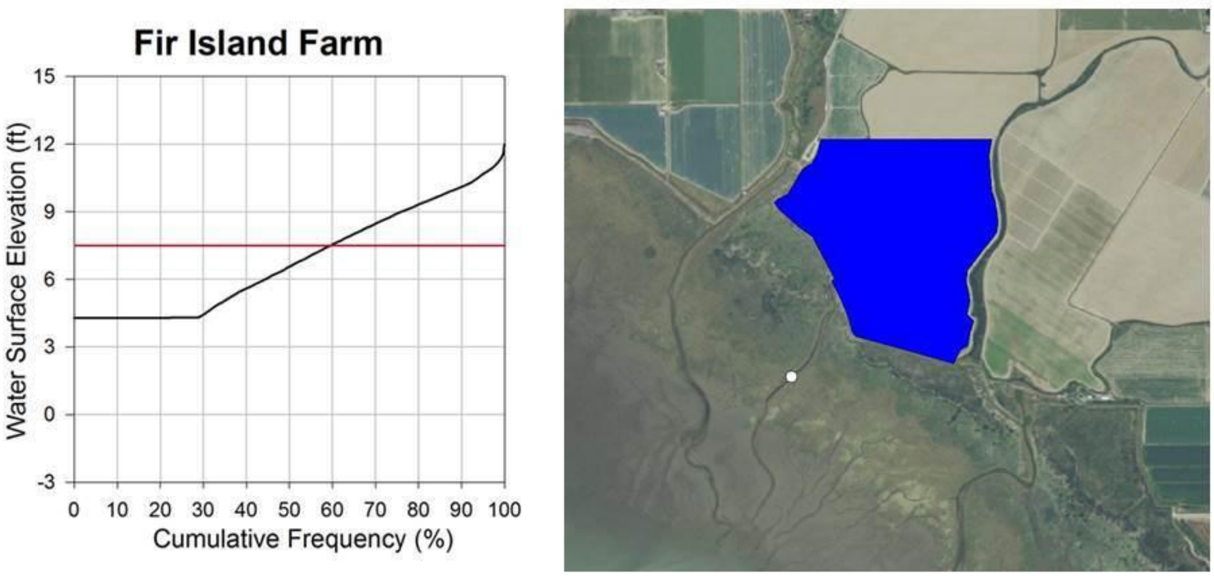

Figure J.13. Cumulative frequency plot and corresponding map for Fir Island Farm during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

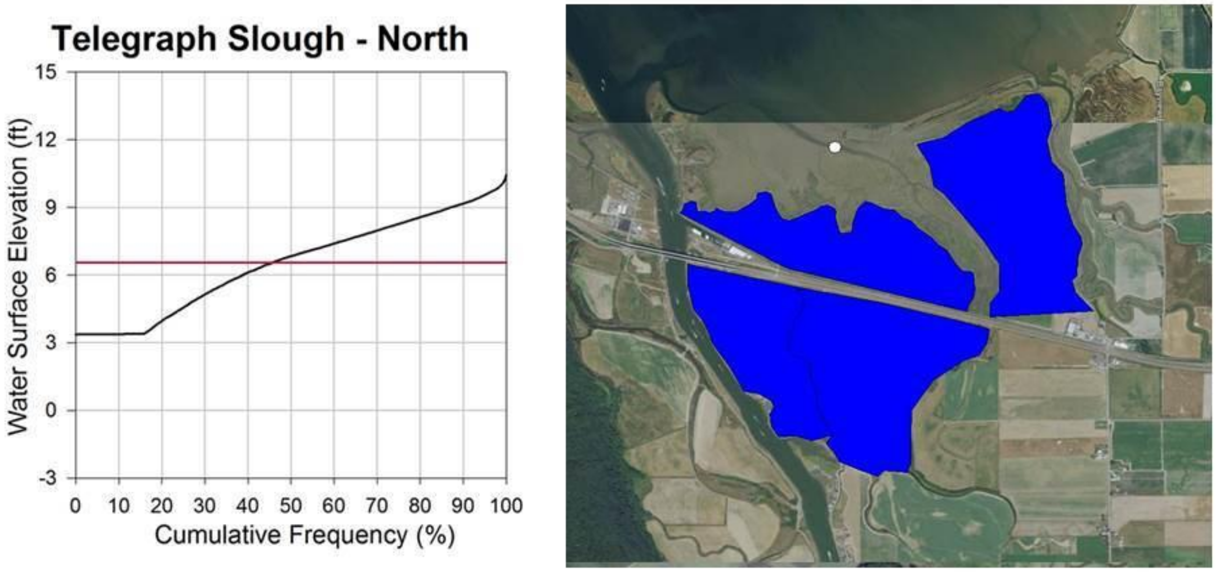

Figure J.14. Cumulative frequency plot and corresponding map for Telegraph Slough (north) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

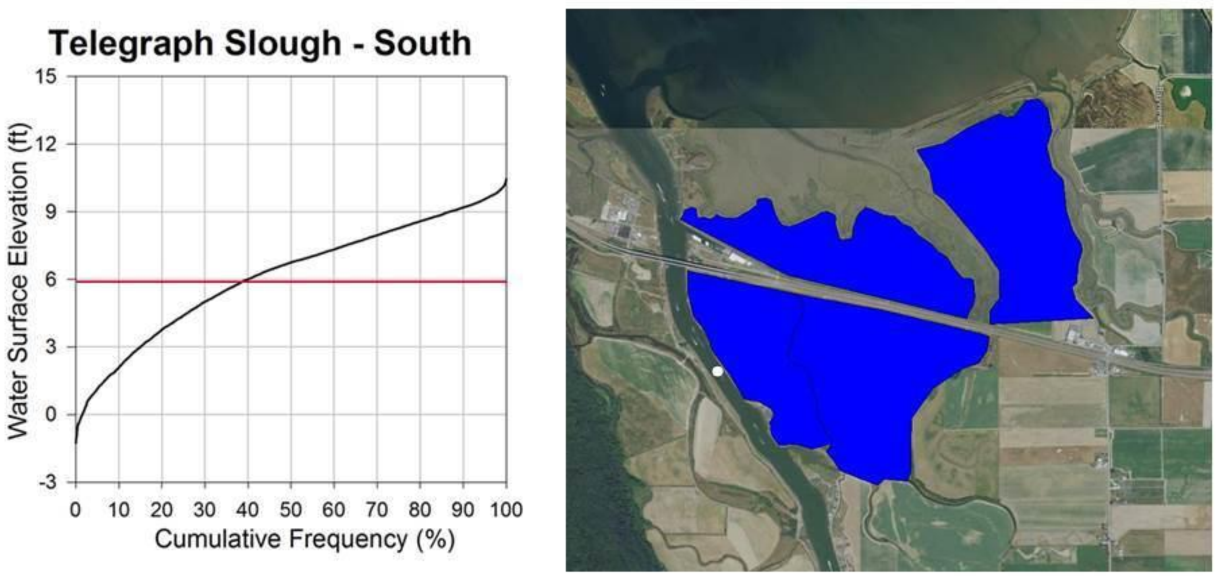

Figure J.15. Cumulative frequency plot and corresponding map for Telegraph Slough (south) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

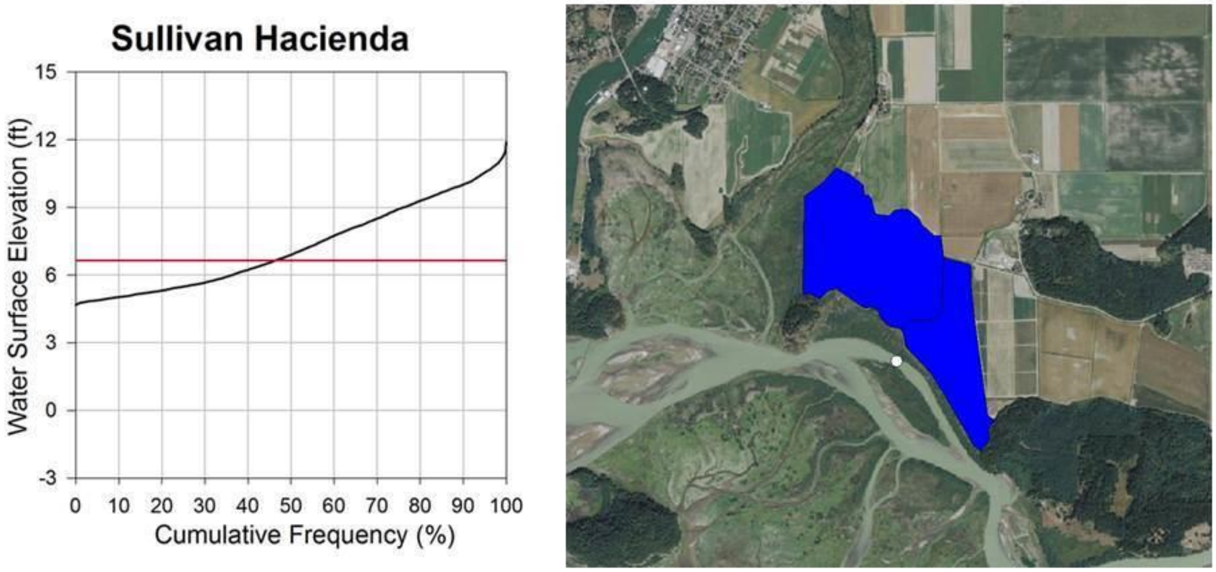

Figure J.16. Cumulative frequency plot and corresponding map for Sullivan Hacienda during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

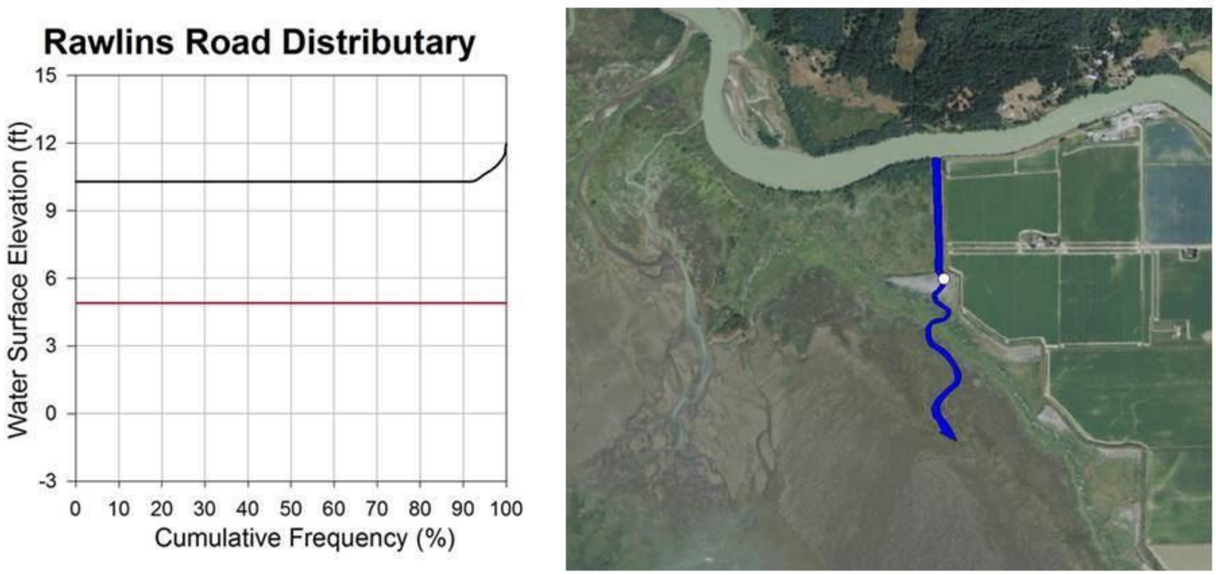

Figure J.17. Cumulative frequency plot and corresponding map for Rawlins Road Distributary during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

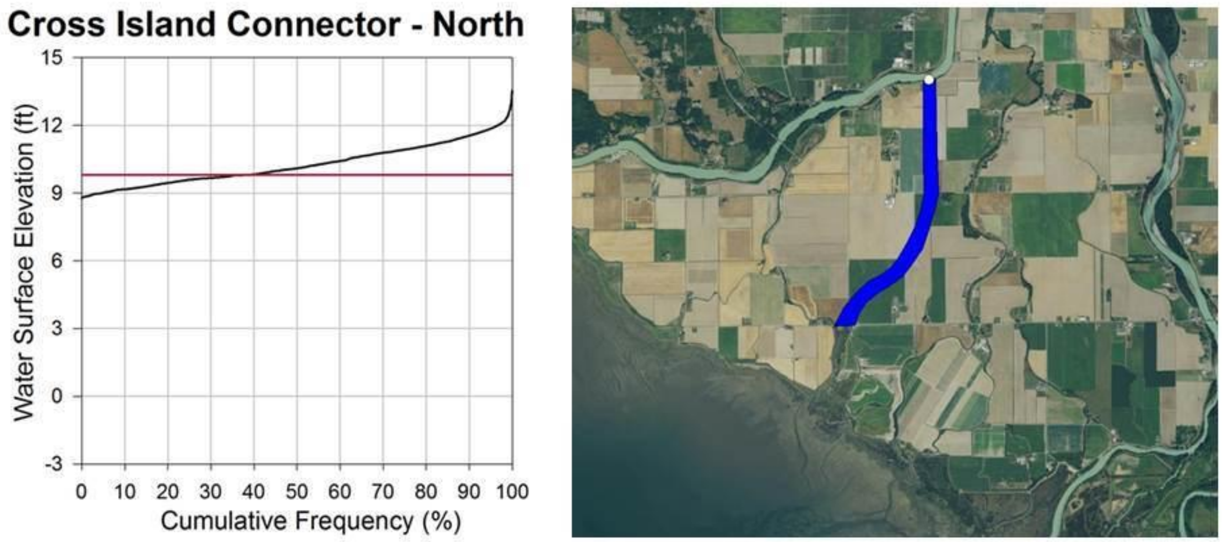

Figure J.18. Cumulative frequency plot and corresponding map for Cross Island Connector (north) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

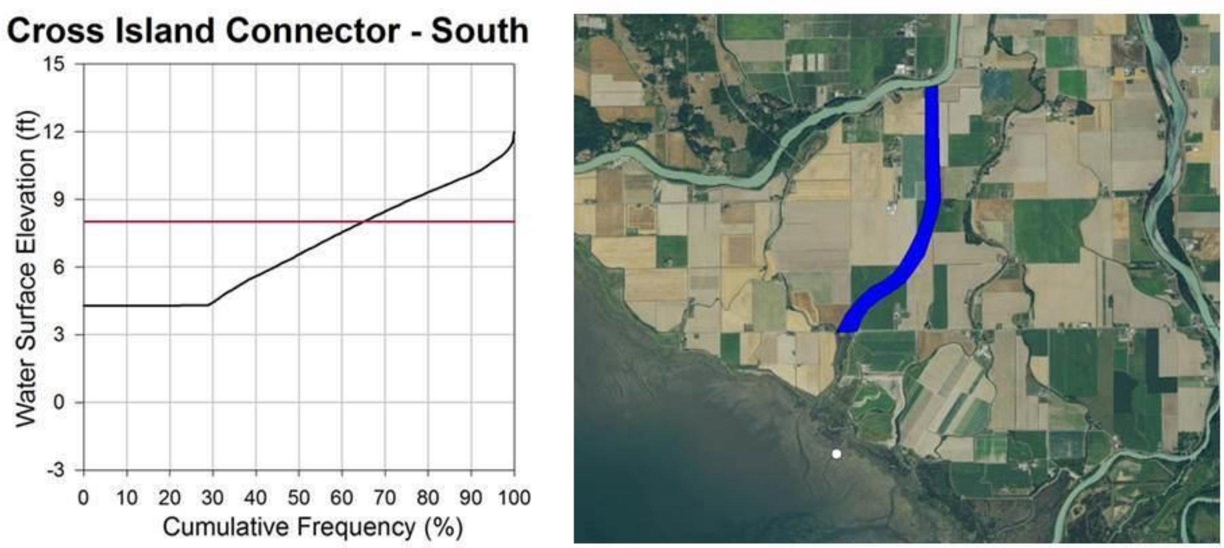

Figure J.19. Cumulative frequency plot and corresponding map for Cross Island Connector (south) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

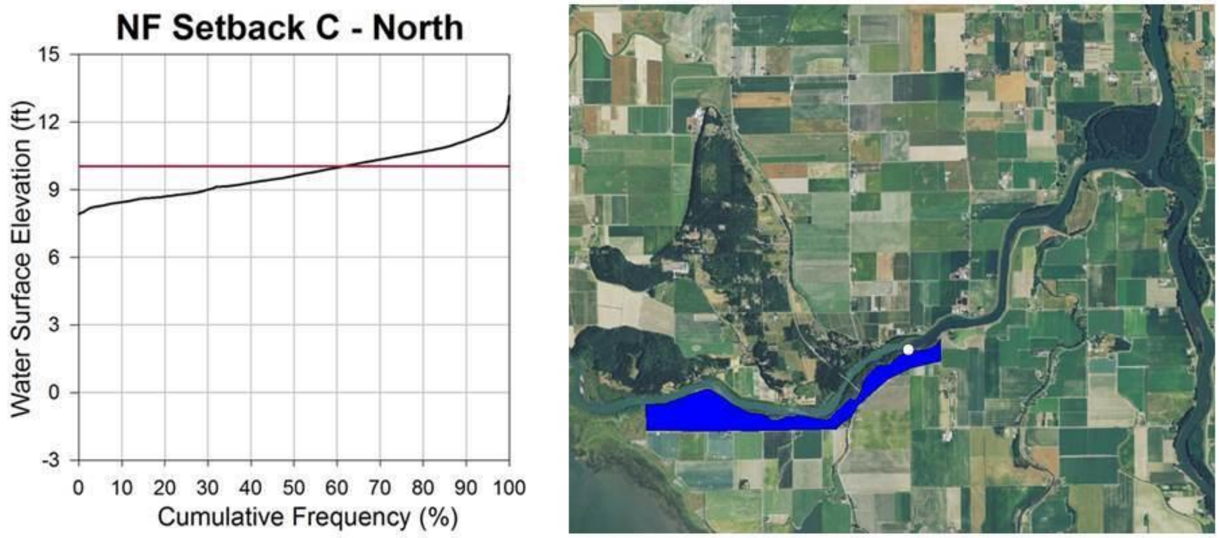

Figure J.20. Cumulative frequency plot and corresponding map for NF Levee Setback C (north) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

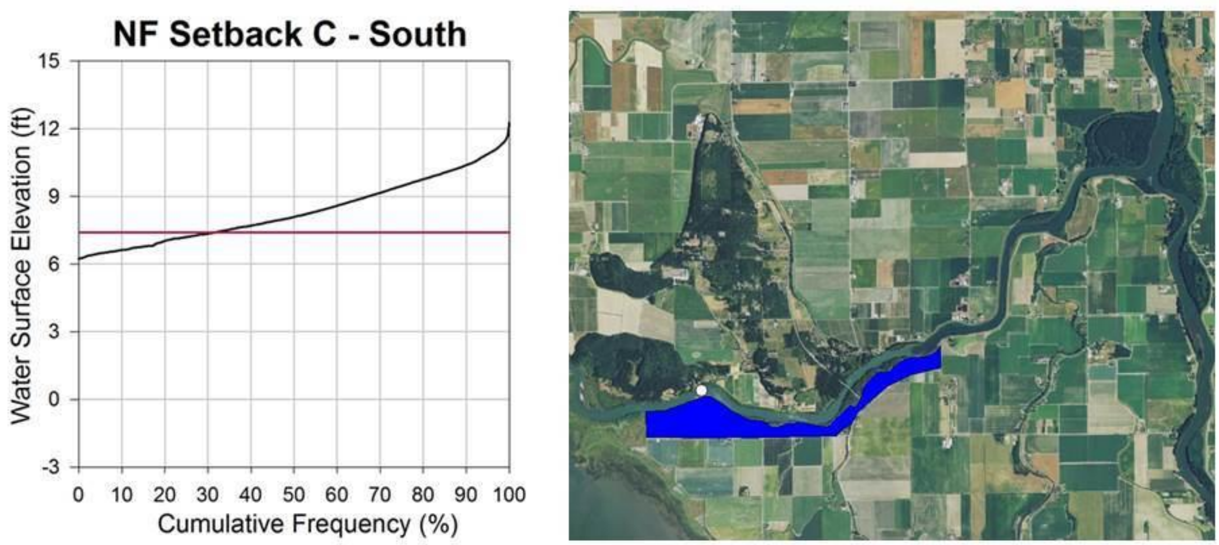

Figure J.21. Cumulative frequency plot and corresponding map for NF Levee Setback C (south) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

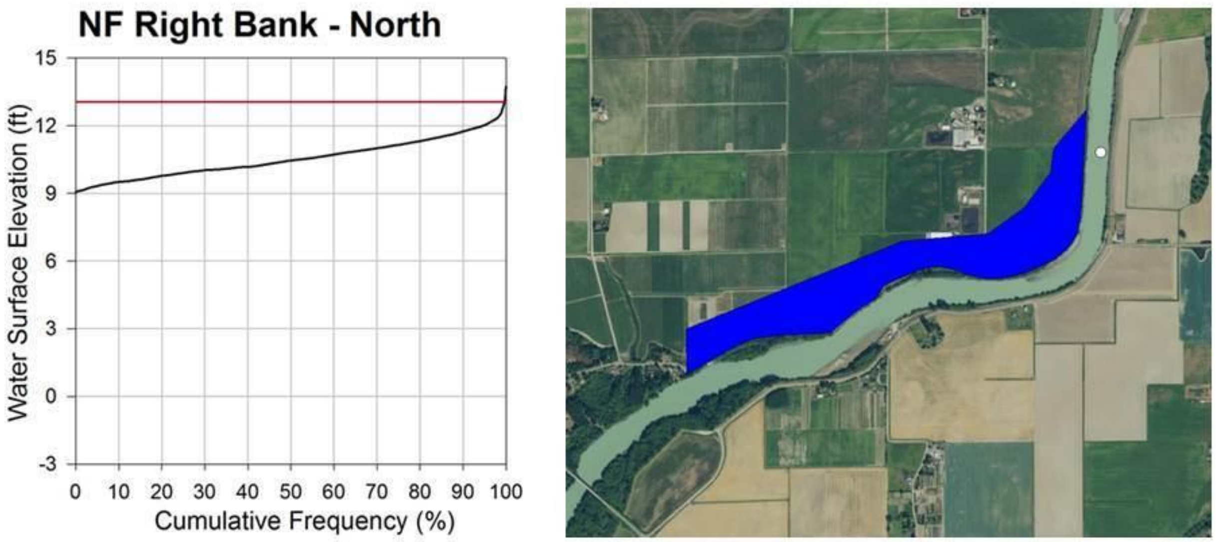

Figure J.22. Cumulative frequency plot and corresponding map for NF Right Bank Levee Setback (north) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

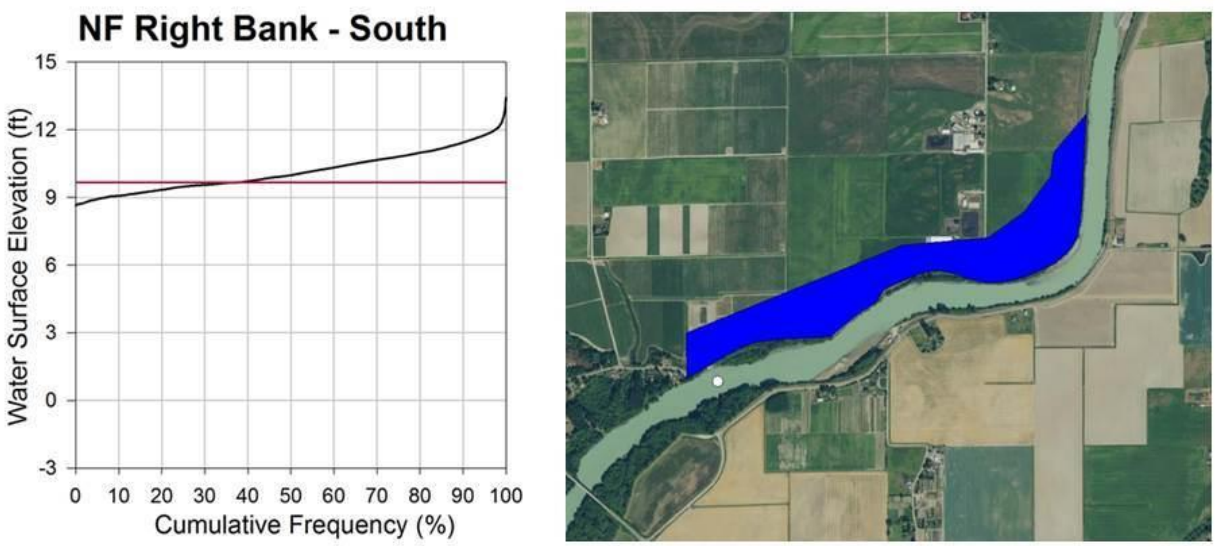

Figure J.23. Cumulative frequency plot and corresponding map for NF Right Bank Levee Setback (south) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

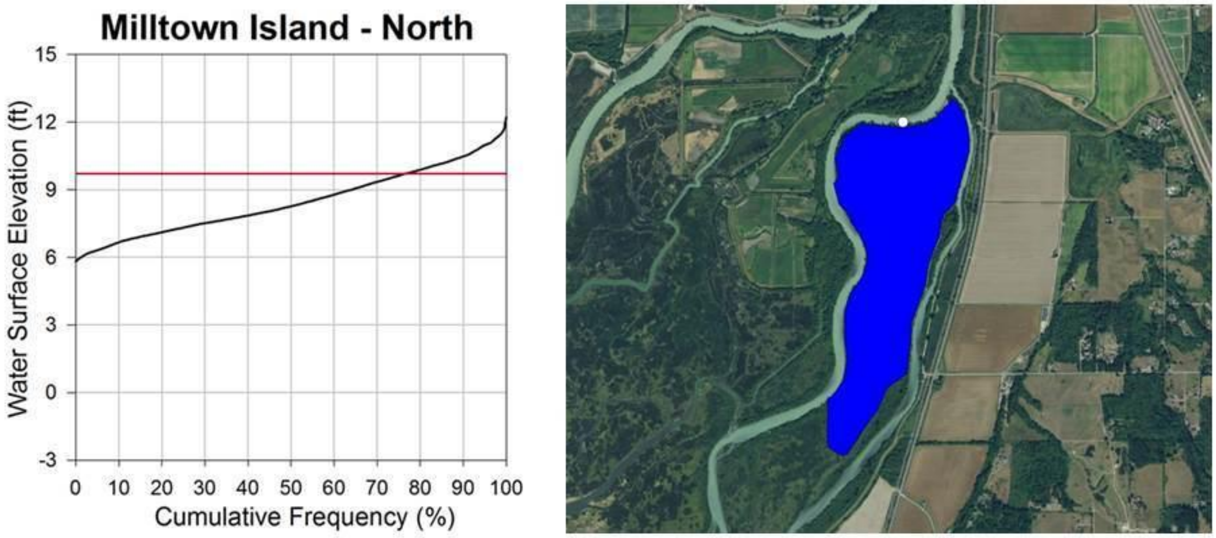

Figure J.24. Cumulative frequency plot and corresponding map for Milltown Island (north) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

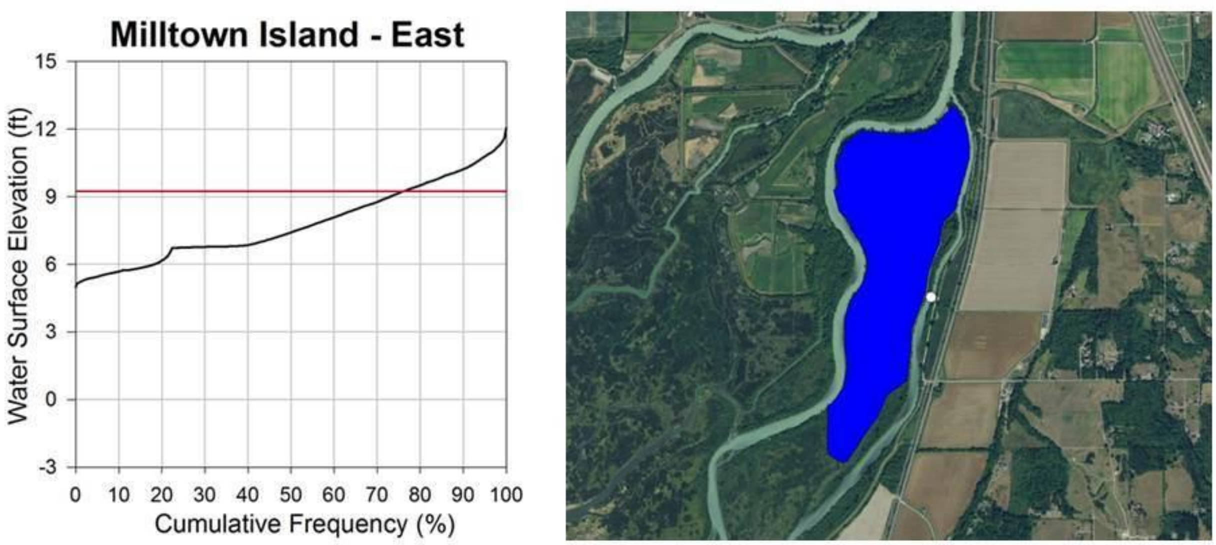

Figure J.25. Cumulative frequency plot and corresponding map for Milltown Island (east) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

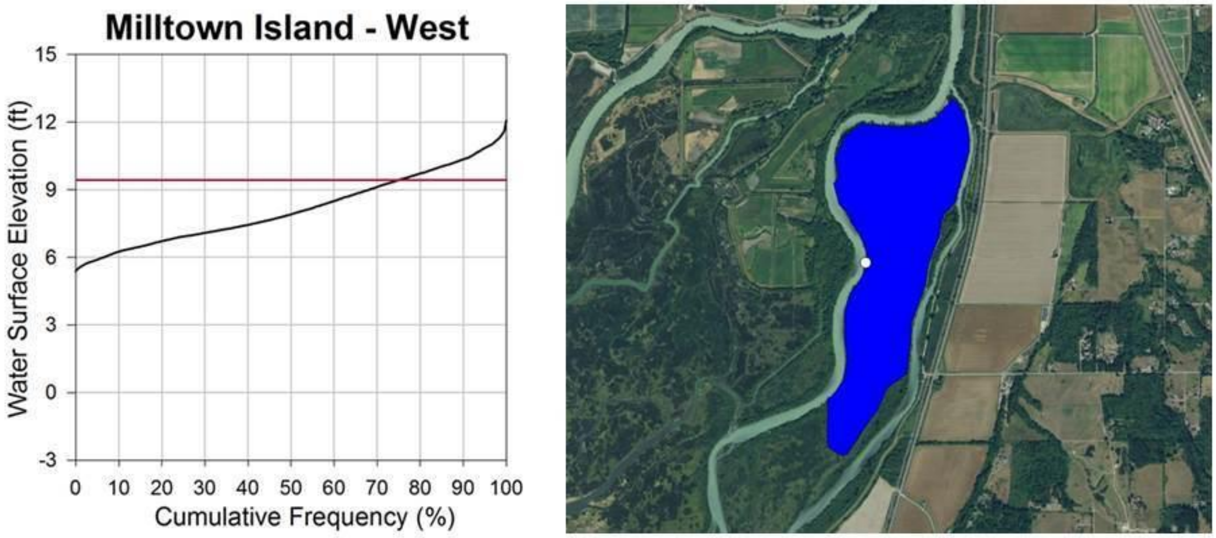

Figure J.26. Cumulative frequency plot and corresponding map for Milltown Island (west) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

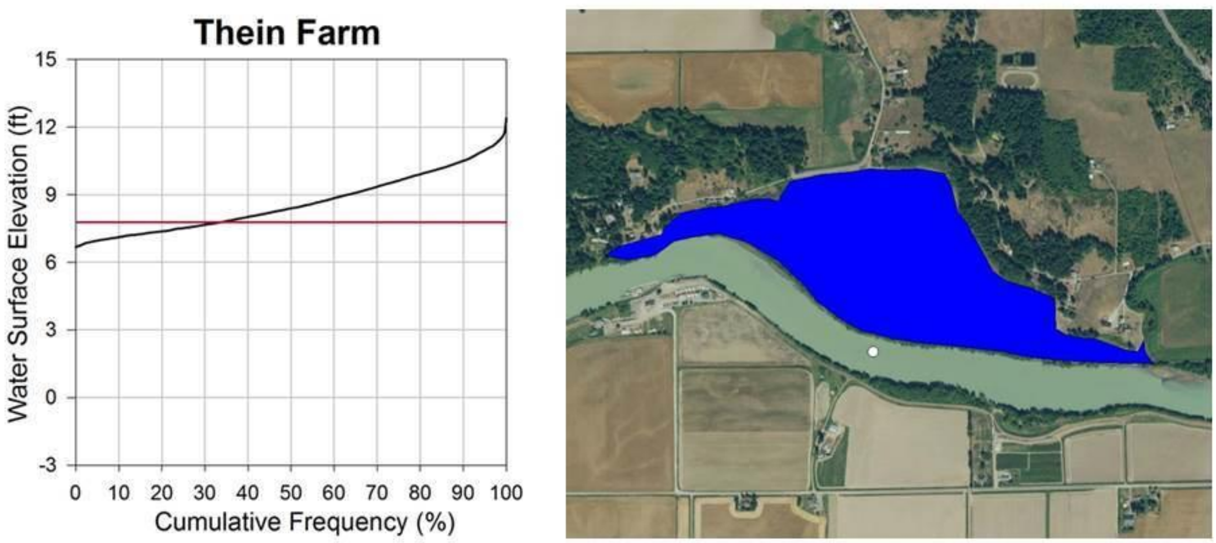

Figure J.27. Cumulative frequency plot and corresponding map for Thein Farm during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

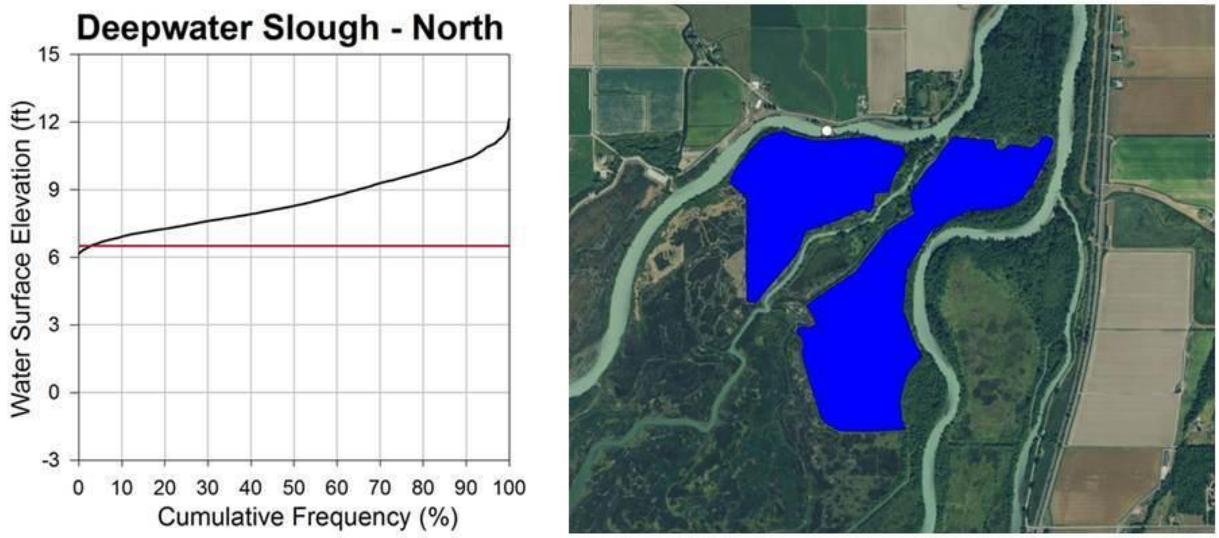

Figure J.28. Cumulative frequency plot and corresponding map for Deepwater Slough (north) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

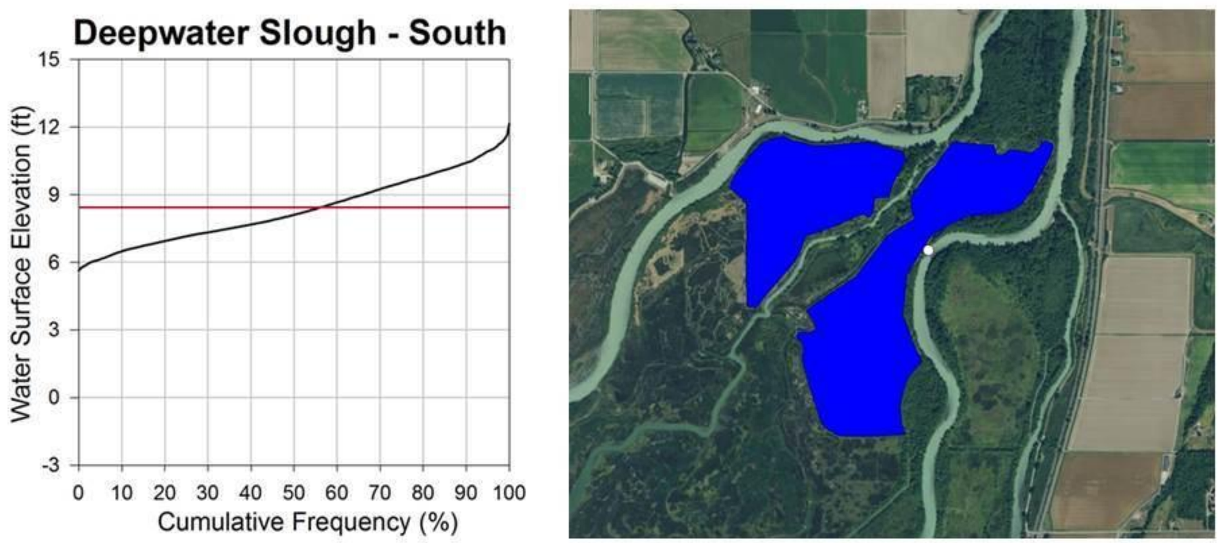

Figure J.29. Cumulative frequency plot and corresponding map for Deepwater Slough (south) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

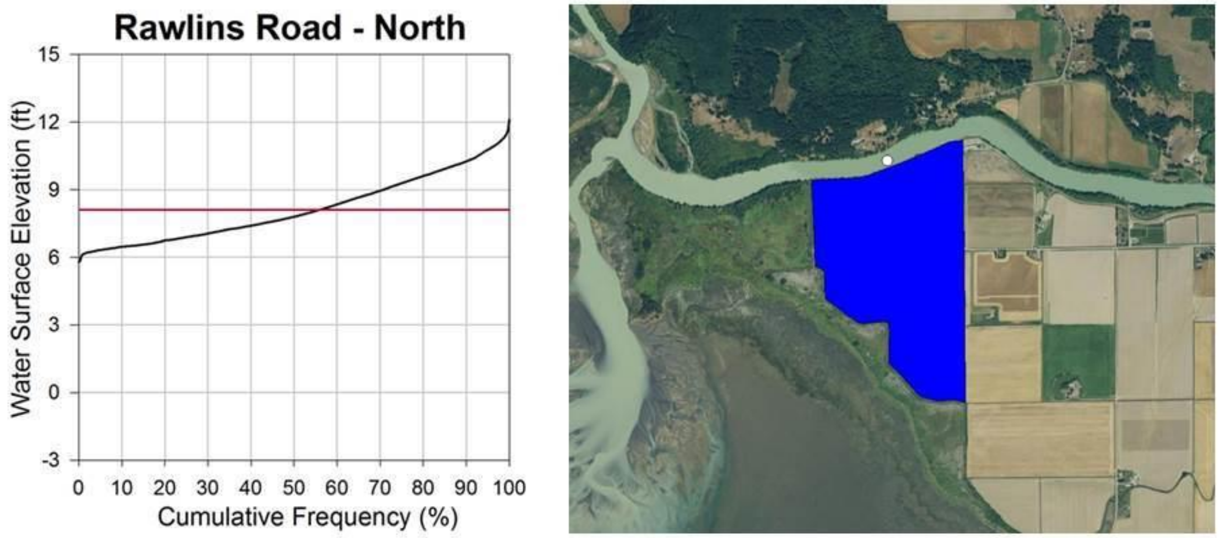

Figure J.30. Cumulative frequency plot and corresponding map for Rawlins Road (north) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

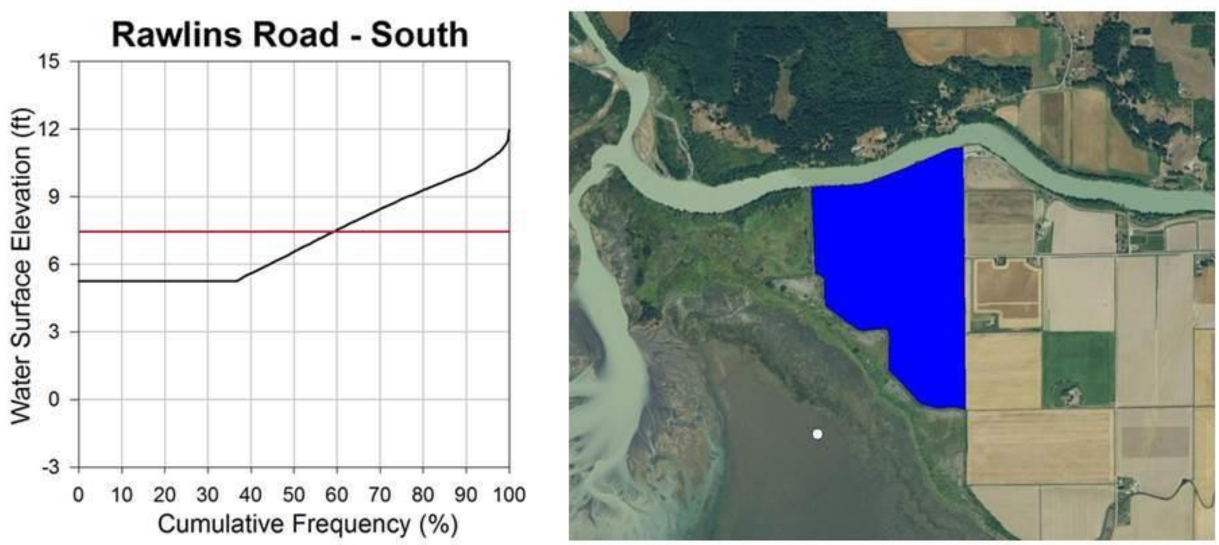

Figure J.31. Cumulative frequency plot and corresponding map for Rawlins Road (south) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

J.6 Climate Change Baseline Deliverable 6

Deliverable 6 is a set of contour maps showing the change in salinity between the Baseline simulation (Simulation 0) and the Climate Change Baseline simulation (Simulation 9). The compared conditions were a low flow (12,000 cfs) and high spring tide (10.8 ft) versus a low flow (12,000 cfs) and future high spring tide (12.67 ft), representing the change from baseline to future baseline conditions and the impact of sea level rise on salinity intrusion without any projects. The compared salinity values represent an average of the bottom 10% of the water depth to show the furthest extent of the salt wedge. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. Changes in salinity could affect habitat suitability, the distribution of fish, and have potential effects on agriculture. The maps can be seen in Figure J.32 through Figure J.47.

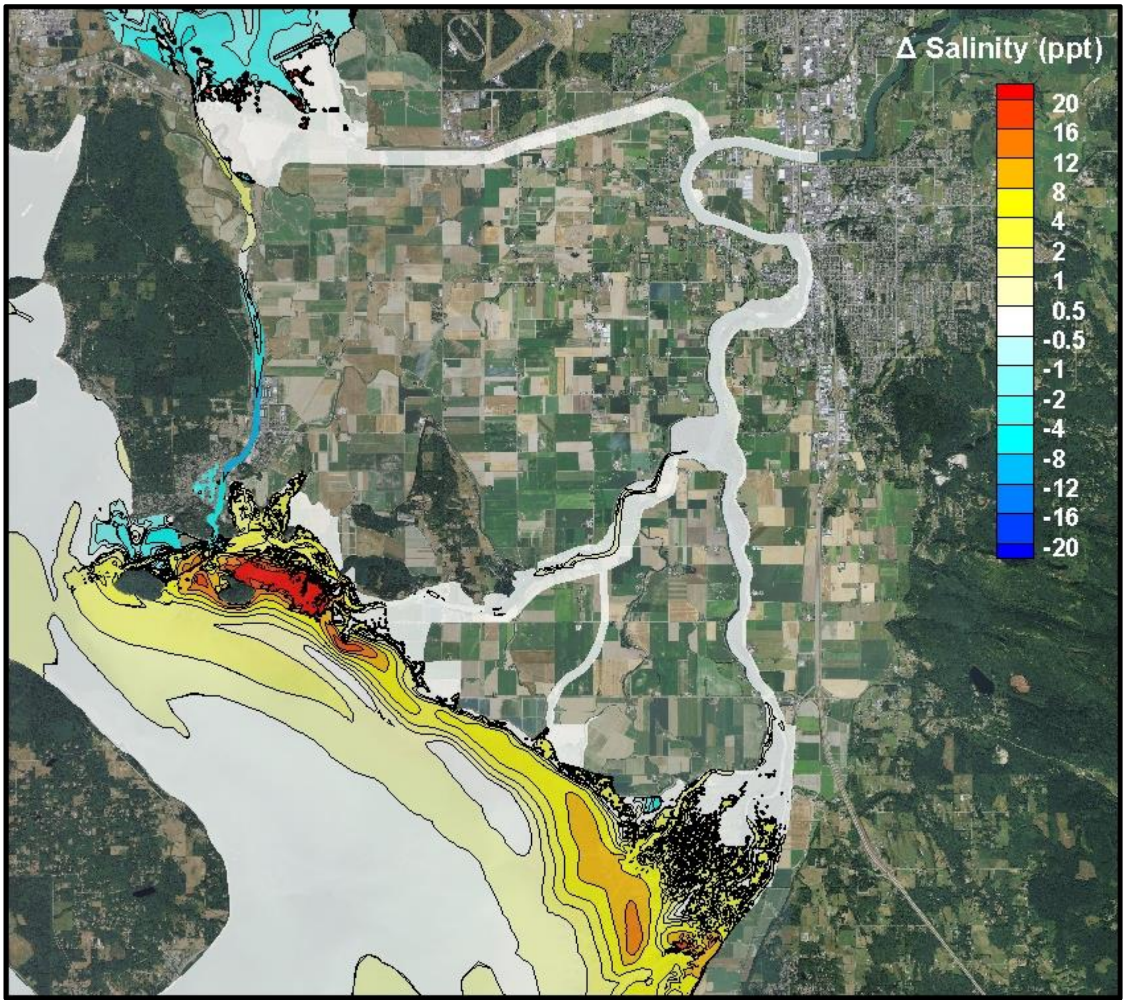

Figure J.32. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation with low flow and high tide.

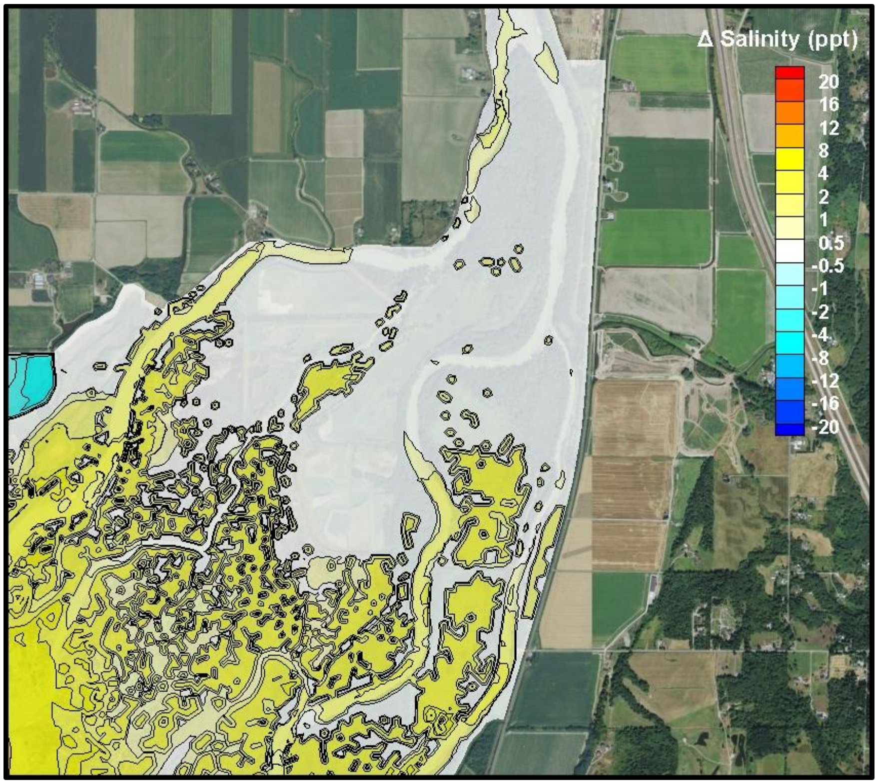

Figure J.33. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for SF Levee Setback 2, 3, 4 with low flow and high tide.

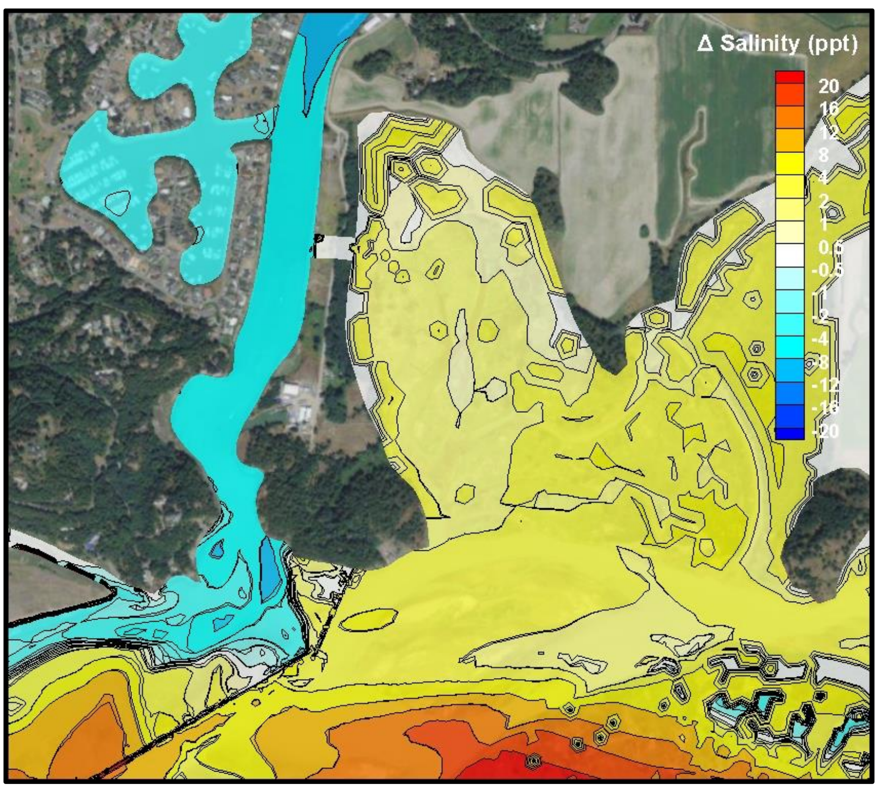

Figure J.34. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for McGlinn Causeway with low flow and high tide.

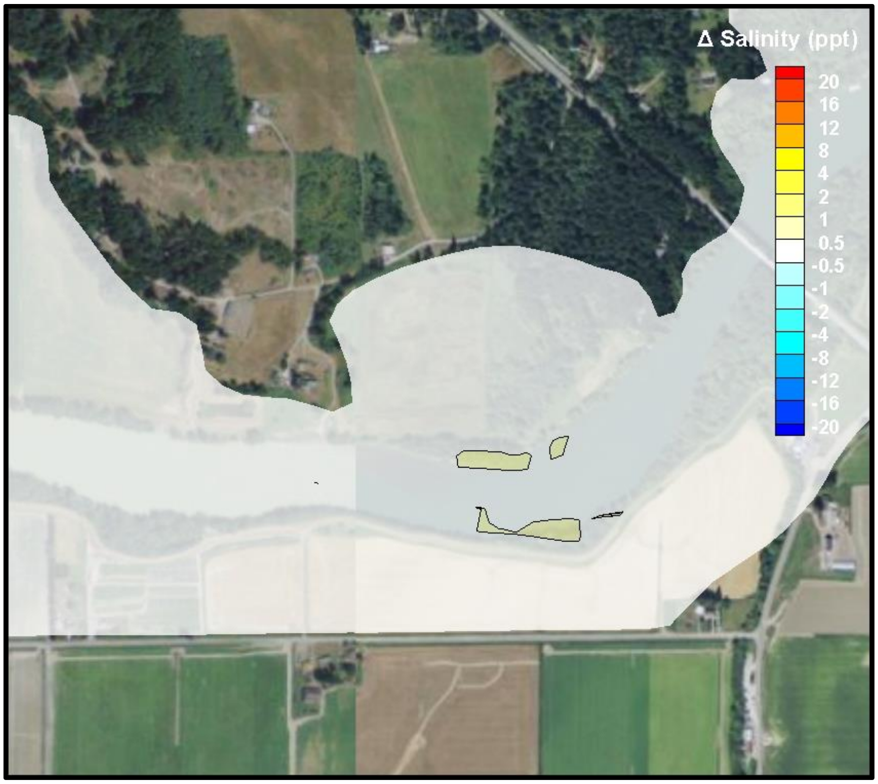

Figure J.35. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Pleasant Ridge South with low flow and high tide.

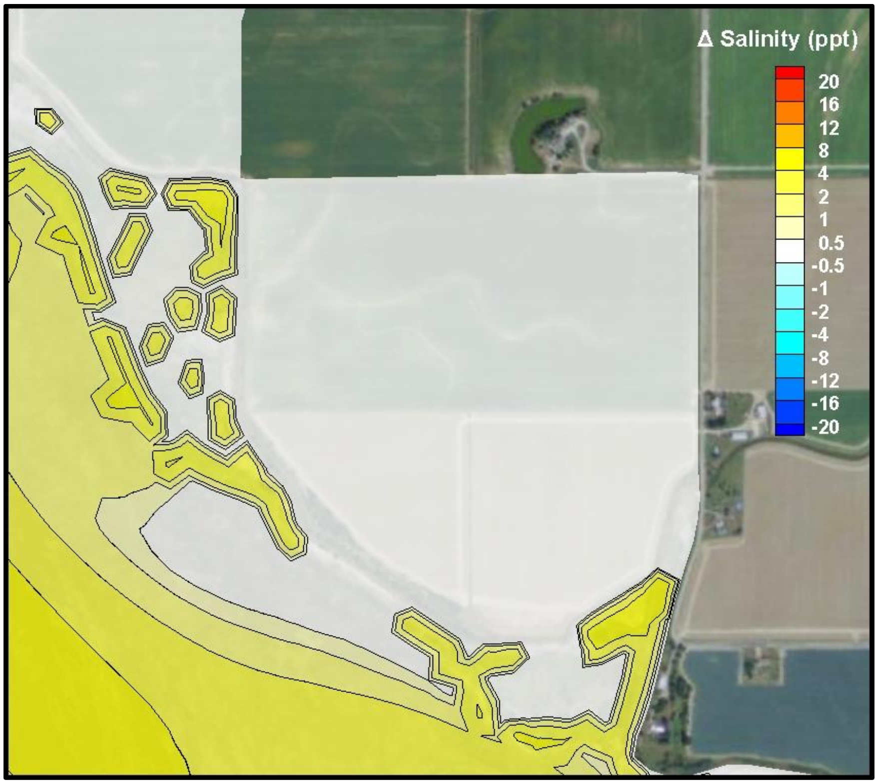

Figure J.36. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Hall Slough with low flow and high tide.

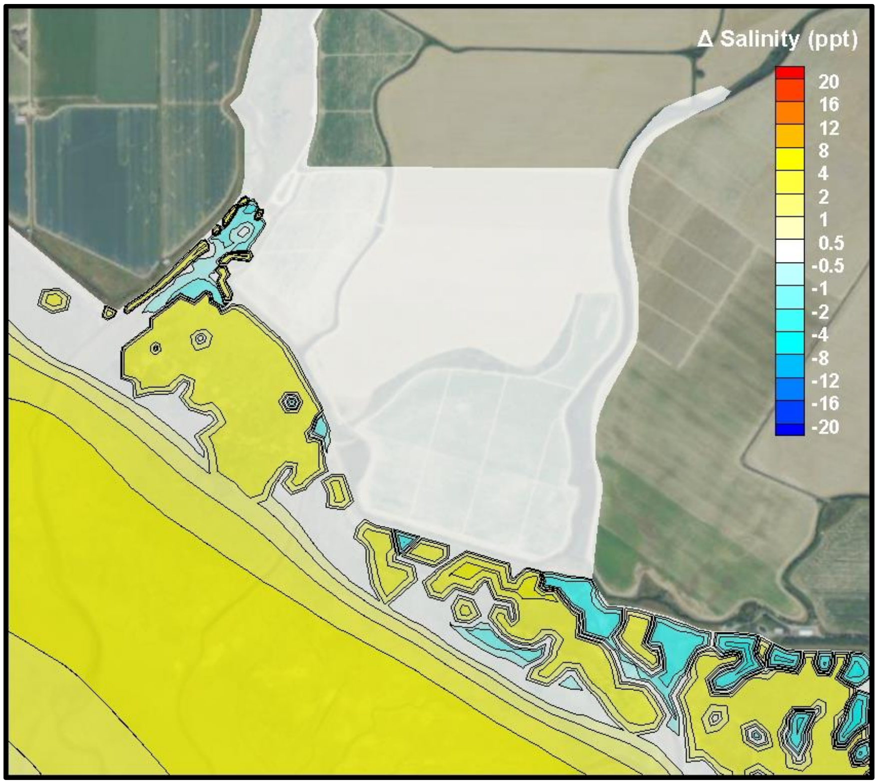

Figure J.37. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Fir Island Farm with low flow and high tide.

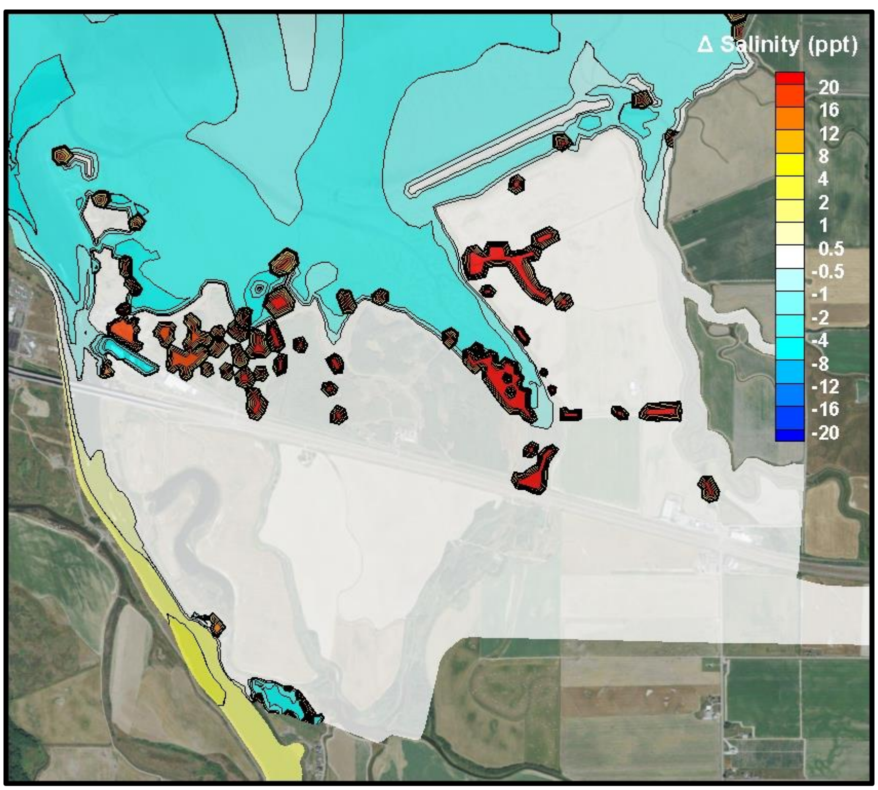

Figure J.38. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Telegraph Slough Full with low flow and high tide.

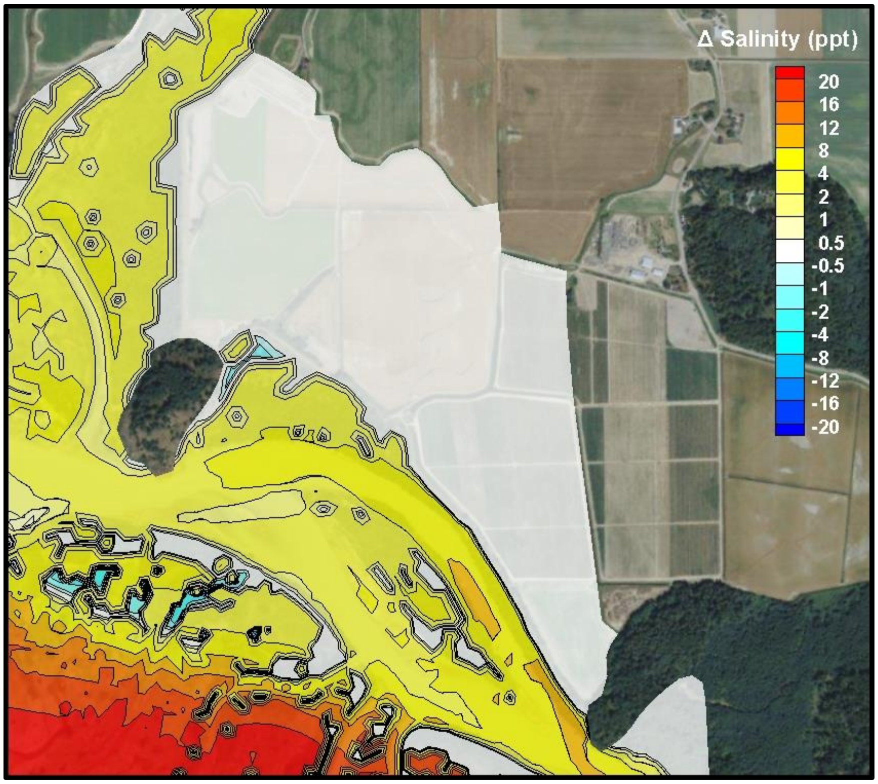

Figure J.39. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Sullivan Hacienda with low flow and high tide.

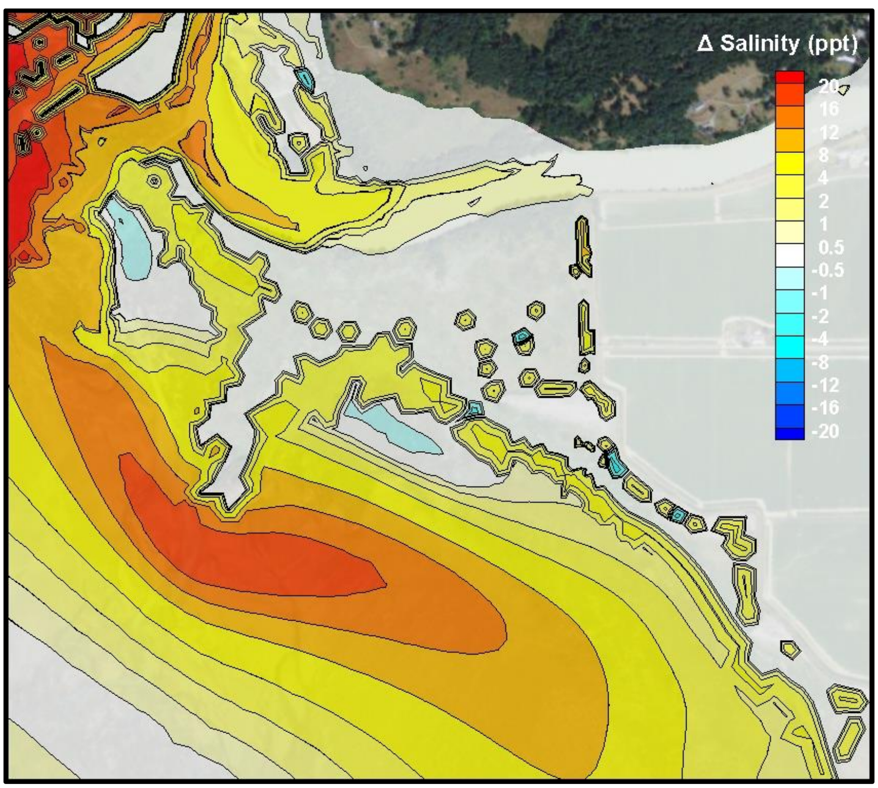

Figure J.40. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Rawlins Distributary with low flow and high tide.

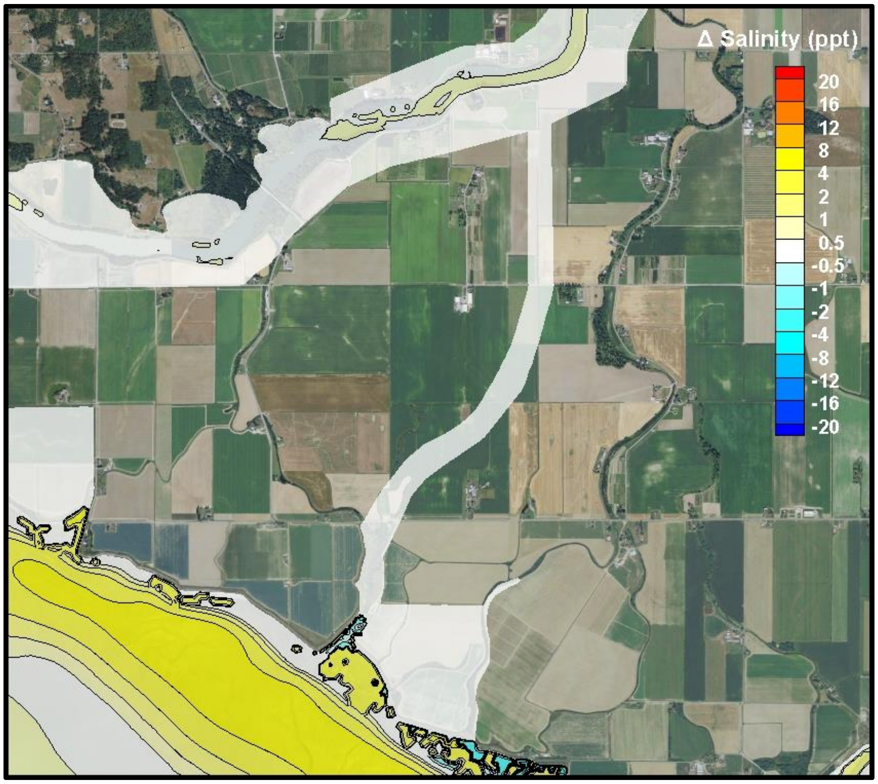

Figure J.41. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Cross Island Connector with low flow and high tide.

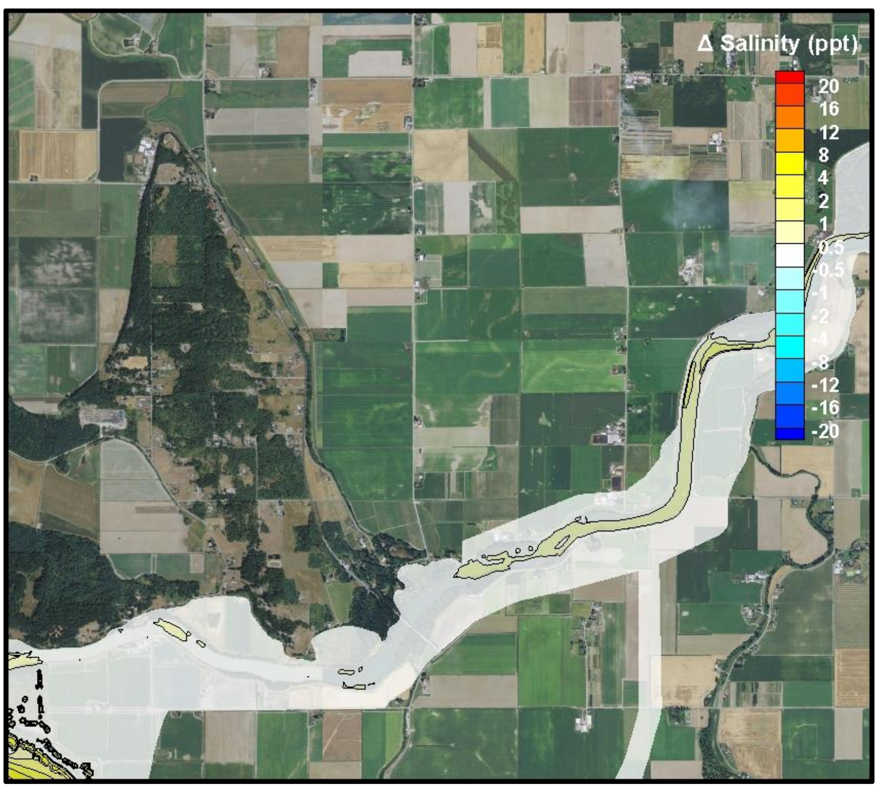

Figure J.42. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for NF Levee Setback C with low flow and high tide.

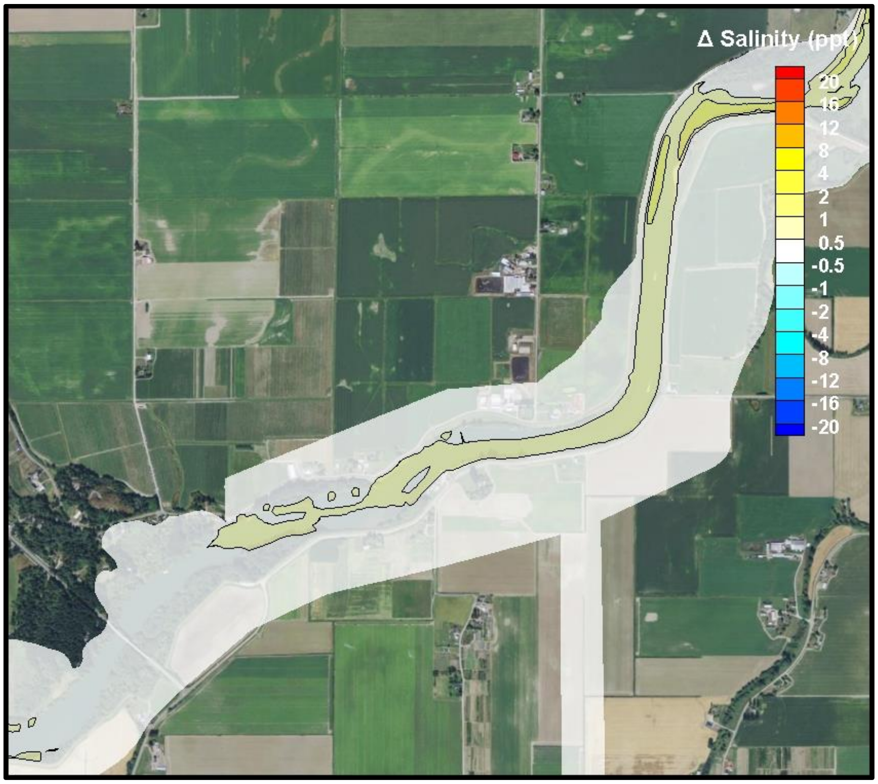

Figure J.43. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for NF Right Bank Levee Setback with low flow and high tide.

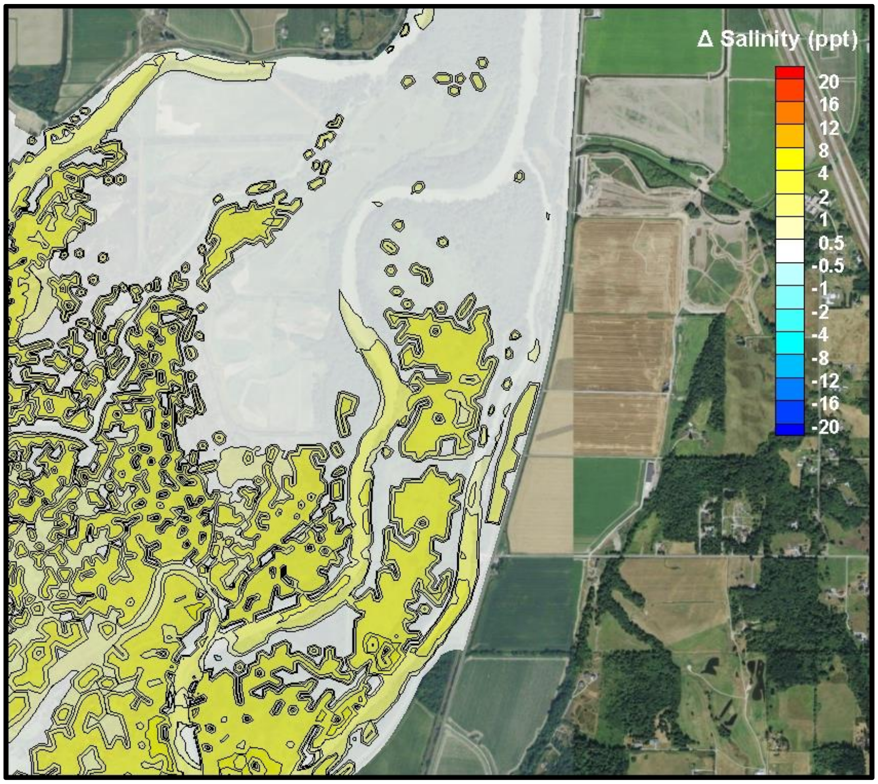

Figure J.44. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Milltown Island with low flow and high tide.

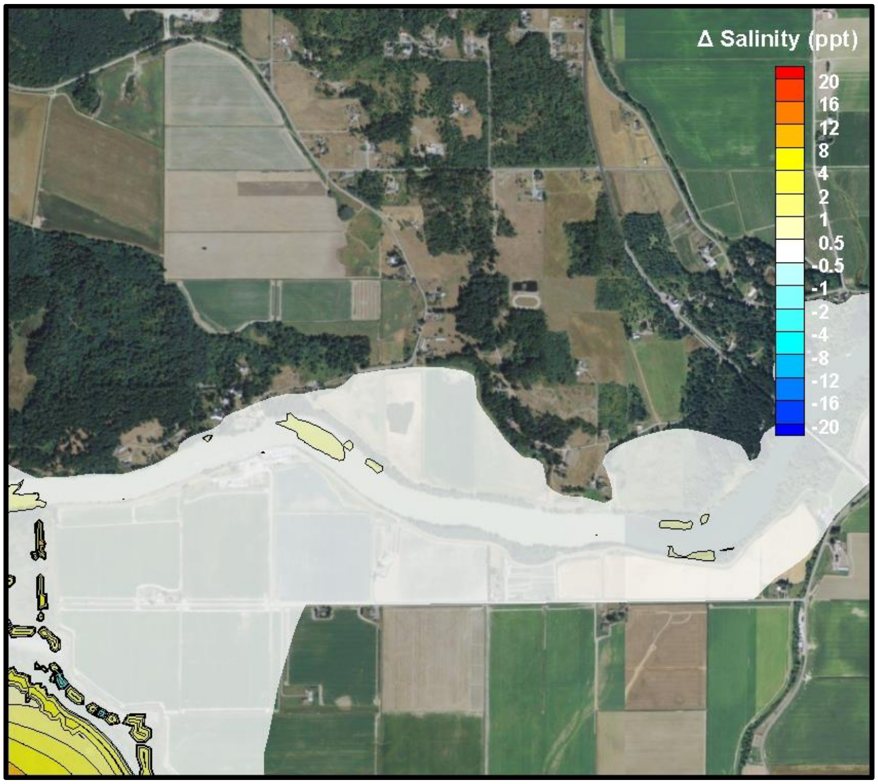

Figure J.45. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Thein Farm with low flow and high tide.

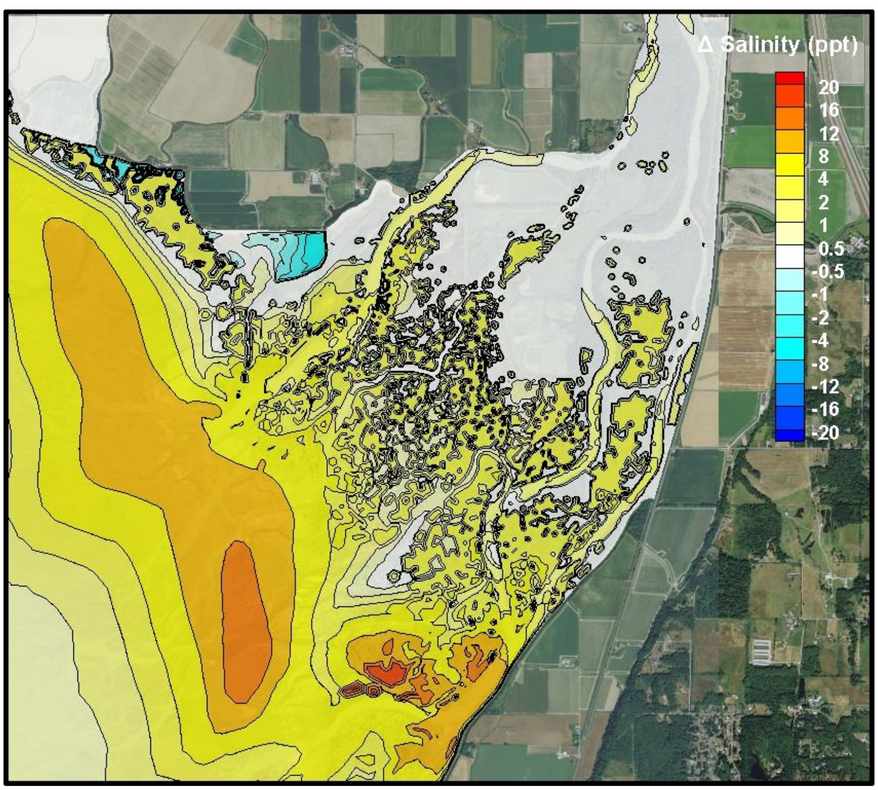

Figure J.46. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Deepwater Slough Phase 2 with low flow and high tide.

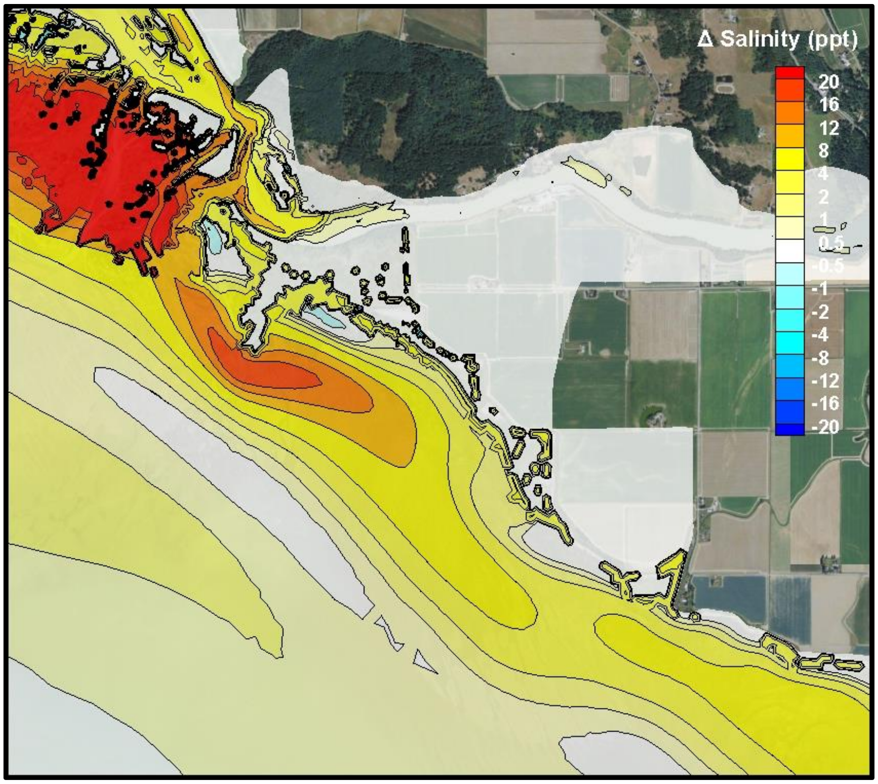

Figure J.47. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Rawlins Road with low flow and high tide.

Appendix K

Simulation 10: Climate Change with Projects Deliverables

Appendix K

Simulation 10: Climate Change with Projects Deliverables

The following list of deliverables is associated with Simulation 10: SF Levee Setbacks 2, 3, and 4, McGlinn Causeway, TNC South Fork, Cottonwood Island, East Cottonwood, Pleasant Ridge South, Hall Slough, Fir Island Farm, Telegraph Slough Full, Sullivan Hacienda, Rawlins Distributary, Cross Island Connector, NF Levee Setback C, NF Right Bank Levee Setback, Milltown Island, Thein Farm, Deepwater Slough Phase 2, Rawlins Road (Figure K.1). These deliverables were created by the SHDM Team to address specific objectives for the alternative analysis (Friebel et al., in preparation).

1. Contour maps showing change in WSE from climate change baseline (Simulation 9) to climate change with projects (Simulation 10) during (1) future Q2 flow and future low spring tide and (2) future Q2 flow and future high spring tide. High-resolution, georeferenced maps were also provided (not shown).

2. Contour maps showing WSE for climate change with projects (Simulation 10) during (1) future Q2 flow and future low spring tide and (2) future Q2 flow and future high spring tide. High-resolution, georeferenced maps were also provided (not shown).

3. Contour maps showing change in WSE from climate change baseline (Simulation 9) to climate change with projects (Simulation 10) during (1) low flow and future high spring tide. High-resolution, georeferenced maps were also provided (not shown).

4. Contour maps showing WSE for climate change with projects (Simulation 10) during (1) low flow and future high spring tide. High-resolution, georeferenced maps were also provided (not shown).

5. At points in the main channel and bay front selected by the SHDM Team, cumulative frequency of WSE (for the months of March, April, and May). An Excel file of the data associated with the plot data was also provided.

6. Contour maps showing change in salinity from climate change baseline (Simulation 9) to climate change with projects (Simulation 10) during (1) low flow and high spring tide. High-resolution, georeferenced maps were also provided, including absolute salinity for both conditions (not shown).

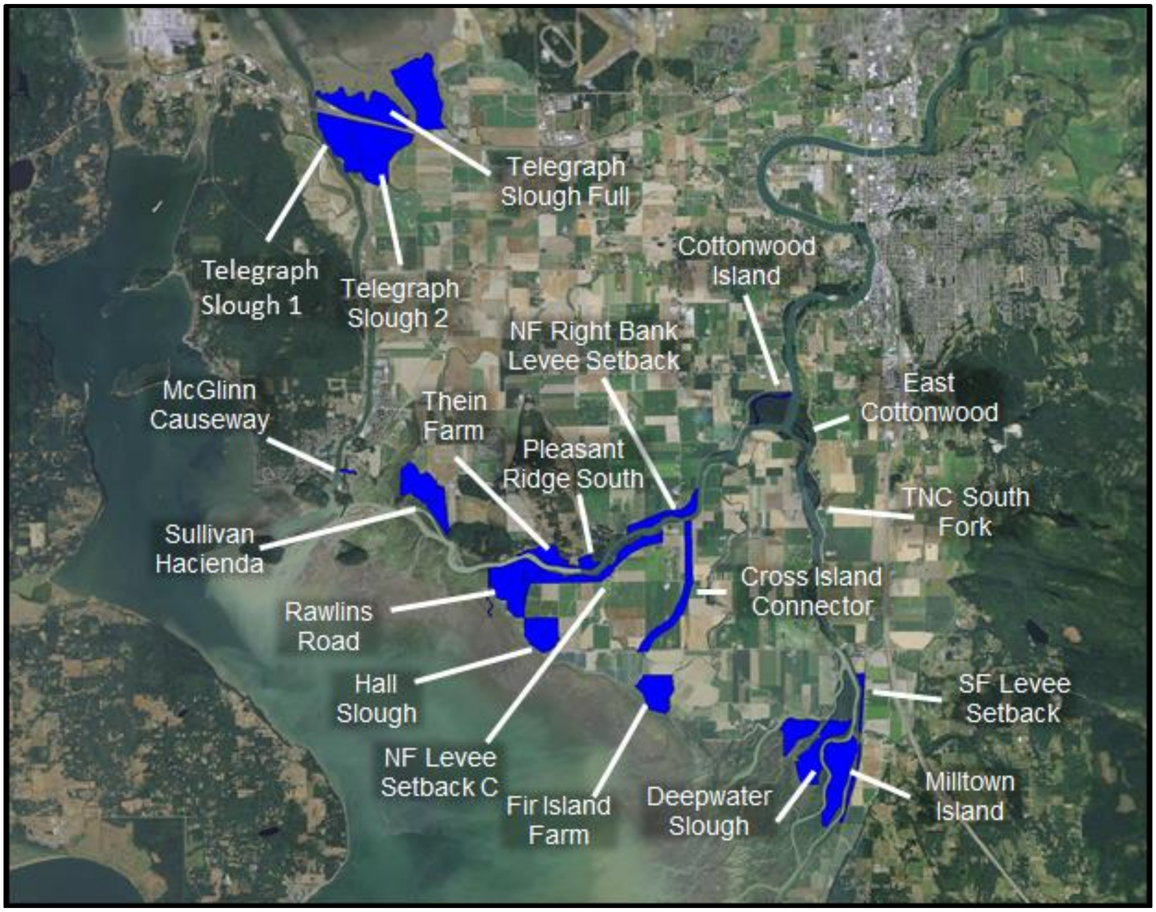

Figure K.1. A map of project area in the Climate Change with Projects simulation.

K.1 Climate Change with Projects Deliverable 1

Deliverable 1 is a set of contour maps showing the change in water surface elevation between the 2080 Climate Change Baseline Simulation (Simulation 9) and the 2080 Climate Change with Projects simulation (Simulation 10). Two conditions were compared: (1) a future low spring tide (-1.43 ft) and future Q2 flow (103,237 cfs) and (2) a future high spring tide (12.67 ft) and future Q2 flow (103,237 cfs), representing the change from future baseline and future restored conditions. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The map can be seen in Figure K.2 through Figure K.21.

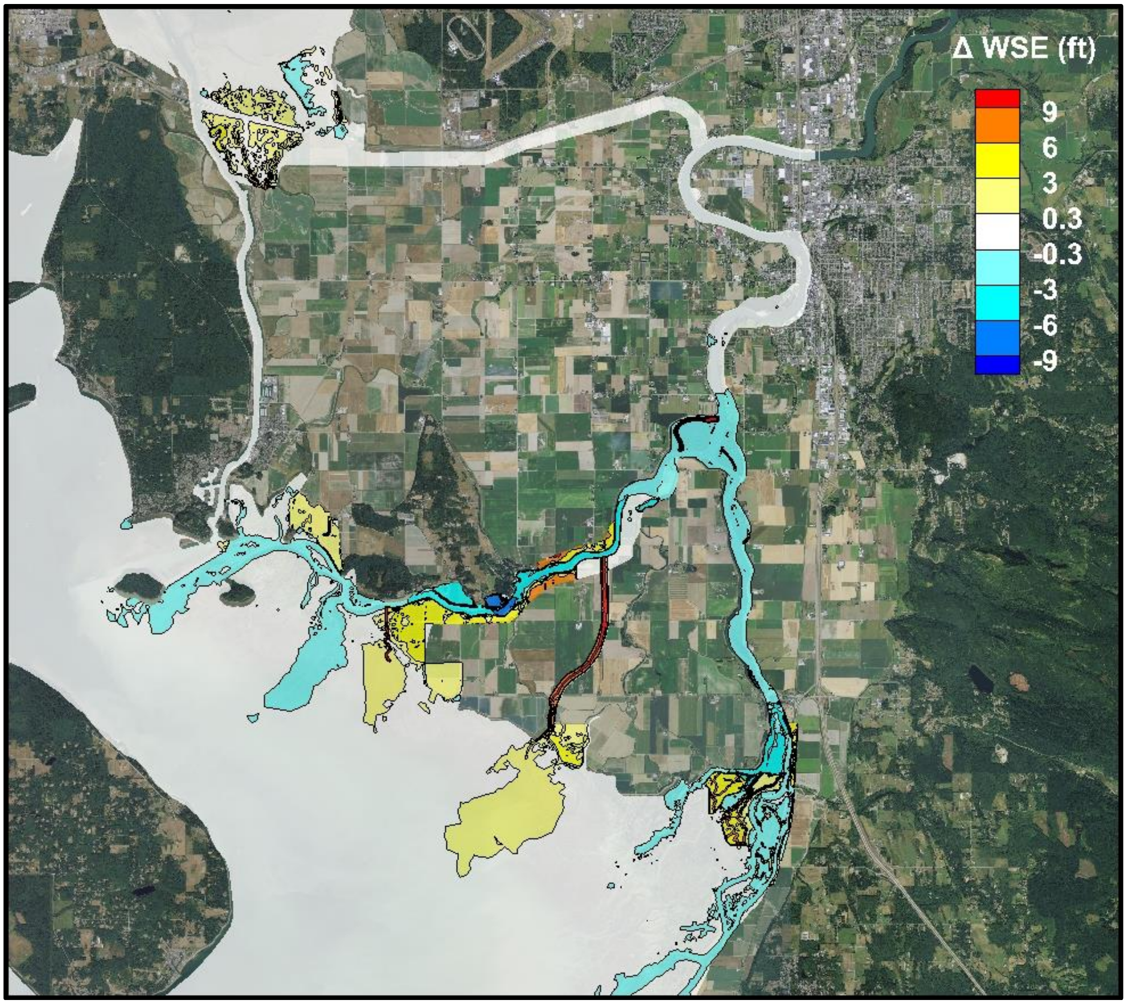

Figure K.2. Contour map of change in WSE for future Q2 and future low tide for the full basin, comparing Climate Change Baseline and Climate Change Projects simulations.

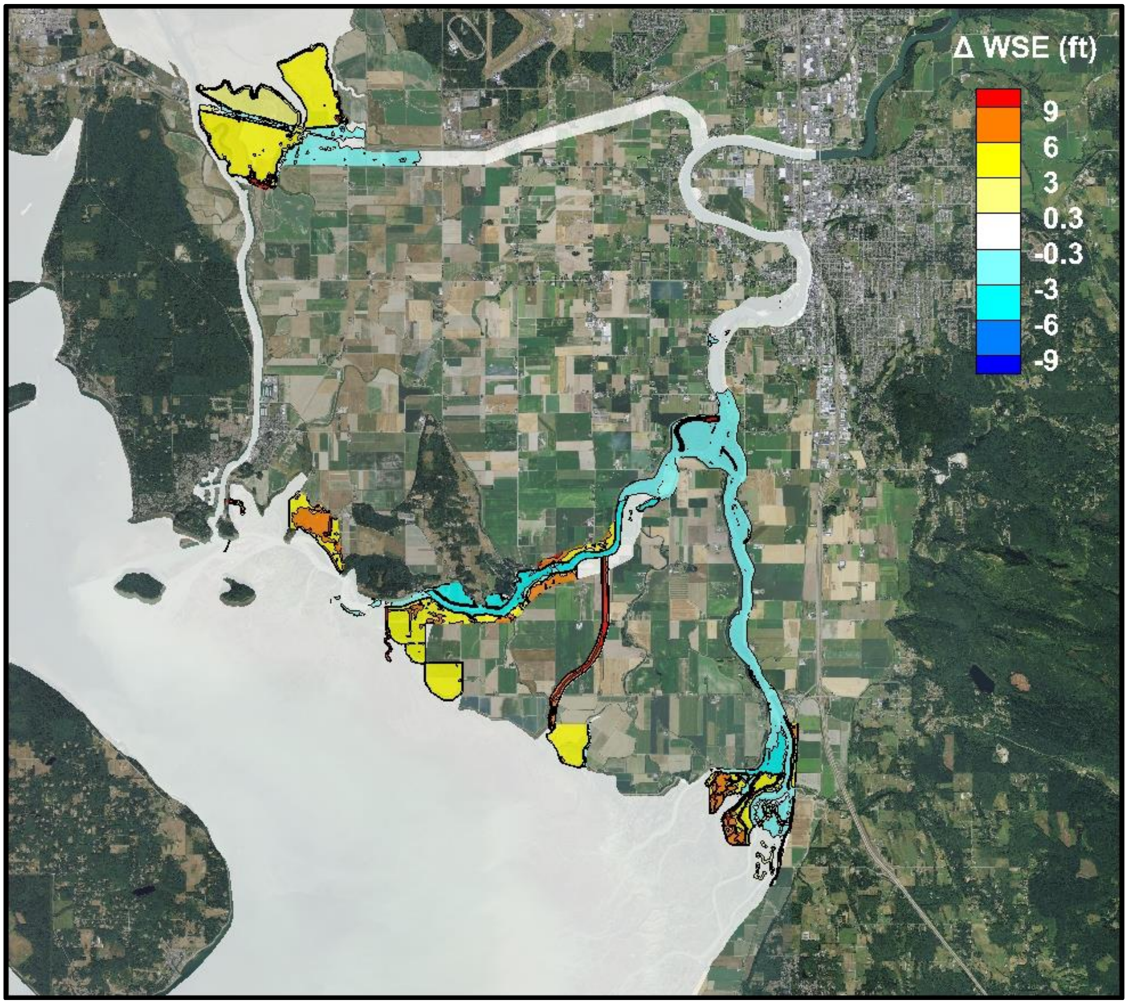

Figure K.3. Contour map of change in WSE for a future Q2 and future high tide for the full basin, comparing Climate Change Baseline and Climate Change Projects simulations.

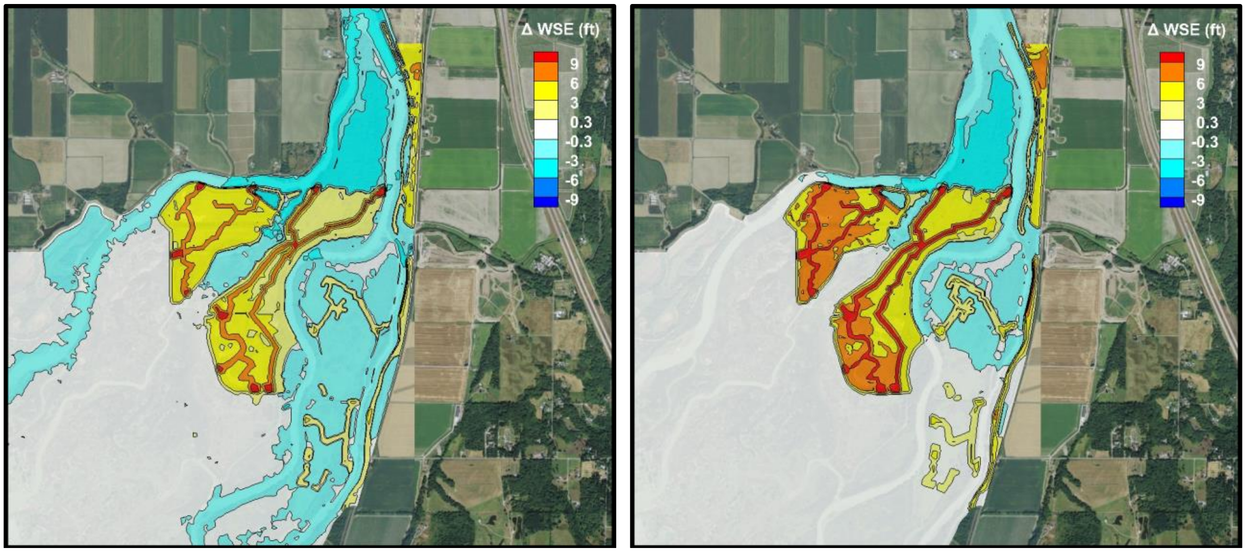

Figure K.4. Contour maps showing the change in WSE for SF Levee Setbacks 2, 3, and 4 with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

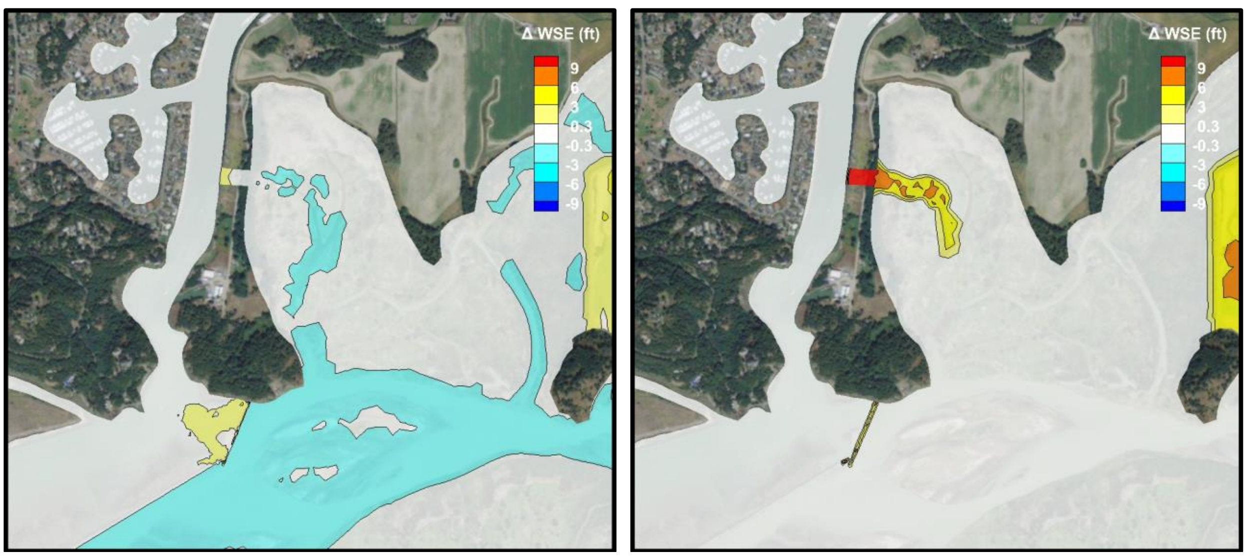

Figure K.5. Contour maps showing the change in WSE for McGlinn Causeway with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

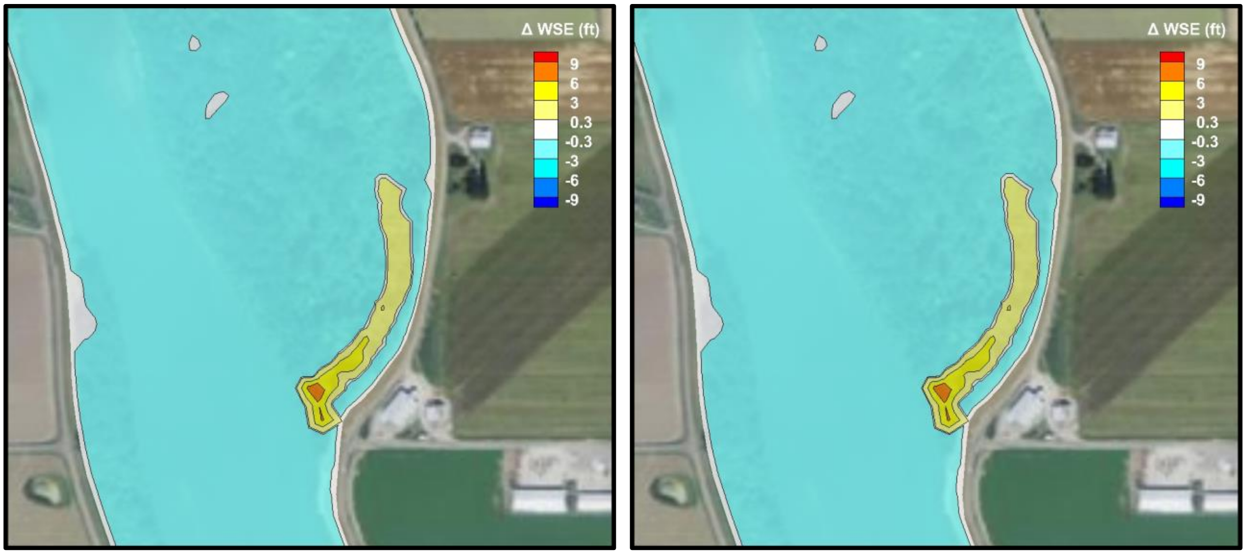

Figure K.6. Contour maps showing the change in WSE for TNC South Fork with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

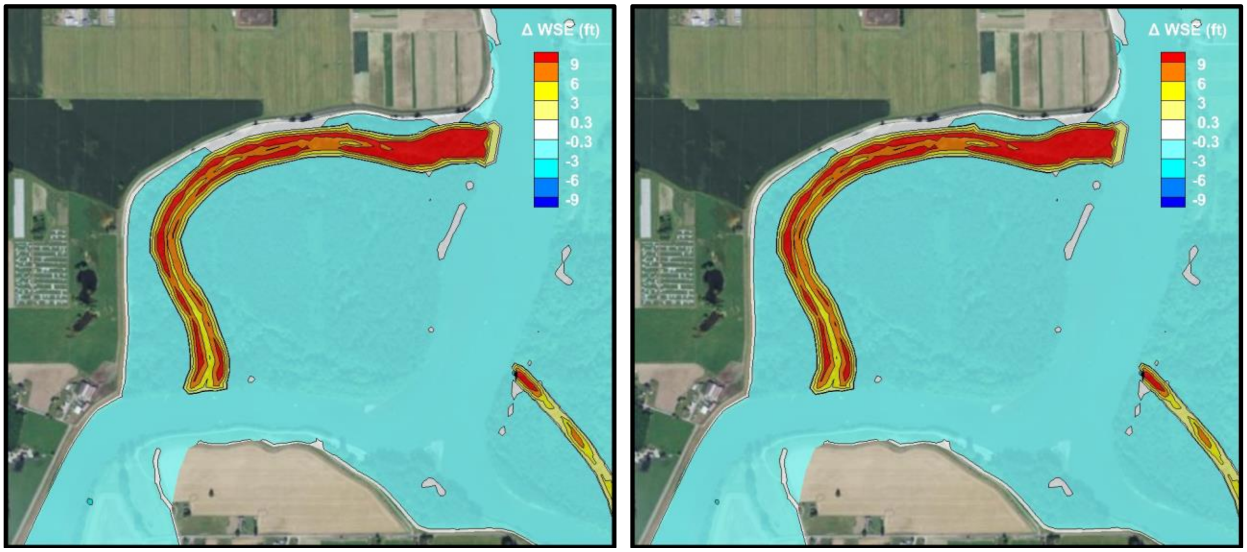

Figure K.7. Contour maps showing the change in WSE for Cottonwood Island with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

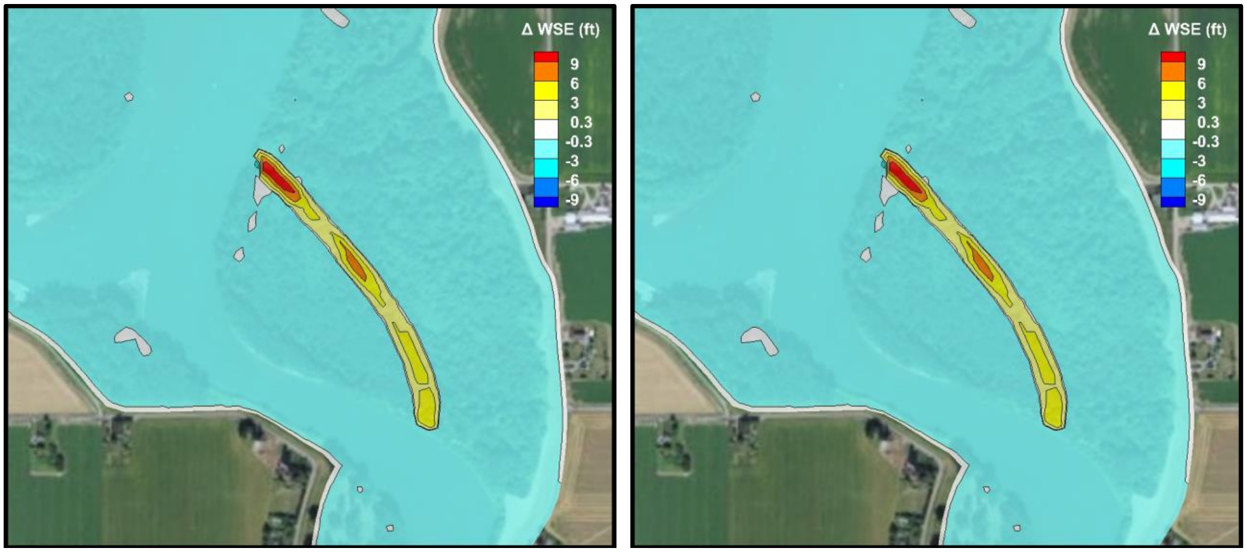

Figure K.8. Contour maps showing the change in WSE for East Cottonwood with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

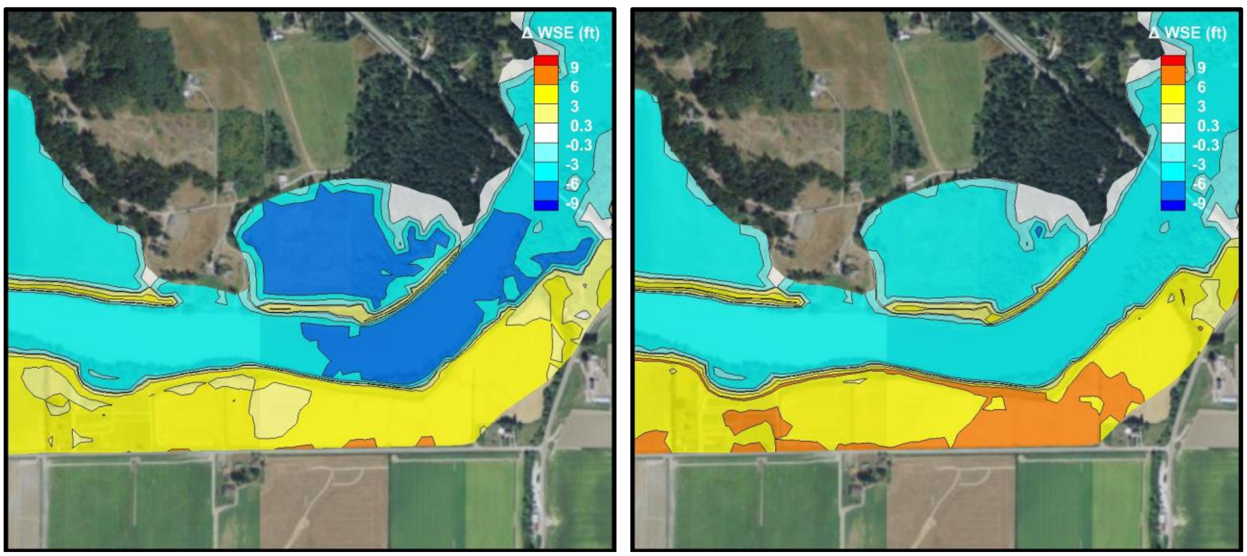

Figure K.9. Contour maps showing the change in WSE for Pleasant Ridge South with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations. A decrease in WSE is caused by water overtopping the dikes during future baseline and flowing through the upstream Cross Island Connector project during restored conditions.

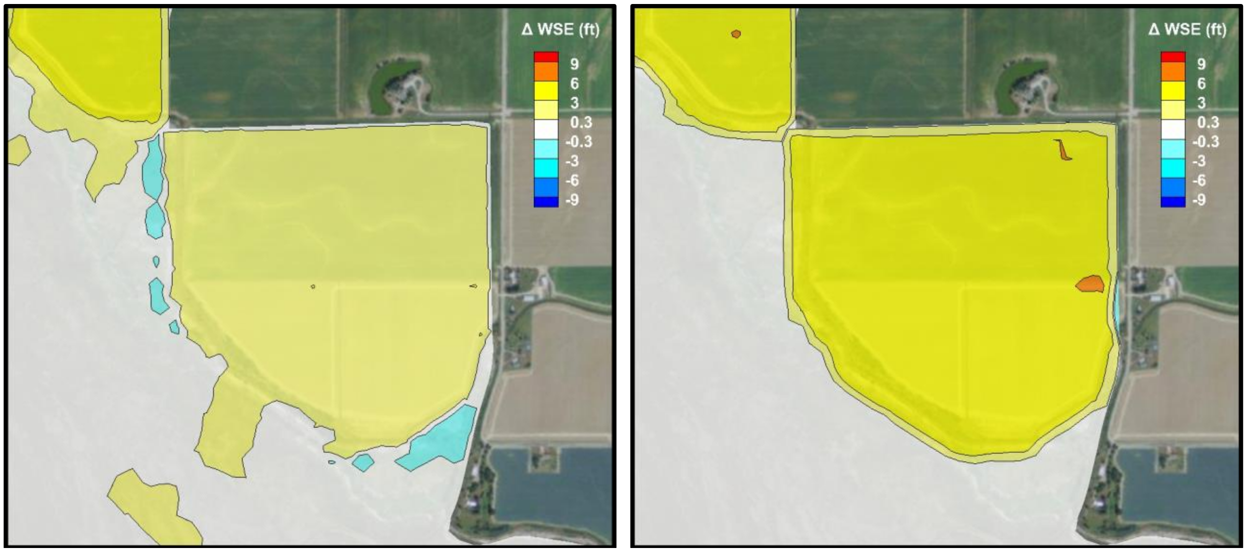

Figure K.10. Contour maps showing the change in WSE for Hall Slough with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations. Small blue reduction areas are caused by the removal of the dike, because the removed dikes acted as ramps to create drainage before.

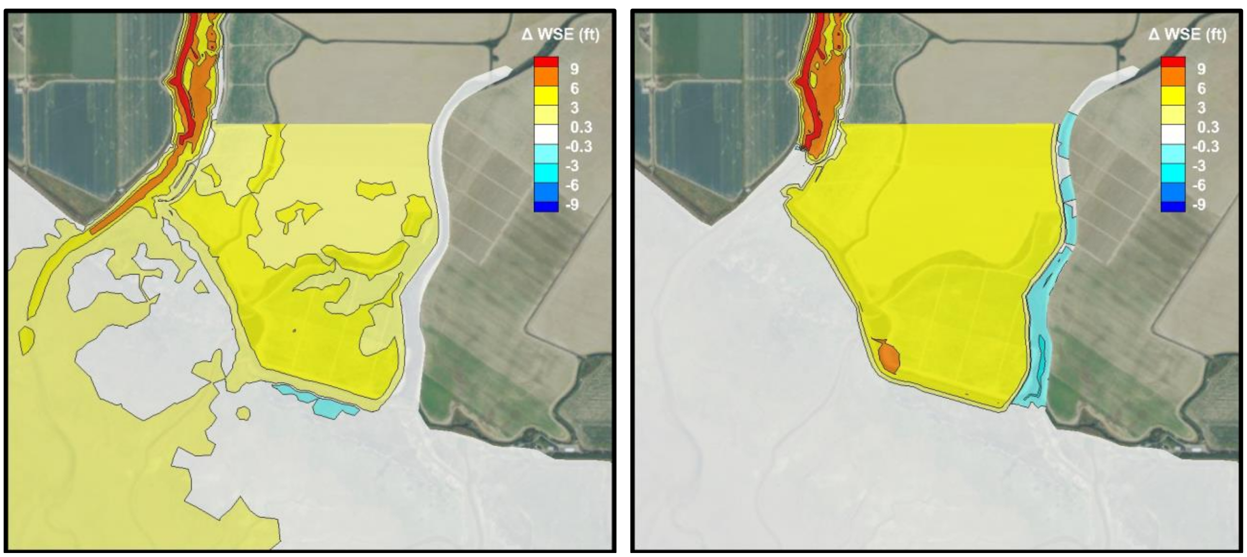

Figure K.11. Contour maps showing the change in WSE for Fir Island Farm with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

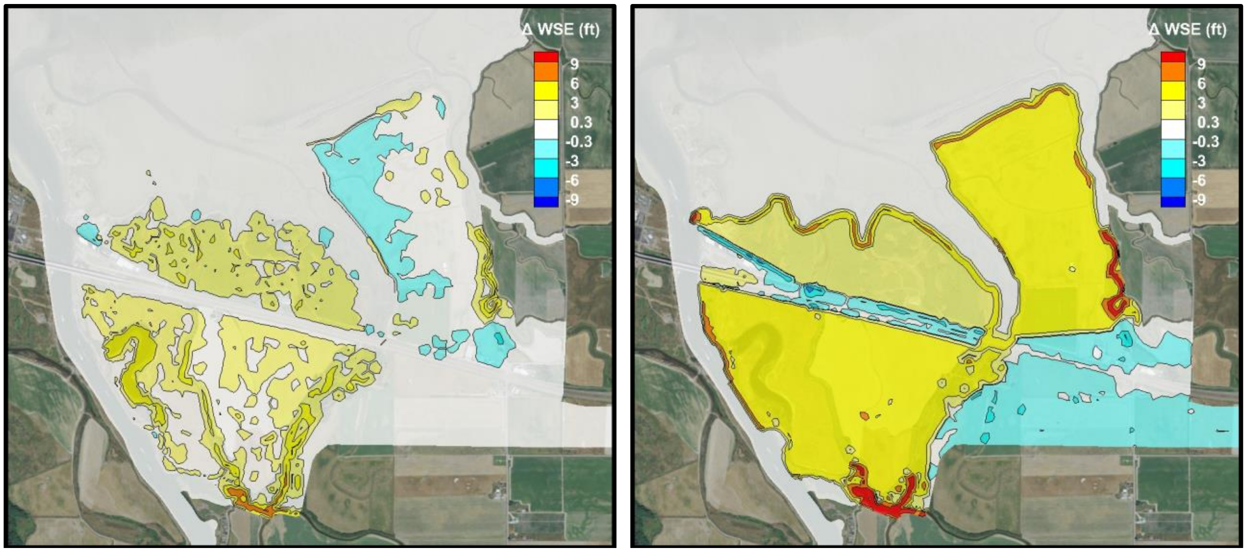

Figure K.12. Contour maps showing the change in WSE for Telegraph Slough Full with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations. Increases in WSE during low tide.

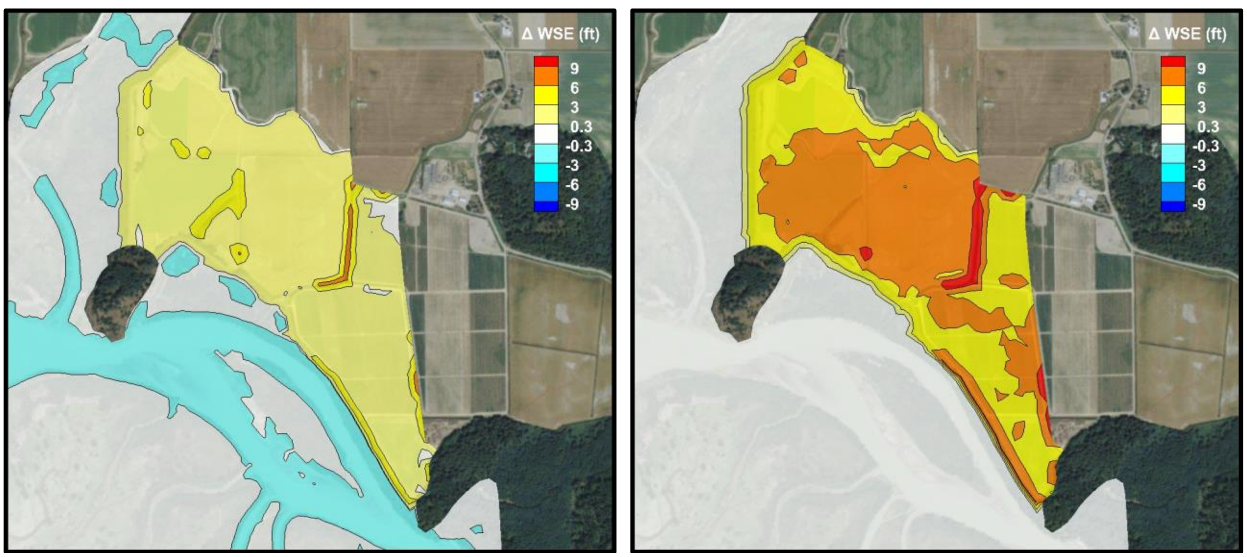

Figure K.13. Contour maps showing the change in WSE for Sullivan Hacienda with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

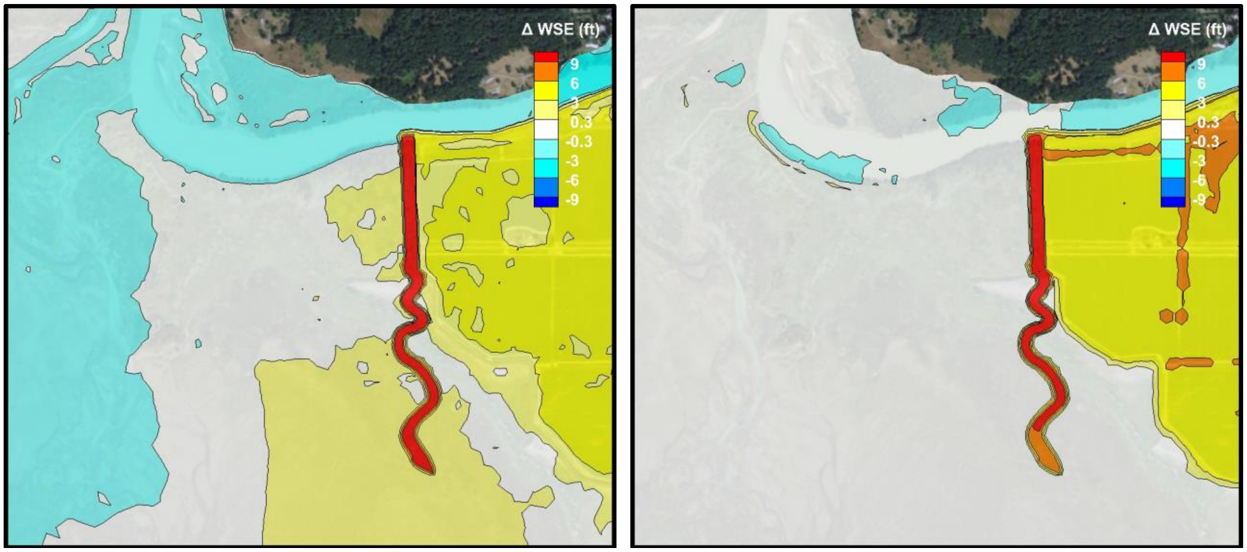

Figure K.14. Contour maps showing the change in WSE for Rawlins Road Distributary with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

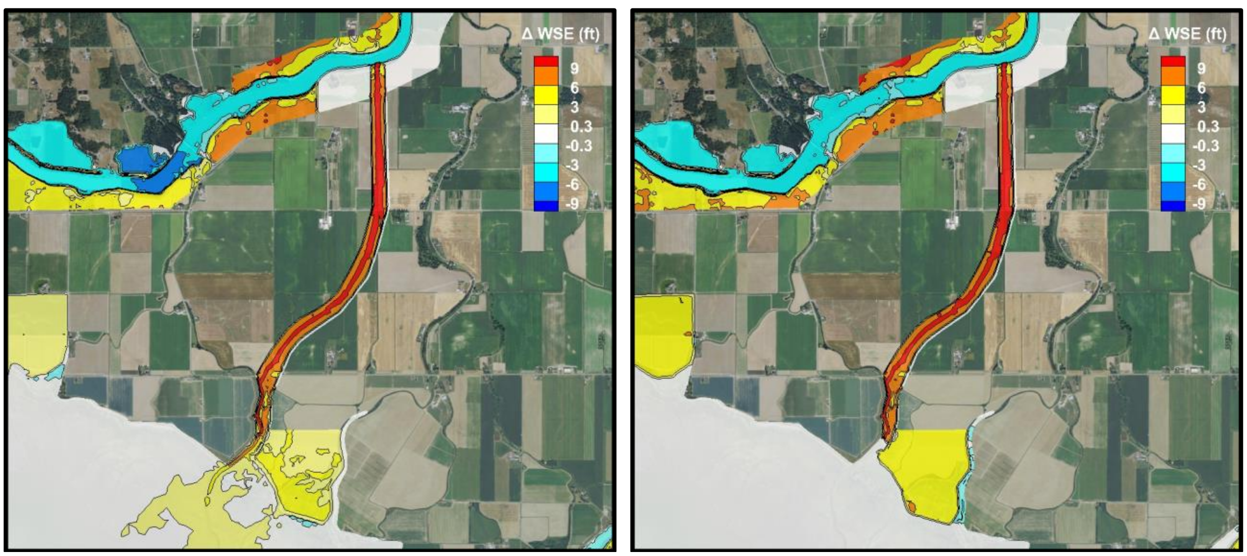

Figure K.15. Contour maps showing the change in WSE for Cross Island Connector with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

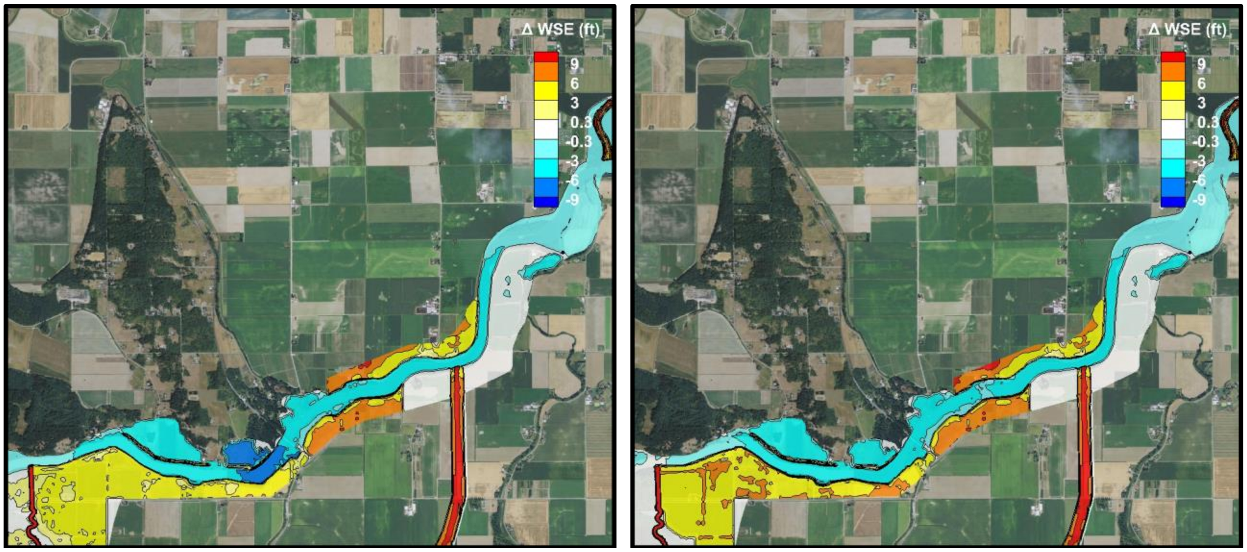

Figure K.16. Contour maps showing the change in WSE for NF Levee Setback C with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

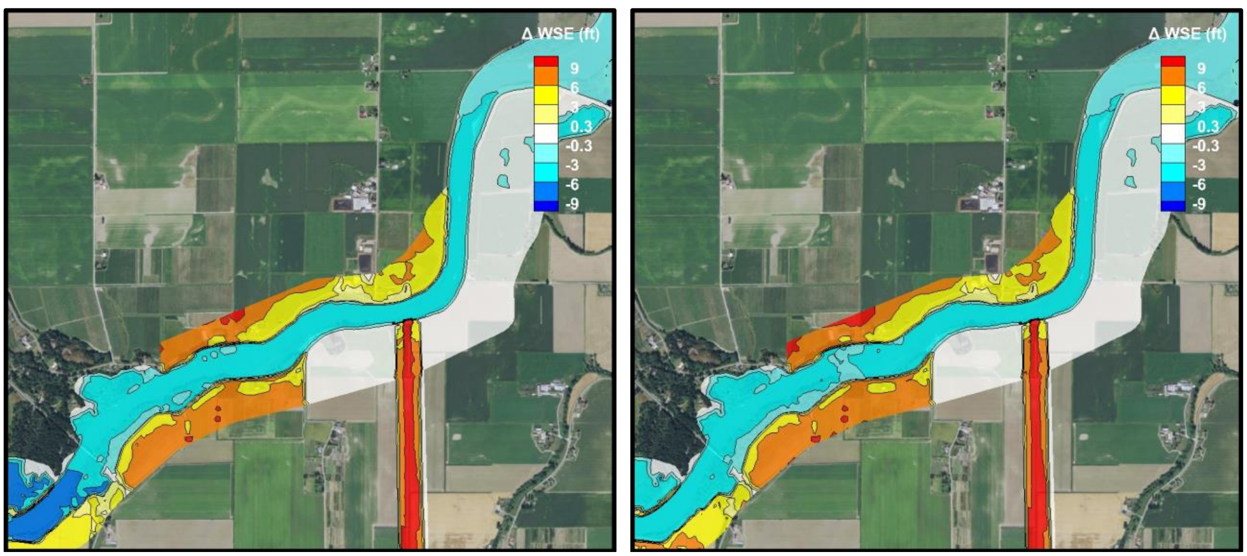

Figure K.17. Contour maps showing the change in WSE for NF Right Bank Levee Setback with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

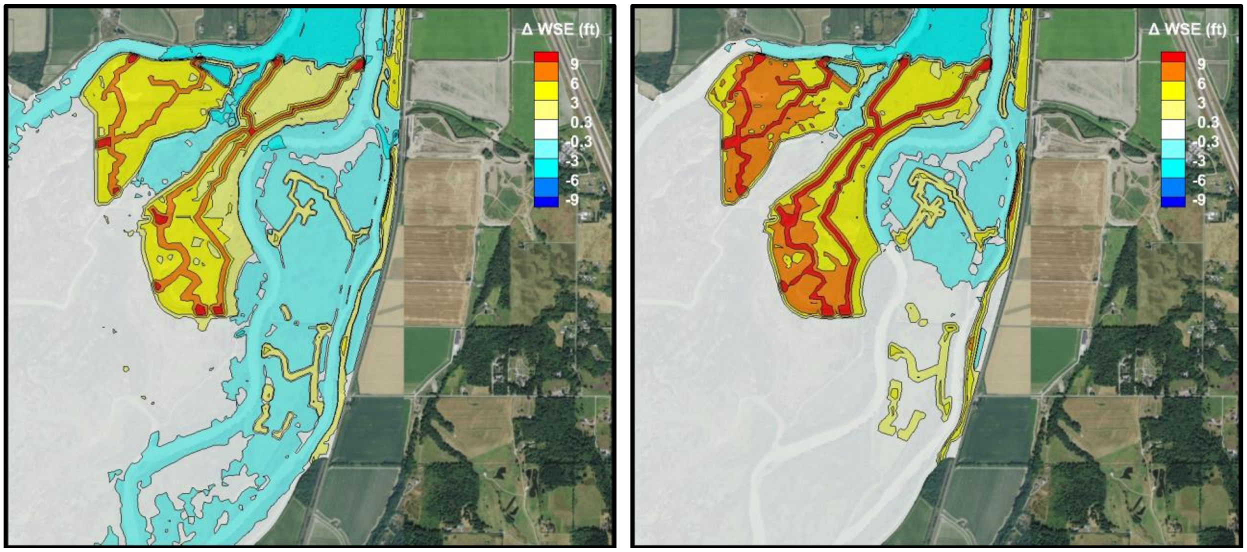

Figure K.18. Contour maps showing the change in WSE for Milltown Island with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

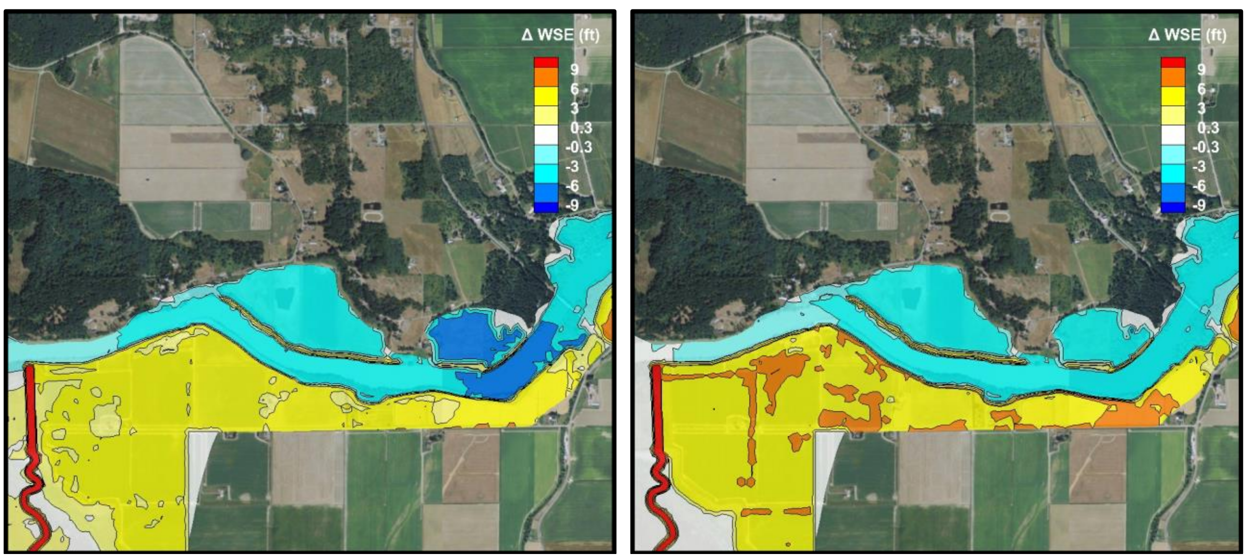

Figure K.19. Contour maps showing the change in WSE for Thein Farm with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations. A decrease in WSE is caused by water overtopping the dikes during future baseline and flowing through the upstream Cross Island Connector project during restored conditions.

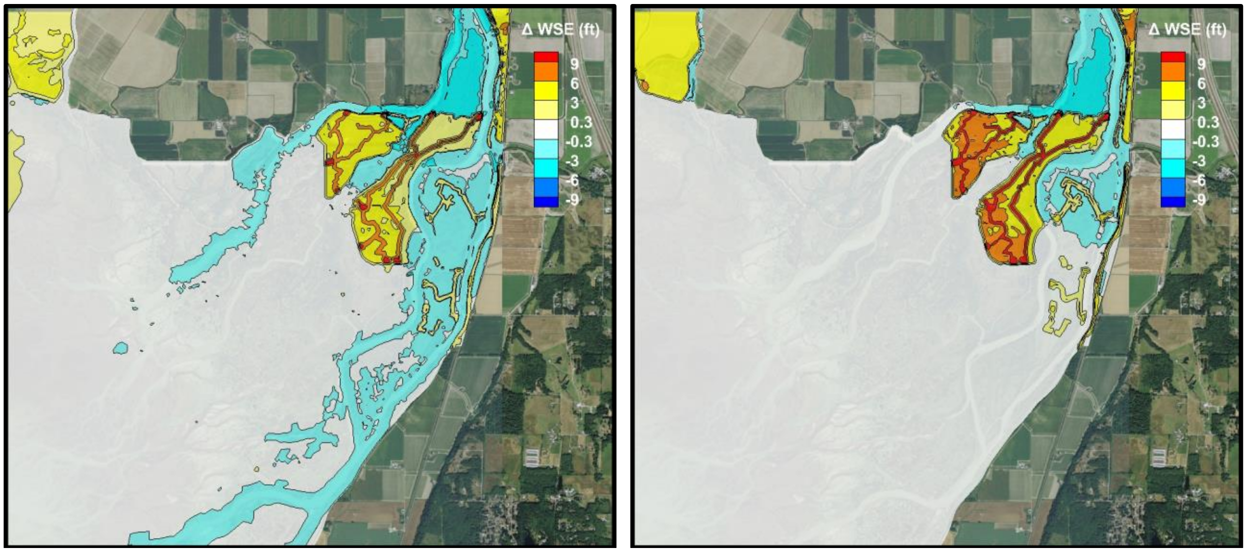

Figure K.20. Contour maps showing the change in WSE for Deepwater Slough Phase 2 with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

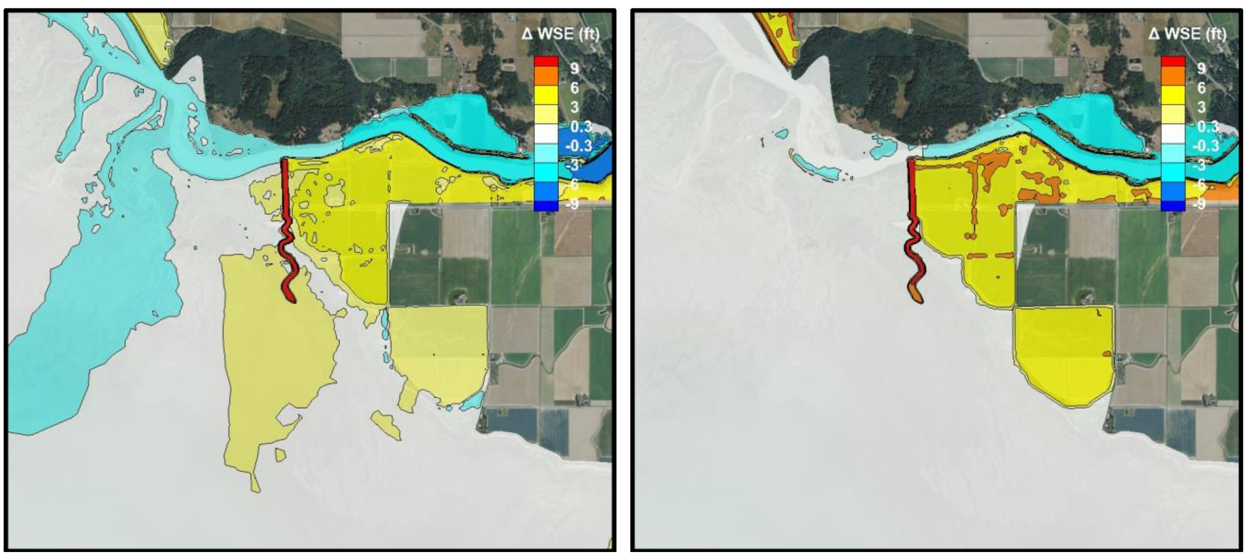

Figure K.21. Contour maps showing the change in WSE for Rawlins Road with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

K.2 Climate Change with Projects Deliverable 2

Deliverable 2 is a set of contour maps showing the water surface elevation during the 2080 Climate Change with Projects simulation (Simulation 10). Two conditions were plotted: (1) a future low spring tide (-1.43 ft) and future Q2 flow (103,237 cfs) and (2) a future high spring tide (12.67 ft) and a future Q2 flow (103,237 cfs). All WSE values are relative to the NAVD88 datum. Areas that are not inundated are blanked out. The small polygons seen in some Bayfront maps are artifacts of a previous high tide caused by small pooling that does not dissipate because the model does not calculate evaporation or seepage of water into the ground. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure K.22 through Figure K.41.

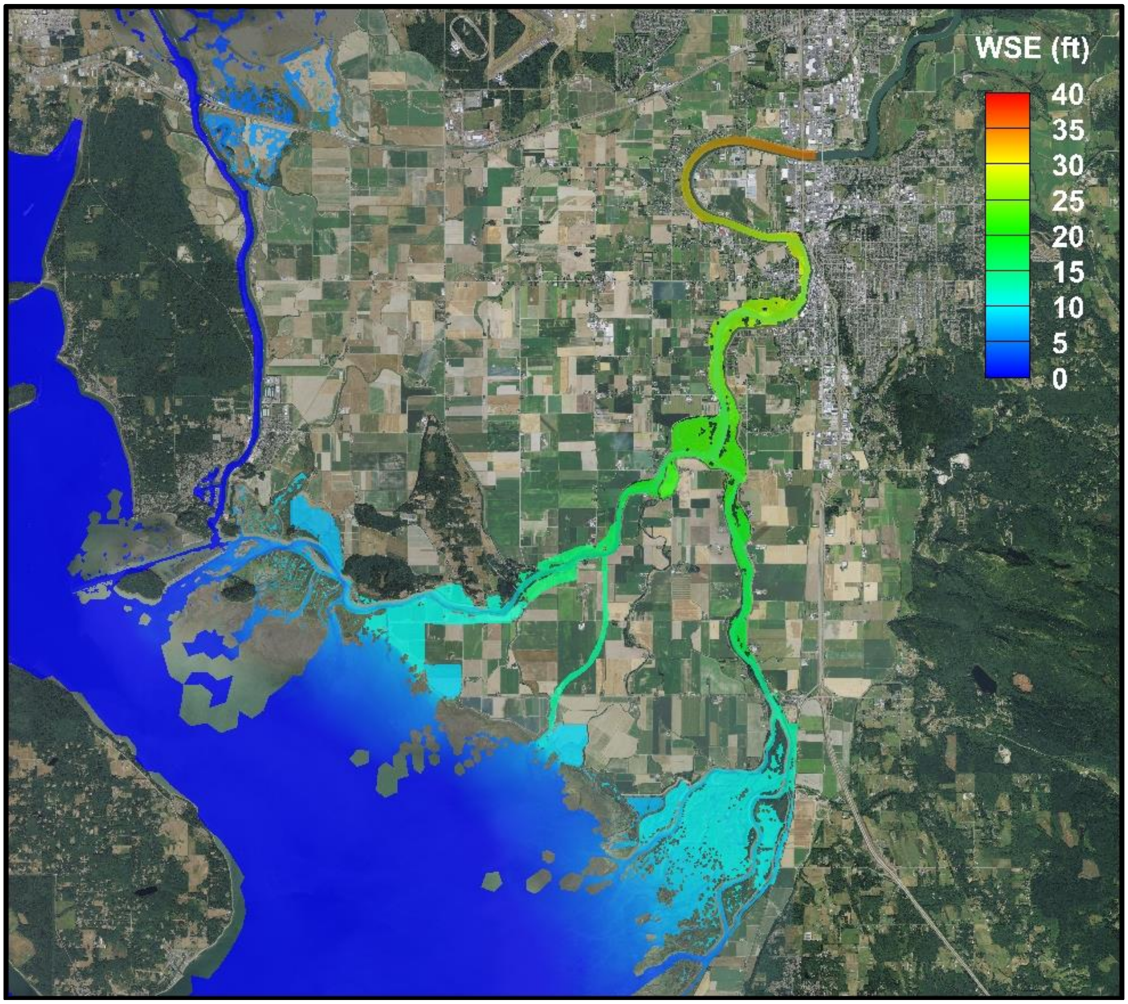

Figure K.22. Contour map of water surface elevation for the full domain during the 2080 Climate Change with Projects simulation with future Q2 flow and future low spring tide.

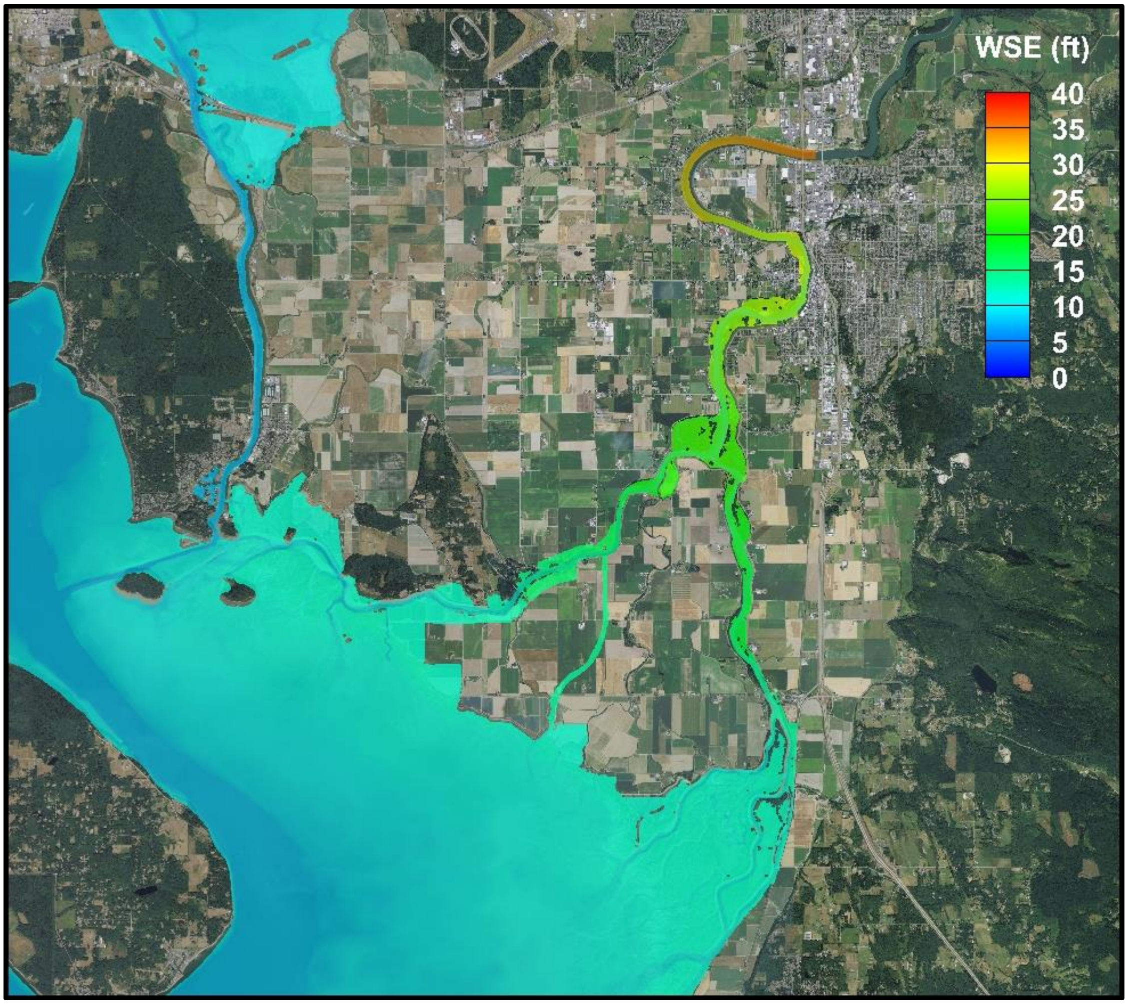

Figure K.23. Contour map of water surface elevation for the full domain during the 2080 Climate Change Baseline Simulation with future Q2 flow and future high spring tide.

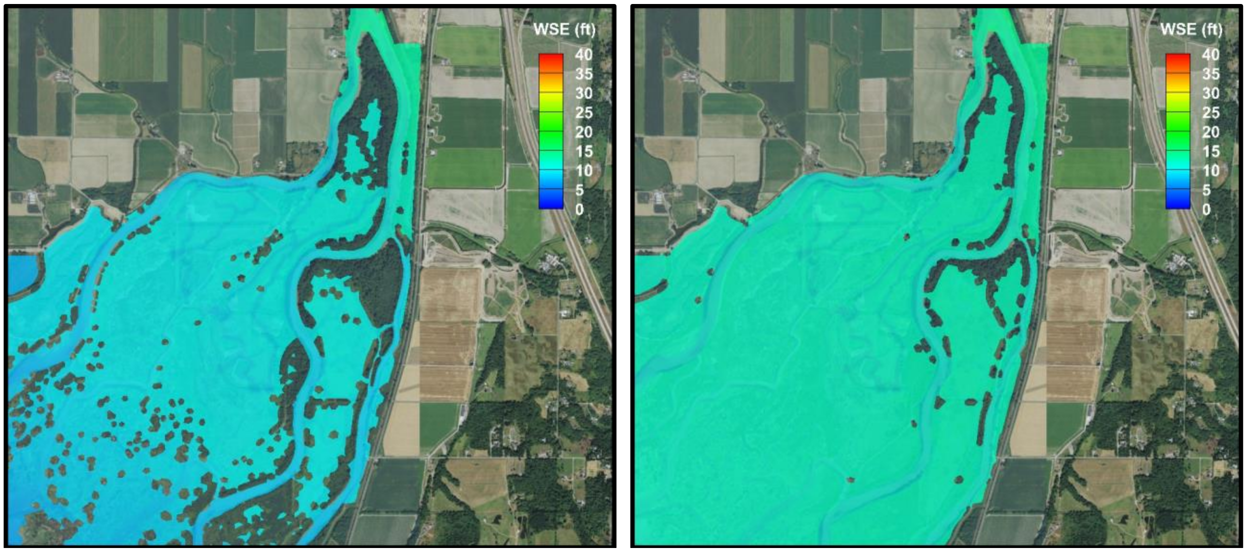

Figure K.24. Contour maps of water surface elevation for SF Levee Setbacks 2, 3, and 4 during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

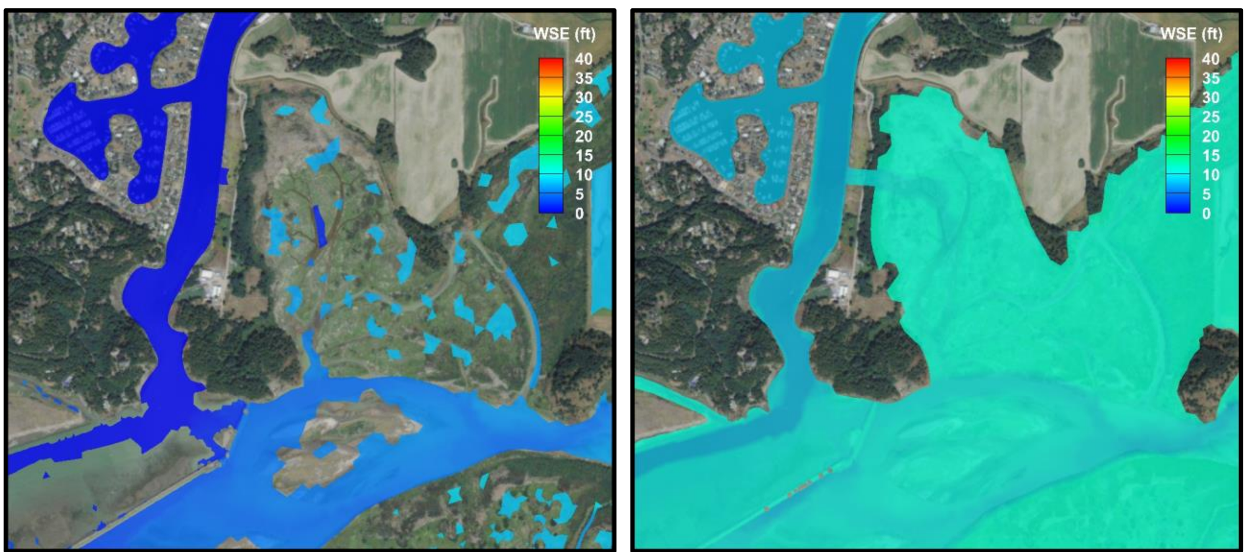

Figure K.25. Contour maps of water surface elevation for McGlinn Causeway during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

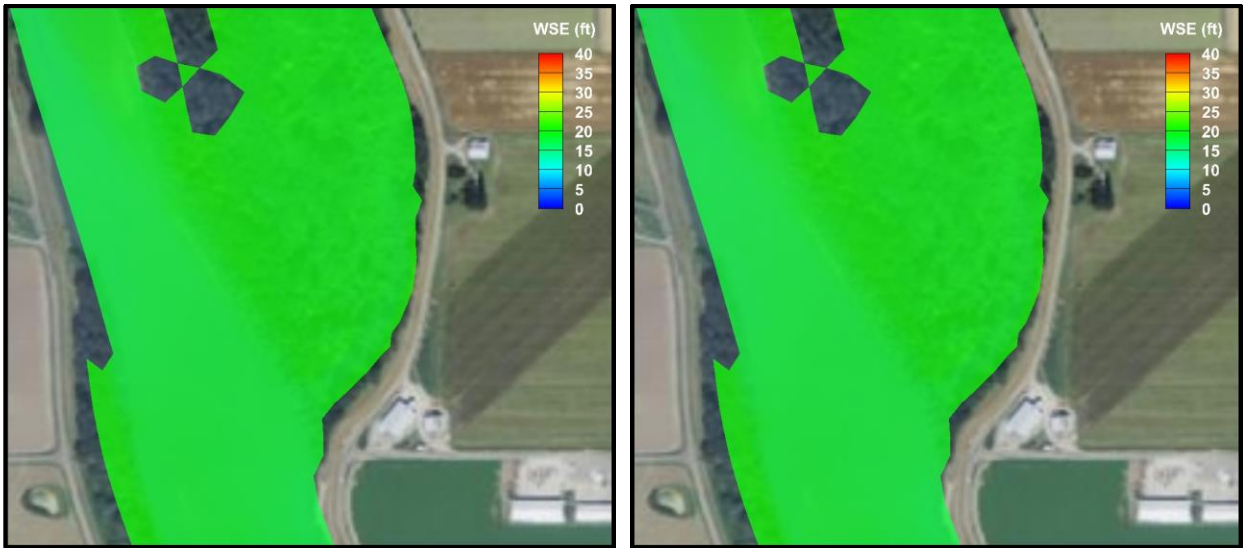

Figure K.26. Contour maps of water surface elevation for TNC South Fork during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

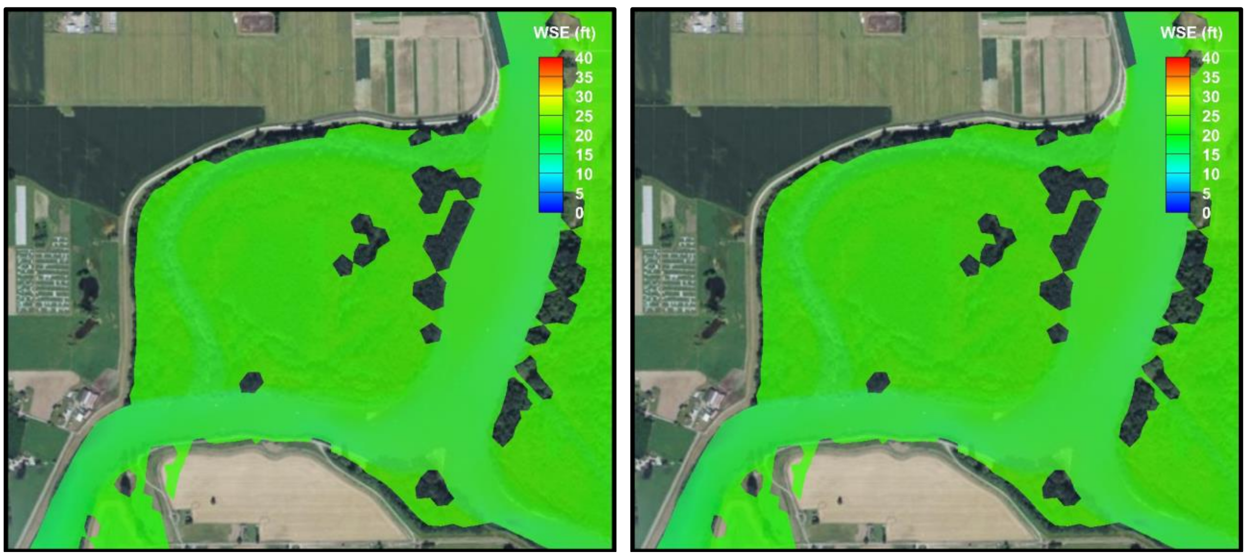

Figure K.27. Contour maps of water surface elevation for Cottonwood Island during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

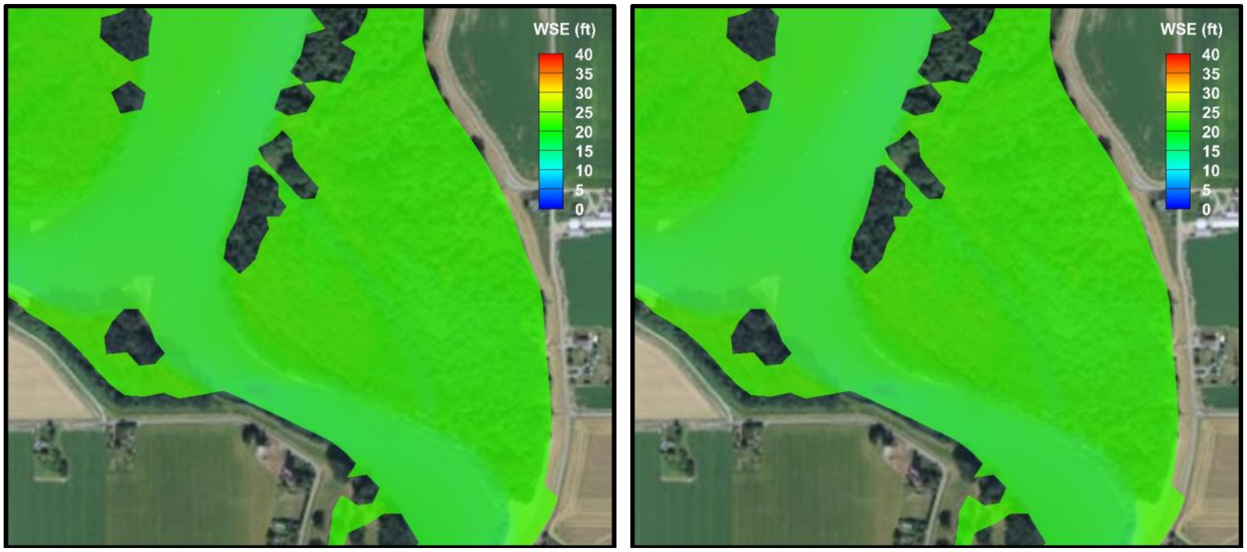

Figure K.28. Contour maps of water surface elevation for East Cottonwood during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

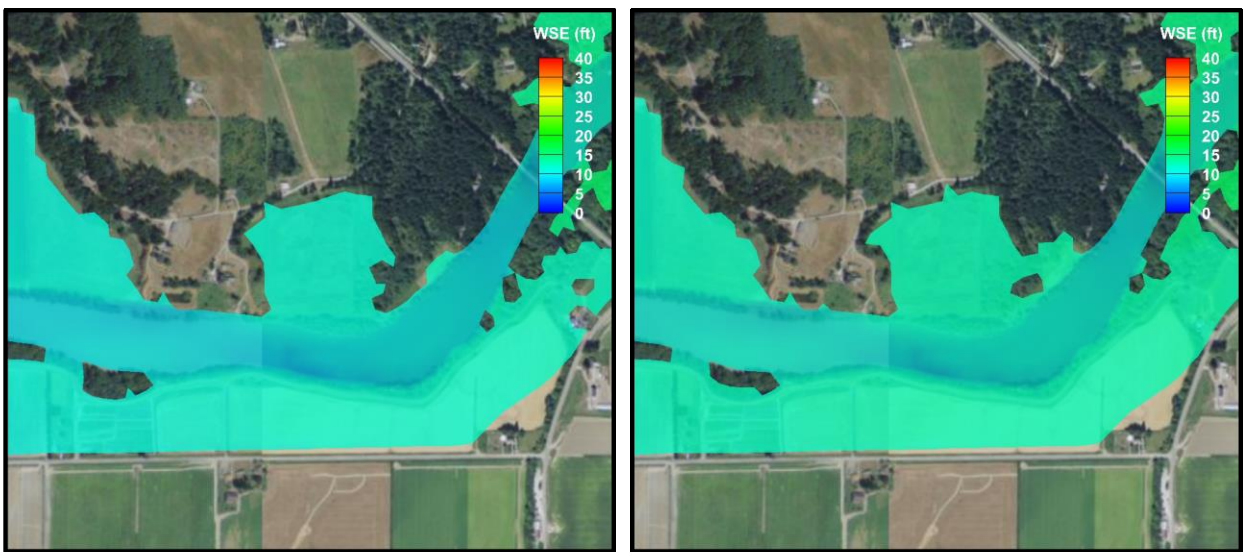

Figure K.29. Contour maps of water surface elevation for Pleasant Ridge South during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

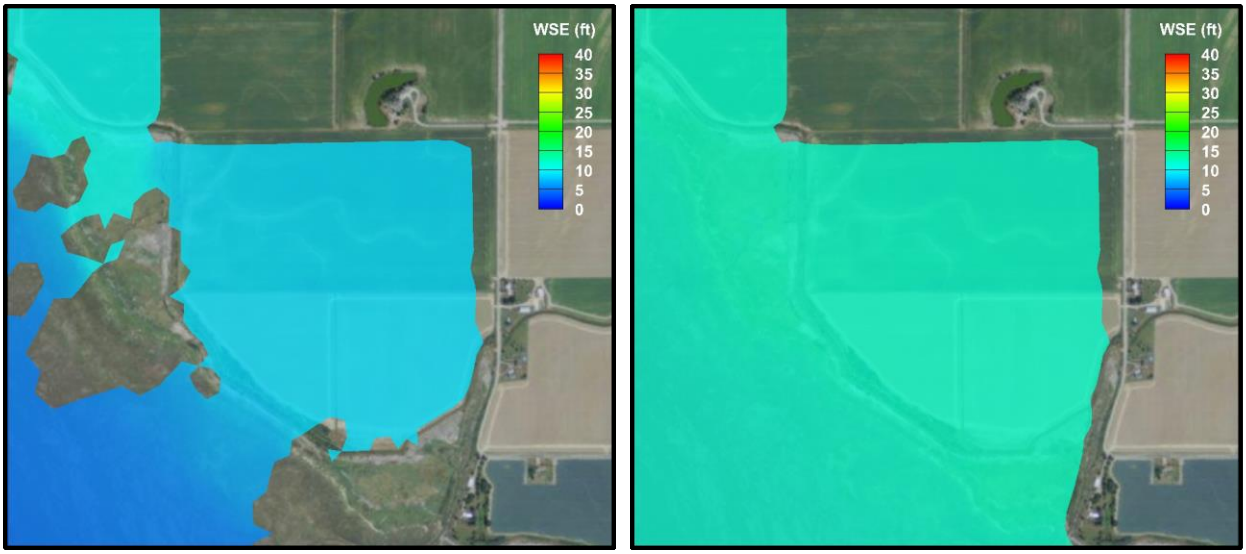

Figure K.30. Contour maps of water surface elevation for Hall Slough during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

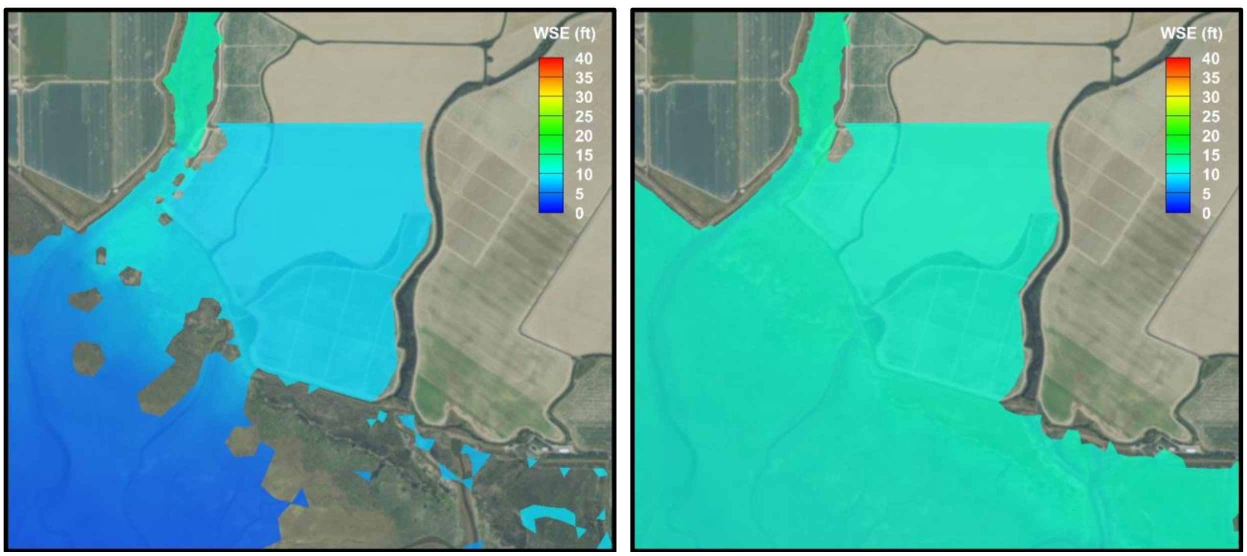

Figure K.31. Contour maps of water surface elevation for Fir Island Farm during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

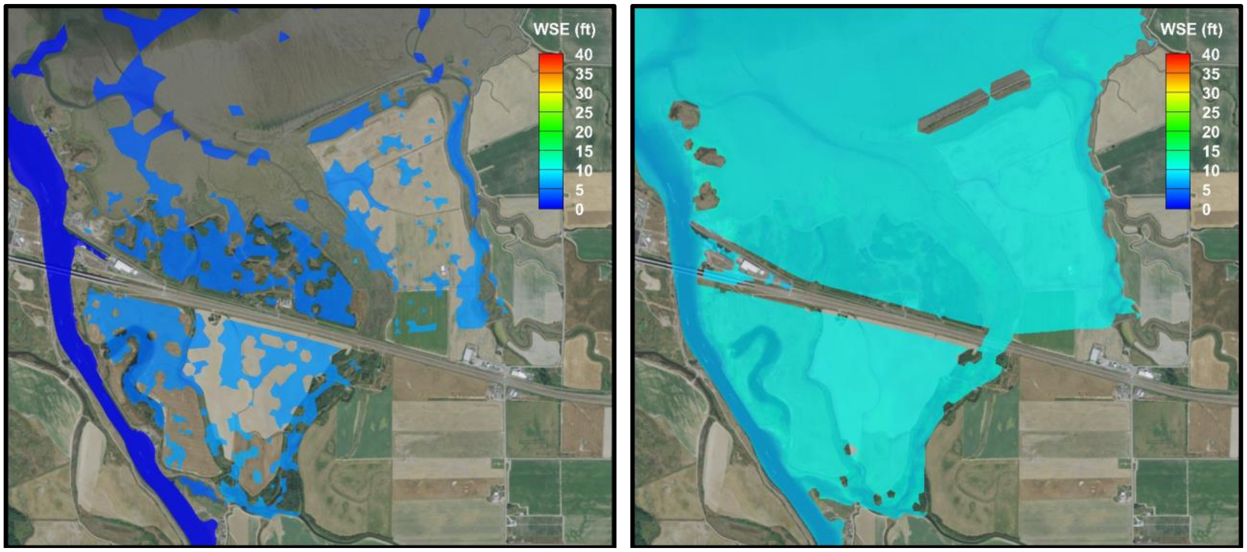

Figure K.32. Contour maps of water surface elevation for Telegraph Slough Full during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

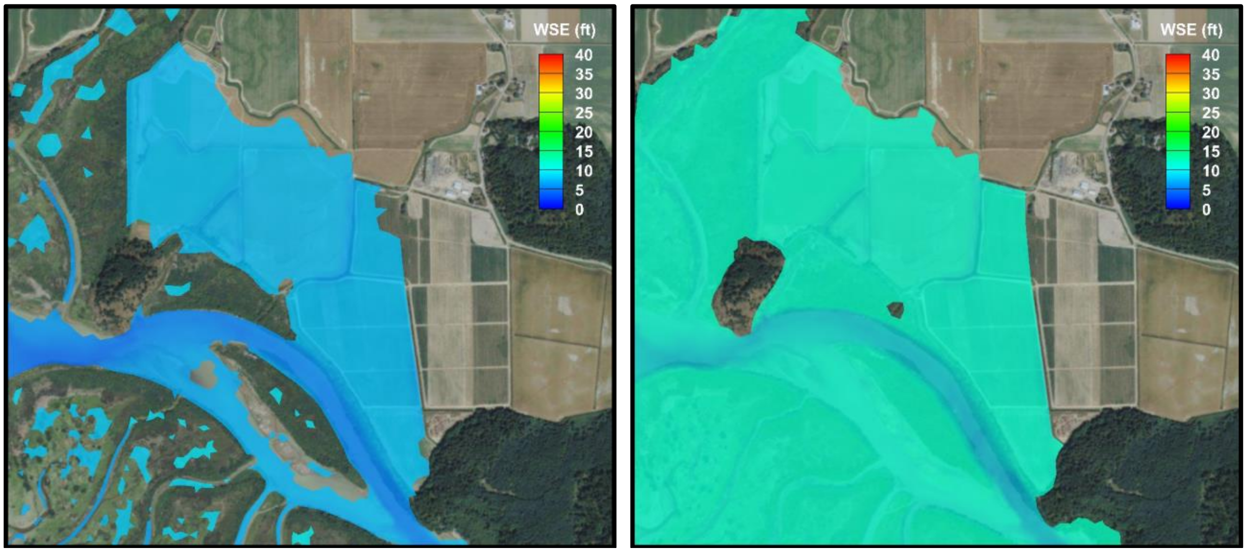

Figure K.33. Contour maps of water surface elevation for Sullivan Hacienda during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

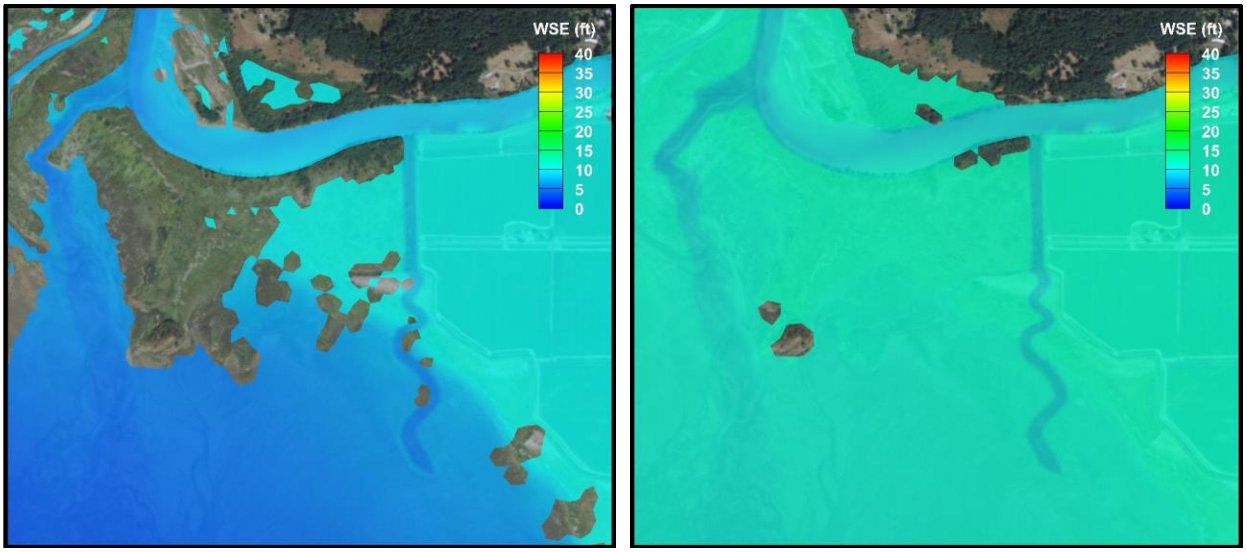

Figure K.34. Contour maps of water surface elevation for Rawlins Road Distributary during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

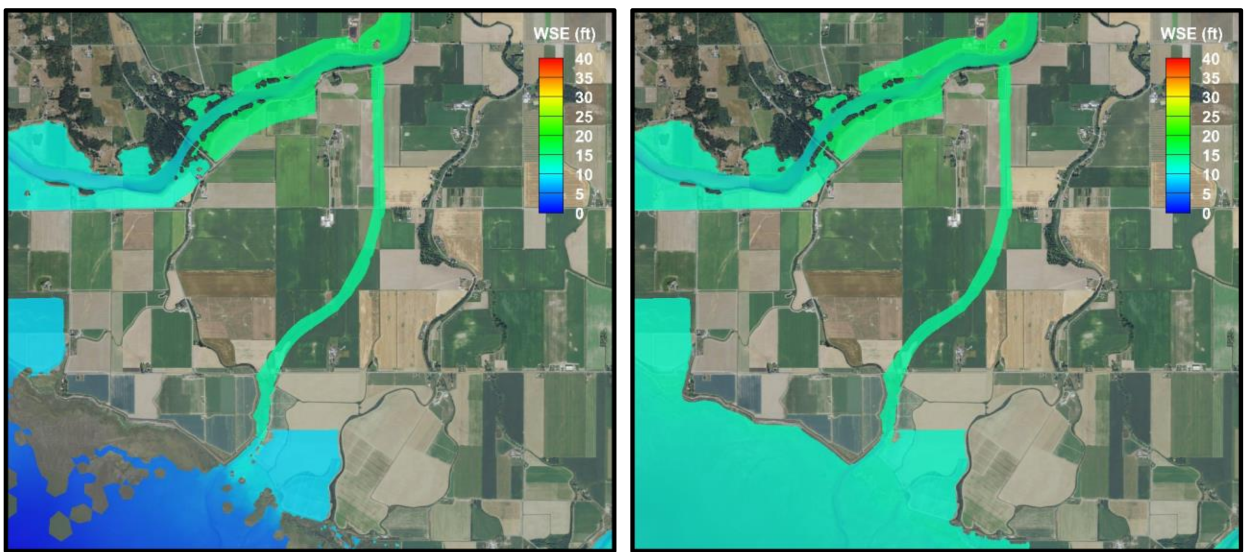

Figure K.35. Contour maps of water surface elevation for Cross Island Connector during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

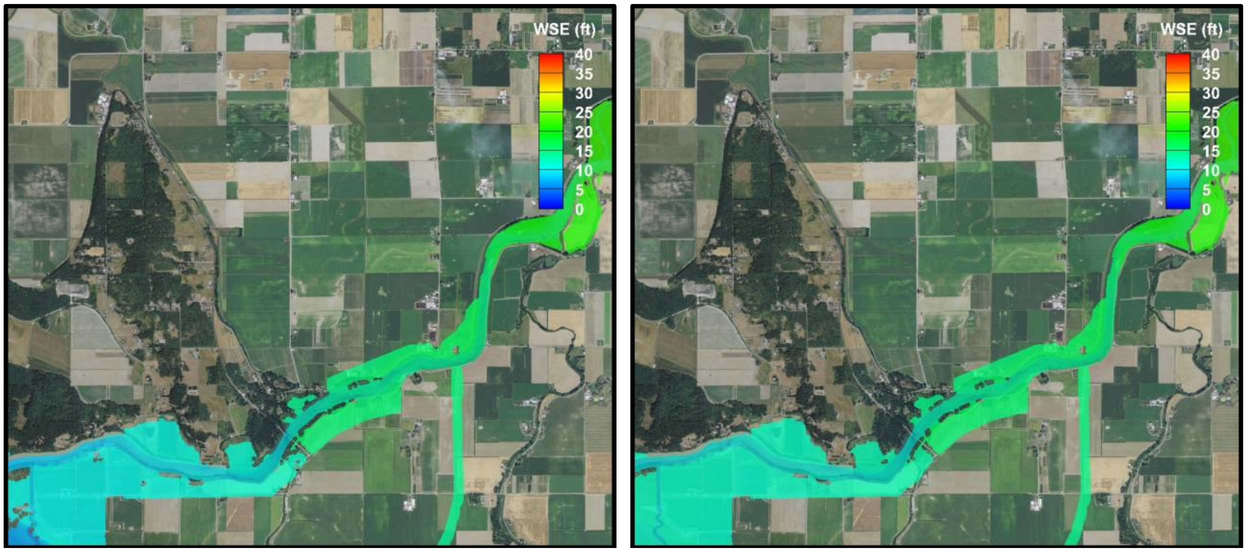

Figure K.36. Contour maps of water surface elevation for NF Levee Setback C during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

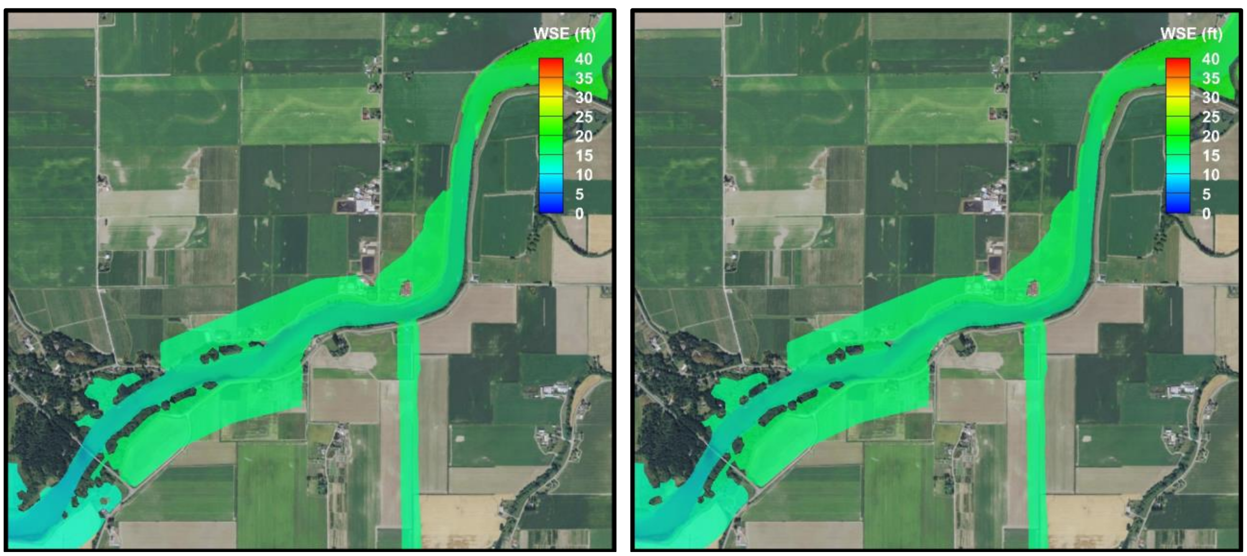

Figure K.37. Contour maps of water surface elevation for NF Right Bank Levee Setback during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

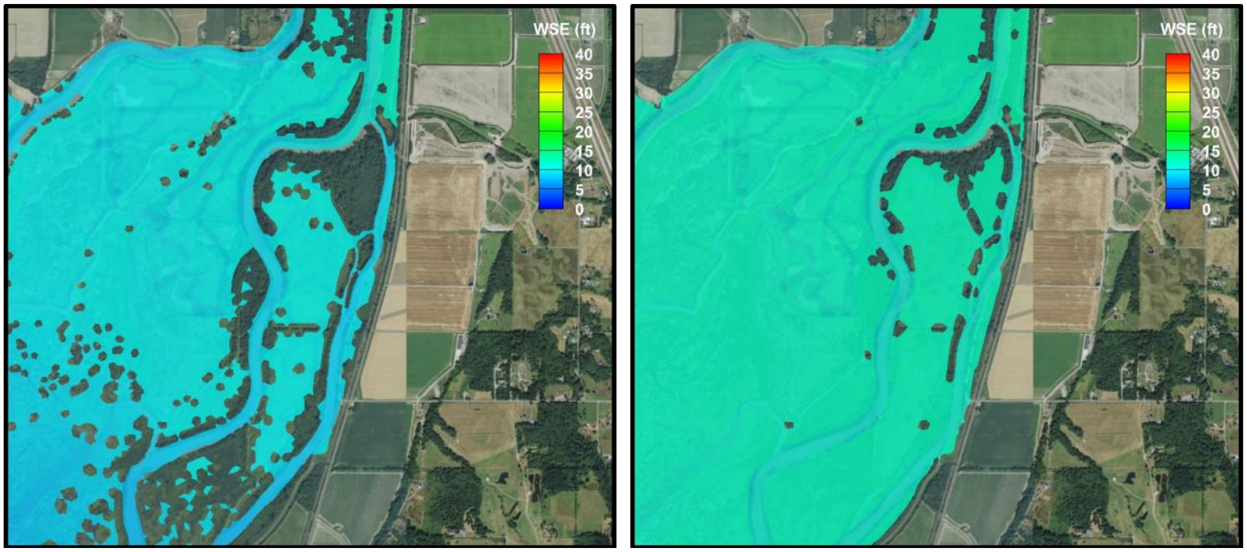

Figure K.38. Contour maps of water surface elevation for Milltown Island during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

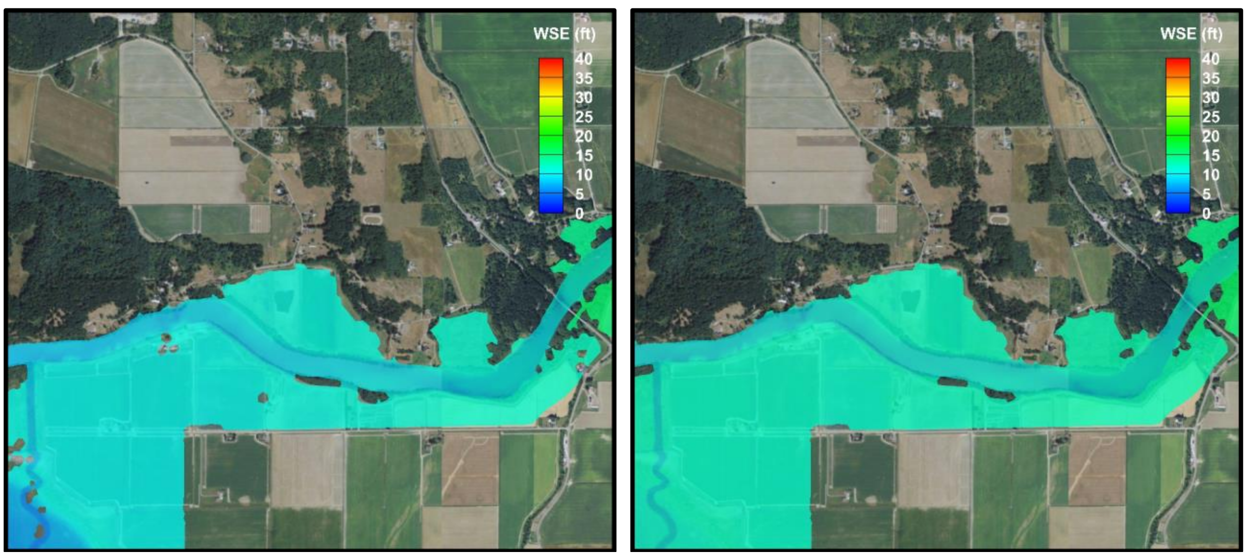

Figure K.39. Contour maps of water surface elevation for Thein Farm during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

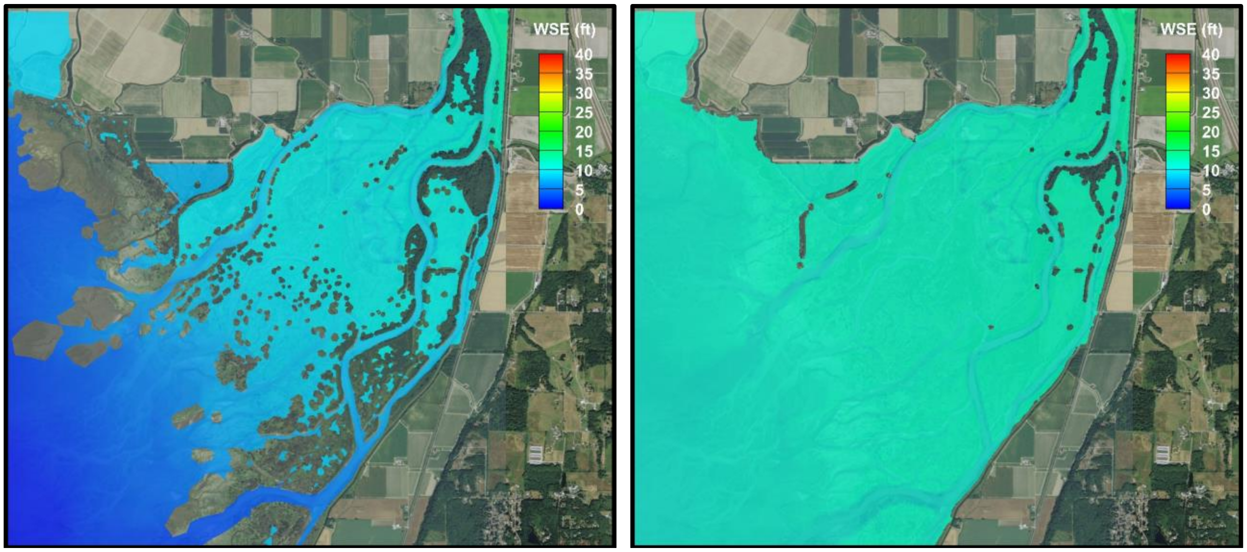

Figure K.40. Contour maps of water surface elevation for Deepwater Slough Phase 2 during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

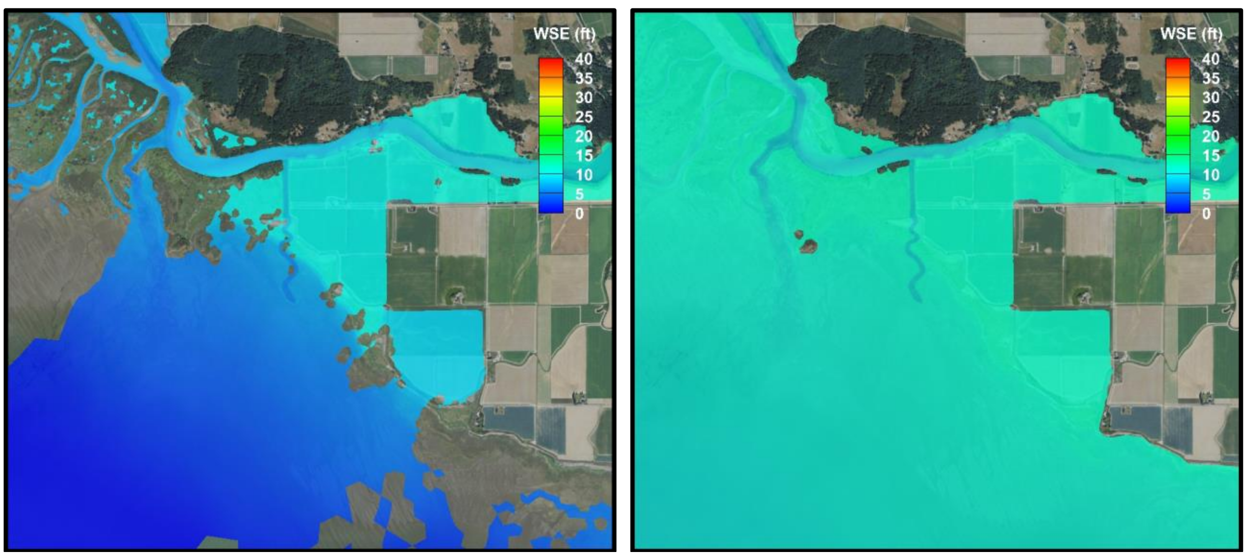

Figure K.41. Contour maps of water surface elevation for Rawlins Road during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

K.3 Climate Change with Projects Deliverable 3

Deliverable 3 is a set of contour maps showing the change in water surface elevation between the 2080 Climate Change Baseline Simulation (Simulation 9) and the 2080 Climate Change with Projects simulation (Simulation 10). The compared conditions were a low flow (12,000 cfs) and future high spring tide (12.67 ft), representing the change from future baseline and future restored conditions. No change is represented as white across the extent of the model grid. A high-resolution, georeferenced map with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The map can be seen in Figure K.42 to Figure K.60.

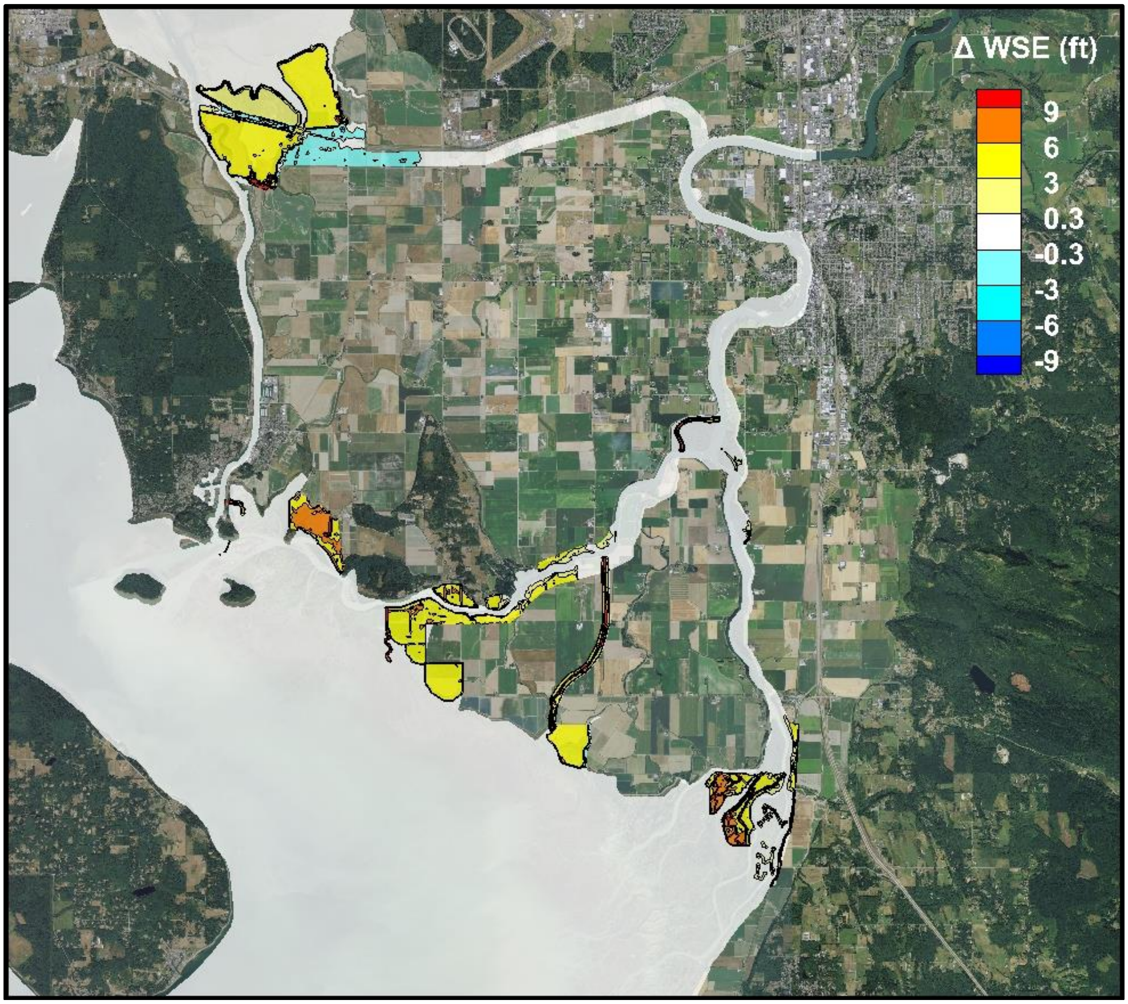

Figure K.42. Contour map of change in WSE for low flow and high tide for the full basin, comparing Climate Change Baseline and Climate Change Projects simulations.

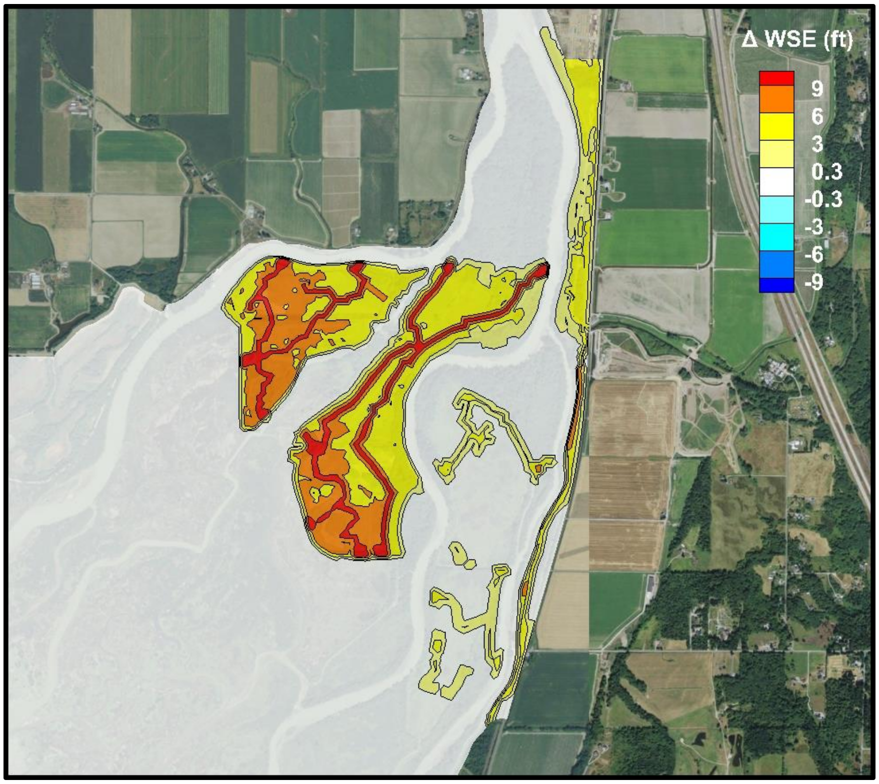

Figure K.43. Contour map of change in WSE for low flow and high tide for SF Levee Setbacks 2, 3, and 4, comparing Climate Change Baseline and Climate Change Projects simulations.

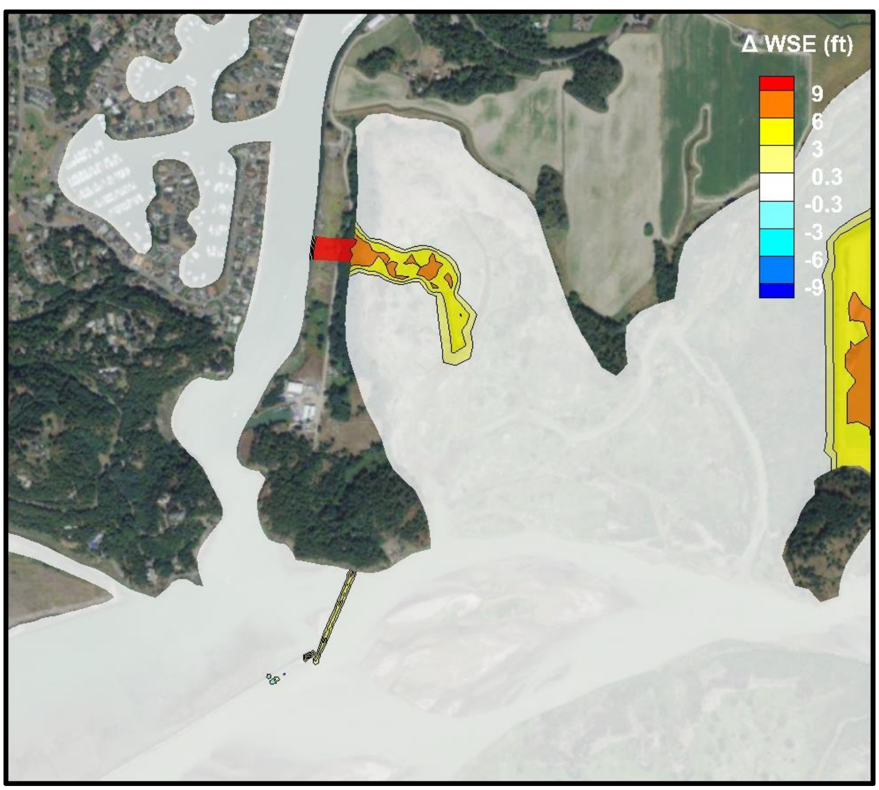

Figure K.44. Contour map of change in WSE for low flow and high tide for McGlinn Causeway, comparing Climate Change Baseline and Climate Change Projects simulations.

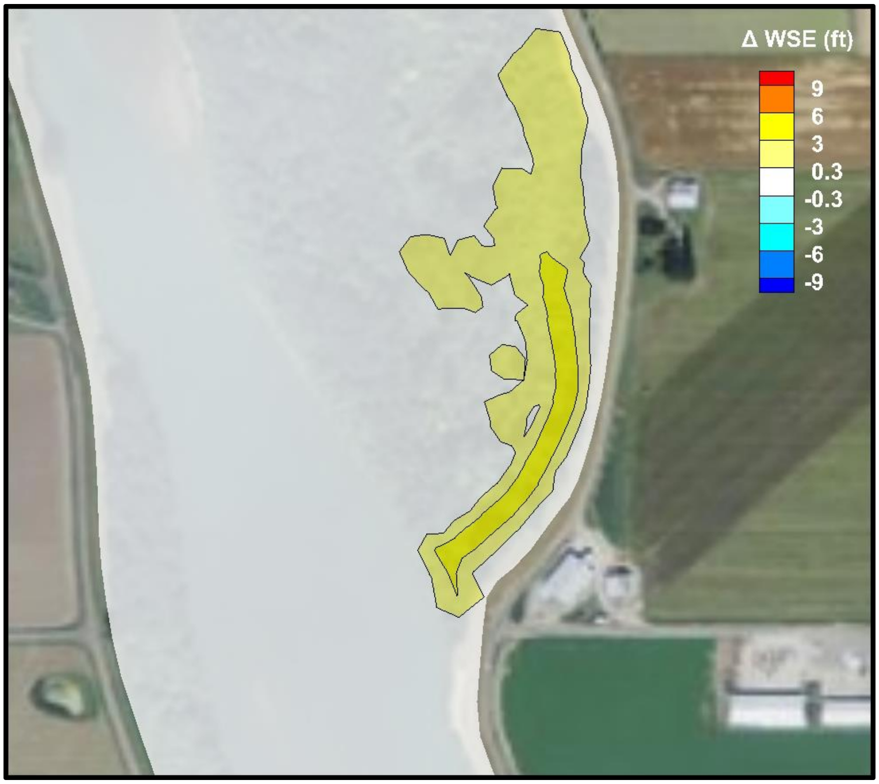

Figure K.45. Contour map of change in WSE for low flow and high tide for TNC South Fork, comparing Climate Change Baseline and Climate Change Projects simulations.

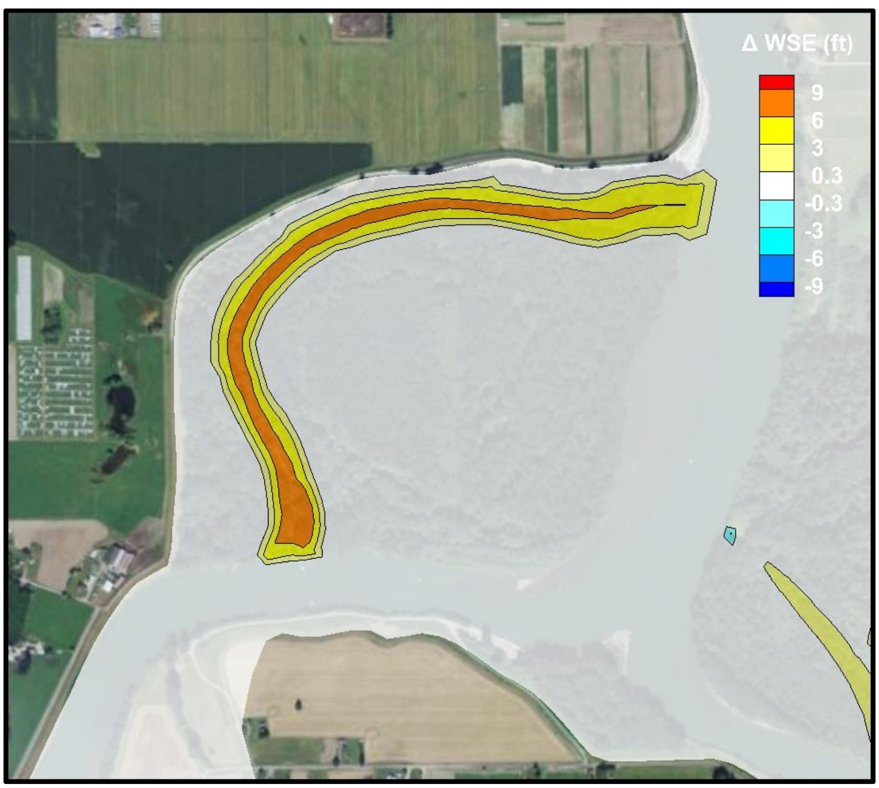

Figure K.46. Contour map of change in WSE for low flow and high tide for Cottonwood Island, comparing Climate Change Baseline and Climate Change Projects simulations.

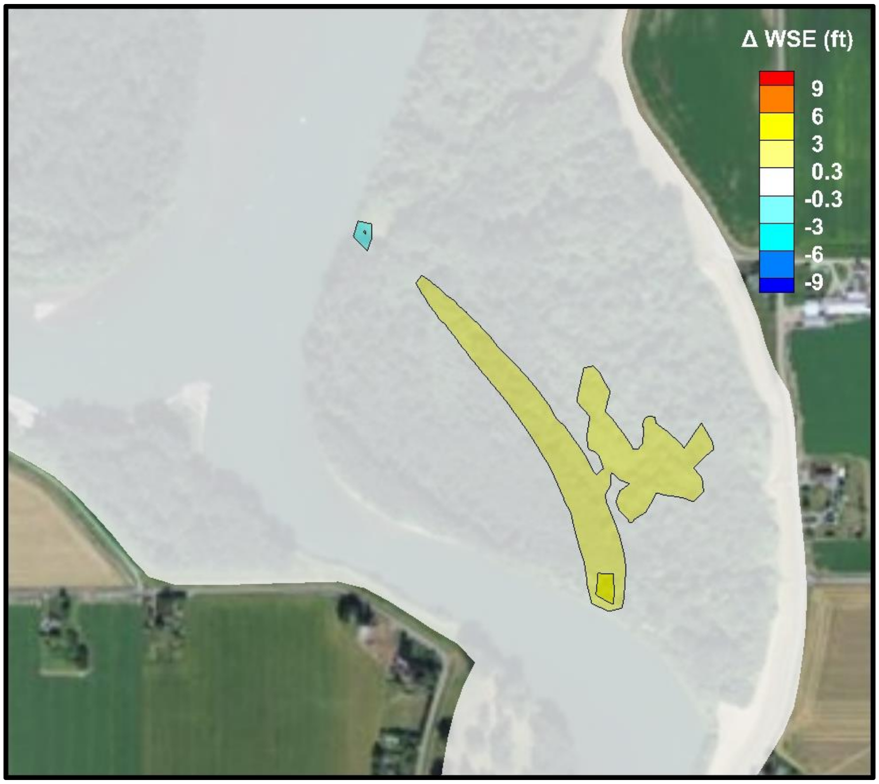

Figure K.47. Contour map of change in WSE for low flow and high tide for East Cottonwood, comparing Climate Change Baseline and Climate Change Projects simulations.

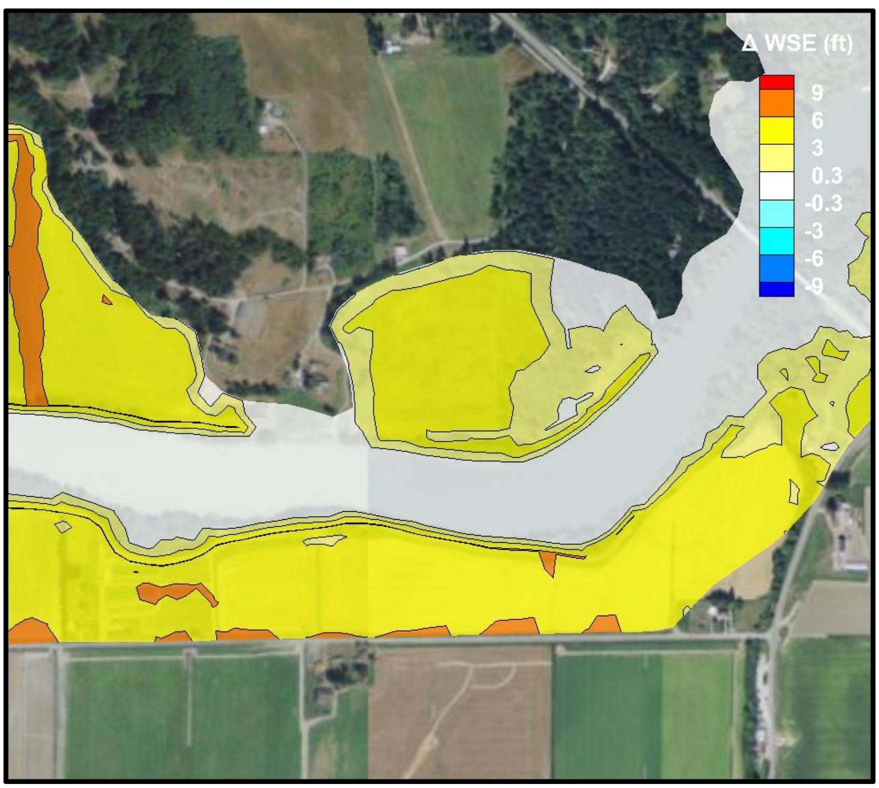

Figure K.48. Contour map of change in WSE for low flow and high tide for Pleasant Ridge South, comparing Climate Change Baseline and Climate Change Projects simulations.

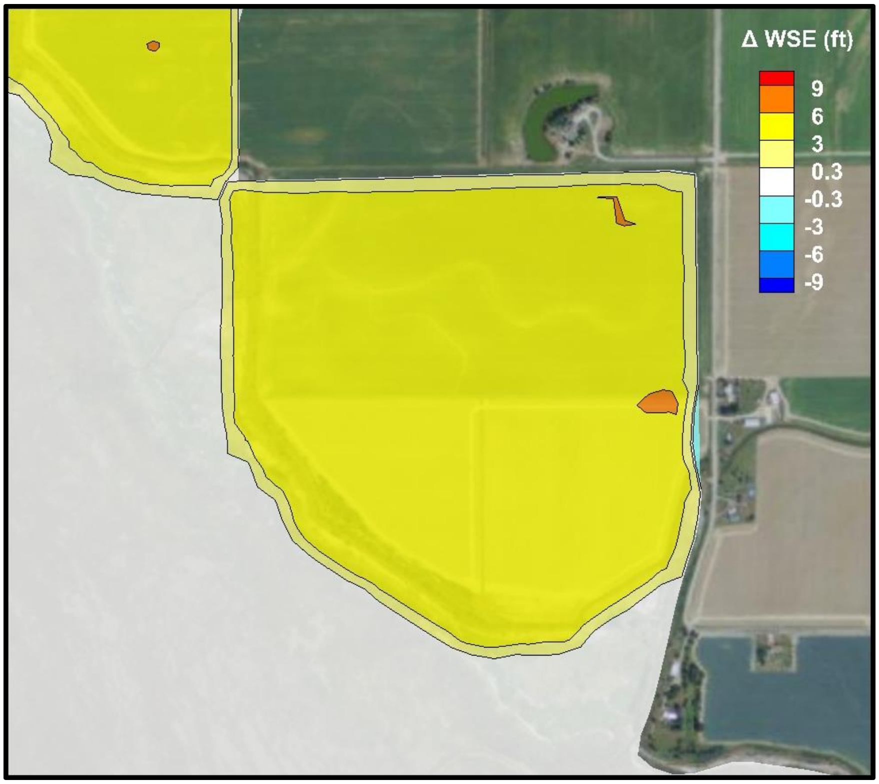

Figure K.49. Contour map of change in WSE for low flow and high tide for Hall Slough, comparing Climate Change Baseline and Climate Change Projects simulations.

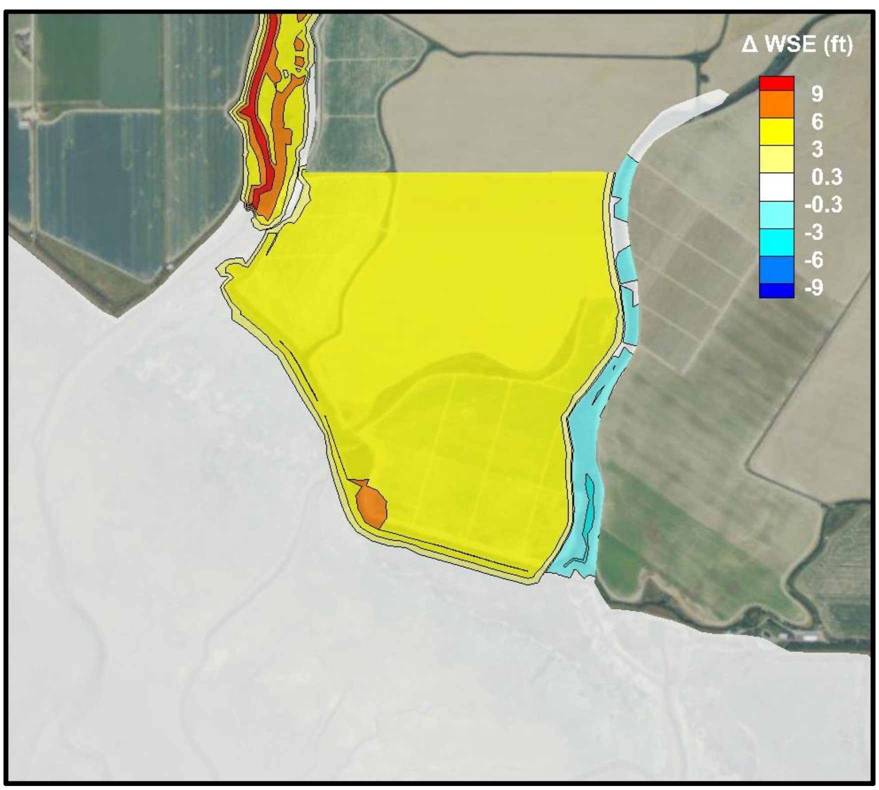

Figure K.50. Contour map of change in WSE for low flow and high tide for Fir Island Farm, comparing Climate Change Baseline and Climate Change Projects simulations.

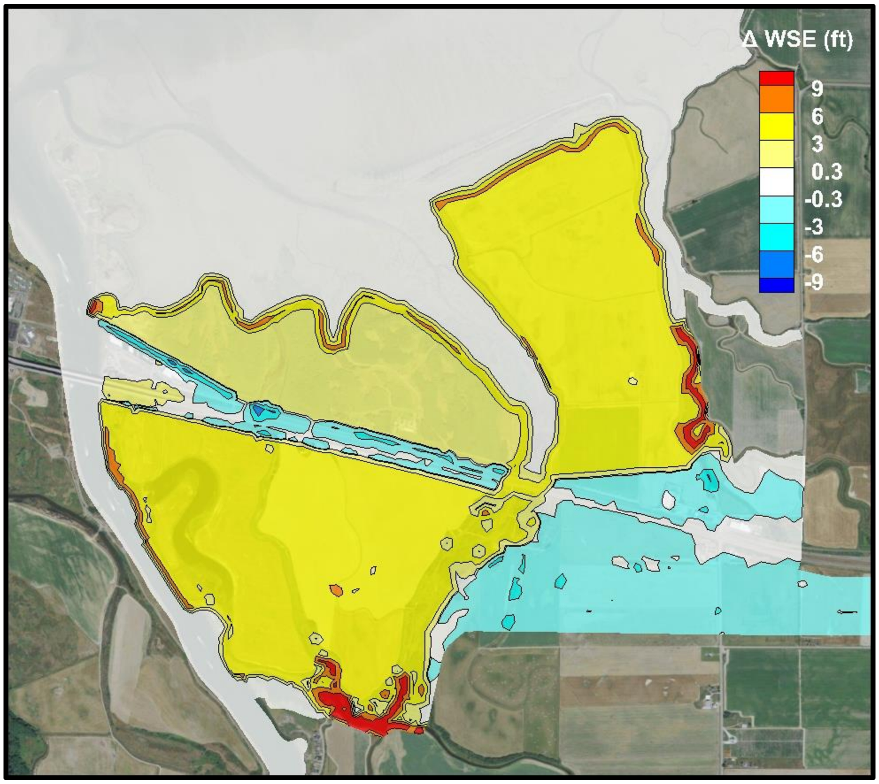

Figure K.51. Contour map of change in WSE for low flow and high tide for Telegraph Slough Full, comparing Climate Change Baseline and Climate Change Projects simulations.

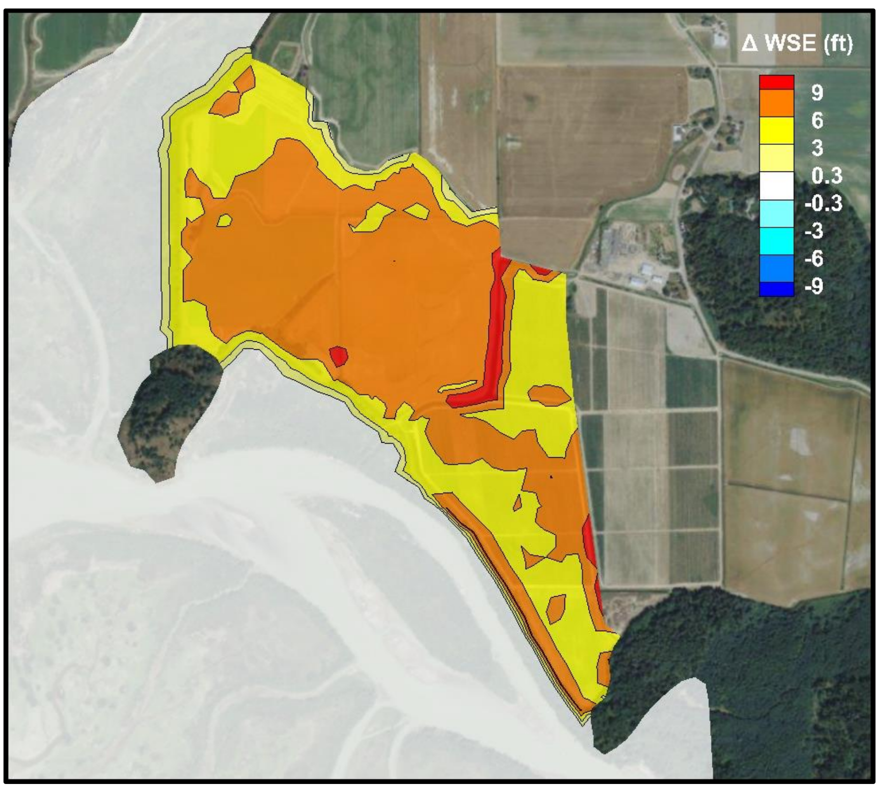

Figure K.52. Contour map of change in WSE for low flow and high tide for Sullivan Hacienda, comparing Climate Change Baseline and Climate Change Projects simulations.

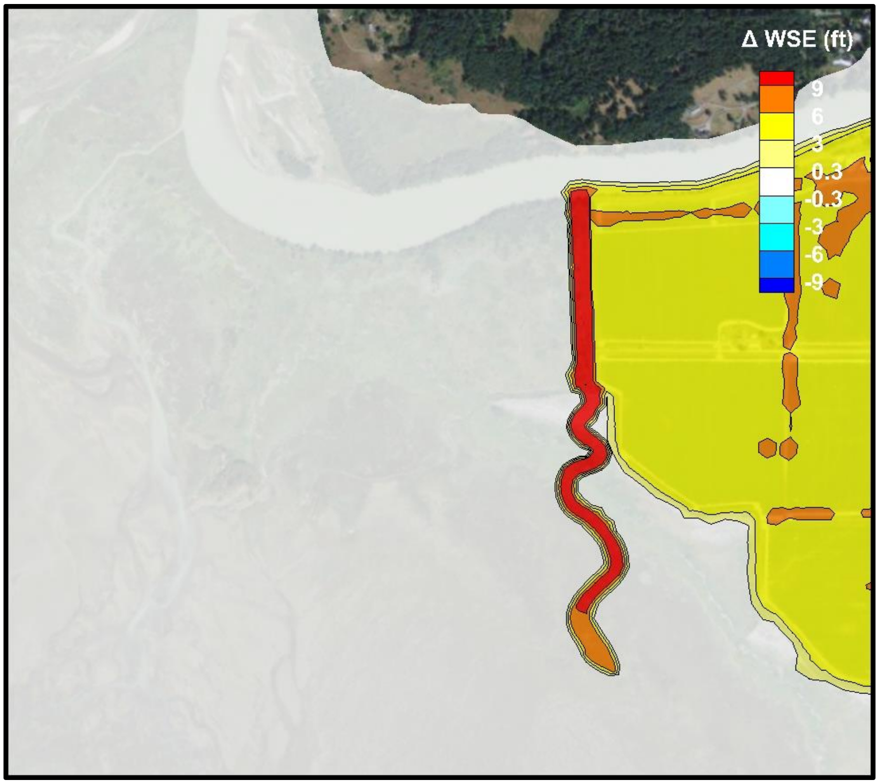

Figure K.53. Contour map of change in WSE for low flow and high tide for Rawlins Road Distributary, comparing Climate Change Baseline and Climate Change Projects simulations.

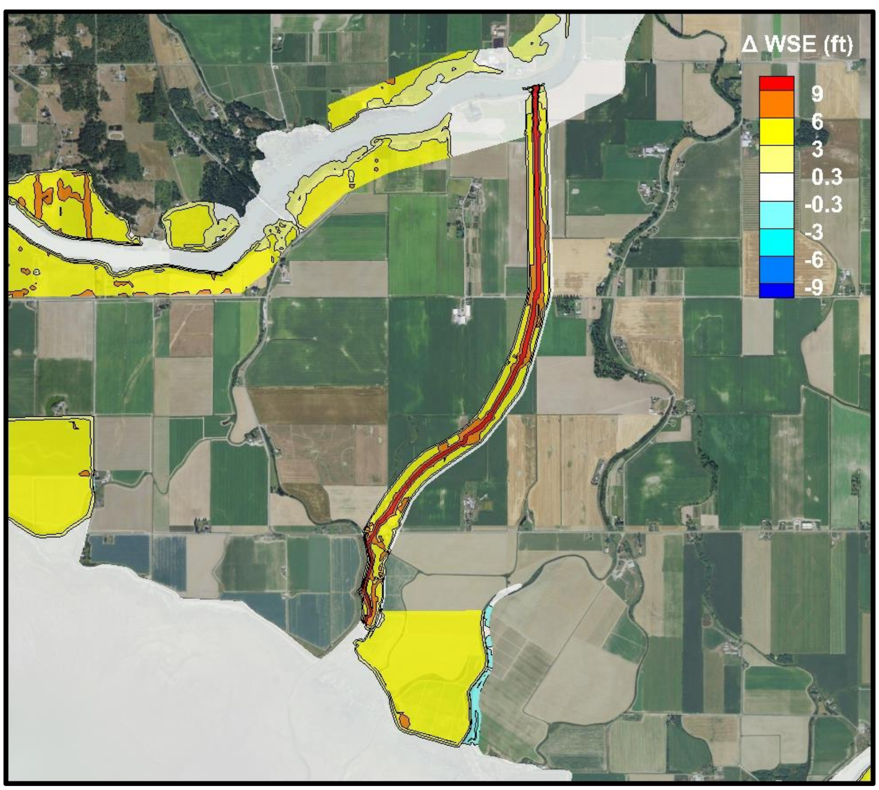

Figure K.54. Contour map of change in WSE for low flow and high tide for Cross Island Connector, comparing Climate Change Baseline and Climate Change Projects simulations.

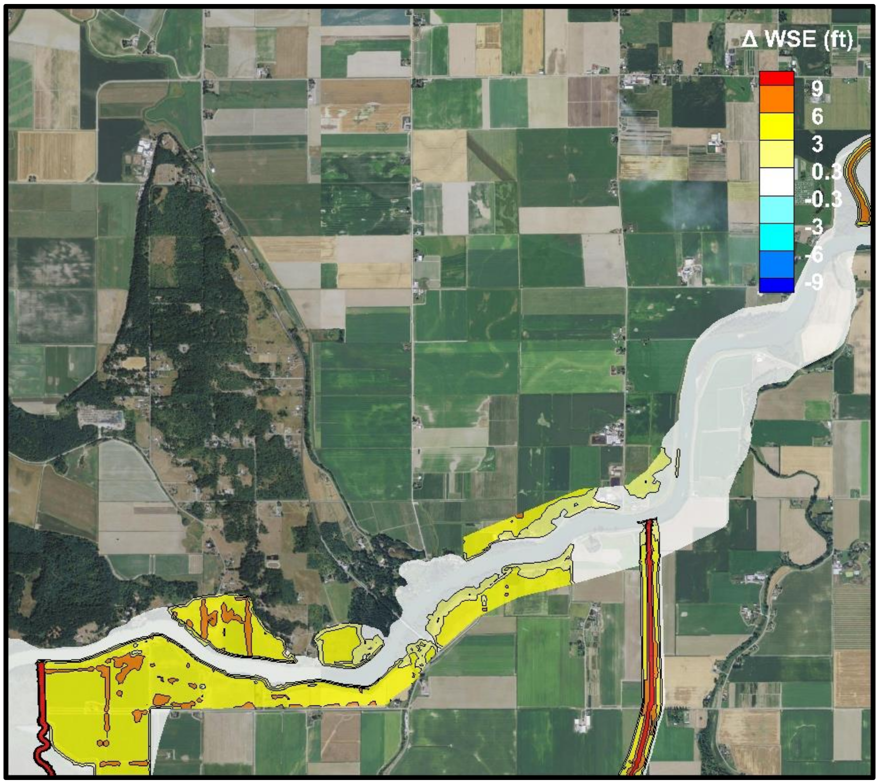

Figure K.55. Contour map of change in WSE for low flow and high tide for NF Levee Setback C, comparing Climate Change Baseline and Climate Change Projects simulations.

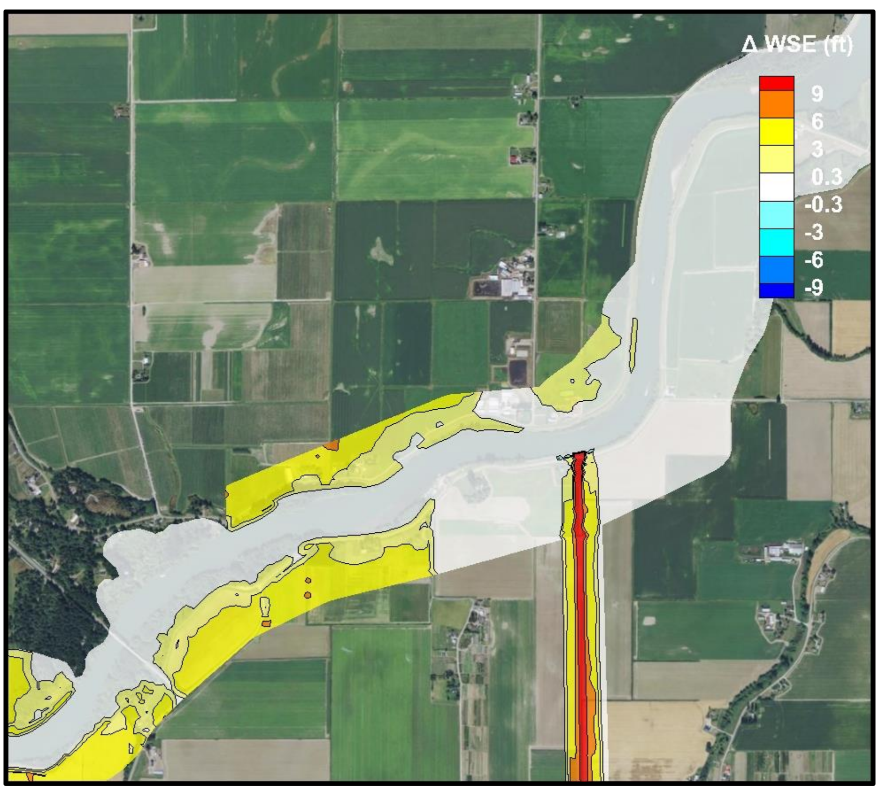

Figure K.56. Contour map of change in WSE for low flow and high tide for NF Right Bank Levee Setback, comparing Climate Change Baseline and Climate Change Projects simulations.

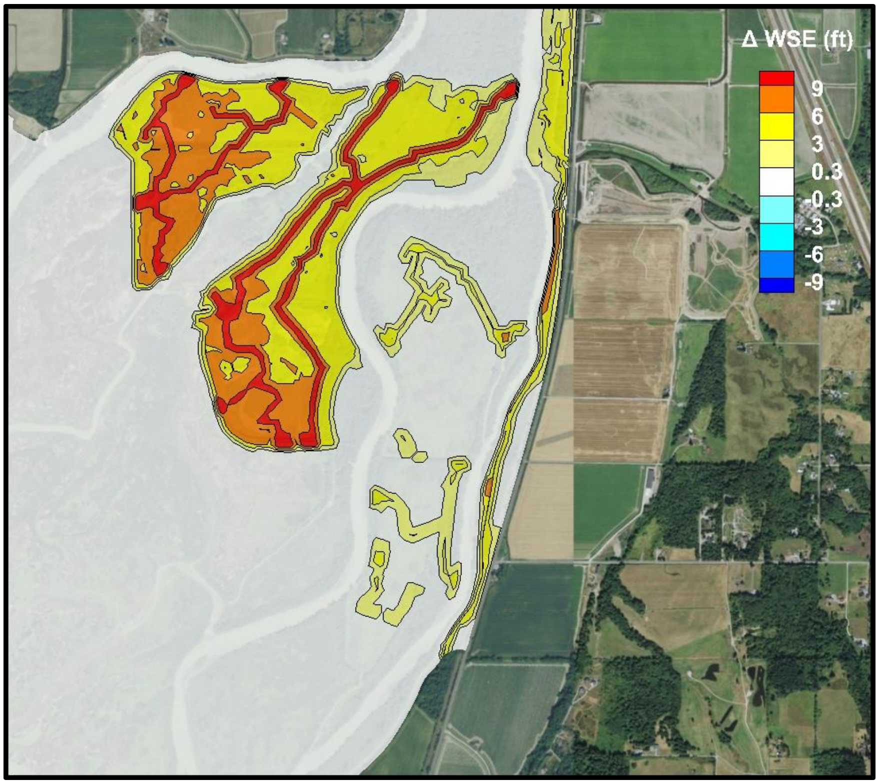

Figure K.57. Contour map of change in WSE for low flow and high tide for Milltown Island, comparing Climate Change Baseline and Climate Change Projects simulations.

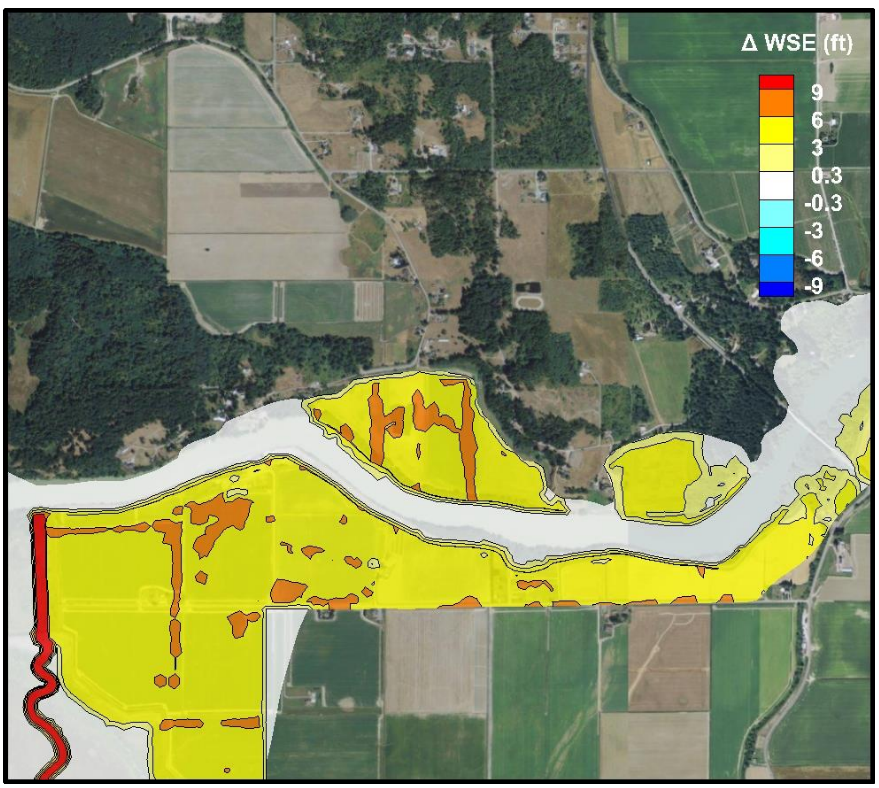

Figure K.58. Contour map of change in WSE for low flow and high tide for Thein Farm, comparing Climate Change Baseline and Climate Change Projects simulations.

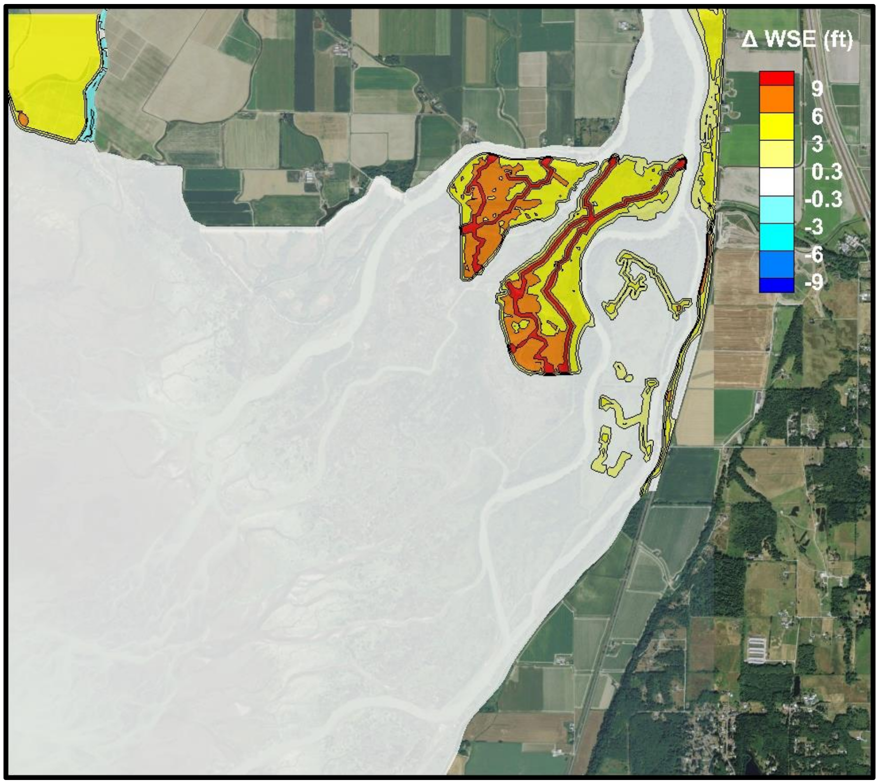

Figure K.59. Contour map of change in WSE for low flow and high tide for Deepwater Slough Phase 2, comparing Climate Change Baseline and Climate Change Projects simulations.

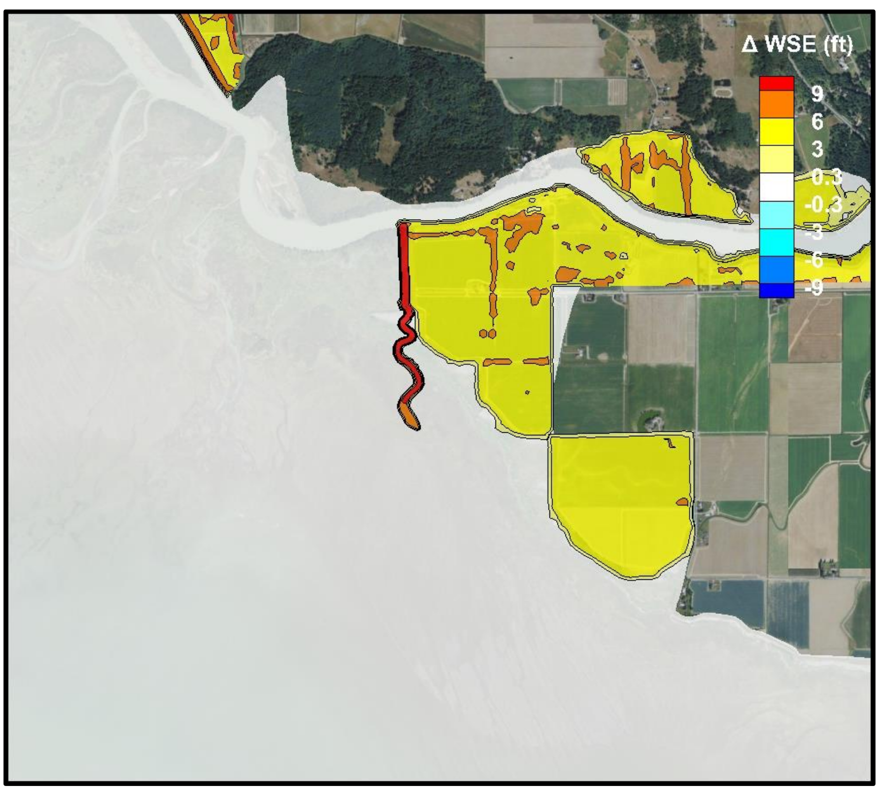

Figure K.60. Contour map of change in WSE for low flow and high tide for Rawlins Road, comparing Climate Change Baseline and Climate Change Projects simulations.

K.4 Climate Change with Projects Deliverable 4

Deliverable 4 is a set of contour maps showing water surface elevation during the 2080 Climate Change with Projects simulation (Simulation 10). The plotted conditions were a low flow (12,000 cfs) and future high spring tide (12.67 ft). All WSE values are relative to the NAVD88 datum. Areas that are not inundated are blanked out. A high-resolution, georeferenced map with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. The maps can be seen in Figure K.61 through Figure K.79.

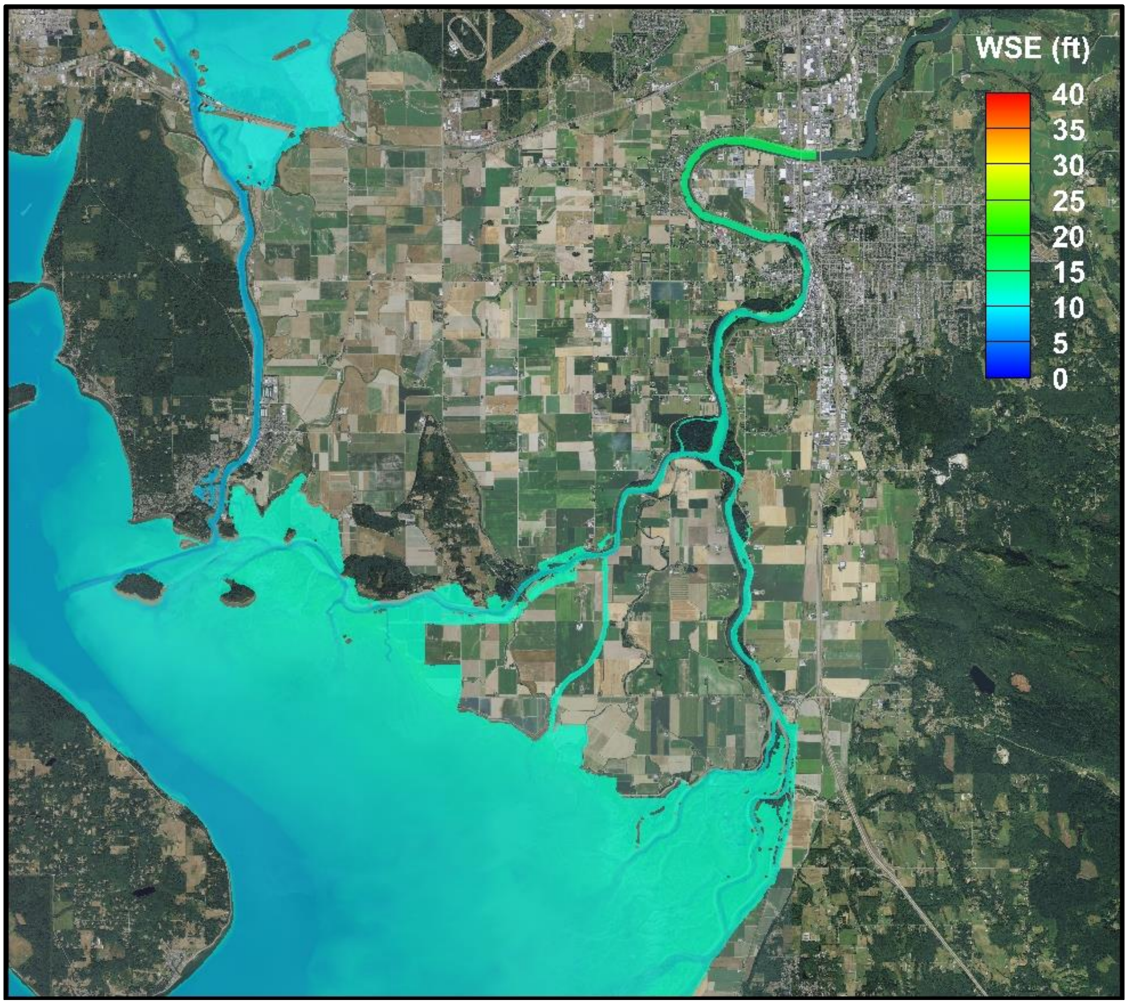

Figure K.61. Contour map of water surface elevation for the full domain during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

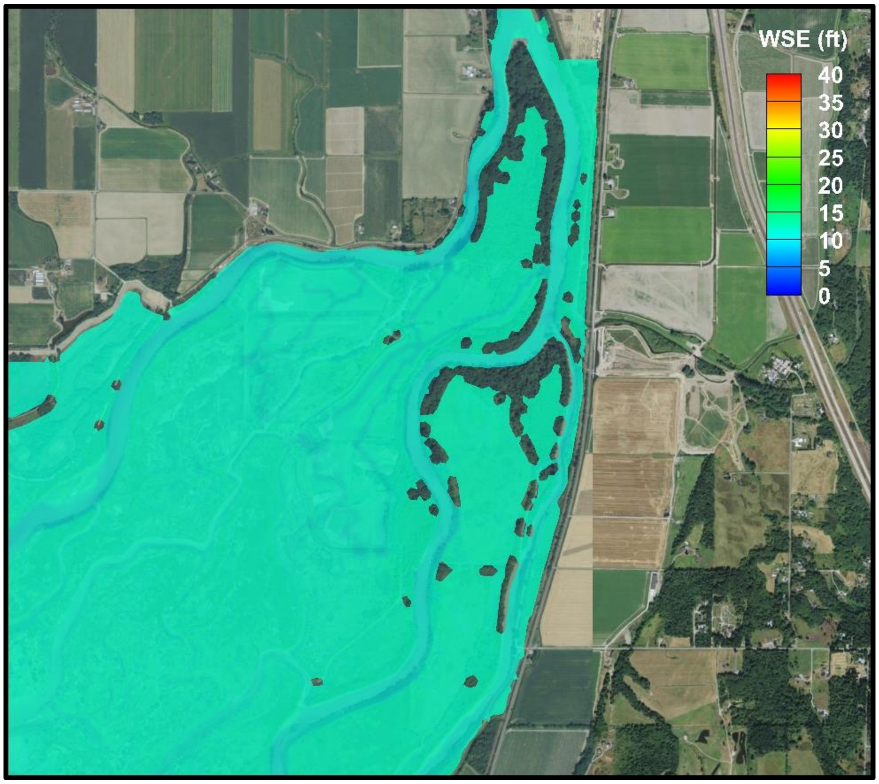

Figure K.62. Contour map of water surface elevation for SF Levee Setbacks 2, 3, and 4 during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

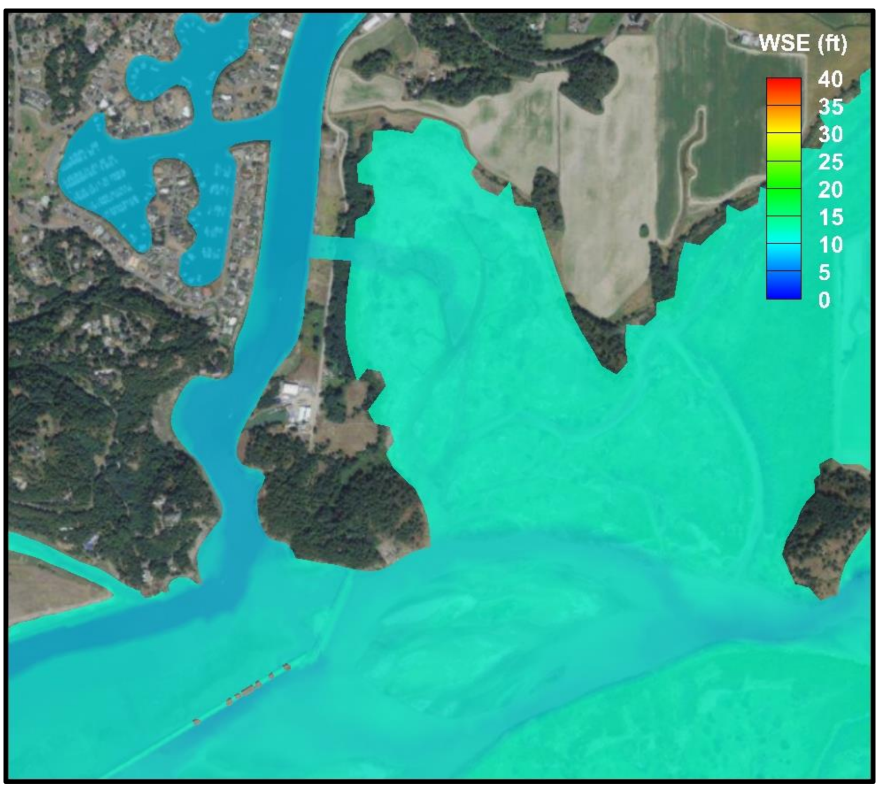

Figure K.63. Contour map of water surface elevation for McGlinn Causeway during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

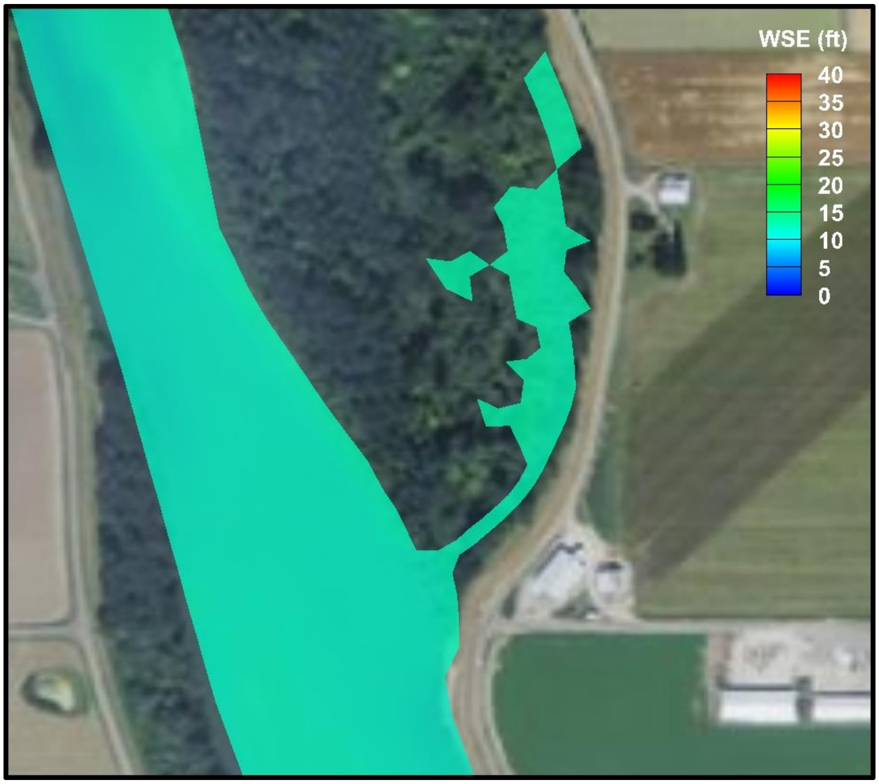

Figure K.64. Contour map of water surface elevation for TNC South Fork during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

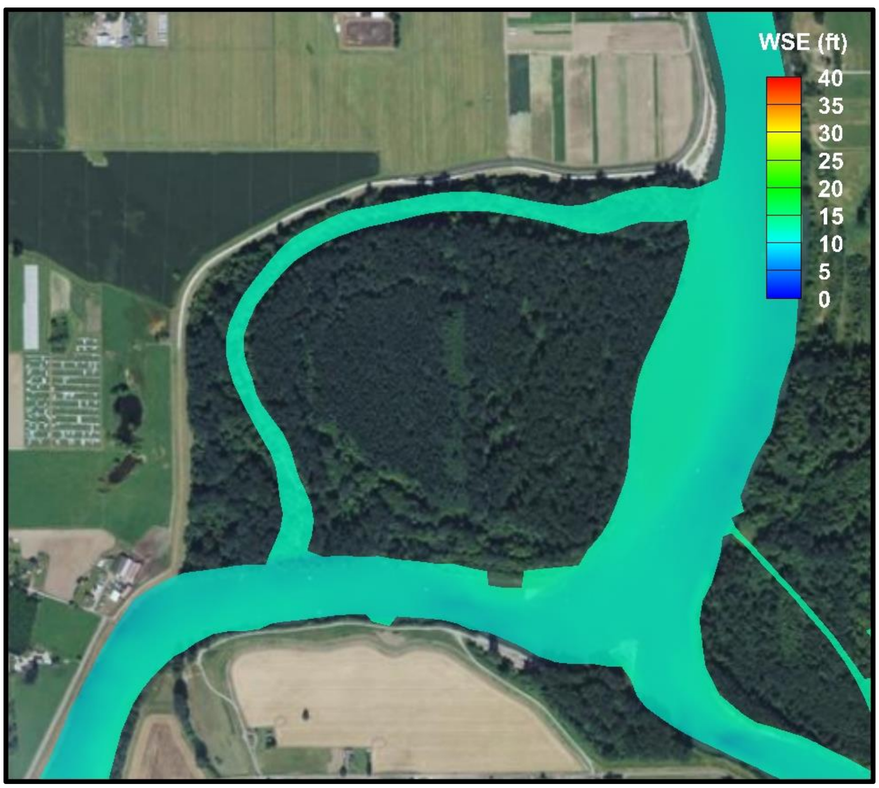

Figure K.65. Contour map of water surface elevation for Cottonwood Island during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

Figure K.66. Contour map of water surface elevation for East Cottonwood during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

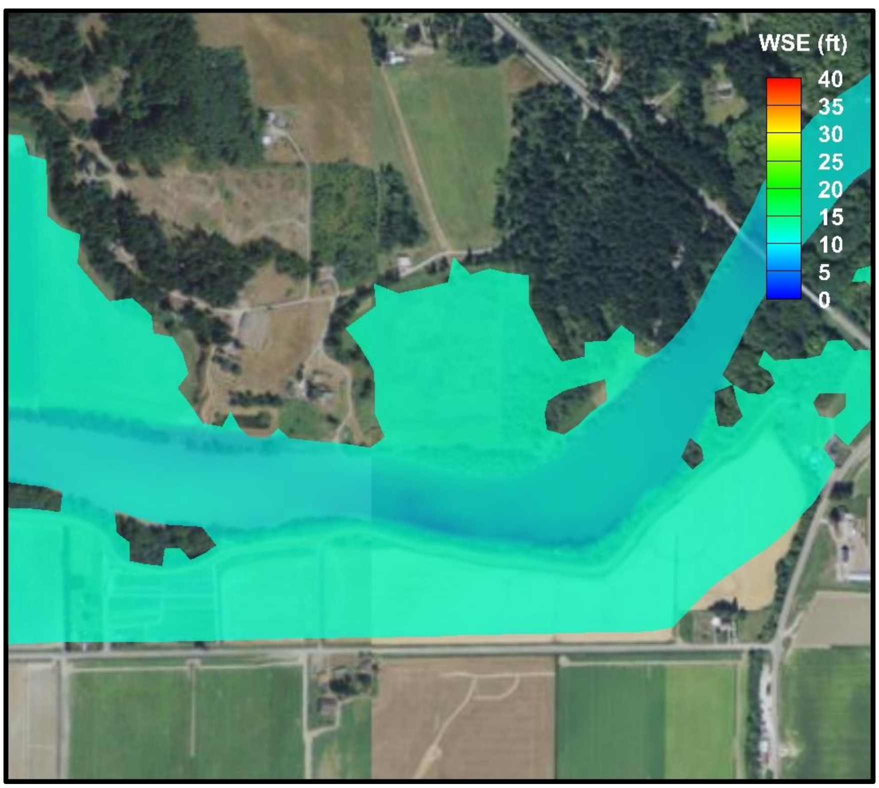

Figure K.67. Contour map of water surface elevation for Pleasant Ridge South during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

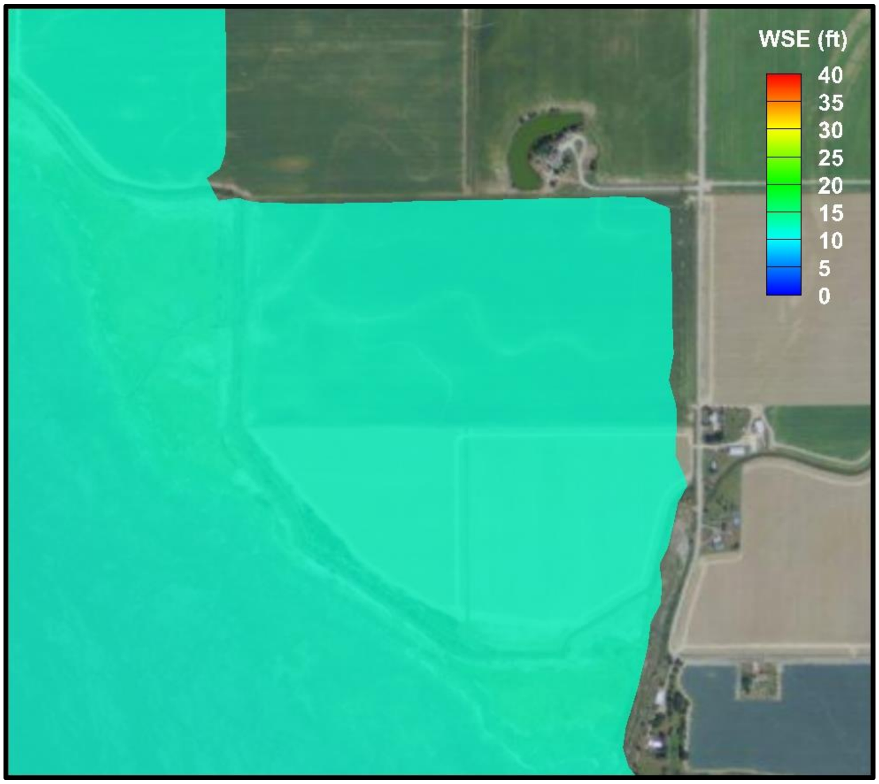

Figure K.68. Contour map of water surface elevation for Hall Sough during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

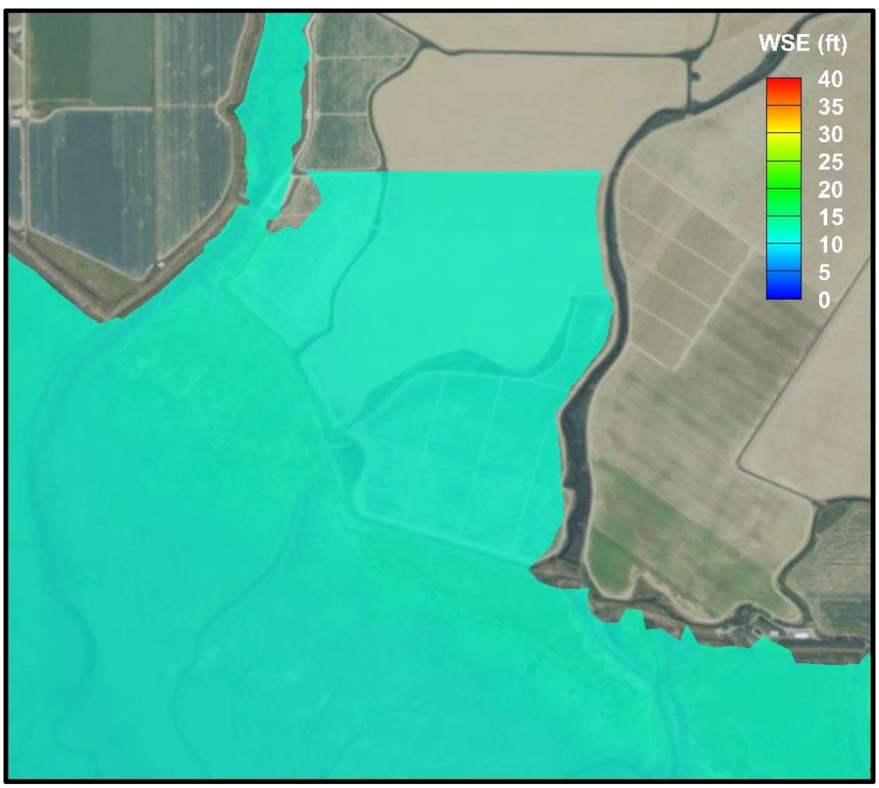

Figure K.69. Contour map of water surface elevation for Fir Island Farm during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

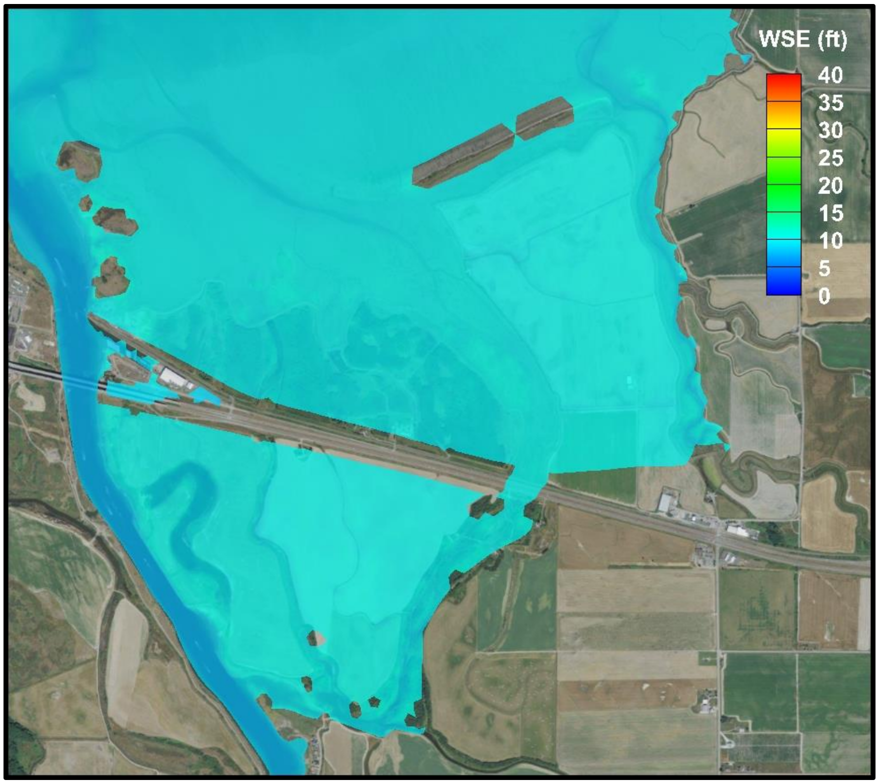

Figure K.70. Contour map of water surface elevation for Telegraph Slough Full during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

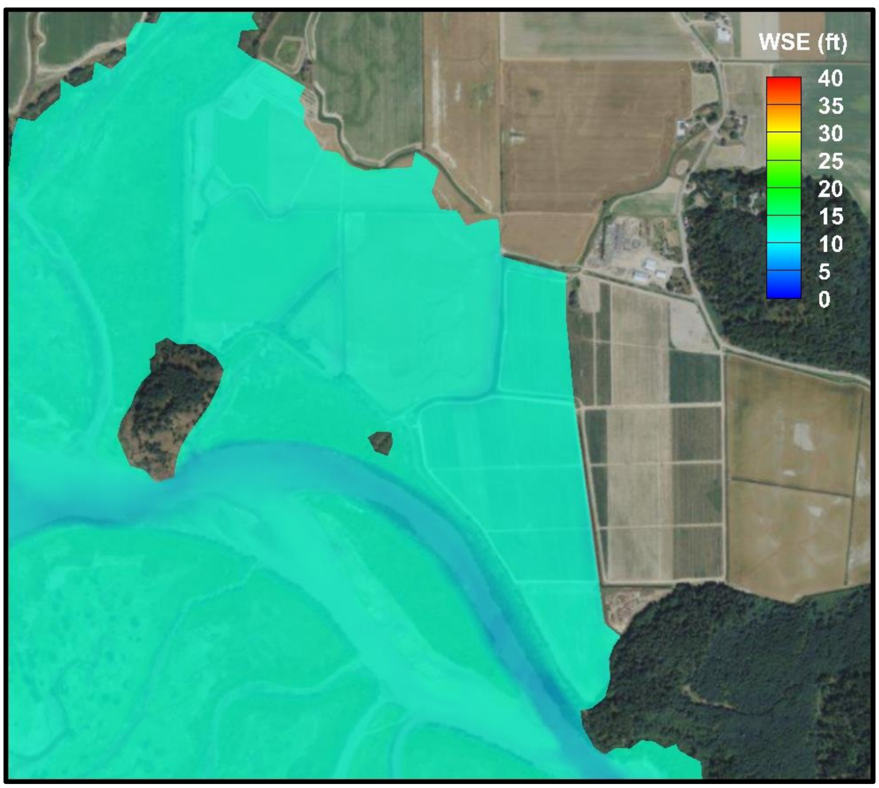

Figure K.71. Contour map of water surface elevation for Sullivan Hacienda during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

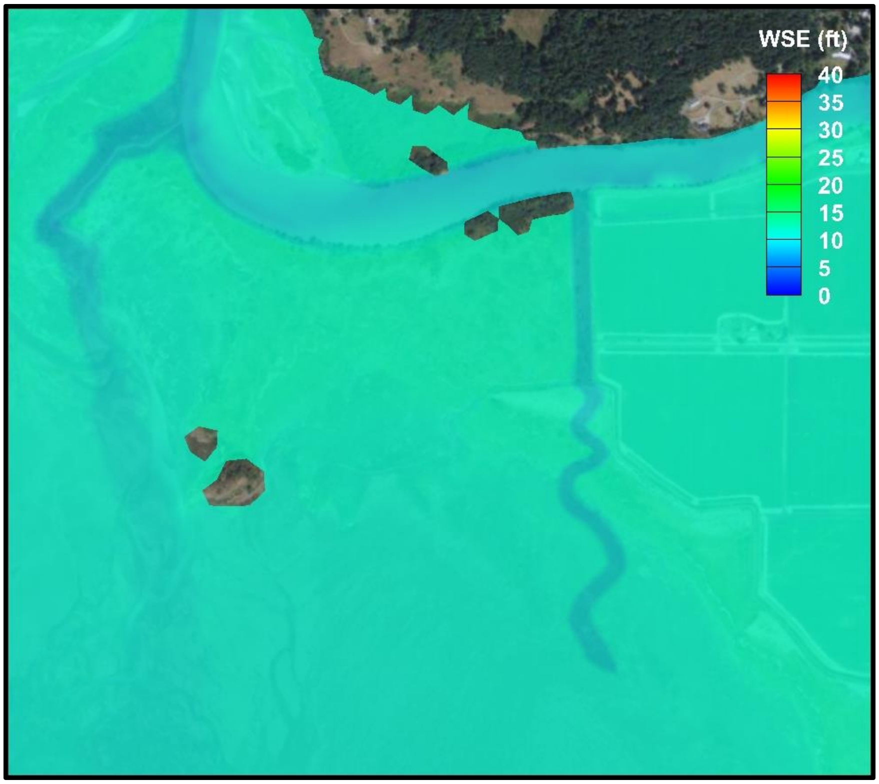

Figure K.72. Contour map of water surface elevation for Rawlins Road Distributary during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

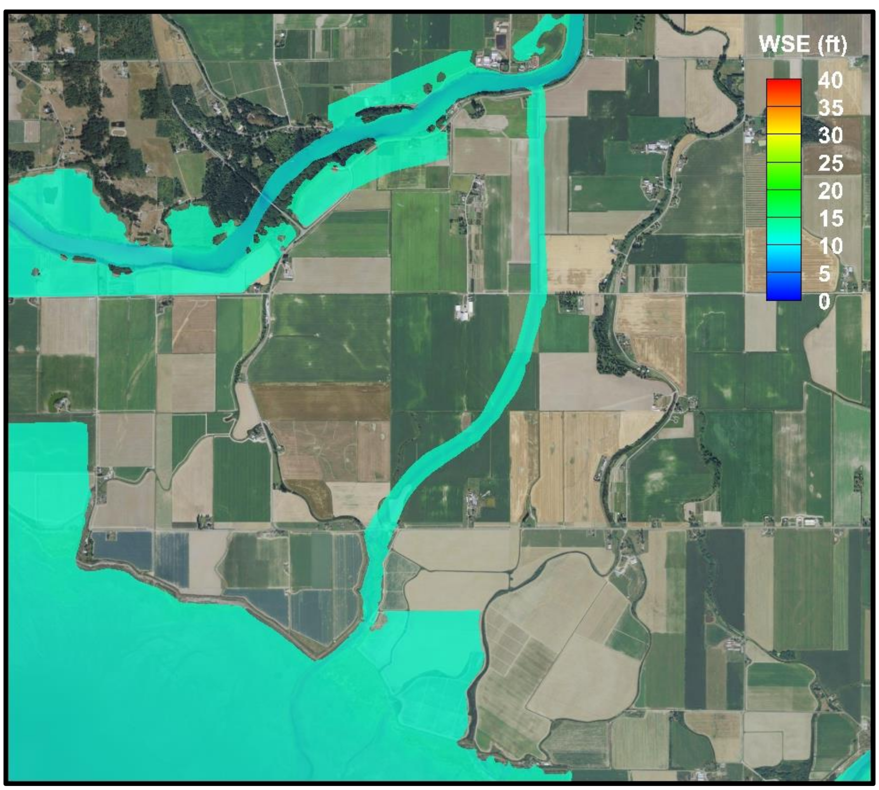

Figure K.73. Contour map of water surface elevation for Cross Island Connector during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

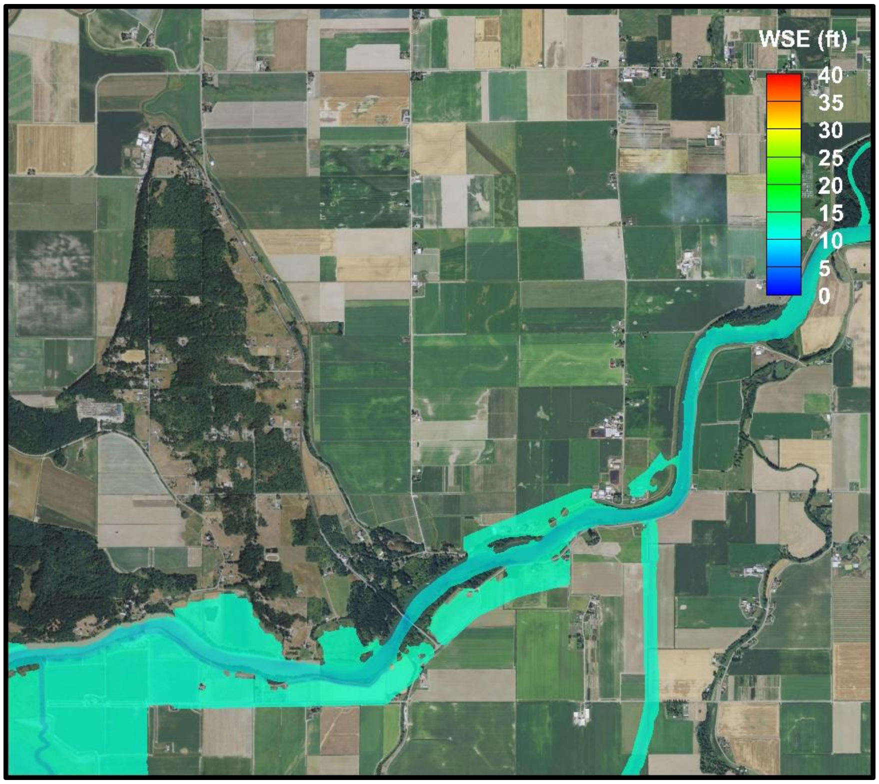

Figure K.74. Contour map of water surface elevation for NF Levee Setback C during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

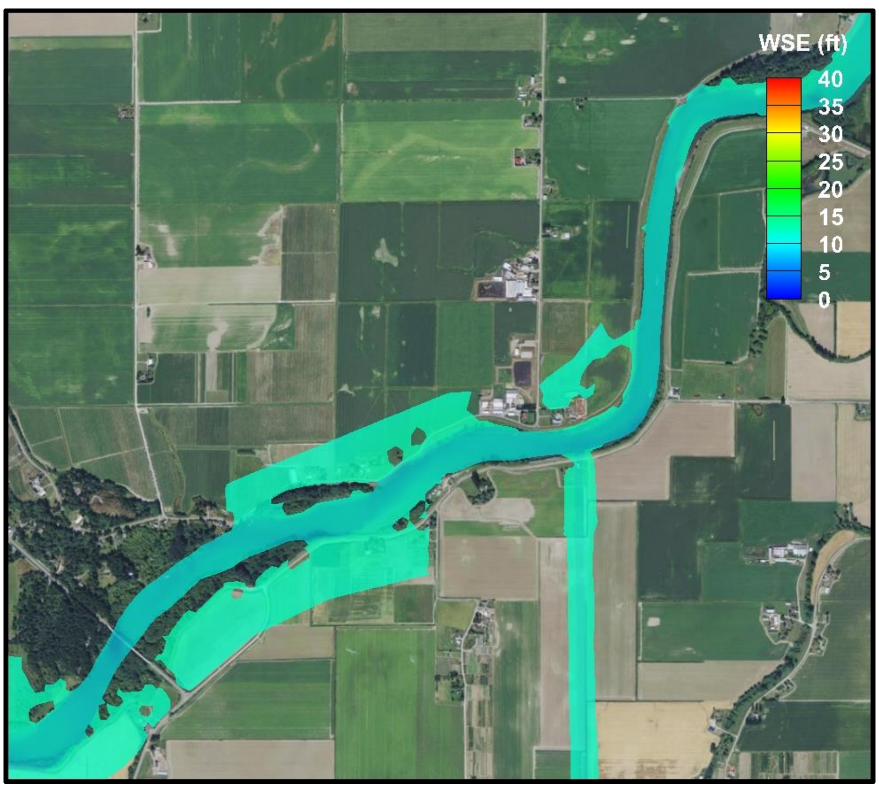

Figure K.75. Contour map of water surface elevation for NF Right Bank Levee Setback during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

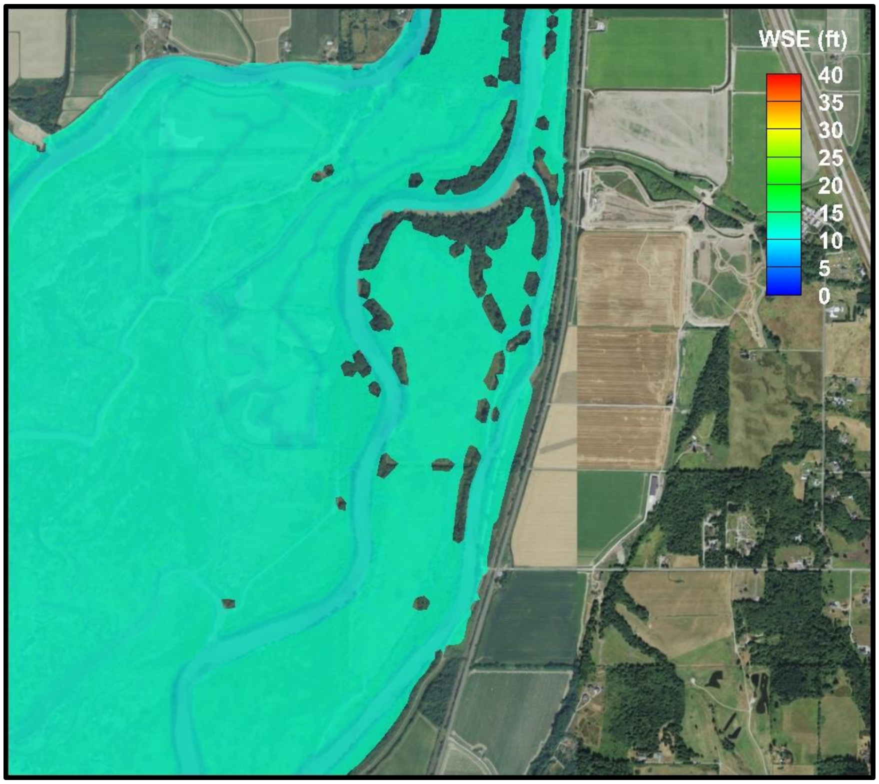

Figure K.76. Contour map of water surface elevation for Milltown Island during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

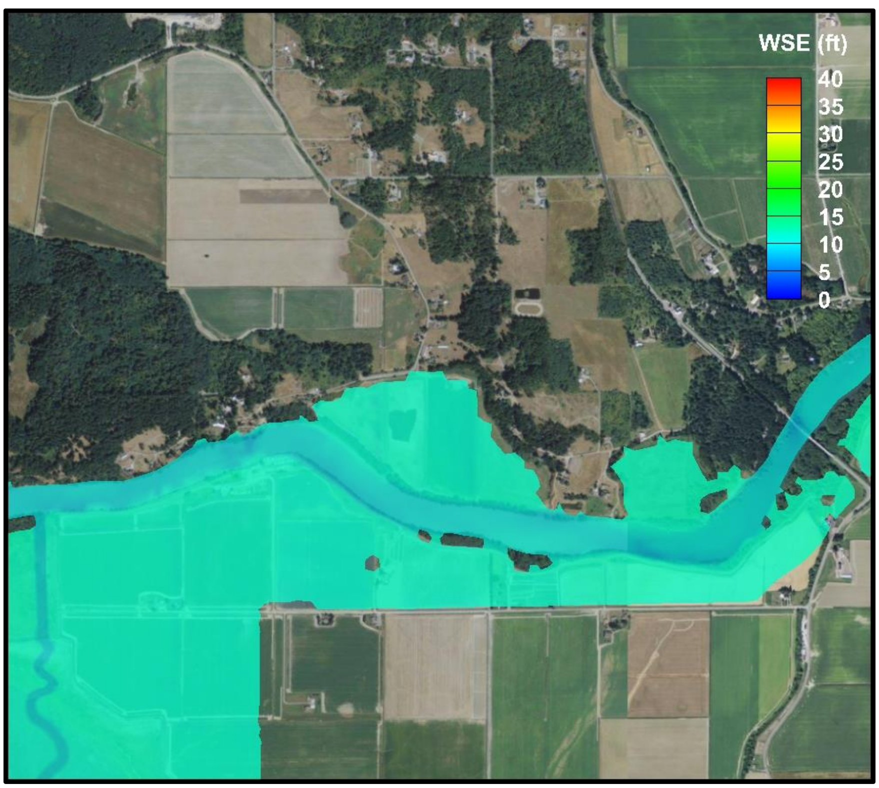

Figure K.77. Contour map of water surface elevation for Thein Farm during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

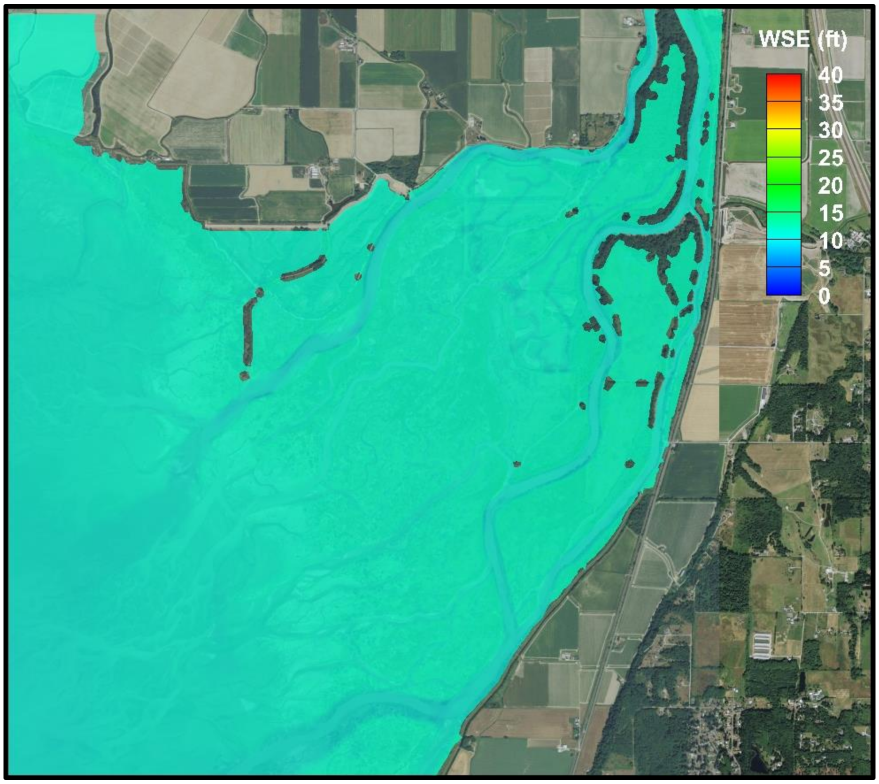

Figure K.78. Contour map of water surface elevation for Deepwater Slough Phase 2 during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

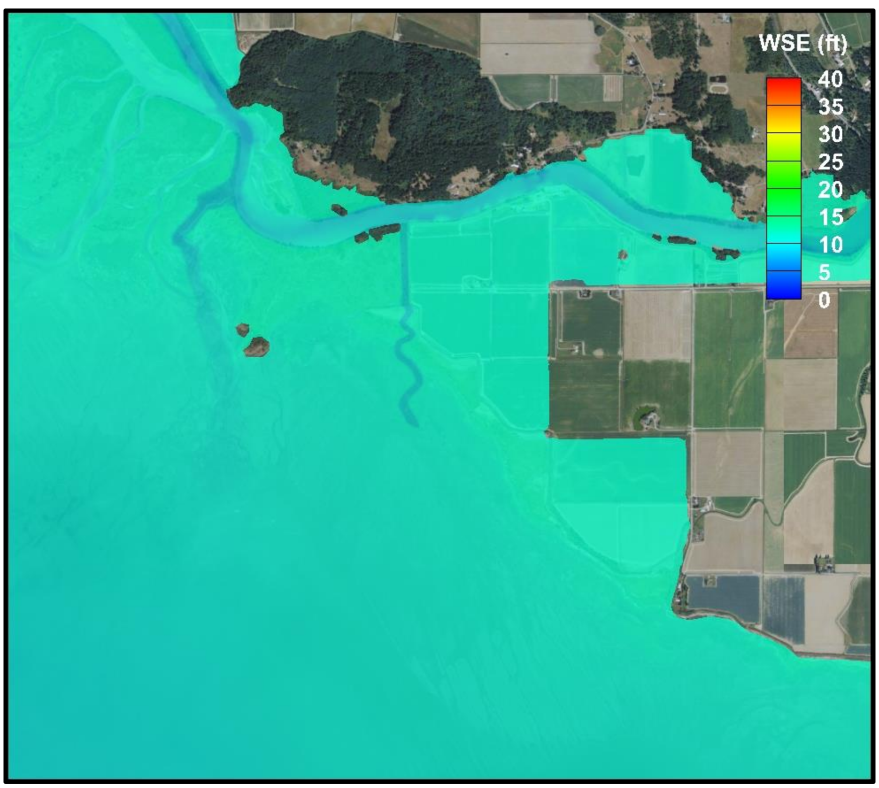

Figure K.79. Contour map of water surface elevation for Rawlins Road during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

K.5 Climate Change with Projects Deliverable 5

Deliverable 5 is a set of cumulative frequency plots showing the water surface elevation at a point in the main channel or Bayfront near each project site. These are from the spring months of the 2080 Climate Change with Projects simulation (Simulation 10), representing March 1 – May 22, 2015, a time period chosen to coincide with the primary fish outmigration. A red mark line was provided with every point to represent an approximation of the average elevation of the project area bed. All WSE values are relative to the NAVD88 datum. An Excel file was also generated with WSE at each node location. The plots can be seen in Figure K.80 to Figure K.105.

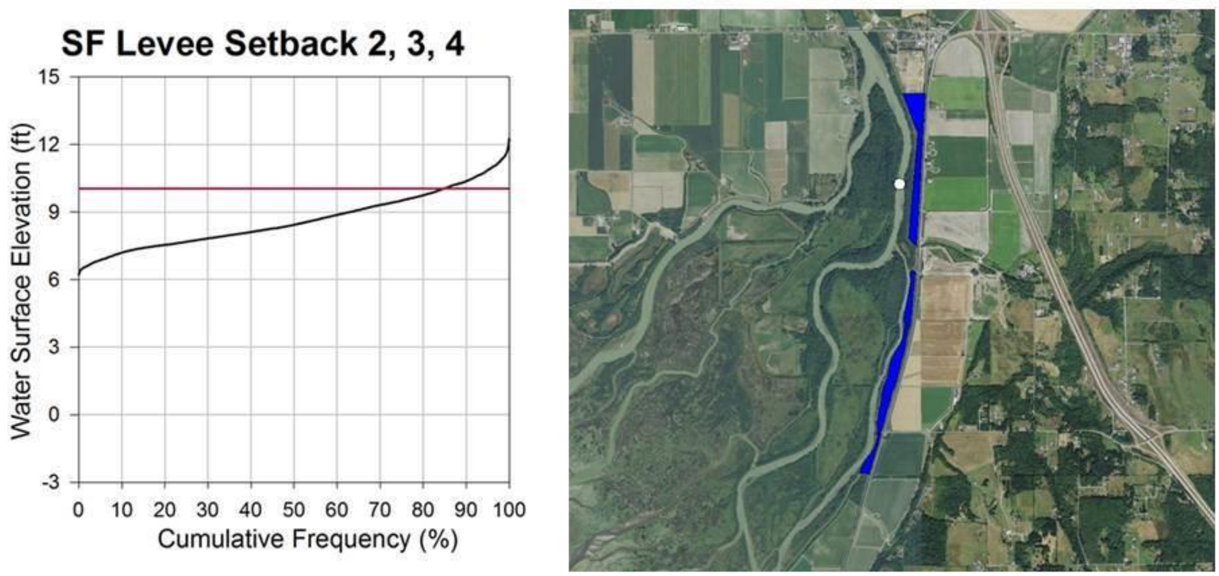

Figure K.80. Cumulative frequency plot and corresponding map for SF Levee Setbacks 2, 3, and 4 during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

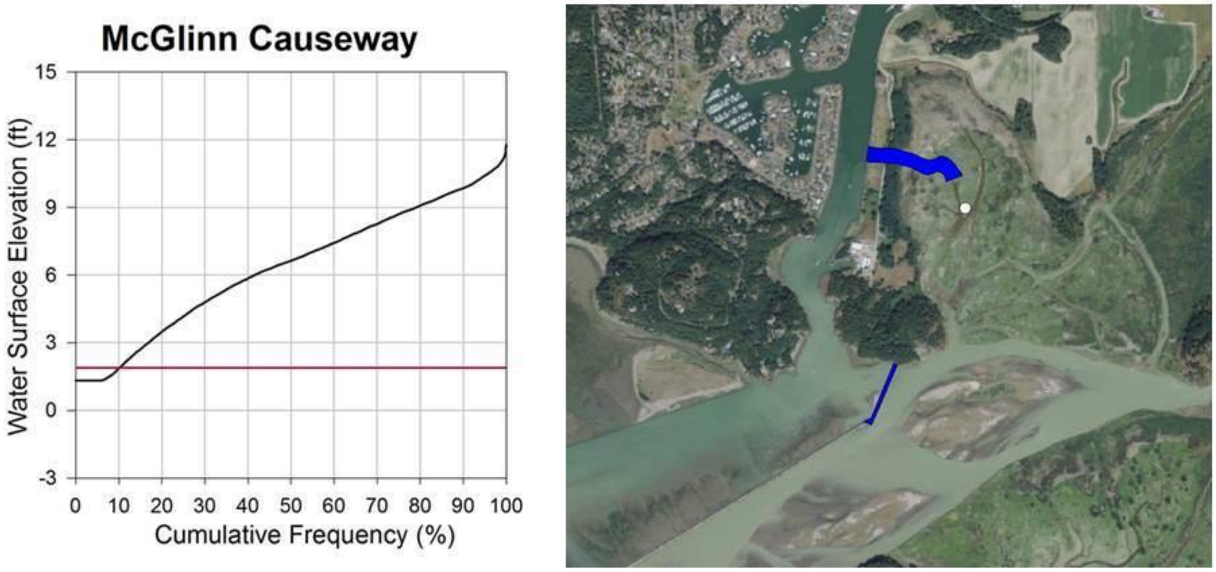

Figure K.81. Cumulative frequency plot and corresponding map for McGlinn Causeway during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

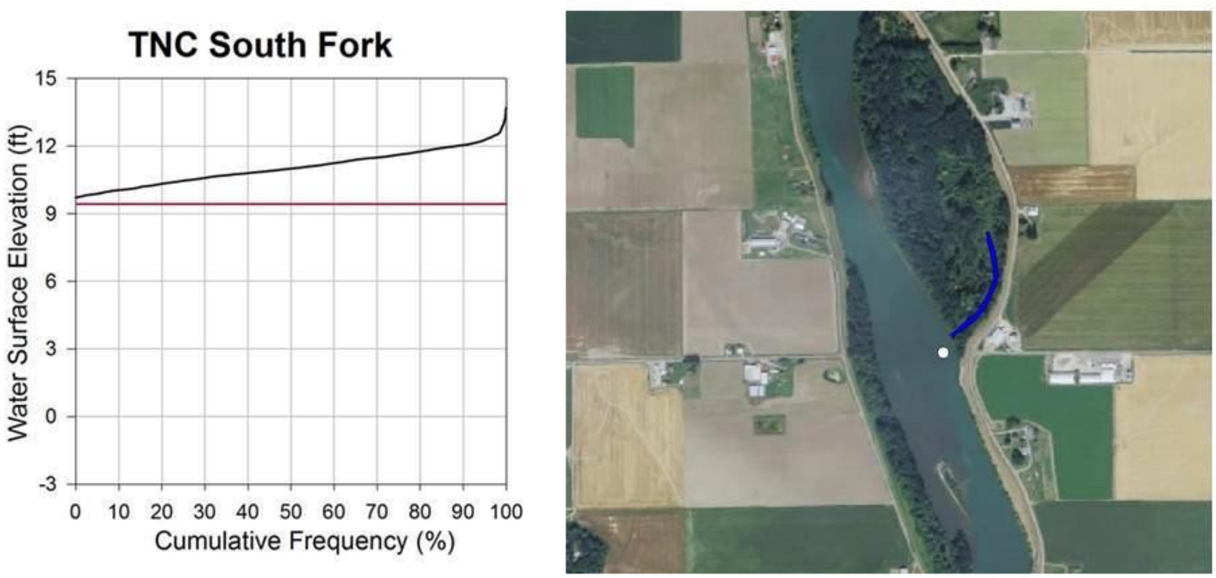

Figure K.82. Cumulative frequency plot and corresponding map for TNC South Fork during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

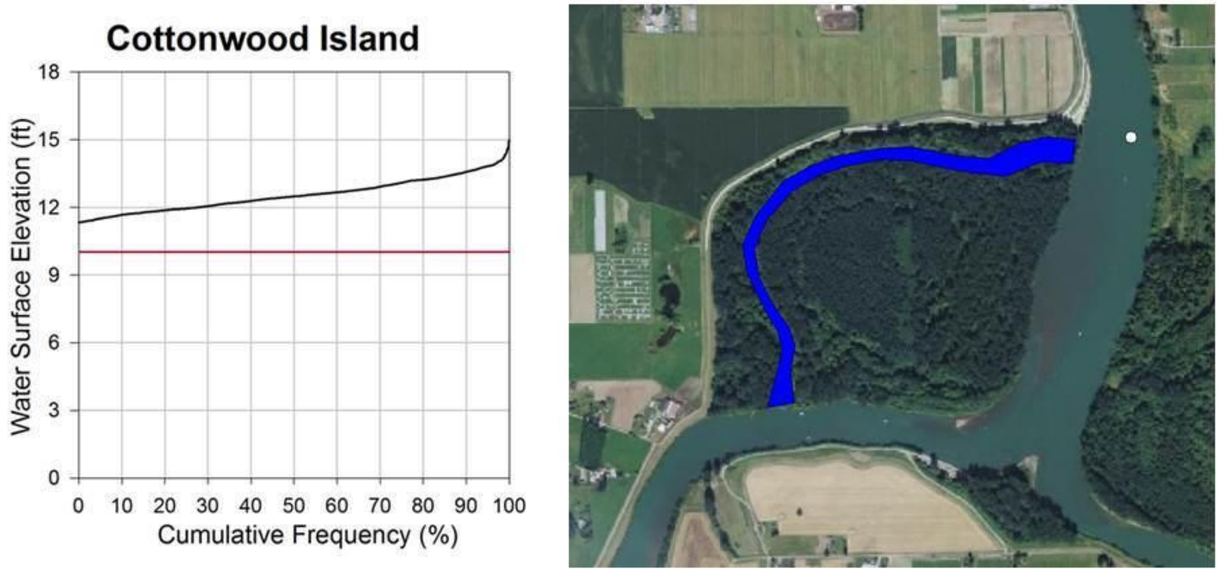

Figure K.83. Cumulative frequency plot and corresponding map for Cottonwood Island during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

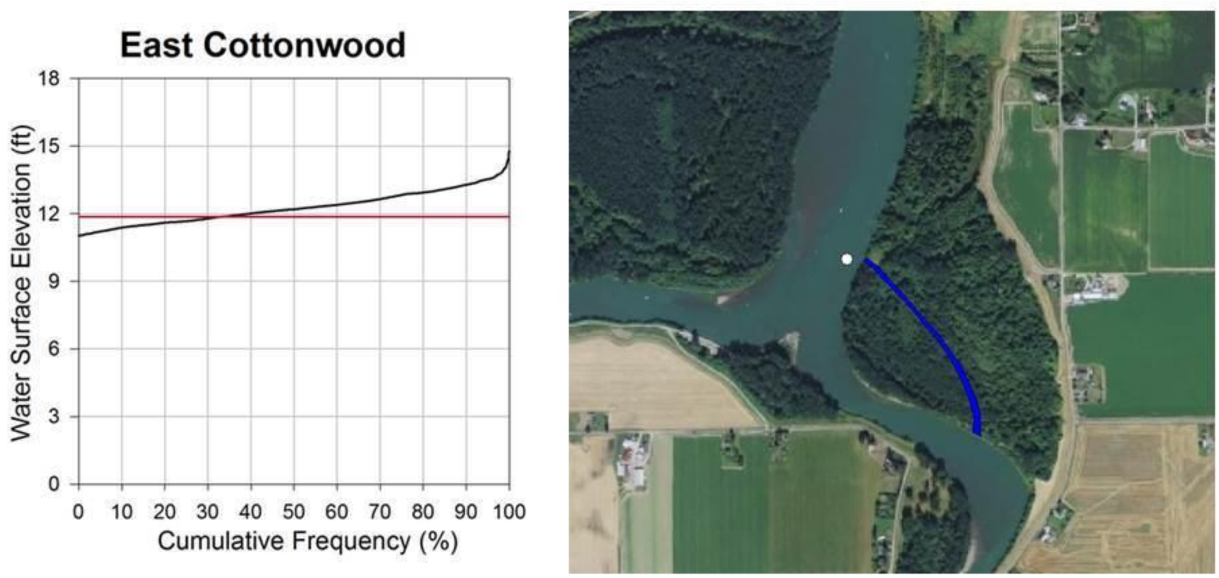

Figure K.84. Cumulative frequency plot and corresponding map for East Cottonwood during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

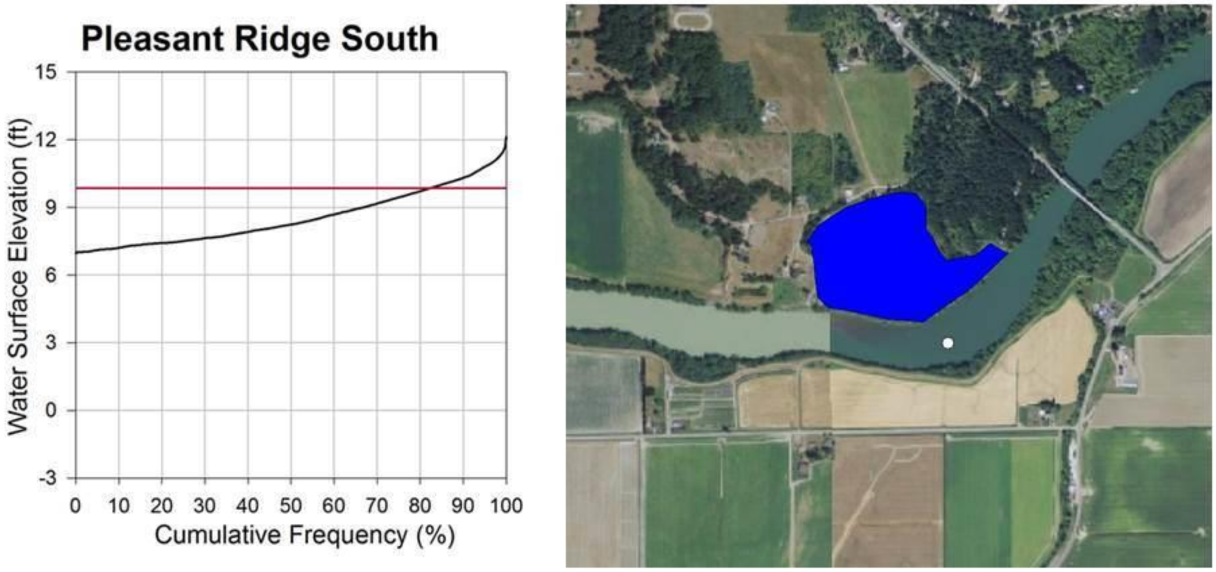

Figure K.85. Cumulative frequency plot and corresponding map for Pleasant Ridge South during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

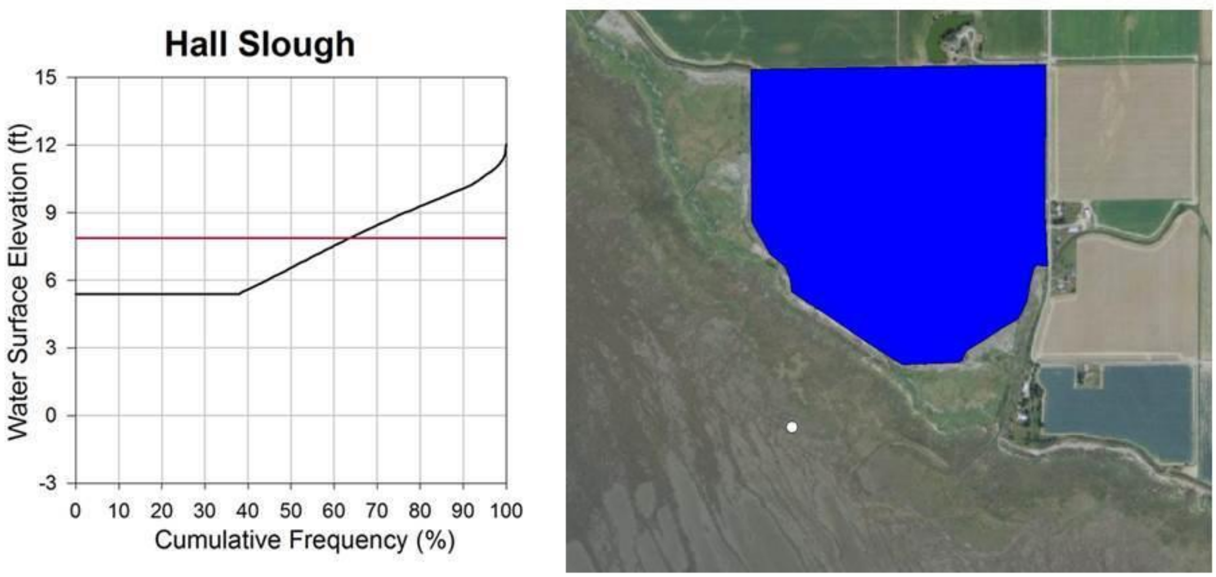

Figure K.86. Cumulative frequency plot and corresponding map for Hall Slough during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

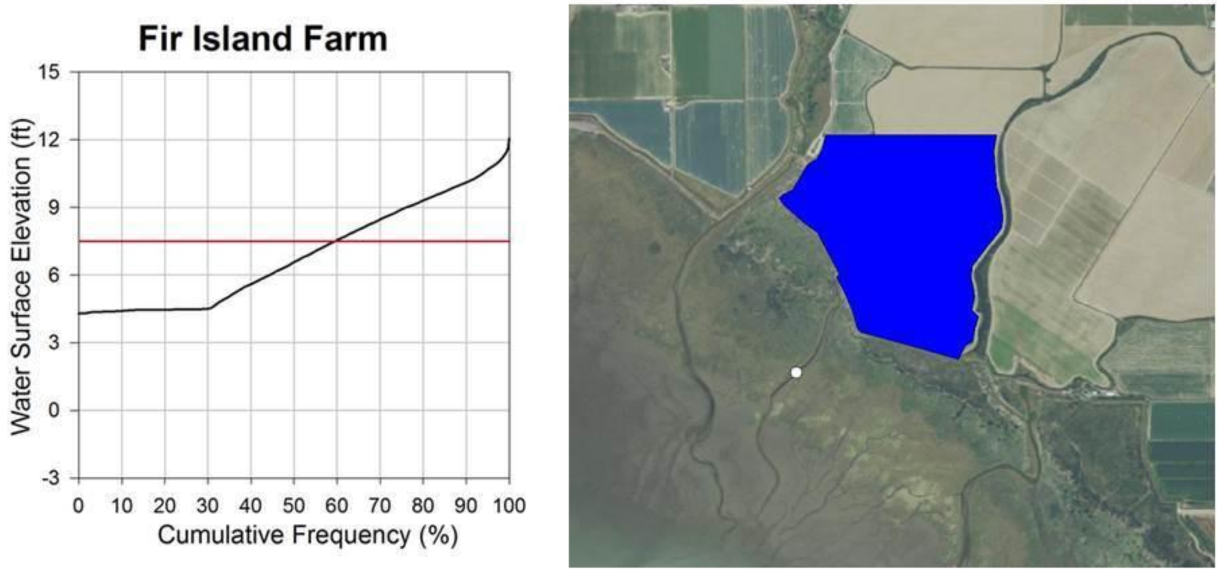

Figure K.87. Cumulative frequency plot and corresponding map for Fir Island Farm during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

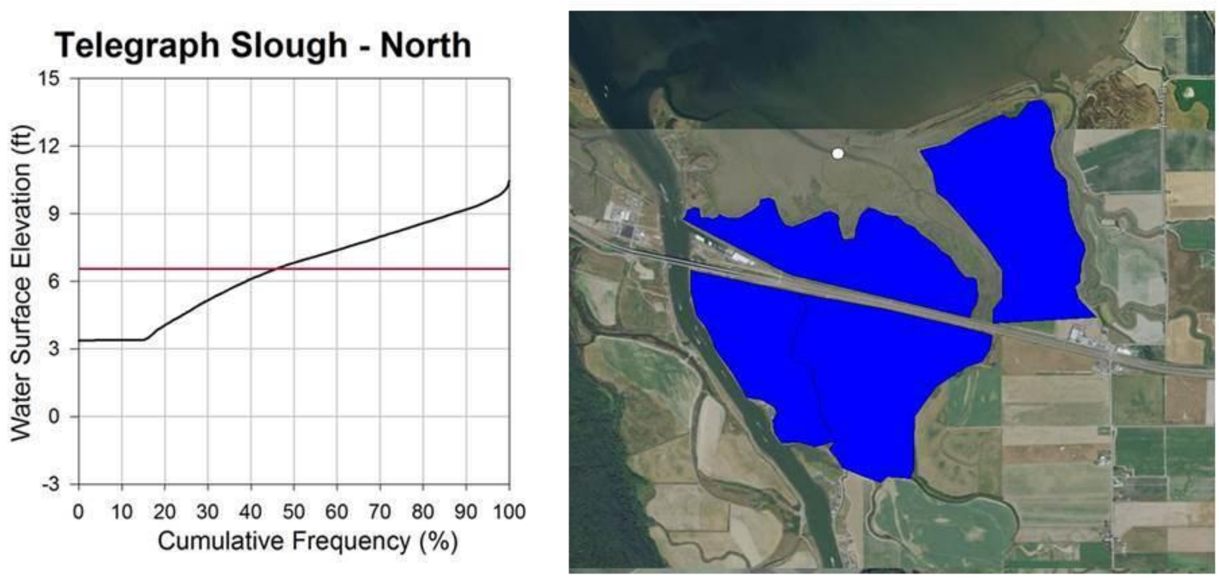

Figure K.88. Cumulative frequency plot and corresponding map for Telegraph Slough (north) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

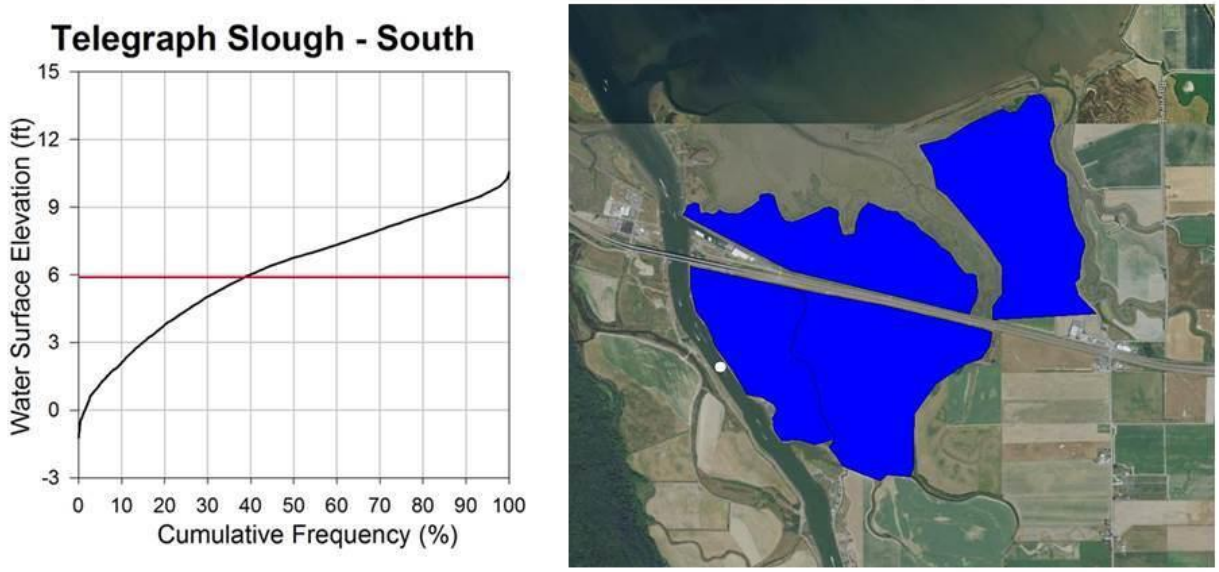

Figure K.89. Cumulative frequency plot and corresponding map for Telegraph Slough (south) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

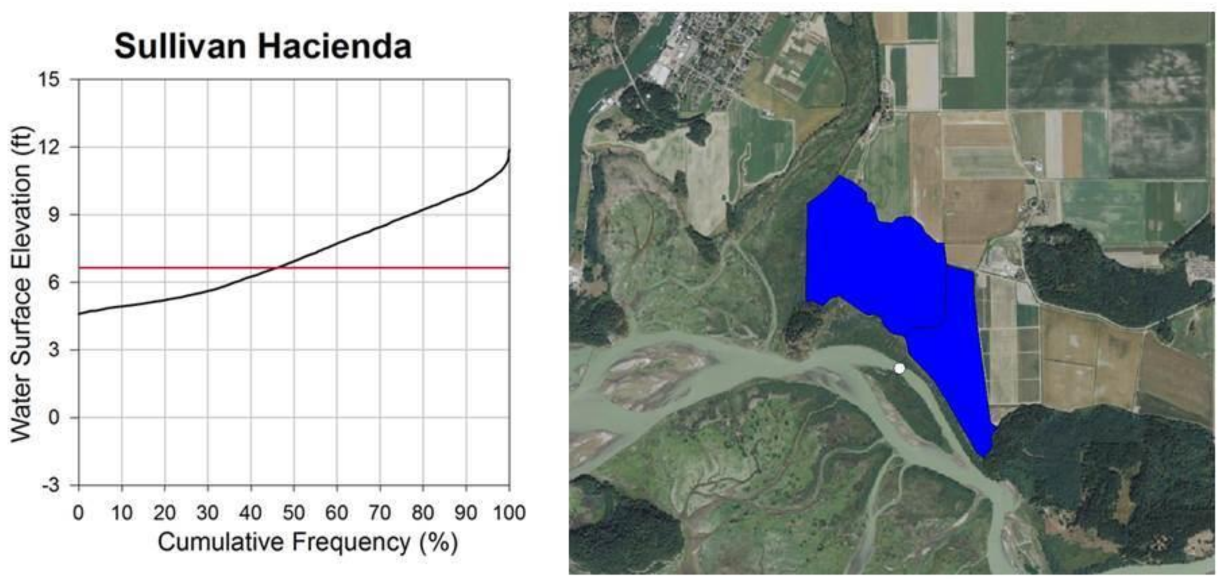

Figure K.90. Cumulative frequency plot and corresponding map for Sullivan Hacienda during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

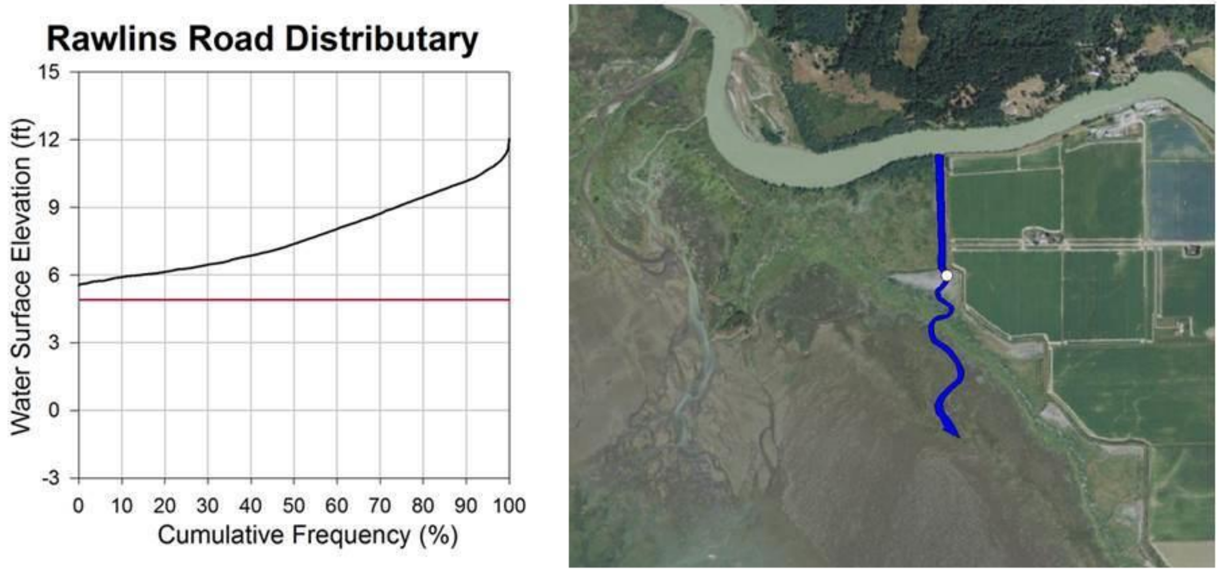

Figure K.91. Cumulative frequency plot and corresponding map for Rawlins Road Distributary during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

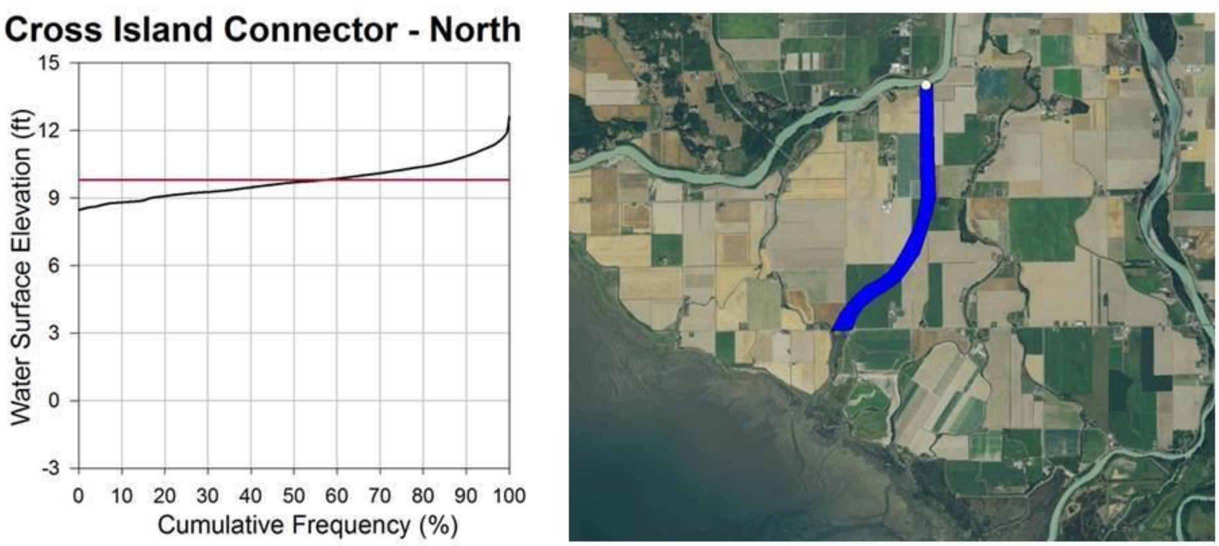

Figure K.92. Cumulative frequency plot and corresponding map for Cross Island Connector (north) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

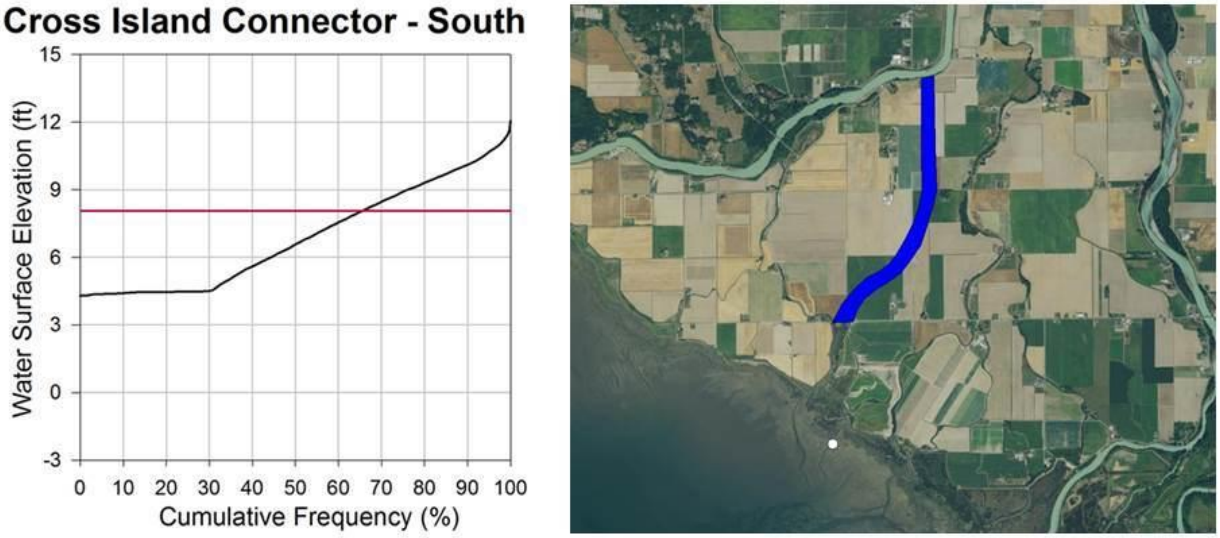

Figure K.93. Cumulative frequency plot and corresponding map for Cross Island Connector (south) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

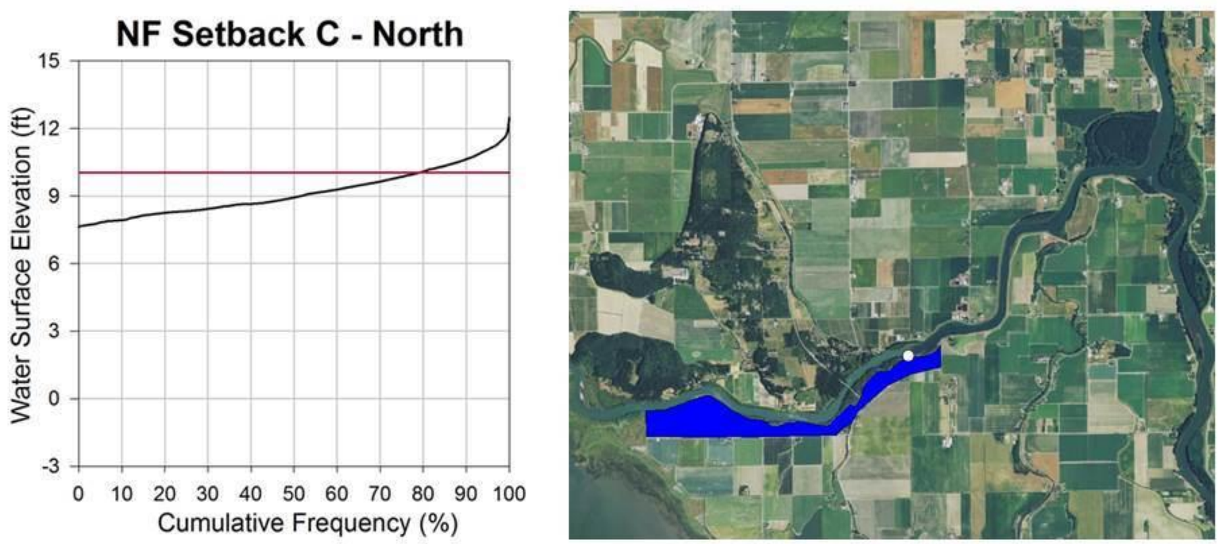

Figure K.94. Cumulative frequency plot and corresponding map for NF Levee Setback C (north) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

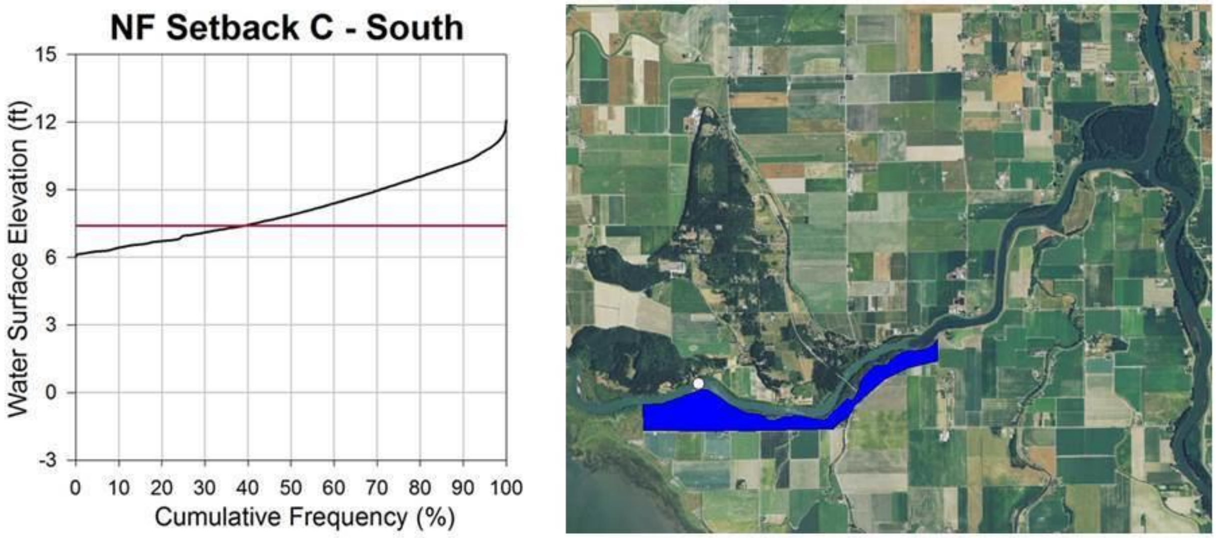

Figure K.95. Cumulative frequency plot and corresponding map for NF Levee Setback C (south) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

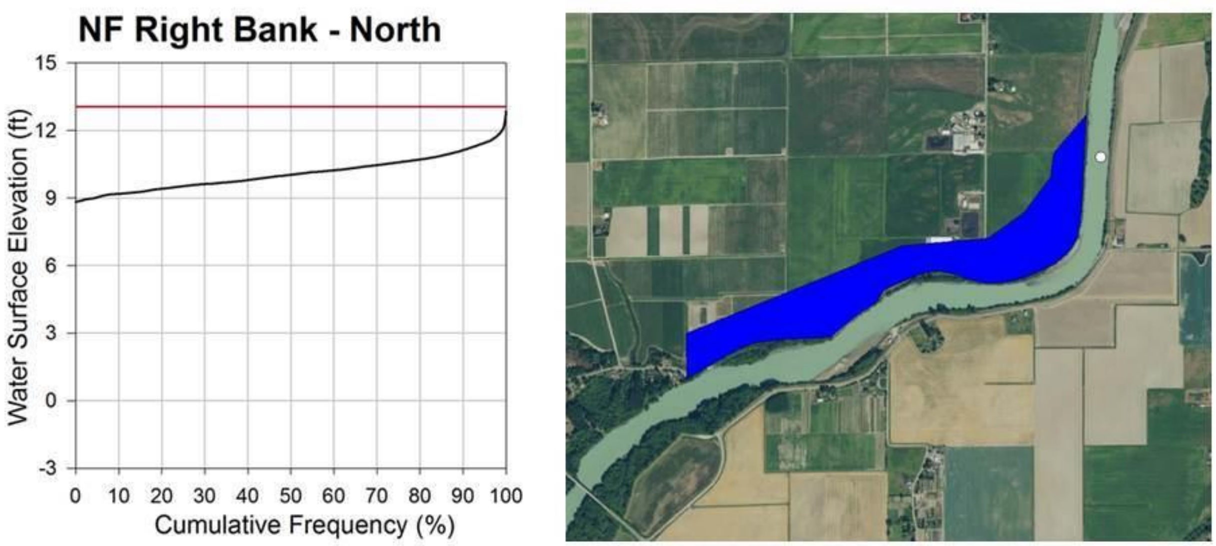

Figure K.96. Cumulative frequency plot and corresponding map for NF Right Bank Levee Setback (north) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

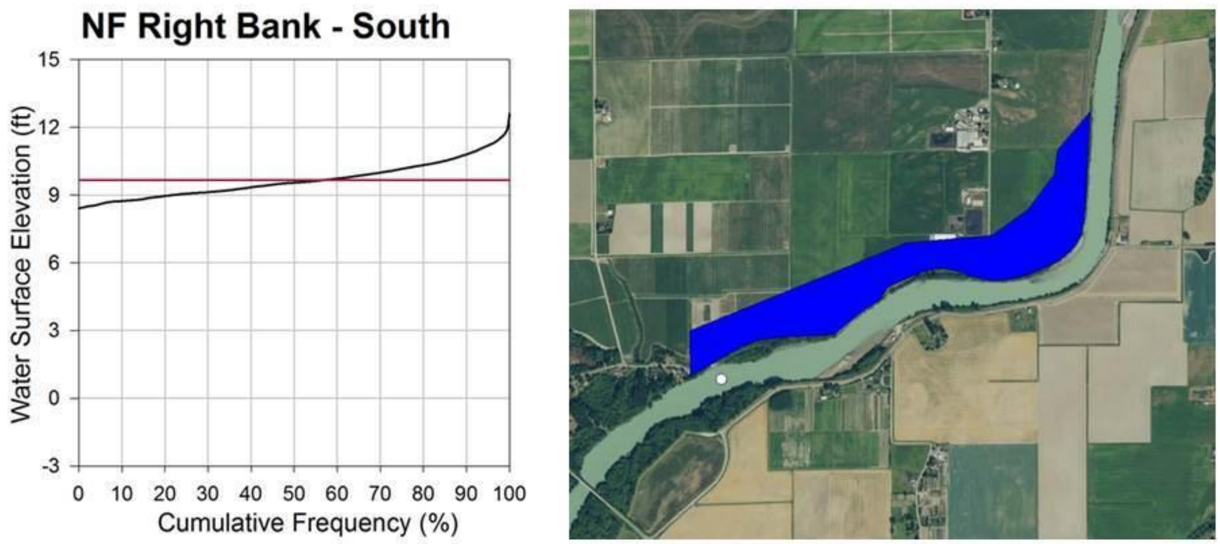

Figure K.97. Cumulative frequency plot and corresponding map for NF Right Bank Levee Setback (south) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

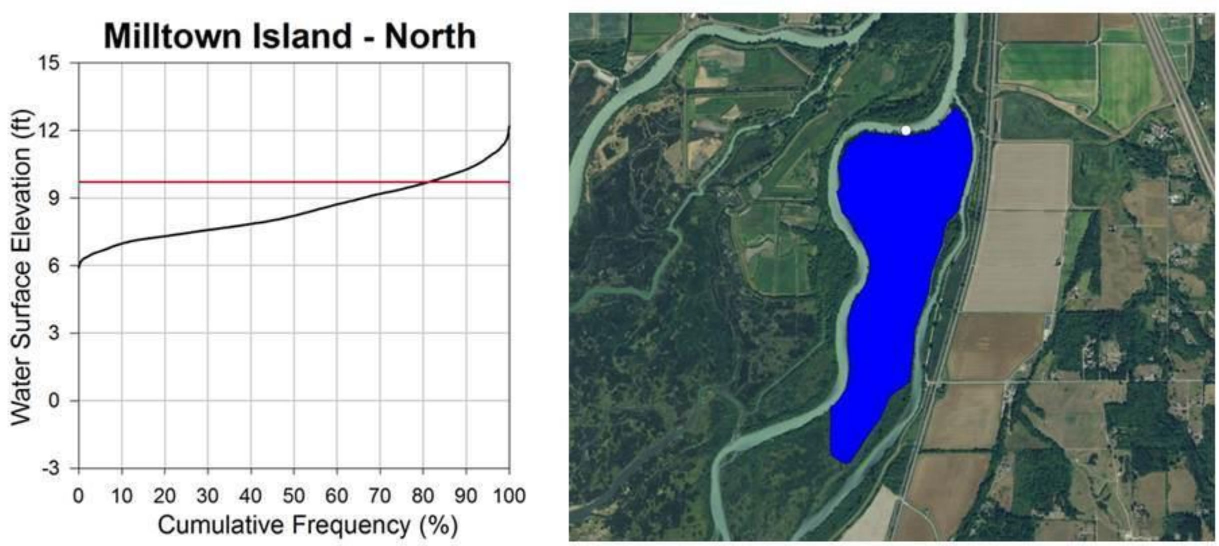

Figure K.98. Cumulative frequency plot and corresponding map for Milltown Island (north) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

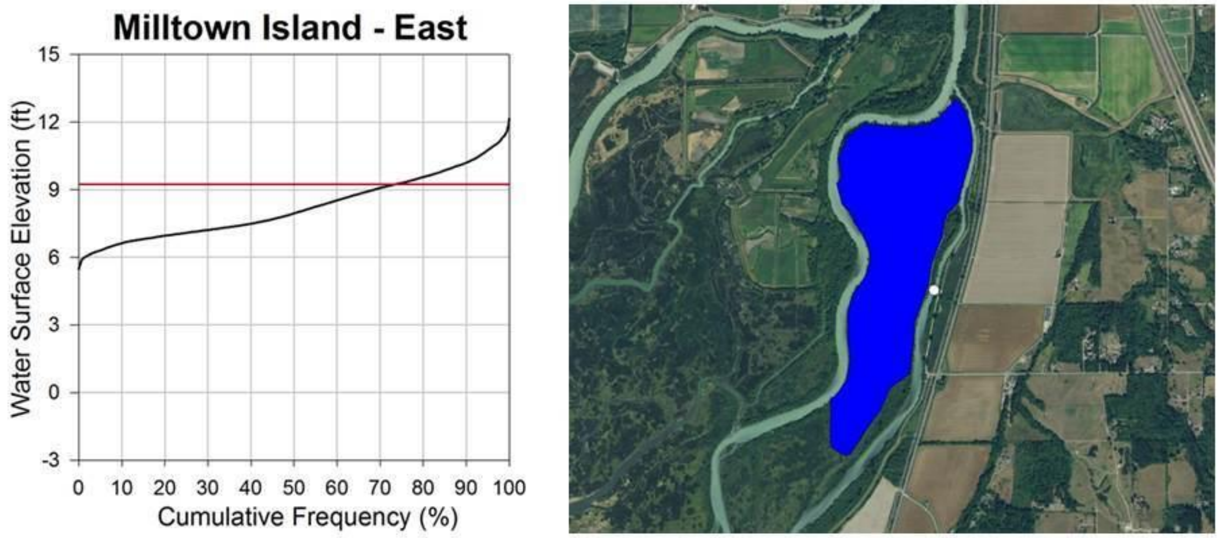

Figure K.99. Cumulative frequency plot and corresponding map for Milltown Island (east) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

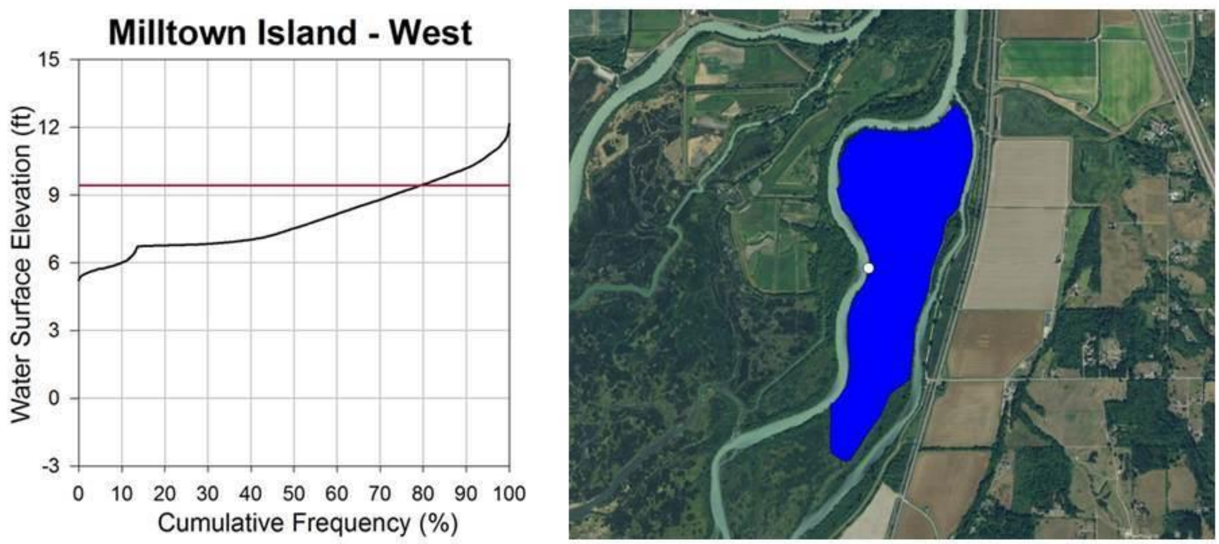

Figure K.100. Cumulative frequency plot and corresponding map for Milltown Island (west) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

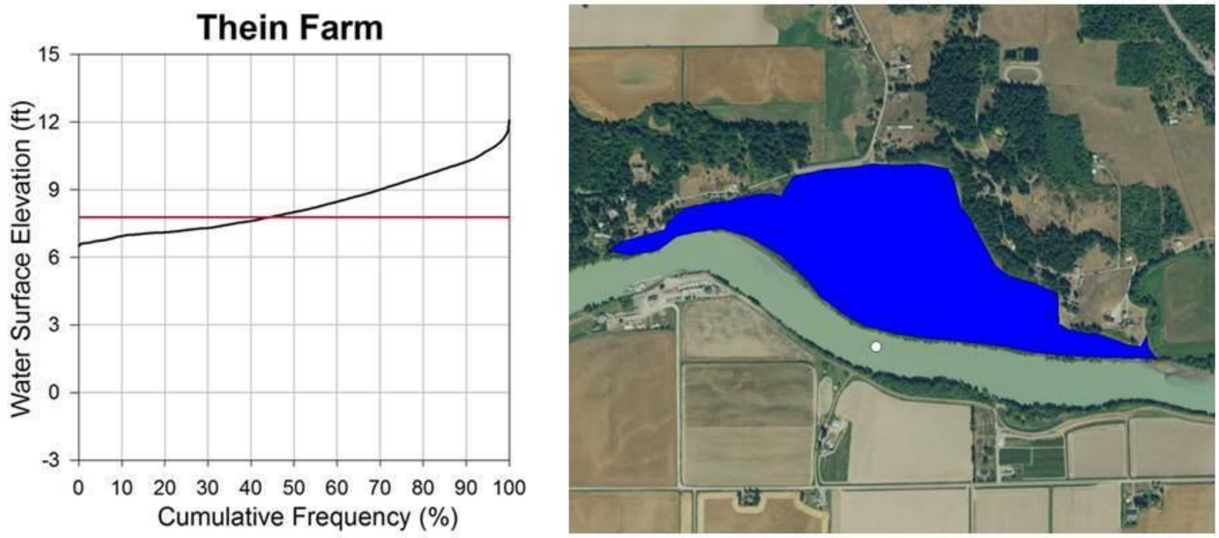

Figure K.101. Cumulative frequency plot and corresponding map for Thein Farm during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

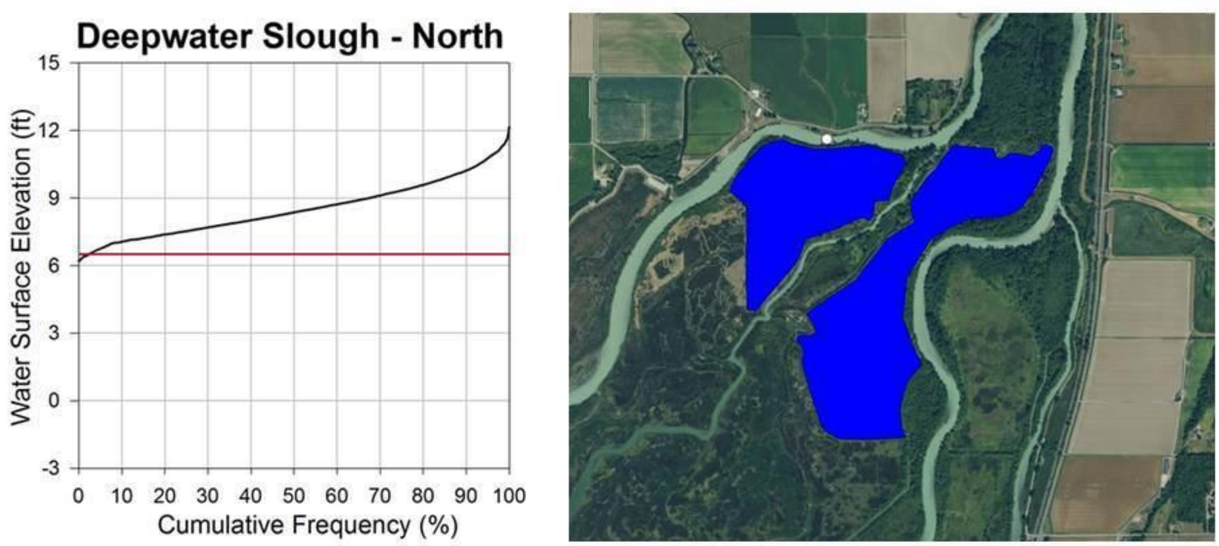

Figure K.102. Cumulative frequency plot and corresponding map for Deepwater Slough (north) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

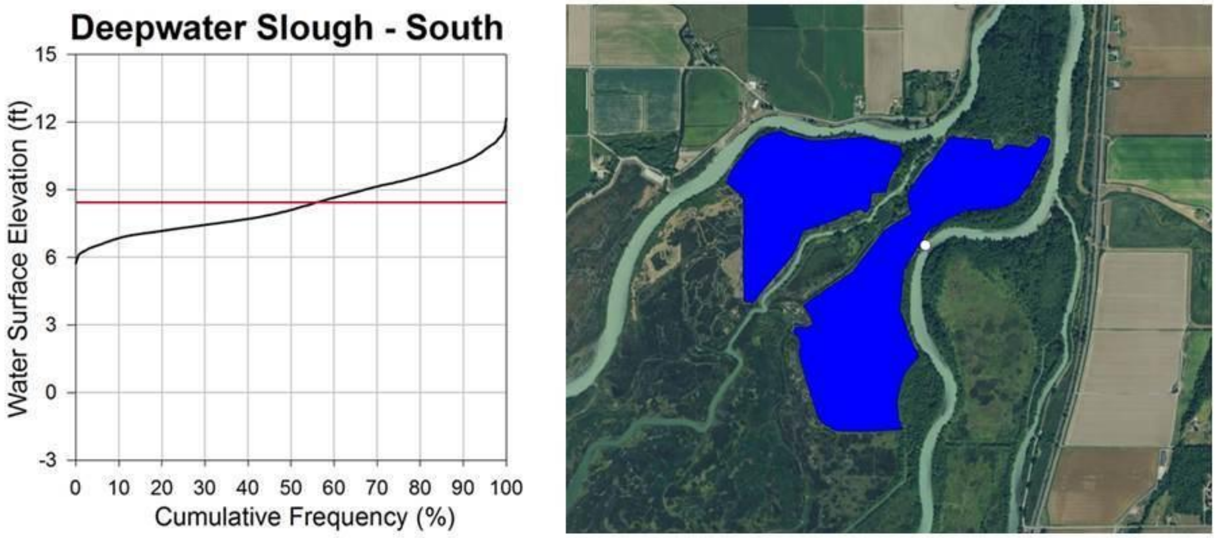

Figure K.103. Cumulative frequency plot and corresponding map for Deepwater Slough (south) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

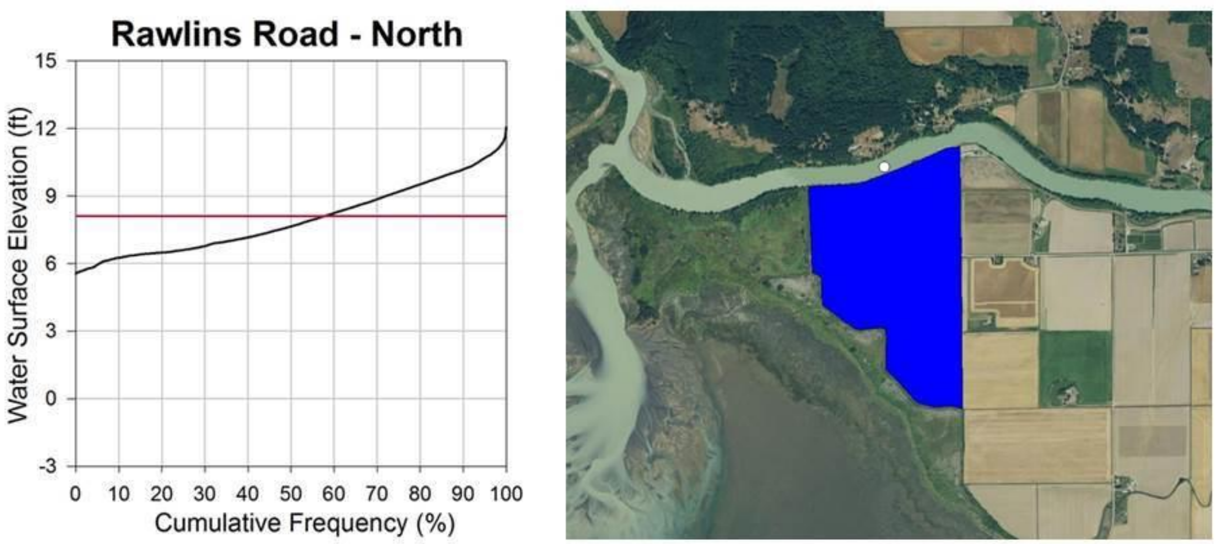

Figure K.104. Cumulative frequency plot and corresponding map for Rawlins Road (north) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

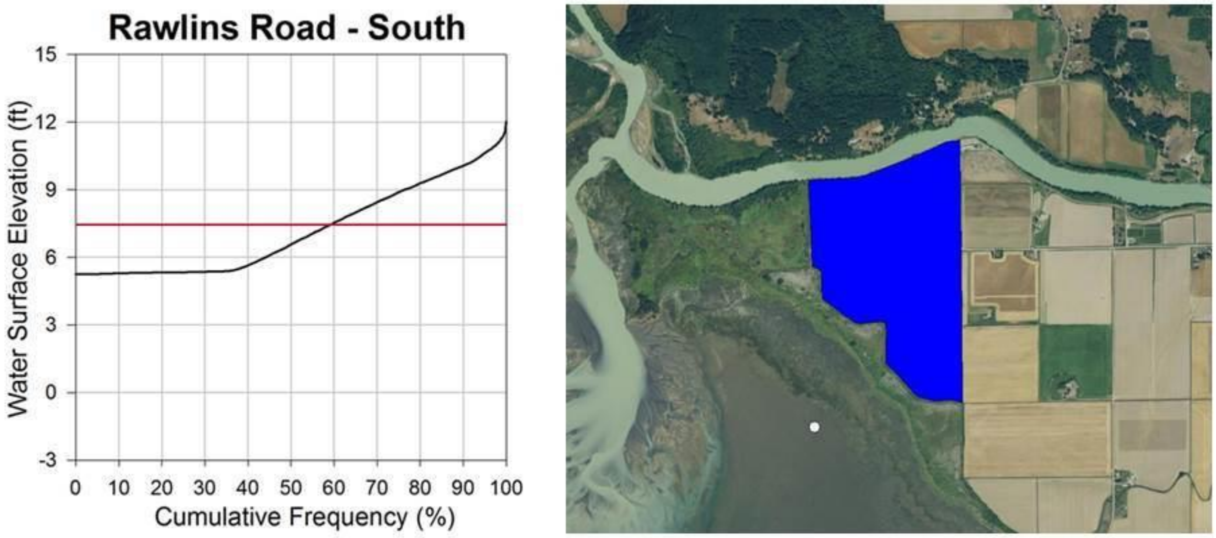

Figure K.105. Cumulative frequency plot and corresponding map for Rawlins Road (south) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

K.6 Climate Change with Projects Deliverable 6

Deliverable 6 is a set of contour maps showing the change in salinity between the Climate Change Baseline simulation (Simulation 9) and the Climate Change with Projects simulation (Simulation 10). The compared conditions were a low flow (12,000 cfs) and future high spring tide (12.67 ft) representing the change from future baseline to future restored conditions and the effect of restoration action on curbing the impact of sea level rise. The compared salinity values represent an average of the bottom 10% of the water depth to show the furthest extent of the salt wedge. No change is represented as white across the extent of the model grid. High-resolution, georeferenced maps with more detailed contour gradients were also generated for the simulation and provided to the SHDM Team. Changes in salinity could affect habitat suitability, the distribution of fish, and have potential effects on agriculture. The maps can be seen in Figure K.106 through Figure K.121.

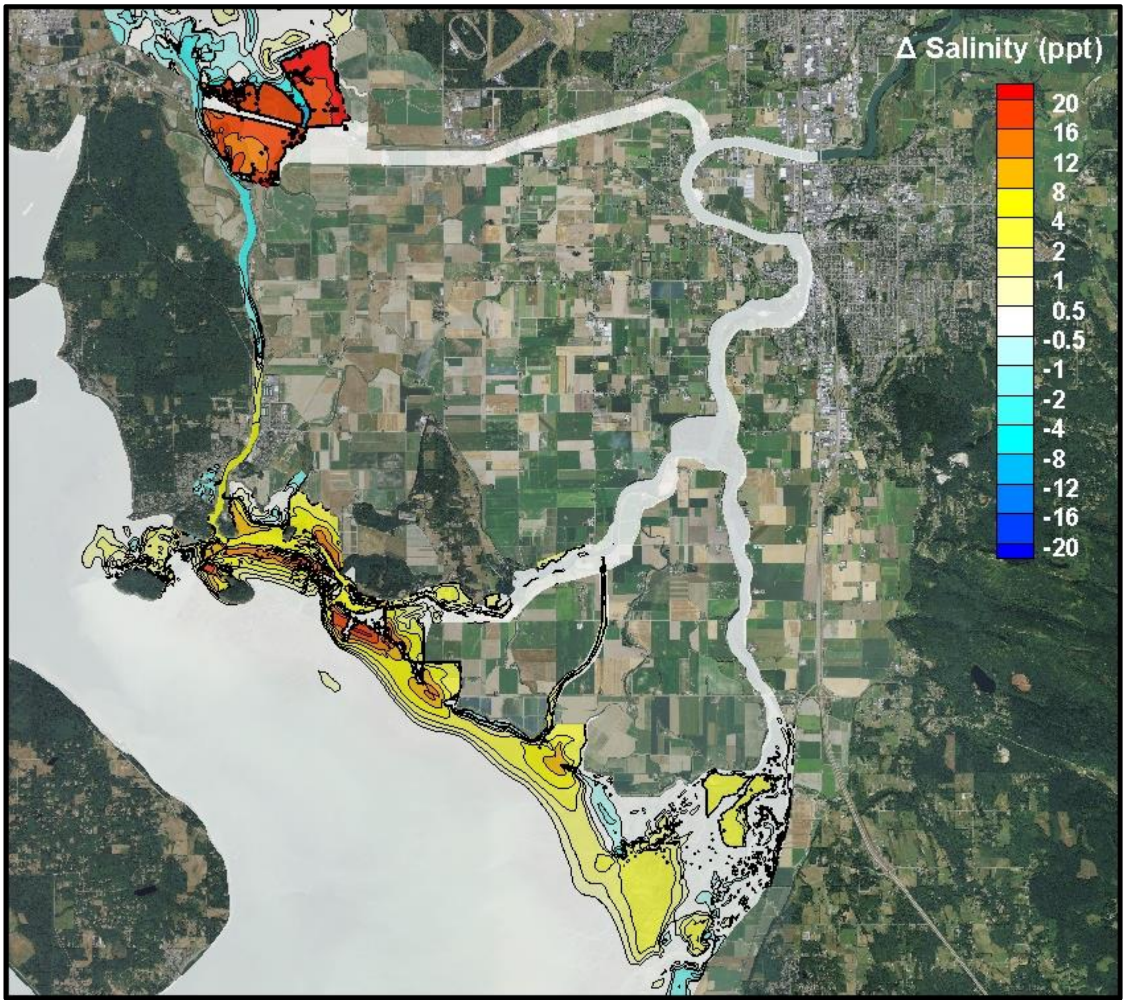

Figure K.106. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation with low flow and high tide.

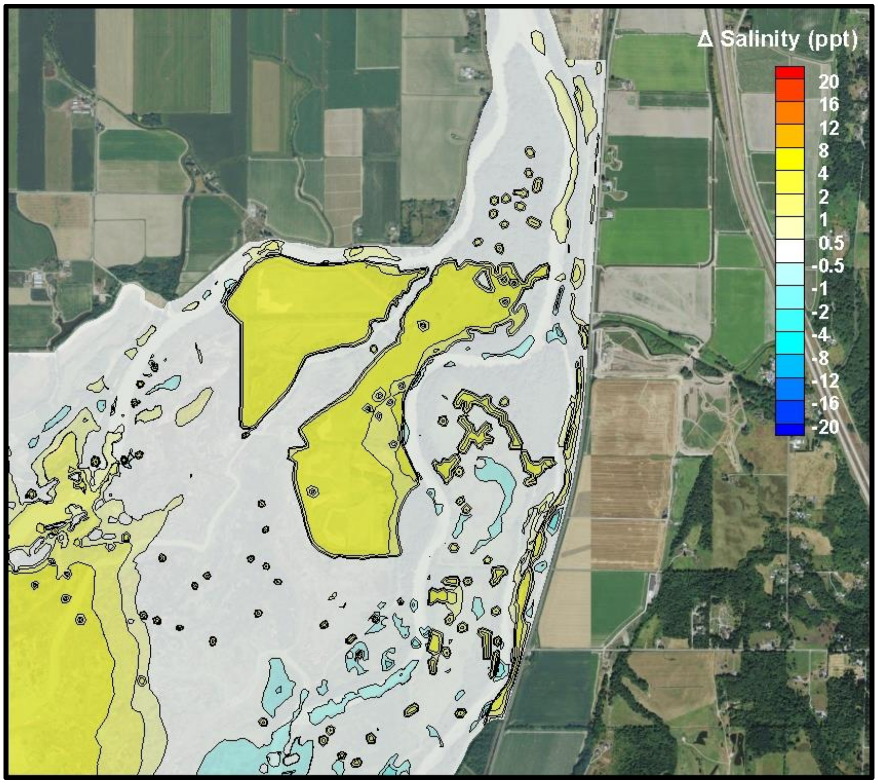

Figure K.107. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for SF Levee Setback 2, 3, 4 with low flow and high tide

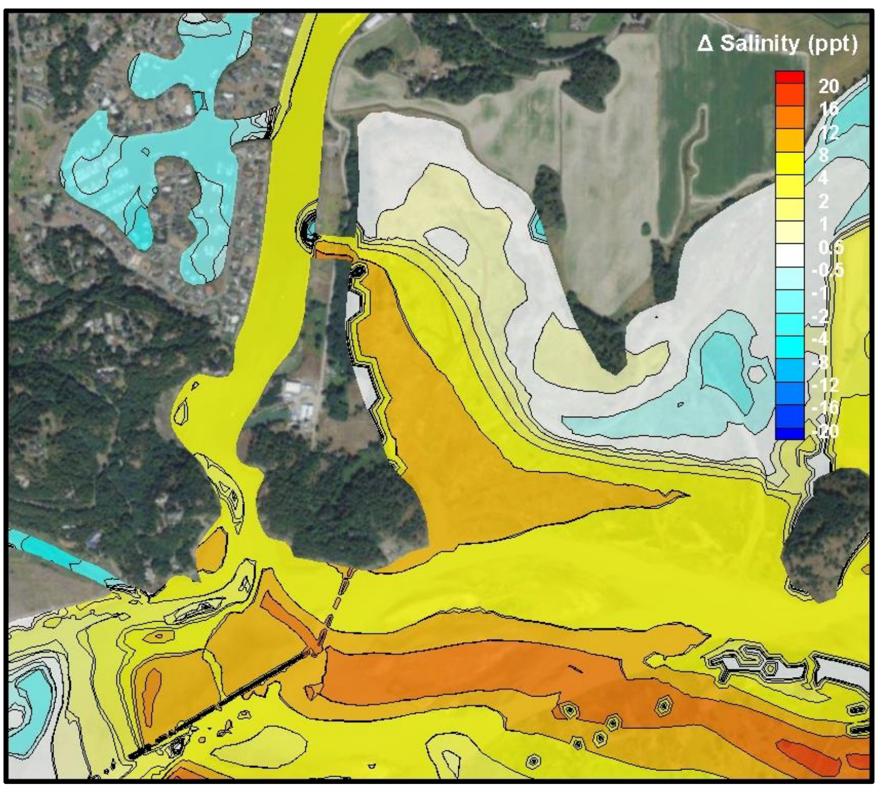

Figure K.108. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for McGlinn Causeway with low flow and high tide

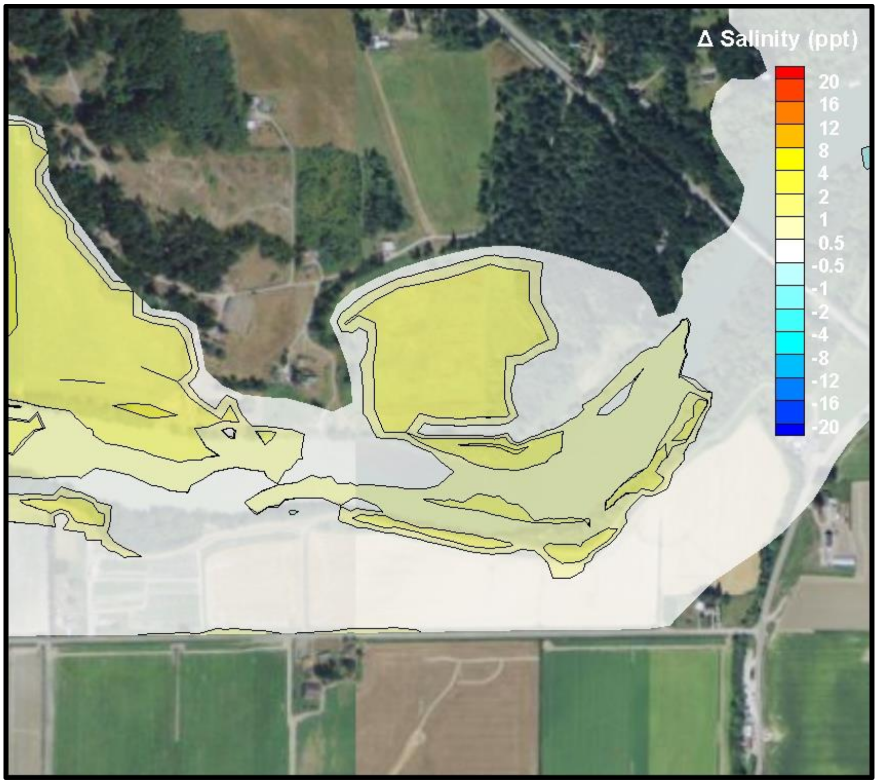

Figure K.109. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Pleasant Ridge South with low flow and high tide

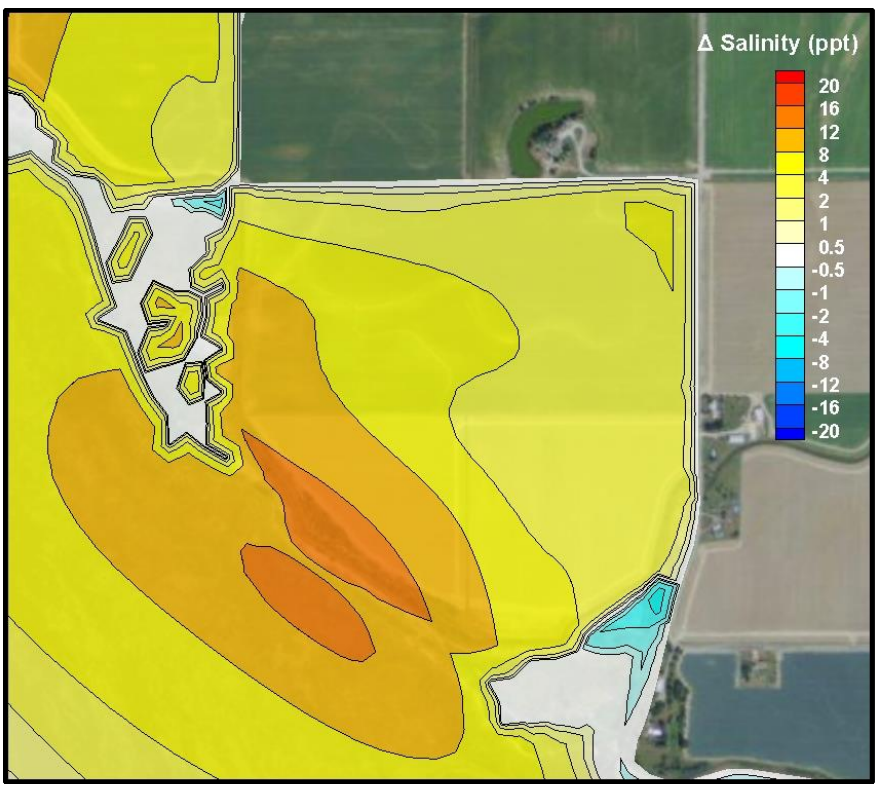

Figure K.110. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Hall Slough with low flow and high tide

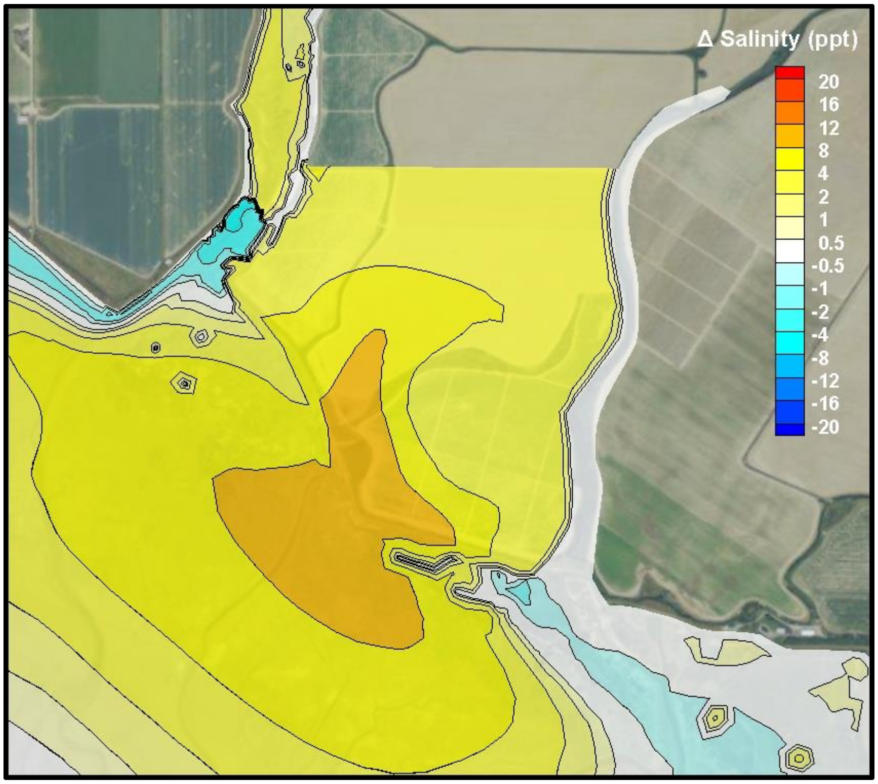

Figure K.111. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Fir Island Farm with low flow and high tide

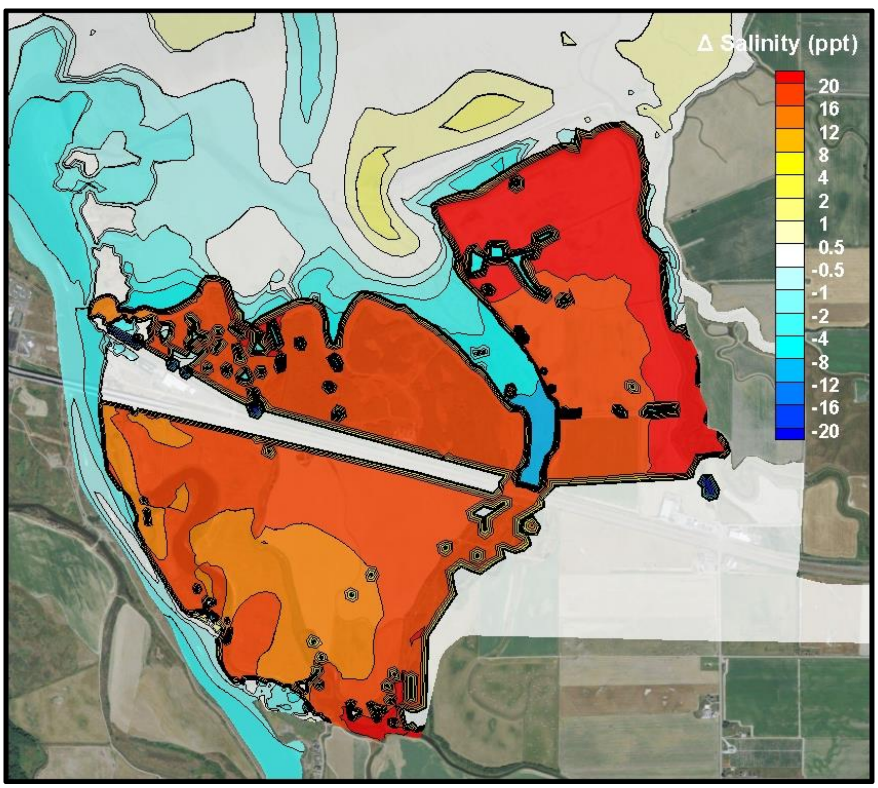

Figure K.112. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Telegraph Slough Full with low flow and high tide

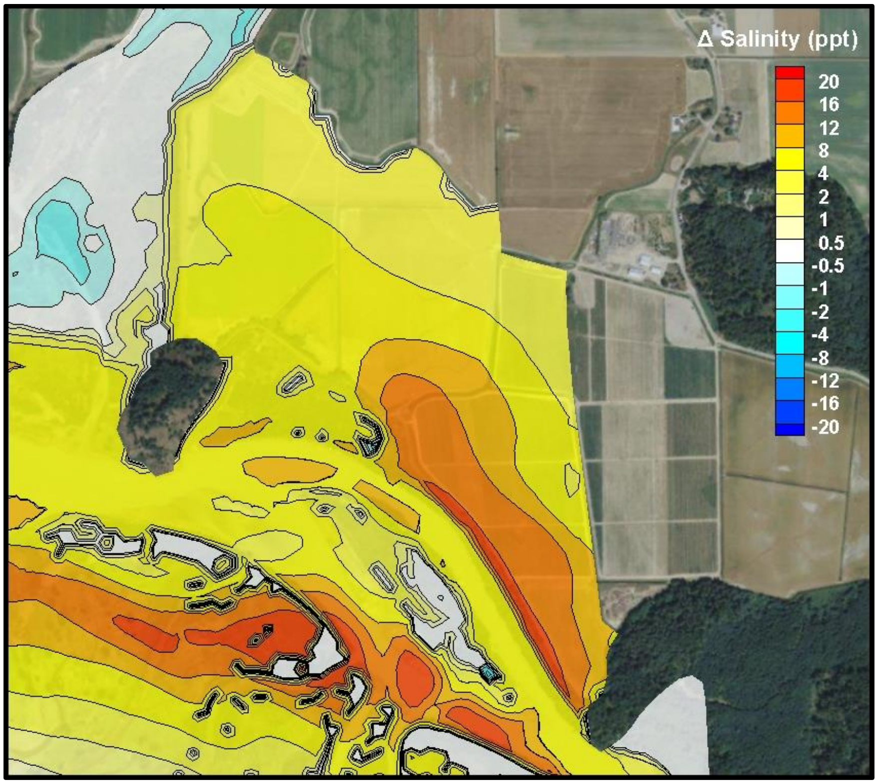

Figure K.113. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Sullivan Hacienda with low flow and high tide

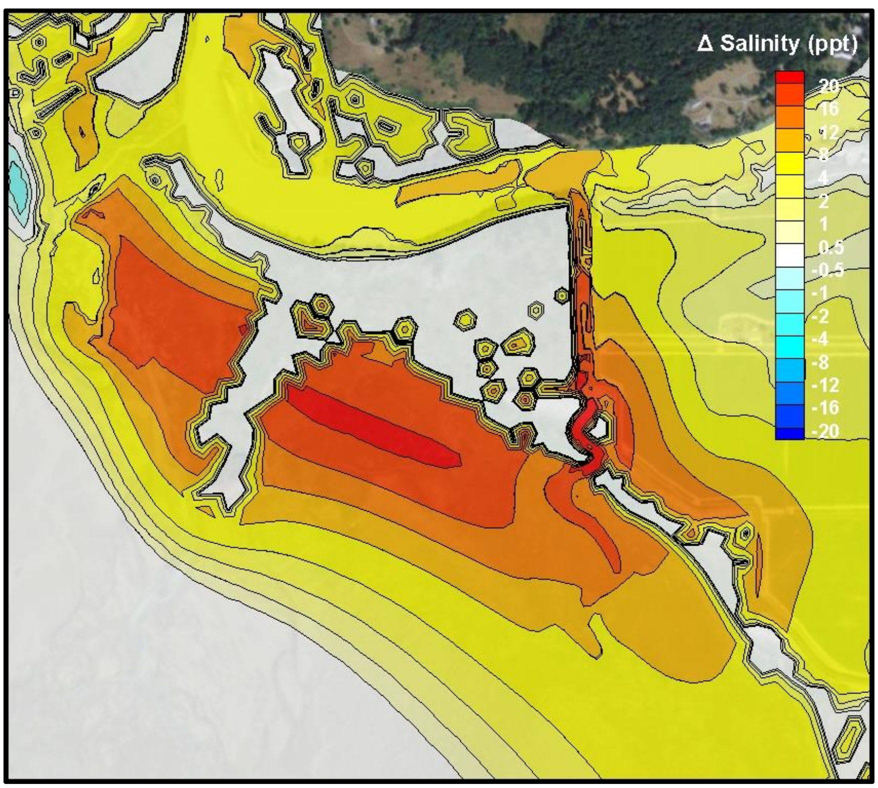

Figure K.114. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Rawlins Distributary with low flow and high tide

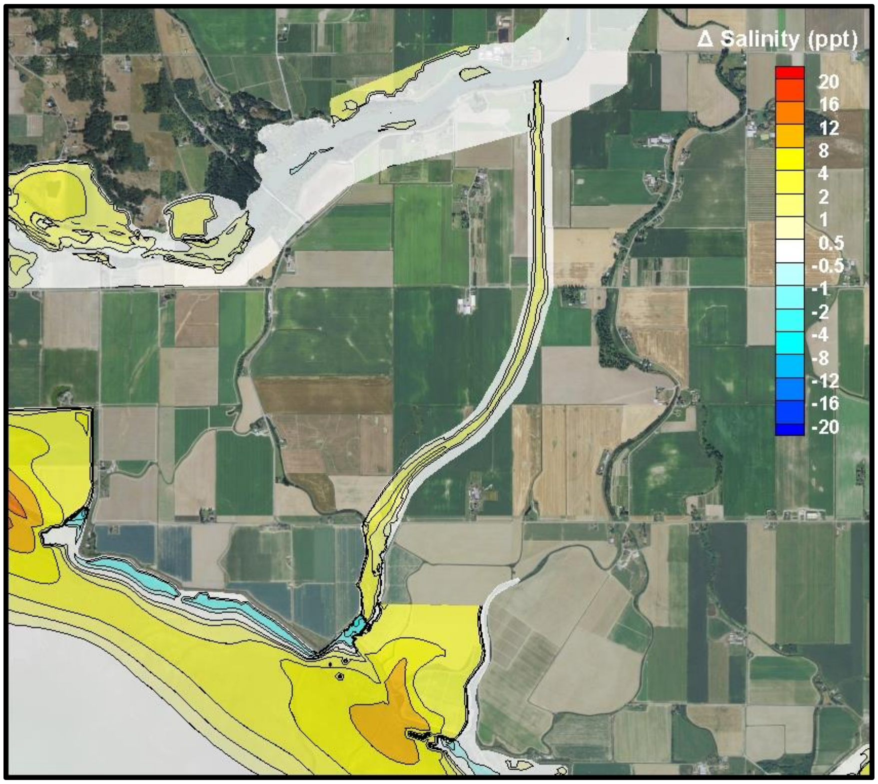

Figure K.115. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Cross Island Connector with low flow and high tide

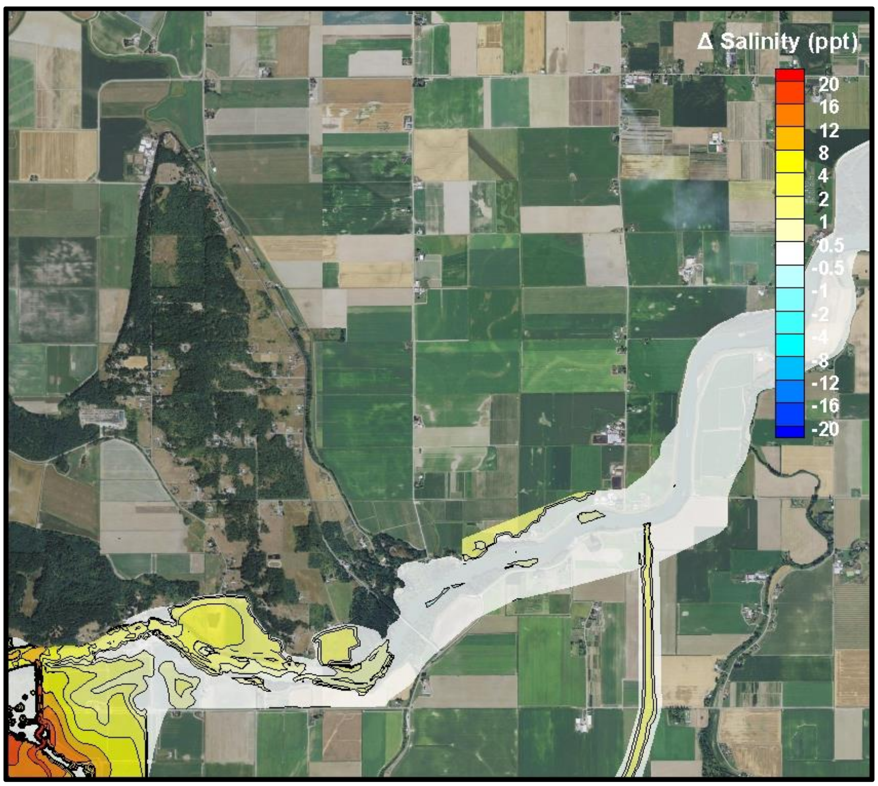

Figure K.116. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for NF Levee Setback C with low flow and high tide

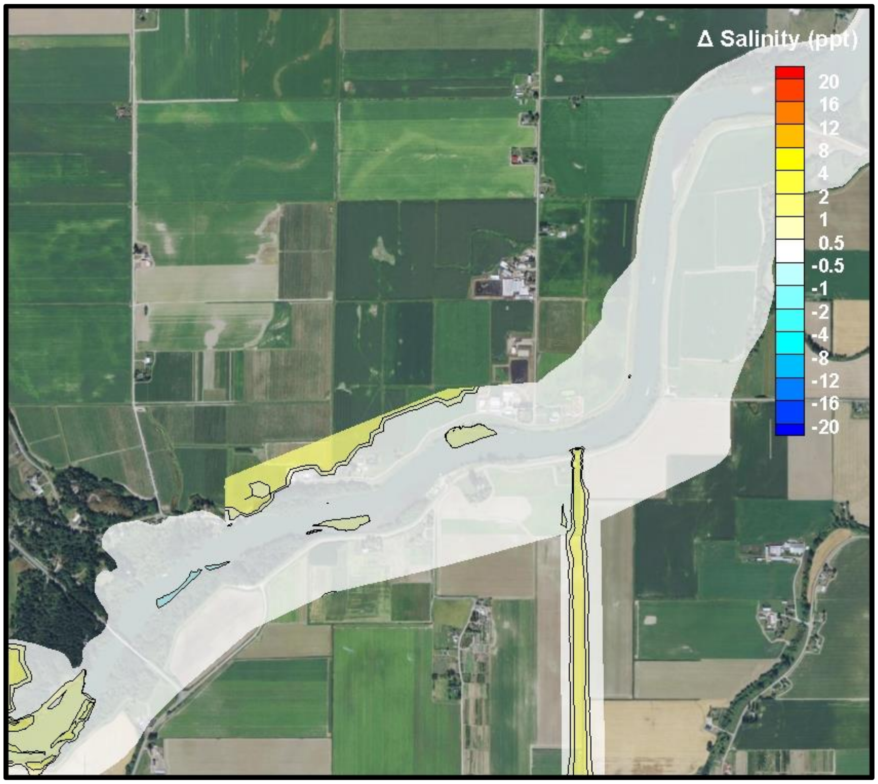

Figure K.117. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for NF Right Bank Levee Setback with low flow and high tide

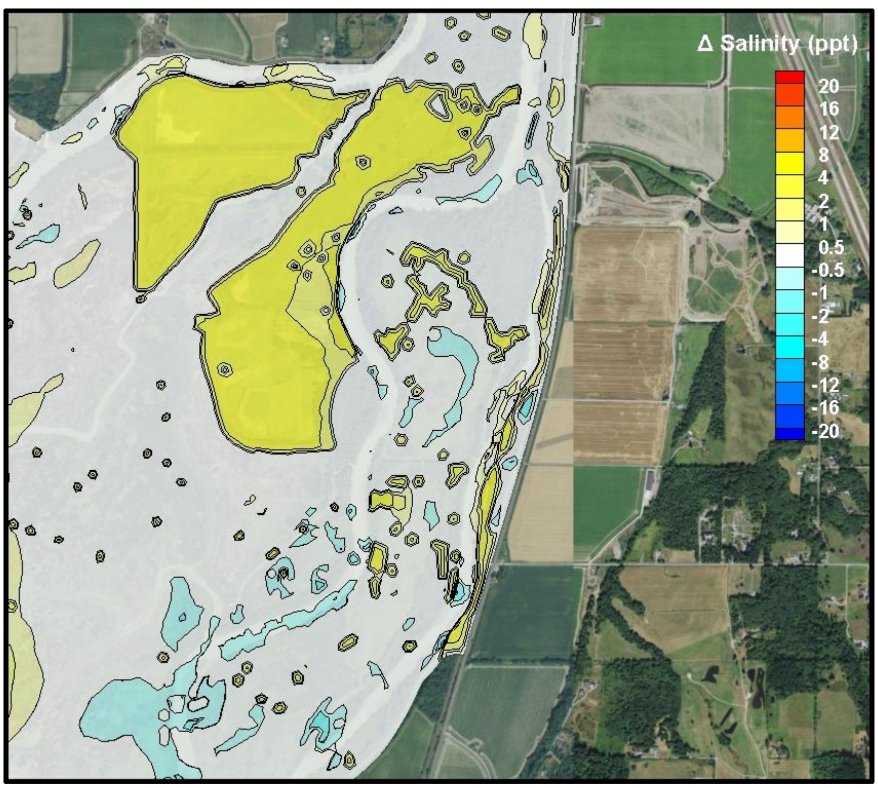

Figure K.118. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Milltown Island with low flow and high tide

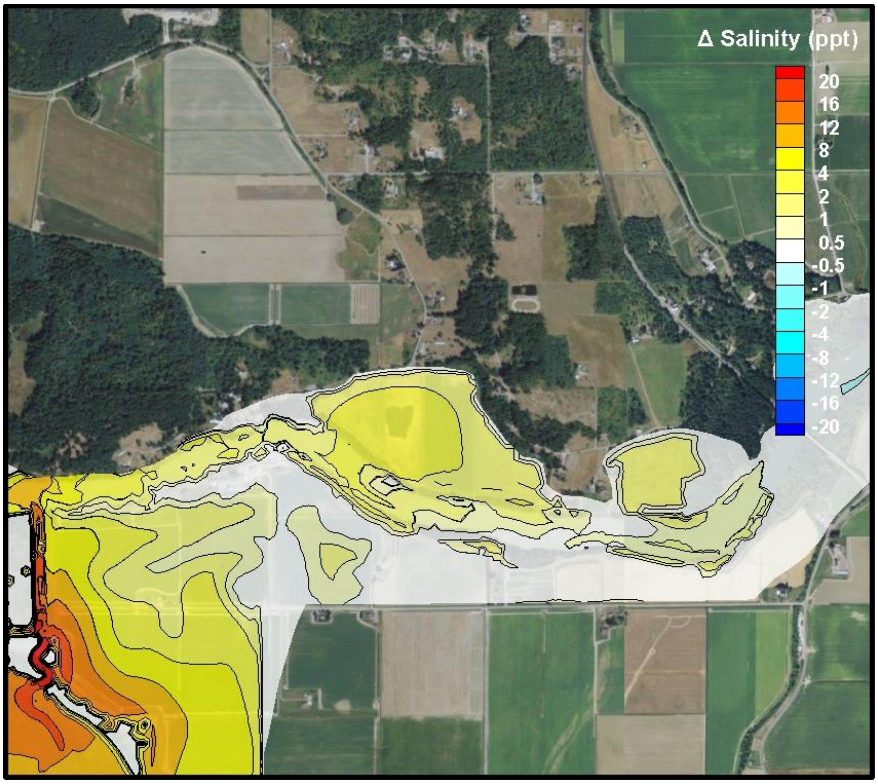

Figure K.119. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Thein Farm with low flow and high tide

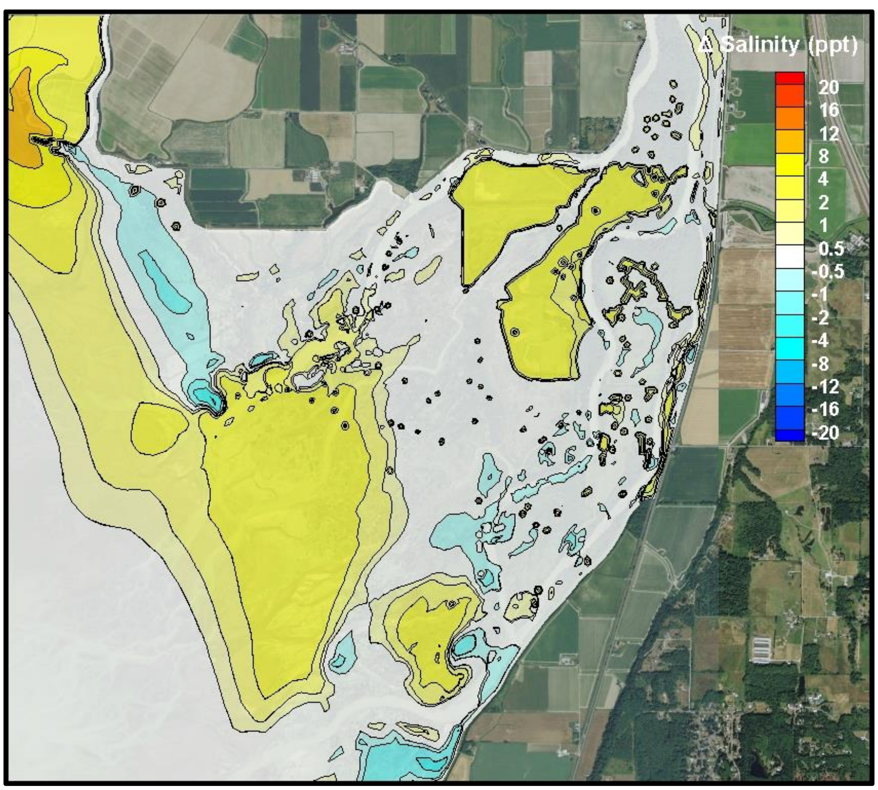

Figure K.120. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Deepwater Slough Phase 2 with low flow and high tide

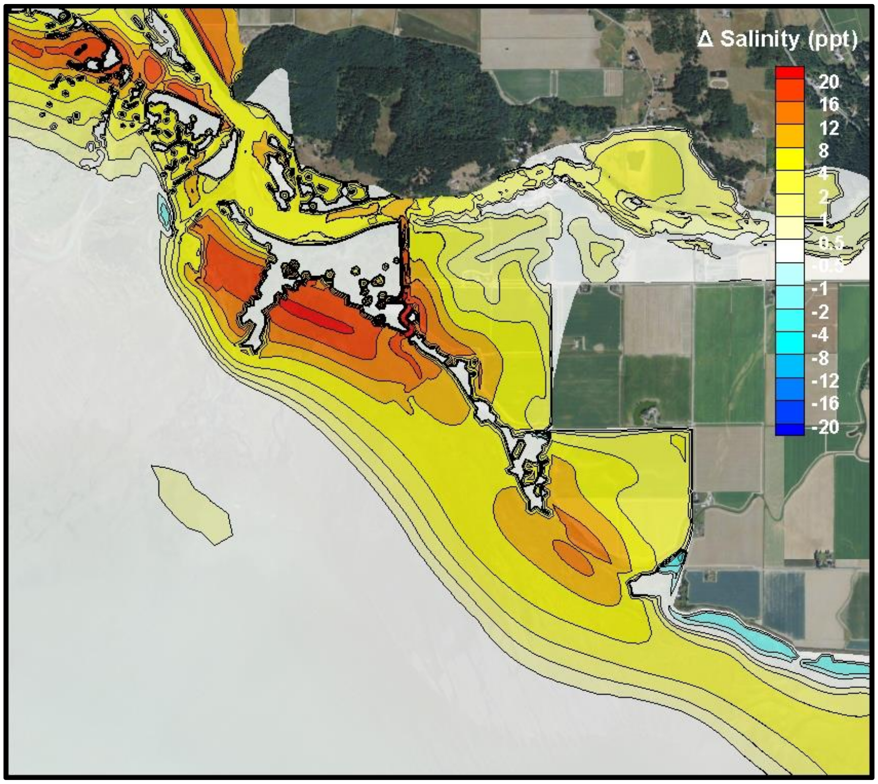

Figure K.121. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Rawlins Road with low flow and high tide

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Appendix D: Beamer et al 2016 Report

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Memorandum

To: Polly Hicks (NOAA Restoration Center), Jenny Baker (TNC), Jenna Friebel (WDFW)

Cc: Steve Hinton (SRSC Restoration Program)

From: Eric Beamer, Greg Hood, and Karen Wolf (SRSC Research Program)

Date: December 27, 2016

Subject: Habitat and juvenile Chinook benefit predictions of candidate restoration projects within the Skagit tidal delta

This memo is partial fulfillment of an agreement between the SRSC Research Program and the NOAA/WRCO SRFB Skagit Hydrodynamic Model (SHDM) Project (P104051-A102542-n/a) where we were asked to make predictions of 1) channel habitat formed, 2) landscape connectivity, and 3) juvenile Chinook benefit (carrying capacity) for 18 of 23 candidate restoration projects within the Skagit tidal delta. We provide results for all requested SHDM projects per our agreement (Table 1).

Table 1. Summary of SHDM project name and number. Projects included in this memo are shaded.

SHDM project #	Project name	Prediction results in this memo
1	SF Levee Setback 2, 3, 4	Yes
2	McGlinn Causeway	Yes
3	TNC South Fork	Yes
4	Cottonwood Island	No
5	East Cottonwood	Yes
6	Pleasant Ridge South	Yes
7	Hall Slough	Yes
8	Fir Island Farm	No
9	Telegraph Slough Full	Yes
10	Sullivan Hacienda	Yes
11	Rawlins Road Distributary Channel	Yes
12	Fir Island Cross Island Connector	No
13	Avon-Swinomish Bypass	Yes
14	NF Left Bank Levee Setback C	Yes
15	NF Left Bank Levee Setback A	Yes
No # given	NF Left Bank Levee Setback B	Yes
16	NF Right Bank Levee Setback	Yes
17	Milltown Island	No
18	Telegraph Slough 1	Yes
19	Thein Farm	No
20	Deepwater Slough Phase 2	Yes
21	Rawlins Road	Yes
22	Telegraph Slough 1&2	Yes

Contents

Executive Summary

We made predictions of 1) channel habitat formed, 2) landscape connectivity, and 3) juvenile Chinook benefit (carrying capacity) for 18 of 23 candidate restoration projects within the Skagit tidal delta as part of the Skagit Hydrodynamic Model (SHDM) Project. Midpoint channel area predictions by individual projects, if constructed, ranged from a low of 0.08 hectares (Pleasant Ridge South) to a high of 32.46 hectares (Telegraph Slough Full) (Table 2). Midpoint juvenile Chinook salmon carrying capacity estimates for individual projects, if constructed, ranged from a low of 3,000 (South Fork Setback) to a high of 275,000 fish per year (Avon-Swinomish Bypass) (Table 3). Each SHDM project is discussed in detail below, but we highlight a few important topics in the executive summary.

<u>Avon-Swinomish Bypass</u>: This project is unique compared to all other projects. Many assumptions must be accepted to believe the predictions for this project. The project is very conceptual and required us to utilize input data that are outside the data range used to develop the models for calculating landscape connectivity and predicting juvenile Chinook carrying capacity. The Avon-Swinomish Bypass, if constructed, would have large negative offsite impacts to inundation of the main Skagit tidal delta and could move many downstream migrating juvenile Chinook away from the majority of habitat in the Skagit estuary. We were unable to predict habitat areas for the bypass channel reach with the information provided. Nevertheless, we provide meaningful discussion of some pros and cons to juvenile Chinook salmon for this project, which may be helpful to managers as they decide which suite of SHDM projects are pursued further.

<u>Prediction bias potential</u>: In addition to the Avon-Swinomish Bypass project, several other projects utilize input data that are outside the range used to develop the models for predictions. The TNC South Fork and East Cottonwood projects are good examples. Both projects are located upstream of sites used to make the juvenile Chinook carrying capacity model and therefore have higher landscape connectivity values than what was used to create the carrying capacity model. We believe juvenile Chinook predictions for these two projects are likely biased high based on their comparison to fish monitoring data collected after the dataset used to create the juvenile Chinook carrying capacity model.

<u>Comparison to the Skagit Chinook Recovery Plan (‘Chinook Plan’)</u>: Three SHDM projects are listed in the Chinook Plan (SRSC and WDFW 2005). These projects are included in our analysis because improved prediction tools are thought to change the results presented in the Chinook Plan.

- The North Fork Left Bank Levee Setback A project in our analysis has the same project footprint as the North Fork Levee Setback project listed on page 191 of the Chinook Plan. Our analysis of North Fork Left Bank Levee Setback A uses 1) an improved habitat predictor method (Hood 2015) over what was used in the Chinook Plan and 2) breaks the restoration area up into smaller, more realistic, hydrologic units for estimating channel formation. Our analysis results in significantly less Chinook benefit compared to the Chinook Plan. The midpoint prediction for North Fork Left Bank Levee Setback A is approximately 85,000 fish per year whereas the Chinook Plan’s estimate is over 600,000 fish per year.

- Two other projects, Sullivan Hacienda and Deepwater Slough Phase 2, have significantly more juvenile Chinook predicted in our analysis than estimated in the Chinook Plan. Our midpoint predictions for the Sullivan Hacienda and Deepwater Slough Phase 2 are 220,000 and 160,000 fish per year, respectively. In contrast, Chinook Plan estimates are approximately 37,000 and 96,000 fish per year for Sullivan Hacienda and Deepwater Slough Phase 2, respectively. The main reason for the increase in Chinook benefit is our inclusion of new channel area forming in adjacent downstream marshes caused by the increased tidal flushing due to the restoration project. The Chinook Plan did not account for this issue.

McGlinn Causeway: We examined how recent distributary channel changes within the North Fork Skagit delta would affect the McGlinn Causeway Project. We concluded landscape connectivity within the North Fork tidal delta and Dunlap Bay areas has not changed enough between 2004 and 2013 to predict the McGlinn Causeway project will have a different outcome for juvenile Chinook carrying capacity than what was already predicted in the Chinook Plan.

Table 2. Summary of channel habitat area estimates for SHDM projects.

SHDM project	Predicted channel area (ha) Midpoint	Lower 80% CI	Higher 80% CI	Comment
1 South Fork Setback	0.17	0.05	0.50	Allometry model
3 TNC South Fork	0.405			Midpoint is constructed channel area provided by SHDM Project Team (2016)
5 East Cottonwood	0.809			Midpoint is constructed channel area provided by SHDM Project Team (2016)
6 Pleasant Ridge South	0.08	0.03	0.25	Allometry model
7 Hall Slough	2.73	0.92	8.16	Allometry model
9 Telegraph Slough Full	32.46	12.70	82.91	Allometry model
10 Sullivan Hacienda	14.06	5.67	34.86	Allometry model
11 Rawlins Rd. Dist. Ch.	0.42			Midpoint is constructed channel area provided by SHDM Project Team (2016)
13 Avon-Swinomish Bypass	16.70	6.49	42.94	Allometry model for Telegraph 1 & 2 polygons. No habitat estimates were provided or made for the bypass reach
14 NF Left Bank Levee Setback C	1.82	0.61	5.51	Allometry model
15 NF Left Bank Levee Setback A	2.436	0.807	7.410	Allometry model
(no#) NF Left Bank Levee Setback B	2.08	0.694	6.32	Allometry model
16 NF RB Setback	0.193	0.063	0.600	Allometry model
18 Telegraph Slough 1	3.74	1.49	9.37	Allometry model
20 DW Slough Phase 2	9.10	3.63	22.89	Allometry model
21 Rawlins Road	3.81	1.43	10.20	Allometry model
22 Telegraph Slough 1 & 2	16.70	6.49	42.94	Allometry model

Table 3. Summary of juvenile Chinook carrying capacity (fish per year) estimates for SHDM projects. The variability column is coefficient of variation in carrying capacity estimates due to landscape connectivity differences for projects with multiple pathways to the same polygon.

SHDM project	Juvenile Chinook carrying capacity			Variability due to connectivity	Comment
	Average midpoint	Lowest estimate	Highest estimate		
1 South Fork Setback	3,027	883	8,940		no range estimated for connectivity
3 TNC South Fork	31,678				no range estimated for habitat or connectivity
5 East Cottonwood	178,230	129,089	227,371	38.99%	no range estimated for habitat
6 Pleasant Ridge South	2,488	933	7,776		no range estimated for connectivity
7 Hall Slough	22,889	7,381	69,429	2.42%	
9 Telegraph Slough Full	102,855	37,746	282,719	6.15%	
10 Sullivan Hacienda	219,936	67,183	619,089	15.67%	
11 Rawlins Rd Dist Ch	9,268				no range estimated for habitat or connectivity
13 Avon-Swinomish Bypass	275,506	71,057	946,651	47.56%	unique project; requires accepting untested assumptions
14 NF Left Bank Levee Setback C	53,476	17,937	161,883		no range estimated for connectivity
15 NF Left Bank Levee Setback A	85,239	28,079	259,946		no range estimated for connectivity
(no#) NF Left Bank Levee Setback B	65,468	21,811	199,243		no range estimated for connectivity
16 NF RB Setback	8,119	2,650	25,245		no range estimated for connectivity
18 Telegraph Slough 1	13,956	5,421	35,836	3.53%	
20 DW Slough Phase 2	160,334	52,141	477,023	14.91%	
21 Rawlins Road	49,936	10,069	250,405	75.66%	
22 Telegraph Slough 1 & 2	61,365	22,593	162,389	4.57%	

Methods

Habitat predictions

Tidal channel count, length, and surface area are predicted for the SHDM projects using an allometric model that links marsh area to channel geometry (Hood 2007, Hood 2015). This is essentially an empirical regression model, i.e., patterns in reference marshes are used to predict outcomes in restoration marshes. The simplest form of the model finds that marsh area alone is sufficient to predict channel metrics (Hood 2007). However, more recent work finds that there is geographic variation in tidal channel allometry, and that tide range, storm wave fetch, and sediment supply also affect channel geometry in predictable ways to explain that geographic variation throughout Puget Sound (Hood 2015).

The current project to investigate the possible benefits of tidal marsh habitat restoration requires consideration of spatial variation within the Skagit River delta because of the widespread distribution of many of the potential project sites. To accomplish this, several variations of the allometric model were employed. The standard model (Hood 2007) was used for sites within the lower portion of the South Fork Skagit delta and for the Telegraph Slough cluster of projects. The Telegraph Slough area is similar to the South Fork Skagit delta in that it has similar tide range and similar storm fetch. The North Fork Skagit delta experiences considerable fetch, so the standard model was modified by sorting reference sites according to the degree of exposure to fetch (Hood 2015); reference marshes were categorized as being either windward or leeward sites and an allometric regression model (with marsh area as the predictive variable and tidal channel metrics as the response variable) was made for each category. Windward sites were within 650 m of the Skagit Bay shoreline. R^2 values for leeward and windward marsh, respectively, were 0.94 and 0.92 for total channel surface area, 0.97 and 0.89 for total channel length, and 0.80 and 0.79 for channel outlet count. P-values were all < 0.001.

For sites located along the North and South Fork distributaries, tide range becomes an important consideration, because the tide range decays to zero as one approaches the head of tide near Mount Vernon. The tide range at any point along the distributaries was assumed to decay at a constant rate from a mean of 3.1 m in Skagit Bay to zero at the I-5 bridge in Mount Vernon. An allometric model was built with marsh area and tide range as predictive variables using data for sites throughout Puget Sound (see details in Hood 2015). Regression equations and confidence limits for the predictions were generated using the Systat 13 statistical package. The resulting multiple regression equations are as follows:

- Total channel surface area: $R^2 = 0.85$; $p << 0.0001$; $\log A_C = 1.412 \log A_M + 0.67T - 4.288$
- Total channel outlet count: $R^2 = 0.67$; $p << 0.0001$; $\log O_C = 0.602 \log A_M + 0.391T - 1.000$
- Total channel length: $R^2 = 0.87$; $p << 0.0001$; $\log L_C = 1.176 \log A_M + 0.584T\ 0.093$,

where A_M = marsh area; T = mean tide range; A_C = channel surface area; O_C = channel outlet count; and L_C = channel length.

Tidal marsh restoration through dike breaching or removal can have direct effects on channel network geometry in the restored site, as well as indirect effects on the channel network of the existing adjacent tidal marsh (Hood 2004). Restoration of upstream tidal prism via new tidal channels or restored tidal marsh surface drainage area will typically increase the width and surface area of downstream tidal channels in existing adjacent downstream marsh as the channels adjust (erode) to accommodate the increased tidal prism contributed by the newly restored site. Channel length is less likely to be increased unless new tidal channels develop in the downstream marsh. This indirect effect is expressed in the empirical allometric model as a non-linear effect of marsh area on tidal channel surface area and length. For example, one 100-acre marsh site typically has more tidal channel area and length than do two 50-acre sites, which typically have more channel area and length than four 25-acre sites, and so on. Restoring a site adjacent to existing tidal marsh produces more tidal channel than one would calculate separately for the restored site and the adjacent existing marsh, i.e., the whole is greater than the sum of its parts.

To calculate the likely indirect (i.e., off-site) effects of site restoration on existing, adjacent, downstream tidal marshes, the allometric model was applied to the sum of the surface areas of the restoration site and the adjacent downstream tidal marsh to generate channel geometry predictions for both sites as a collective unit. Then the allometric model was applied only to the restoration site and the result subtracted from the prediction for the collective site and adjacent off-site area. This produced an estimate of the channel surface area and length in the adjacent downstream marsh that would result from the indirect effect of project site restoration. This estimate can be compared to the currently existing amount of tidal channel area and length to see if a significant increase would be likely in the adjacent downstream marsh. In some cases, the existing adjacent marsh already has an unusually large number and size of tidal channels so that the prediction can be less than existing. This is a circumstance which prevents confident estimation of off-site effects of restoration. In most cases the predicted channel area and length is greater than the existing amount so that confidence in an off-site effect is greater.

Offsite impacts: We included the SHDM Project Team's offsite habitat change results for each SHDM project. The SHDM Project Team estimated offsite impacts that would result from building an individual restoration project using hydrodynamic modeling results from PNNL (2016). The modelling effort calculated a) area inundated by sub-area of the Skagit delta and b) created inundation maps for with- and without-candidate restoration projects for two hydrologic scenarios: 1) two-year flood event at low tide and 2) low flow at high tide. Only gains and losses that occurred outside of the hydrodynamic model's error (i.e., over 0.3ft) were included in calculations of offsite impacts. The SHDM Project Team estimated some projects have offsite impacts under the two-year flood event at low tide scenario but no projects have offsite impacts under the low flow at high tide scenario. The results for offsite impacts presented in this technical memo are draft estimates; final estimates were in development at the time this technical memo was completed.

Landscape connectivity

Landscape connectivity was calculated for the SHDM projects. Landscape connectivity, or large-scale connectivity, refers to the relative distances and pathways that salmon must travel to find habitat over a very large area. As this concept is applied in the Skagit River delta, landscape connectivity is a function of both the distance and complexity of the pathway that salmon must follow to specific habitat areas (e.g., candidate restoration sites). Connectivity decreases as complexity of the route the fish must swim increases and the distance the fish must swim increases. Within the delta, the complexity of the route fish must take to find habitat is measured by the distributary bifurcation order and distance traveled. Habitat that is less connected to the source of fish has lower densities of fish. We use landscape connectivity to help predict juvenile Chinook benefits for candidate restoration areas and to interpret juvenile Chinook monitoring results from sites throughout the Skagit tidal delta.

Landscape connectivity (LC) for each site is calculated:

$$LC = \frac{1}{\sum_{j=1}^{j_{end}} (O_j * D_j)}$$

where O_j = distributary channel order for channel segment j, D_j = distance along segment j of order O_j, j = count (1...j_{end}) of distributary channel segments, and j_{end} = total number of channel segments at destination or sample point. Methods are more completely described in Beamer and Wolf (2011).

For this project we updated the fish migration pathways to account for changes in delta connectivity as a result of the North Fork avulsion into a new distributary, as well as other channel changes throughout the delta. The new fish migration pathway arc layer was developed over 2013 orthophotos. Using the 2013 fish migration pathway arc layer, landscape connectivity was calculated to the geometric center (centroid) of each polygon representing the candidate restoration projects. In some cases, the candidate restoration project polygon was divided into multiple polygons because they would act as independent hydrologic units for channel formation. For each polygon, we identified points (primary or secondary) located on the dike boundary to represent a pathway fish would use to access habitat within the candidate restoration project. Primary points are logical fish access points due to evidence of existing or historic channels; secondary points serve to illustrate possible variability in landscape connectivity to the candidate restoration site to help account for the number of channel outlets predicted for each candidate project. Landscape connectivity results, along with maps figures, are presented below by SHDM project for each candidate project and point combination. We also calculated landscape connectivity to nine fish monitoring sites used to compare monitored values of juvenile Chinook density to predicted juvenile Chinook carrying capacity.

Juvenile Chinook carrying capacity predictions

Juvenile Chinook carrying capacity was predicted for the SHDM projects using an empirical model developed for the Skagit Chinook Recovery Plan that predicts carrying capacity estimates for candidate restoration projects within the Skagit tidal delta based on channel area and landscape connectivity. Overall, the model explained 68% of the variation in seasonal Chinook density at six sites over eleven years. The habitat factor (i.e., landscape connectivity) explained 37% of the variation while density dependence (outmigrants) explained the remaining 31%. The methods are described in Beamer et al. (2005) (pages 89-94). Juvenile Chinook salmon carrying capacity is based on two variables: 1) wetted area available to fish; and 2) landscape connectivity. Both variables are positively correlated with juvenile Chinook abundance (i.e., larger habitat areas and higher connectivity values result in higher estimates of juvenile Chinook carrying capacity).

Predicted habitat, landscape connectivity, and juvenile Chinook carrying capacity estimates for each candidate restoration project are presented for each SHDM project below. Per our scope of work and to be consistent with the 2005 Chinook Plan, only point estimates of juvenile Chinook carrying capacity are provided.

Predictions compared to existing fish monitoring results

To compare actual fish monitoring results to predicted juvenile Chinook carrying capacity estimates, we used available fish monitoring data that was not used to develop the juvenile Chinook carrying capacity model. For discussion purposes, we included fish monitoring results from four constructed restoration projects [Edgewater Park (Beamer and Brown 2013); Wiley Slough (Beamer et al 2015); Fisher Slough (Beamer et al 2014); and South Fork Dike Setback (Beamer 2015)].

Fish monitoring data that fit our criteria above came from unpublished data collected as part of the Skagit long term monitoring program (i.e., Greene et al. 2015) and five sources: Beamer et al. (2007), Beamer and Henderson (1995), Beamer et al. (2014), SRSC (2013), and Beamer & Brown (2013) (Figure 1).

For each monitoring site and year combination, we calculated the season-long density of juvenile Chinook salmon. This fish density statistic is termed *cumulative Chinook salmon density*. Cumulative Chinook salmon density was estimated for the periods February 1 through August 15 for timing curves of juvenile Chinook salmon in Skagit River tidal delta habitat. Cumulative Chinook salmon density (C) (fish*days*ha^{-1}) was calculated as:

$$C = \sum_{m=F}^{L} D_m n_m$$

where D_m is the average monthly density, n_m is the number of days in the month, and F and L are the first and last months (m) sampled, respectively.

Cumulative Chinook salmon density for each monitoring site and year combination was divided by the average resident time (35 days) of individual juvenile Chinook salmon rearing in Skagit River tidal delta habitat (Beamer et al. 2000). This calculation procedure is an estimate of the population of juvenile Chinook salmon that used habitat at each monitoring site and year combination standardized to a habitat area of one hectare.

We standardized the juvenile Chinook salmon carrying capacity predictions for each SHDM project/landscape connectivity combination by predicting carrying capacity for a one-hectare area to directly compare to the fish monitoring results. For each SHDM project we used average midpoint predictions for carrying capacity and average landscape connectivity to compare to fish monitoring results.

Figure 1. Location of fish monitoring sites used for comparison to juvenile Chinook carrying capacity predictions for SHDM projects.

Results and Discussion

#1 South Fork Setback

Habitat predictions

Two distinct sites comprise the South Fork Setback project. The northerly site is adjacent marsh/floodplain, while the southerly site is not. Indirect restoration effects on adjacent marsh were considered for the northerly site. The southerly site was further subdivided into three sections, at two narrow constrictions along its length (18 and 23 m in width), which seemed logical points at which to delimit relatively independent areas of marsh (with widths of up to 70-100 m) (Figure 2).

The reference system for allometric prediction (Table 4) consisted of a suite of tidal marshes in river deltas throughout Puget Sound, whose tidal ranges varied from 2.6 to 4.1 m (Hood 2015). This Puget Sound data was modeled through multiple regression to generate predictions, with marsh area and tide range as the independent variables. The tide range of the South Fork Setback site was estimated to vary from 2.2 m at the upstream limit to 2.4 m at the downstream limit of the northerly site, and from 2.4 m to 2.7 m at the southerly site.

Table 4. Allometric predictions of tidal channel geometry for South Fork Setback, with 80% confidence limits of the prediction in parentheses. Row labeled "Total – Upstr" shows the difference between upstream project site plus downstream existing marsh ("Total") predictions and project site only ("Upstr") predictions (i.e., indirect or downstream effects of project site restoration), with currently observed channel metrics in the existing downstream marsh shown in brackets for comparison with indirect effects predictions.

Site	Site area (ha)	Predicted channel count	Predicted channel area (ha)	Predicted channel length (m)
South Fork Setback N	10.47	3 (1 – 7)	0.05 (0.02 – 0.15)	438 (188 – 1,016)
SF Setback N + dwnstr	17.34	4 (2 – 10)	0.10 (0.03 – 0.30)	782 (337 – 1,816)
Total SFN - Upstr	6.87	1 [1]	0.05 [-]	344 [-]
South Fork Setback S up	3.26	2 (1 – 4)	0.01 (0 – 0.04)	138 (59 – 318)
South Fork Setback S mid	7.48	3 (2 – 7)	0.05 (0.02 – 0.14)	412 (179 – 950)
South Fork Setback S down	1.66	1 (1 – 3)	0.01 (0 – 0.02)	78 (34 – 180)

The R^2 for the channel count multiple regression was 0.67 while it was 0.85 and 0.87 for channel surface area and length, respectively. Given the greater reliability of the channel area and length regression models, it should be assumed that at least one channel can be sustained by each of the South Fork Setback sites. The calculated indirect benefit of restoration of the northerly setback site indicates support of one channel with at least 0.033 ha surface area and at least 337 m length. Indeed, one channel is known to exist (i.e., sampling site: Fisher Sl Blind Ch, see Beamer et al. 2014), exiting at the south end of the site, with an area of 0.136 ha, which is 36% greater than predicted, but within the prediction confidence limits. Site restoration would presumably enlarge this channel, perhaps up to the upper end of the prediction confidence limit.

<u>Offsite impacts</u>: The SHDM Project Team found no detectible offsite habitat changes due to this project.

Landscape connectivity and juvenile Chinook carrying capacity predictions

The South Fork Setback project predicted juvenile Chinook carrying capacity point estimate is approximately 3,000 fish per year with four separate sub-project polygons contributing to the total (Table 5). Predicted carrying capacity for this project varies from nearly 900 to 9,000 fish per year as a function of predicted habitat amount for each of the sub-project polygons. The South Fork Setback project consists of narrow strips of setback area (Figure 2) which may not develop channel area in two of the four sub-project polygon areas.

We did not model variability in landscape connectivity within each of the sub-project polygons. However, variability in landscape connectivity ranges from 0.035 to 0.043.

Table 5. Summary of channel habitat area (with 80% confidence limits in parentheses), landscape connectivity, and predicted Chinook carrying capacity for the South Fork Setback project. Chinook carrying capacity estimates are for the habitat point estimate and habitat 80% confidence limits (in parentheses).

Candidate restoration project (from Table 4)		**Fish migration pathway used (from Figure 2)**			**Juvenile Chinook carrying capacity**
Site	**Predicted channel area (ha)**	**Point name**	**Point type**	**Landscape connectivity**	
SF Setback N + dwnstr	0.10 (0.03 – 0.30)	SF Setback N 12	primary	0.037123	1,779 (534 - 5,336)
South Fork Setback S up	0.01 (0 – 0.04)	SF Setback up 13	primary	0.042772	205 (0 – 821)
South Fork Setback S mid	0.05 (0.02 – 0.14)	SF Setback mid 11	primary	0.036435	873 (349 - 2,444)
South Fork Setback S down	0.01 (0 – 0.02)	SF Setback down 10	primary	0.035415	170 (0 – 339)

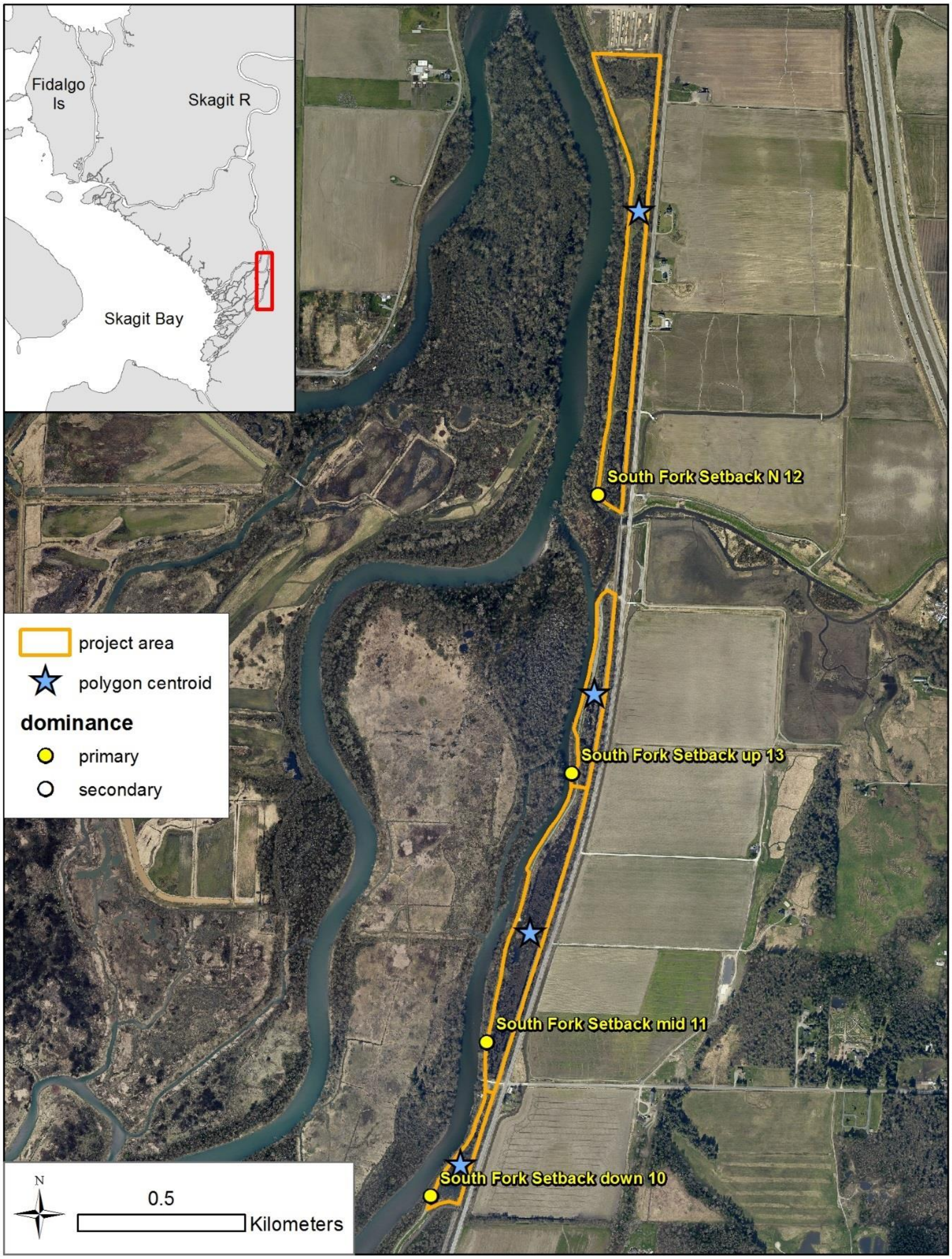

Figure 2. Location of fish migration pathway points used to estimate landscape connectivity for the South Fork Setback project.

#2 McGlinn Causeway

Habitat predictions

The McGlinn Causeway design calls for a 134-ft (toe width) channel cut through the causeway near the southern end of Swinomish Channel (Figure 3) (SHDM Project Team 2016). Habitat areas influenced by this project are the same as described in the Skagit Chinook Recovery Plan (SRSC and WDFW 2005), which are the habitats along the Swinomish Channel corridor and southern Padilla Bay.

Offsite impacts: The SHDM Project Team found no detectible offsite habitat changes due to this project.

Landscape connectivity and juvenile Chinook carrying capacity predictions

McGlinn Causeway restoration will increase connectivity to Swinomish Channel (Table 6). It provides an additional and higher connectivity pathway for fish migration into Swinomish Channel than the Fish Hole pathway. Landscape connectivity within the North Fork tidal delta and Dunlap Bay areas has not changed enough between 2004 and 2013 to predict the McGlinn Causeway project will have a different outcome for juvenile Chinook carrying capacity than what was already predicted in the Skagit Chinook Recovery Plan (Figure 3).

There is evidence of an increase in distributary channel bifurcation order (and reduced landscape connectivity) within the Dunlap Bay area because of a new distributary upstream creating a pathway from Fishtown to Craft Island (Beamer and Wolf 2016a). These changes are caused by distributary channel narrowing patterns between 2004 and 2013 (Figure 3). However, we did not find evidence of reduced channel width for the most direct pathway taken to the McGlinn Causeway site between 2004 and 2013. We assumed the designed 134-ft channel cut through the McGlinn Causeway would maintain a bifurcation order of '6' (Figure 3). However, it is unclear whether flow from a new pathway through the McGlinn Causeway would offset the predicted filling pattern for areas of the North Fork tidal delta downstream of the new distributary near Craft Island (Beamer and Wolf 2016b). The influence of the McGlinn Causeway project should be re-evaluated when: 1) the project is more certain to be constructed; and 2) design elements are more defined. At this future time, it will be more clear how the North Fork tidal delta and Dunlap Bay area have changed in terms of landscape connectivity.

Table 6. McGlinn Causeway Project landscape connectivity values by pathway and year.

Year	**Fish migration pathway**	
	McGlinn Causeway	**Fish Hole**
2004	0.0297 (1/33.7013)	0.0244 (1/41.0420)
2013	0.0297 (1/33.7128)	0.0244 (1/41.0639)

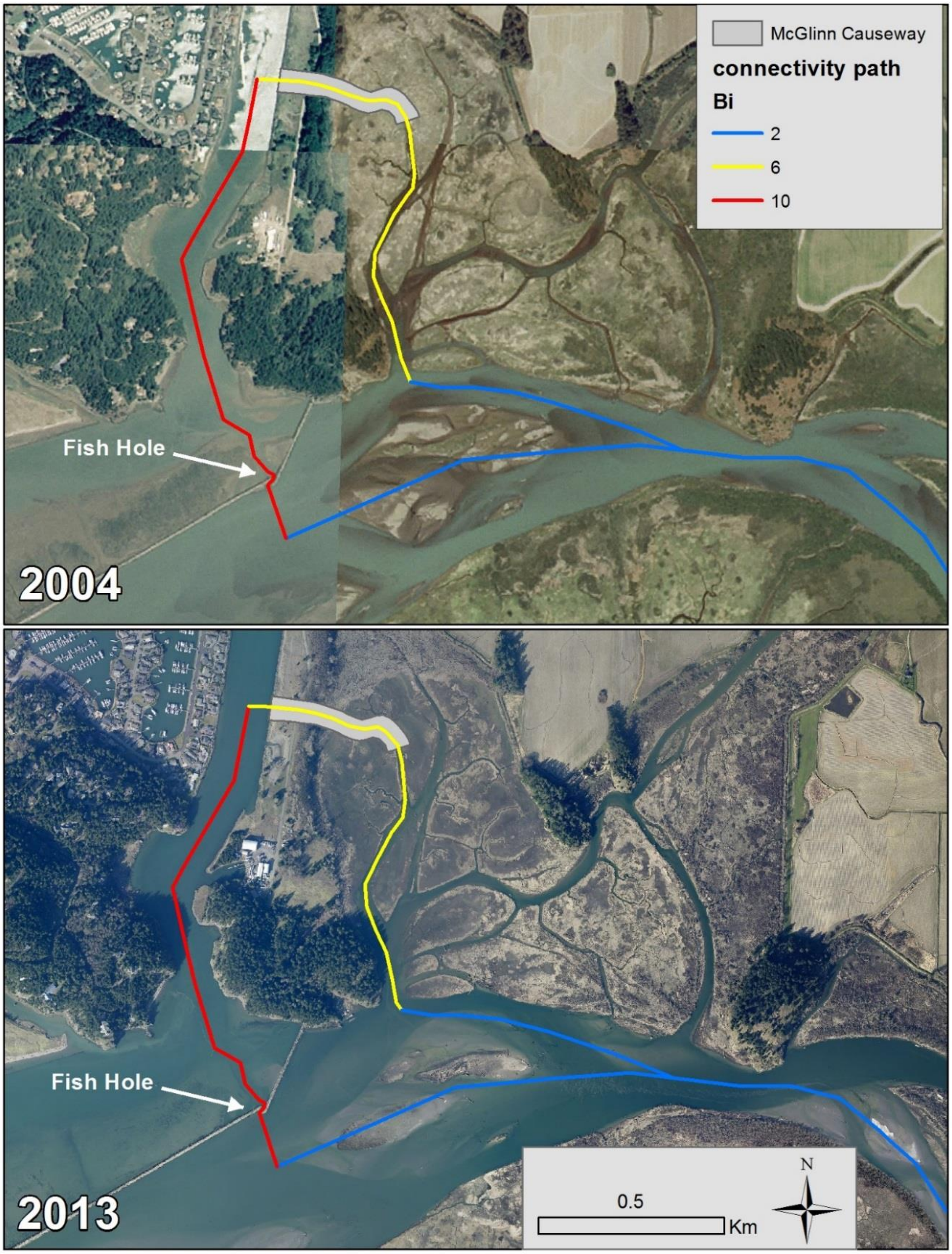

Figure 3. Location of fish migration pathways used to estimate landscape connectivity for the McGlinn Causeway project for the time period when the Skagit Chinook Plan was developed (2004) and after the new North Fork distributary fully formed (2013).

#3 TNC South Fork

Habitat predictions

The SHDM Project Team (2016) provided the predicted habitat area for this project located along the upper South Fork Skagit River (Figure 4). A one acre (0.405 hectare) backwater channel would be created. No range in habitat area was provided.

Ultimately, constructed channel projects will gravitate to the natural range of variability for a site's potential, which is controlled by the natural processes acting on the site and not by what humans construct at one point in time. We thought it would be informative to provide a habitat area range based on Hood (2015) for this project given the fact that: 1) there is uncertainty of sustainability for this channel; and 2) only a single estimate of habitat area was provided. Existing dike setback area for the TNC South Fork project is 20.76 hectares (Figure 4) and is predicted to have 0.049 ha of tidal channel with upper and lower 80% CI of the prediction of 0.163 and 0.015 ha, respectively. The SHDM Project Team (2016) habitat area estimate of 0.405 hectares is much higher than predicted in natural systems.

Offsite impacts: The SHDM Project Team found no detectible offsite habitat changes due to this project.

Landscape connectivity and juvenile Chinook carrying capacity predictions

The TNC South Fork project predicted juvenile Chinook carrying capacity point estimate is nearly 32,000 fish per year (Table 7). We did not model variability in juvenile Chinook carrying capacity because there was no range in predicted habitat area provided. However, there is concern the habitat area created by this project will not be sustainable over more than a few decades (SHDM Project Team 2016). We did not model variability in landscape connectivity because the project is conceived as an engineered channel with a single point of entry from the South Fork Skagit River.

Prediction limitations: The TNC South Fork project utilizes input variables that are outside the data range used to develop the model for juvenile Chinook carrying capacity. The juvenile Chinook prediction for this project may be biased high based on its comparison to fish monitoring data collected after the dataset used to create the juvenile Chinook carrying capacity model (see later section in this memo comparing predictions to existing fish monitoring results).

Table 7. Summary of channel habitat area, landscape connectivity, and predicted Chinook carrying capacity for the TNC South Fork project.

Candidate restoration project		**Fish migration pathway used (from Figure 4)**			**Juvenile Chinook carrying capacity**
Site	**Predicted channel area (ha)**	**Point name**	**Point type**	**Landscape connectivity**	
TNC South Fork	0.405 (no range provided)	TNC South Fork 53	primary	0.160964	31,687*

* No range is predicted for juvenile Chinook carrying capacity because no habitat area range was provided.

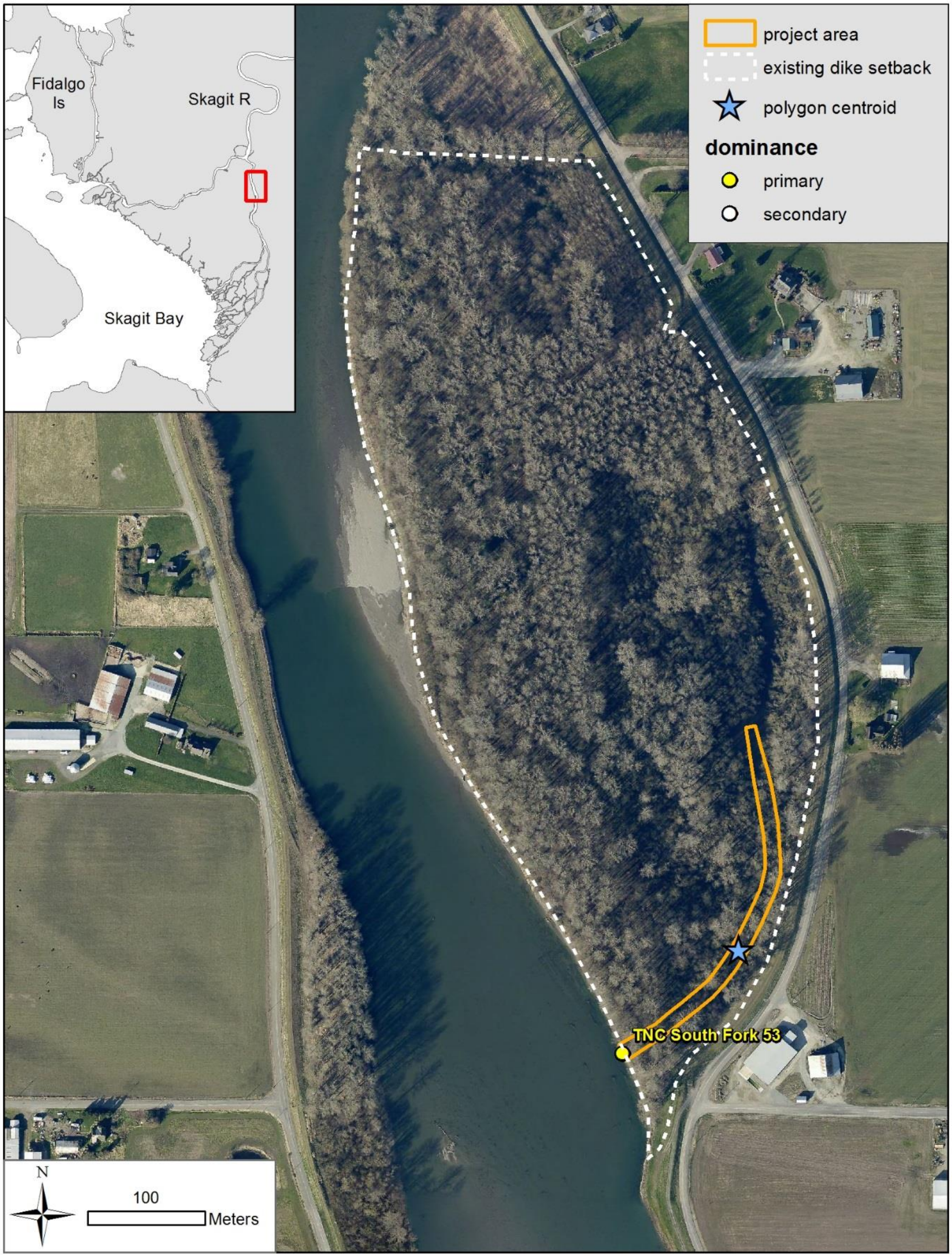

Figure 4. Location of fish migration pathway point used to estimate landscape connectivity for the TNC South Fork project.

#5 East Cottonwood

Habitat predictions

The SHDM Project Team (2016) provided the predicted habitat area for this project located on the east side of the Skagit River where it splits into the North and South Forks (Figure 5). A 2-acre (0.809 hectare) channel would be created. No range in habitat area or discussion of channel sustainability was provided.

Ultimately, constructed channel projects will gravitate to the natural range of variability for a site's potential, which is controlled by the natural processes acting on the site and not by what humans construct at one point in time. We thought it would be informative to provide a habitat area range based on Hood (2015) for this project given the fact that: 1) no discussion of channel sustainability was provided; and 2) only a single estimate of habitat area was provided. Existing dike setback area for the East Cottonwood project is 29.22 hectares (Figure 5) and is predicted to have 0.054 ha of tidal channel with upper and lower 80% CI of the prediction of 0.184 and 0.016 ha, respectively. The SHDM Project Team (2016) habitat area estimate of 0.809 hectares is much higher than predicted in natural systems. However, based on a 2013 orthophoto and 2012 LiDAR, approximately 2.5 hectares of off channel pond area is present within the existing dike setback site. It is unknown whether this ponded area is enhanced by beaver dams or human factors.

<u>Offsite impacts</u>: The SHDM Project Team found no detectible offsite habitat changes due to this project.

Landscape connectivity and juvenile Chinook carrying capacity predictions

The East Cottonwood project predicted juvenile Chinook carrying capacity point estimates range from nearly 130,000 to 230,000 fish per year (Table 8). The large difference between the two estimates is due to differences in calculated landscape connectivity. Per the assumption embedded within the landscape connectivity calculation, if fish access the project's channel via point 52 (Figure 5), fish migrating down the Skagit mainstem have an opportunity to access the project. But if fish access the project's channel via point 54, only fish migrating down the South Fork have an opportunity to access the project. There are presumably only about half the number of fish traveling down the South Fork as the mainstem Skagit River because the other half would take the North Fork pathway. Because the East Cottonwood project is located at the fork, it is likely only fish migrating on the eastern shore of the mainstem Skagit would have a chance to access the project, which would coincide with the number of fish using the South Fork pathway. Thus, we believe the 130,000 fish/year carrying capacity estimate is more realistic than the 230,000-fish estimate.

We did not model variability in juvenile Chinook carrying capacity by access point because there was no range in predicted habitat area provided.

<u>Prediction limitations</u>: The East Cottonwood project utilizes input variables that are outside the data range used to develop the model for juvenile Chinook carrying capacity. The juvenile Chinook prediction for this project may be biased high based on its comparison to fish monitoring data collected after the dataset used to create the juvenile Chinook carrying capacity model (see later section in this memo comparing predictions to existing fish monitoring results). Also, the restoration design for this project has advanced since our calculation for carrying capacity

predictions were completed. The new design does not include the connection to the mainstem Skagit River (i.e., via point East Cottonwood 52). It was outside of our scope of work to recalculate carrying capacity estimates based on new design information.

Table 8. Summary of channel habitat area, landscape connectivity, and predicted Chinook carrying capacity for the East Cottonwood project.

Candidate restoration project		**Fish migration pathway used (from Figure 5)**			**Juvenile Chinook carrying capacity**
Site	**Predicted channel area (ha)**	**Point name**	**Point type**	**Landscape connectivity**	
East Cottonwood	0.809 (no range provided)	East Cottonwood 52	primary	0.571127	227,371*
		East Cottonwood 54	primary	0.326032	129,089*

* No range is predicted for juvenile Chinook carrying capacity because no habitat area range was provided.

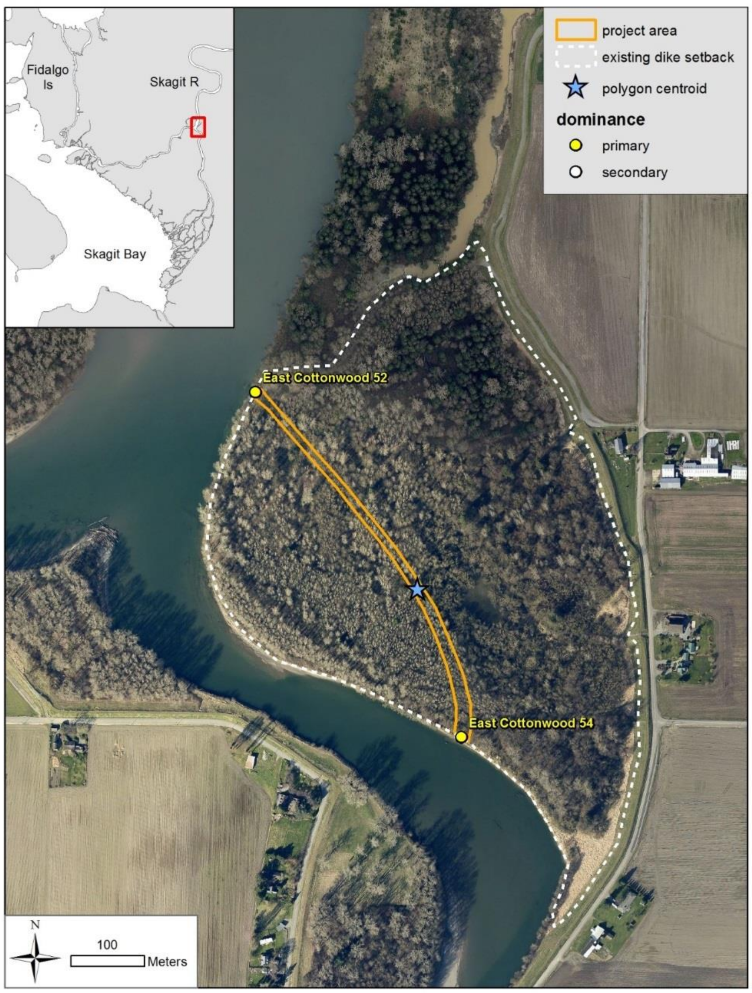

Figure 5. Location of fish migration pathway points used to estimate landscape connectivity for the East Cottonwood project.

#6 Pleasant Ridge South

Habitat predictions

This site is located on the north side of the Skagit North Fork, just downstream of the Best Road bridge over the North Fork (Figure 6). There are no adjacent marshes so downstream effects were not relevant to habitat prediction.

The reference system for allometric prediction (Table 9) consisted of a suite of tidal marshes in river deltas throughout Puget Sound, whose tidal ranges varied from 2.6 to 4.1 m (Hood 2015). This Puget Sound data was modeled through multiple regression to generate predictions, with marsh area and tide range as the independent variables. This site had an estimated tide range of 2.5 m, which is relatively close to the lower limit of the reference marsh data set, so that extrapolation to this site is probably relatively reasonable.

Table 9. Allometric predictions of tidal channel geometry for Pleasant Ridge, with 80% confidence limits of the prediction in parentheses.

Site	Site area (ha)	Predicted channel count	Predicted channel area (ha)	Predicted channel length (m)
Pleasant Ridge	12.16	4 (2 – 10)	0.08 (0.03 – 0.25)	675 (292 – 1,556)

<u>Offsite impacts</u>: The SHDM Project Team found no detectible offsite habitat changes due to this project.

Landscape connectivity and juvenile Chinook carrying capacity predictions

The Pleasant Ridge South project predicted juvenile Chinook carrying capacity point estimate is approximately 2,500 fish per year (Table 10). Predicted carrying capacity for this project varies from approximately 900 to nearly 8,000 fish per year as a function of predicted habitat amount.

We did not model variability in landscape connectivity within this project's polygon. Landscape connectivity to this site would not vary much due to its adjacency to the North Fork Skagit River and its relatively short shoreline length (Figure 6). The fish migration pathway point is located at the outlet of a current drainage channel that is presumably a historic channel.

Table 10. Summary of channel habitat area (with 80% confidence limits in parentheses), landscape connectivity, and predicted Chinook carrying capacity for the Pleasant Ridge South project. Chinook carrying capacity estimates are for the habitat point estimate and habitat 80% confidence limits (in parentheses).

Candidate restoration project (from Table 9)		**Fish migration pathway used (from Figure 6)**			**Juvenile Chinook carrying capacity**
Site	**Predicted channel area (ha)**	**Point name**	**Point type**	**Landscape connectivity**	
Pleasant Ridge	0.08 (0.03 – 0.25)	Pleasant Ridge S 9	primary	0.064568	2,488 (933 - 7,776)

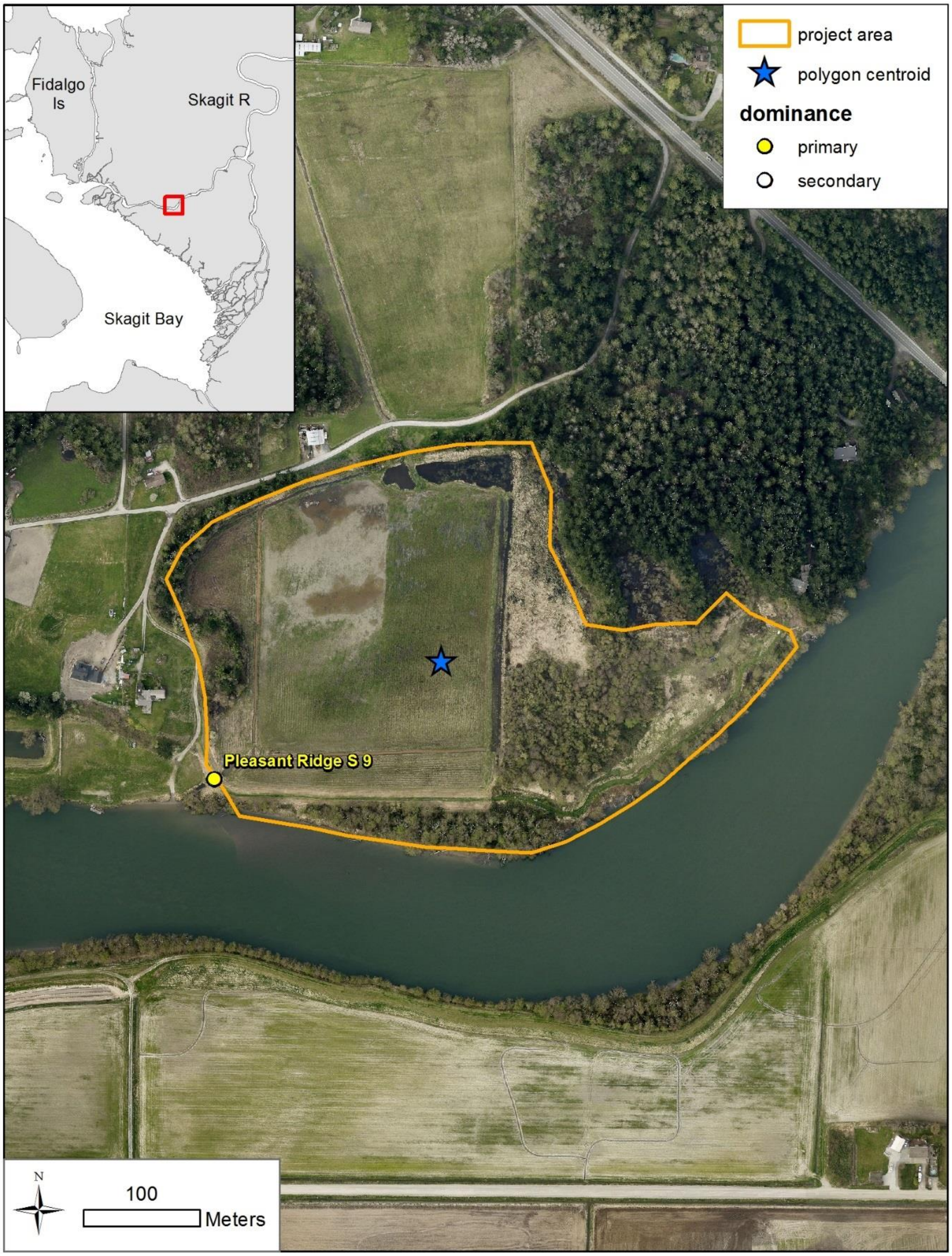

Figure 6. Location of fish migration pathway point used to estimate landscape connectivity for the Pleasant Ridge South project.

#7 Hall Slough

Habitat predictions

This site is located on the bayfront near the outlet of Hall Slough on Fir Island. The site is bordered by adjacent existing tidal marsh to the west and south (Figure 7); downstream effects of site restoration were considered for these adjacent marshes. The reference system for allometric prediction (Table 11) consisted of the windward Skagit North Fork tidal marshes, due to the project site's proximity to the North Fork marshes and similar exposure to Skagit Bay fetch. Distinct differences were detected between tidal marsh directly exposed to the southerly storm fetch across Skagit Bay (windward marshes) and those sheltered from the fetch by intervening marsh (leeward marshes). Hall Slough is clearly exposed to southerly Skagit Bay fetch.

Table 11. Allometric predictions of tidal channel geometry for Hall Slough, with 80% confidence limits of the prediction in parentheses. Row labeled "Total – Upstr" shows the difference between upstream project site plus downstream existing marsh ("Total") predictions and project site only ("Upstr") predictions (i.e., indirect or downstream effects of project site restoration), with currently observed channel metrics in the existing downstream marsh shown in brackets for comparison with indirect effects predictions.

Site	Site area (ha)	Predicted channel count	Predicted channel area (ha)	Predicted channel length (m)
Hall Slough	54.11	11 (6 – 20)	1.10 (0.39 – 3.12)	4,953 (2,303 – 10,653)
Hall Sl. + dwnstr	90.99	14 (8 – 27)	2.73 (0.92 – 8.16)	9,888 (4,425 – 22,095)
Total - Upstr	36.88	3 [6]	1.63 [0.24]	4,935 [1,990]

The 1889 T-sheet of the Skagit delta only shows one large blind tidal channel draining the Hall Slough project site, in the northwest corner of the site (Figure 8). However, the T-sheet shows very few blind tidal channels in the Skagit marshes at that time, only the largest ones. The downstream portion of that historical channel still remains in the adjacent marsh, though it is undoubtedly narrower and shallower than it was historically, due to lost tidal prism. Nevertheless, this remnant channel is the largest tidal channel in the marsh adjacent to the project site.

Given the few channels currently present in the existing adjacent tidal marsh, their small size, and the fact that any channels draining the project site must traverse the adjacent marsh, it is highly likely that significant downstream effects on channel geometry will be experienced by the downstream marsh. Some of those effects may be over-predicted in this case. This is because a portion of the downstream marsh has been eroded away, likely due to sediment starvation following obstruction of the Browns-Hall Slough distributary by dikes at its junction with the North Fork Skagit River and at its outlet with Skagit Bay. The eroded marsh is lower in elevation than uneroded marsh and this lower elevation has resulted in loss of marsh tidal channels (Hood, unpublished observations). It may be hard to establish tidal channels in this lower marsh zone. The new avulsion of the North Fork Skagit River may bring more sediment to this area and potentially result in marsh aggradation that would favor channel development, but this is only a speculative possibility.

Offsite impacts: The SHDM Project Team found no detectible offsite habitat changes due to this project.

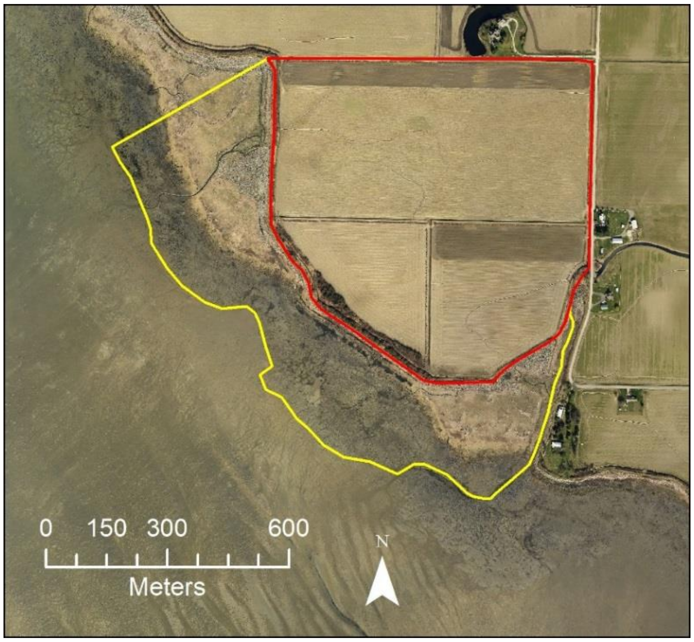

Figure 7. Hall Slough project site (red outline) and adjacent downstream marshes (yellow outline). The southeastern downstream marsh boundary is formed by Hall Slough.

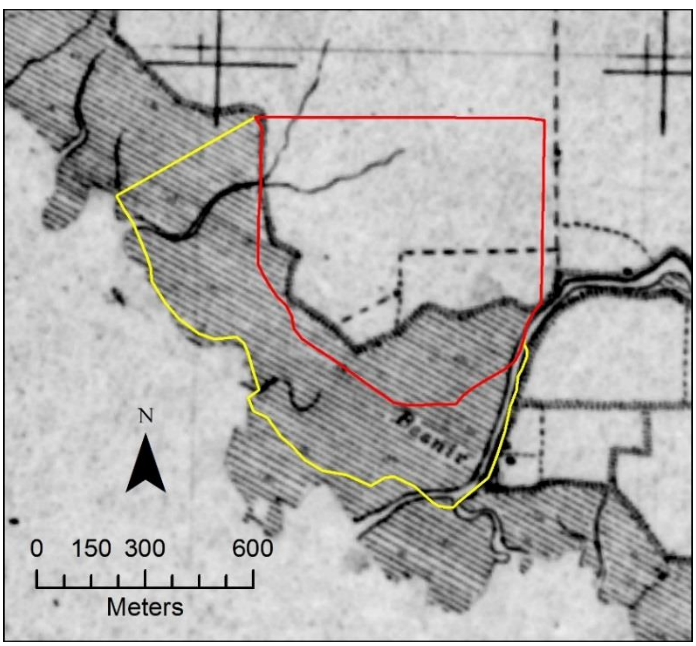

Figure 8. Hall Slough project site (red outline) and adjacent downstream marshes (yellow outline) overlaid on the 1889 T-sheet. The T-sheet shows one large blind tidal channel system draining the project site in 1889. Smaller channels were present, but not mapped. The southeastern downstream marsh boundary is formed by the modern course of Hall Slough.

Landscape connectivity and juvenile Chinook carrying capacity predictions

The Hall Slough project predicted juvenile Chinook carrying capacity average midpoint estimate is nearly 23,000 juvenile Chinook per year (Table 12). Predicted carrying capacity for this project varies by tens of thousands of fish per year as a function of predicted habitat amount from a low of 7,381 to a high of 69,429. Variability in predicted carrying capacity due to landscape connectivity varies by approximately a thousand fish per year (Table 12). The primary fish migration pathway point uses the lower end of Hall Slough to access the site (Figure 9).

Table 12. Summary of channel habitat area (with 80% confidence limits in parentheses), landscape connectivity, and predicted Chinook carrying capacity for the Hall Slough project. Chinook carrying capacity estimates are for the habitat point estimate and habitat 80% confidence limits (in parentheses).

Candidate restoration project (from Table 11)		**Fish migration pathway used (from Figure 9)**			**Juvenile Chinook carrying capacity**
Site	**Predicted channel area (ha)**	**Point name**	**Point type**	**Landscape connectivity**	
Hall Sl. + dwnstr	2.73 (0.92 – 8.16)	Hall Sl 1	primary	0.017814	23,136 (7,797 - 69,154)
		Hall Sl 3	secondary	0.017884	23,228 (7,828 - 69,429)
		Hall Sl 4	secondary	0.017761	23,066 (7,773 - 68,946)
		Hall Sl 5	secondary	0.017795	23,112 (7,789 - 69,082)
		Hall Sl 2	secondary	0.016873	21,903 (7,381 - 65,467)

Figure 9. Location of fish migration pathway points used to estimate landscape connectivity for the Hall Slough project.

#9 Telegraph Slough Full

Habitat predictions

This site at the northern end of Swinomish Channel was analyzed as three parcels: one south of Highway 20 (Telegraph S), and two north of Highway 20 (Telegraph NW and Telegraph NE), separated by what remains of Telegraph Slough (Figure 10). The northern parcels each are bordered by a fringe of existing tidal marsh; downstream effects of site restoration were considered for these marsh fringes.

The Skagit South Fork tidal marshes were used as the reference system for allometric prediction of tidal channel geometry (Table 13), because of similar tide range and fetch.

Table 13. Allometric predictions of tidal channel geometry for Telegraph Slough Full, with 80% confidence limits of the prediction in parentheses. Rows labeled "Total – Upstr" show the difference between upstream project site plus downstream existing marsh ("Total") predictions and project site only ("Upstr") predictions (i.e., indirect or downstream effects of project site restoration), with currently observed channel metrics in the existing downstream marsh shown in brackets for comparison with indirect effects predictions.

Site	Site area (ha)	Predicted channel count	Predicted channel area (ha)	Predicted channel length (m)
Telegraph NW	95.53	32 (15 – 67)	5.42 (2.15 – 13.66)	22,819 (9,121 – 57,086)
Telegraph NW + dwnstr	109.37	35 (17 – 73)	6.66 (2.63 – 16.83)	27,060 (10,780 – 67,928)
Total - Upstr	13.84	3 [18]	1.24 [0.45]	4,241 [4,230]
Telegraph NE	128.52	39 (18 – 81)	8.51 (3.35 – 21.61)	33,161 (13,154 – 83,595)
Telegraph NE + dwnstr	134.34	40 (19 – 83)	9.10 (3.58 – 23.14)	35,064 (13,893 – 88,499)
Total - Upstr	5.82	1 [19]	0.59 [0.09]	1,903 [1,370]
Telegraph S	200.25	51 (24 – 108)	16.70 (6.49 – 42.94)	57,983 (148,045 – 22,710)

Telegraph NW and Telegraph S contain large remnant Swinomish Channel distributaries. These remnant distributaries are oversized as blind tidal channels, so they will very likely fill in with sediment over time, the rate depending on sediment supply. Initially the restoration sites will have much more tidal channel area than predicted and perhaps less channel length. As the historical distributary remnants fill in, the channel area will decline and channel length will increase due to development of one or more meandering channels within the distributary footprint. Reconnection of Telegraph Slough under Highway 20 (placing a bridge in this location) will restore a distributary of the Swinomish Channel that may widen and deepen to some degree to accommodate restored tidal flow. The mainstem Swinomish Channel will likely remain dominant, so it is unclear how much the restored distributary channel will grow.

The degree to which downstream indirect project effects occur will depend on the degree of project site subsidence relative to adjacent downstream marshes. If the project site is greatly subsided, tidal flushing will likely primarily occur directly to the adjacent bay rather than across the higher downstream marsh. In this case, indirect effects on downstream tidal channel geometry will likely be minor. If subsidence is relatively minor, or if channel connections are intentionally excavated between the upstream project and the existing downstream marsh tidal channels, more flow will occur through the adjacent marsh and more downstream channel effects will occur. The downstream effects are likely to be limited to increases in channel area to accommodate restored tidal prism; channel count is unlikely to increase because there is already a large (greater than predicted) number of channels in the existing adjacent marsh.

Offsite impacts: The SHDM Project Team found no detectible offsite habitat changes due to this project.

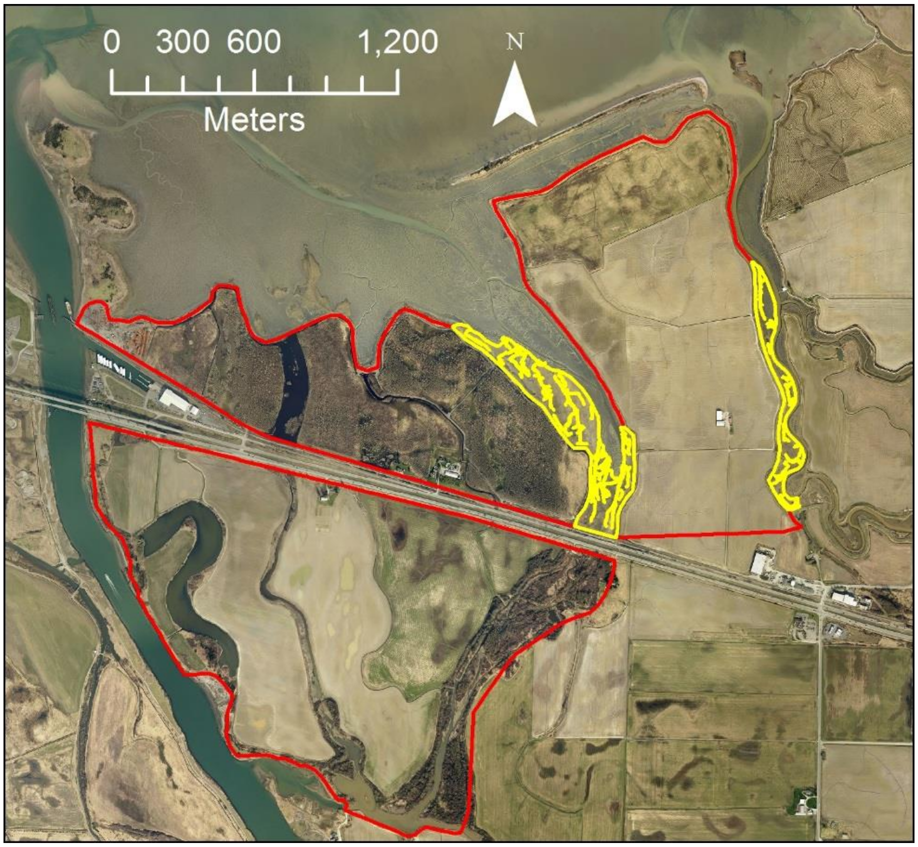

Figure 10. Telegraph Slough Full project sites (red outlines) and adjacent downstream marshes and their tidal channels (yellow outlines). Note the large remnant distributary channels within the two western project sites.

Landscape connectivity and juvenile Chinook carrying capacity predictions

For the Telegraph Slough Full project, each sub-project polygon acts as an individual project area with respect to predicting fish benefits because Highway 20 divides the north and south areas and historic Telegraph Slough divides the NE and NW areas (Figure 11). For the NE and NW areas, we calculated landscape connectivity for fish migration pathways: 1) around the north end of Swinomish Channel; and 2) through Telegraph Slough.

The total Telegraph Slough Full project predicted juvenile Chinook carrying capacity point estimate is approximately 103,000 fish per year with three separate sub-project polygons contributing to the total (Table 14). Predicted juvenile Chinook carrying capacity for each of the sub-project polygon areas varied by tens of thousands of fish per year as a function of predicted habitat amount (Table 14). Conversely, variability in predicted carrying capacity within each of the sub-project polygon areas due to landscape connectivity is a few hundred to a few thousand fish per year. Overall, the carrying capacity predictions for Telegraph Slough Full suggest the highest value area is the southern polygon, due to: 1) total habitat size; and 2) higher landscape connectivity. The project would have significantly higher juvenile Chinook value (5,000 – 8,000 fish per year) to the Telegraph NE area if fish access is via a pathway directly from a reconnected Telegraph Slough and not around the north end of Swinomish Channel.

This entire project is subject to fish migration pathways from the North Fork Skagit delta through the Swinomish Channel corridor in the area of McGlinn Island and its causeway. Improvement of connectivity through the McGlinn Causeway will improve connectivity to Telegraph Slough Full.

Prediction limitations: The Telegraph Slough Full project utilizes input variables that are outside the data range used to develop the model for juvenile Chinook carrying capacity. The juvenile Chinook prediction for this project may be biased high for areas of the project where fish access the restored habitat from southern Padilla Bay, based on its comparison to fish monitoring data collected after the dataset used to create the juvenile Chinook carrying capacity model (see later section in this memo comparing predictions to existing fish monitoring results).

Table 14. Summary of channel habitat area (with 80% confidence limits in parentheses), landscape connectivity, and predicted Chinook carrying capacity for the Telegraph Slough Full project. Chinook carrying capacity estimates are for the habitat point estimate and habitat 80% confidence limits (in parentheses).

Candidate restoration project (from Table 13)		**Fish migration pathway used (from Figure 11)**			**Juvenile Chinook carrying capacity**
Site	**Predicted channel area (ha)**	**Point name**	**Point type**	**Landscape connectivity**	
Telegraph NW + dwnstr	6.66 (2.63 – 16.83)	Telegraph NW 25	primary	0.005669	17,763 (7,015 - 44,888)
		Telegraph NW 26	primary	0.005671	17,770 (7,017 - 44,905)
		Telegraph NW 27	primary	0.005759	18,049 (7,127 - 45,610)
		Telegraph NW 26 via Telegraph Sl	primary	0.006026	18,891 (7,460 – 47,738)
Telegraph NE + dwnstr	9.10 (3.58 – 23.14)	Telegraph NE 19	primary	0.005550	23,755 (9,345 - 60,404)
		Telegraph NE 20	primary	0.005535	23,693 (9,321 - 60,247)
		Telegraph NE 21	primary	0.005448	23,313 (9,172 - 59,282)
		Telegraph NE 22	primary	0.005102	21,821 (8,584 - 55,487)
		Telegraph NE 23	primary	0.005093	21,781 (8,569 - 55,385)
		Telegraph NE 24	primary	0.004839	20,687 (8,138 - 52,603)
		Telegraph NE 21 via Telegraph Sl	primary	0.006658	28,547 (11,231 – 72,592)
Telegraph S	16.70 (6.49 – 42.94)	Telegraph S 28	primary	0.007967	62,804 (24,407 - 161,485)
		Telegraph S 29	primary	0.008011	63,155 (24,544 - 162,389)
		Telegraph S 30	primary	0.007381	58,137 (22,593 - 149,486)

Figure 11. Location of fish migration pathway points used to estimate landscape connectivity for the Telegraph Slough Full project.

#10 Sullivan Hacienda

Habitat predictions

This site is located near the mouth of the North Fork Skagit River, between Fishtown and Sullivan Slough. The site is bordered by adjacent existing tidal marsh to the west and south (Figure 12); downstream effects of site restoration were considered for these adjacent marshes.

The reference system for allometric prediction (Table 15) of tidal channel geometry consisted of the leeward Skagit North Fork tidal marshes. Distinct differences were detected between tidal marsh directly exposed to the southerly storm fetch across Skagit Bay (windward marshes) and those sheltered from the fetch by intervening marsh (leeward marshes). Sullivan Hacienda is considered a leeward site.

Table 15. Allometric predictions of tidal channel geometry for Sullivan Hacienda, with 80% confidence limits of the prediction in parentheses. The row labeled "Total – Upstr" shows the difference between upstream project site plus downstream existing marsh ("Total") predictions and project site only ("Upstr") predictions (i.e., indirect or downstream effects of project site restoration), with currently observed channel metrics in the existing downstream marsh shown in brackets for comparison with indirect effects predictions.

Site	Site area (ha)	Predicted channel count	Predicted channel area (ha)	Predicted channel length (m)
Sullivan Hacienda	82.97	17 (9 – 30)	7.28 (3.01 – 17.59)	21,045 (13,492 – 32,826)
Sullivan Hacienda + dwnstr	120.91	20 (11 – 38)	14.06 (5.67 – 34.86)	34,726 (21,982 – 54,859)
Total - Upstr	37.94	3 [13]	6.78 [1.77]	13,681 [6,165]
1937 S. Hacienda	82.97	11 observed	3.04 observed	8,750 observed
1937 S. Hacienda + dwnstr	107.54	12 observed	-	-

Sullivan Hacienda was not diked in the 1937 aerial photographs, but it was diked in the 1956 and subsequent photos. Thus, for this site we know exactly where the larger historical tidal channels were located on the project site and their approximate size. This can be used in developing a conceptual restoration design for this site. The 1937 photos are of lower resolution and quality than modern photos taken since 2004. Consequently, direct comparisons of tidal channel network geometry are not possible; the 1937 photos do not allow relatively small tidal channels to be distinguished. The 11 tidal channels crossing the current project site boundary observed in the 1937 photos are likely an underestimate of the number of tidal channels on the site in 1937. This suggests that the allometric prediction of 17 channels that should drain the project site is likely a reasonable estimate. Channel network surface area and length are also underestimated from the 1937 photos, though channel area is less sensitive to poor photo resolution than length; very small channels which cannot be distinguished in the 1937 photos have small surface area, but often have significant length, so their omission has a smaller effect on surface area estimates than it does on length estimates. The channel network area and length observed in 1937 provide lower bounds on the area and length to be expected following site restoration, with the length bound being much lower than the likely outcome.

Downstream effects on tidal channel geometry for the adjacent marshes can be evaluated by comparison of the current condition to that of the 1937 photos. For example, restored channels in the western portion of the project site would drain to existing channels in the adjacent marsh and merely increase their width and surface area to accommodate the restored tidal prism in the project site. Restored channels in the eastern portion of the project site would in many cases cross adjacent marsh that currently has no existing channels, so that there would be an increase in the number, length, and area of channels in this adjacent marsh.

Offsite impacts: The SHDM Project Team found no detectible offsite habitat changes due to this project.

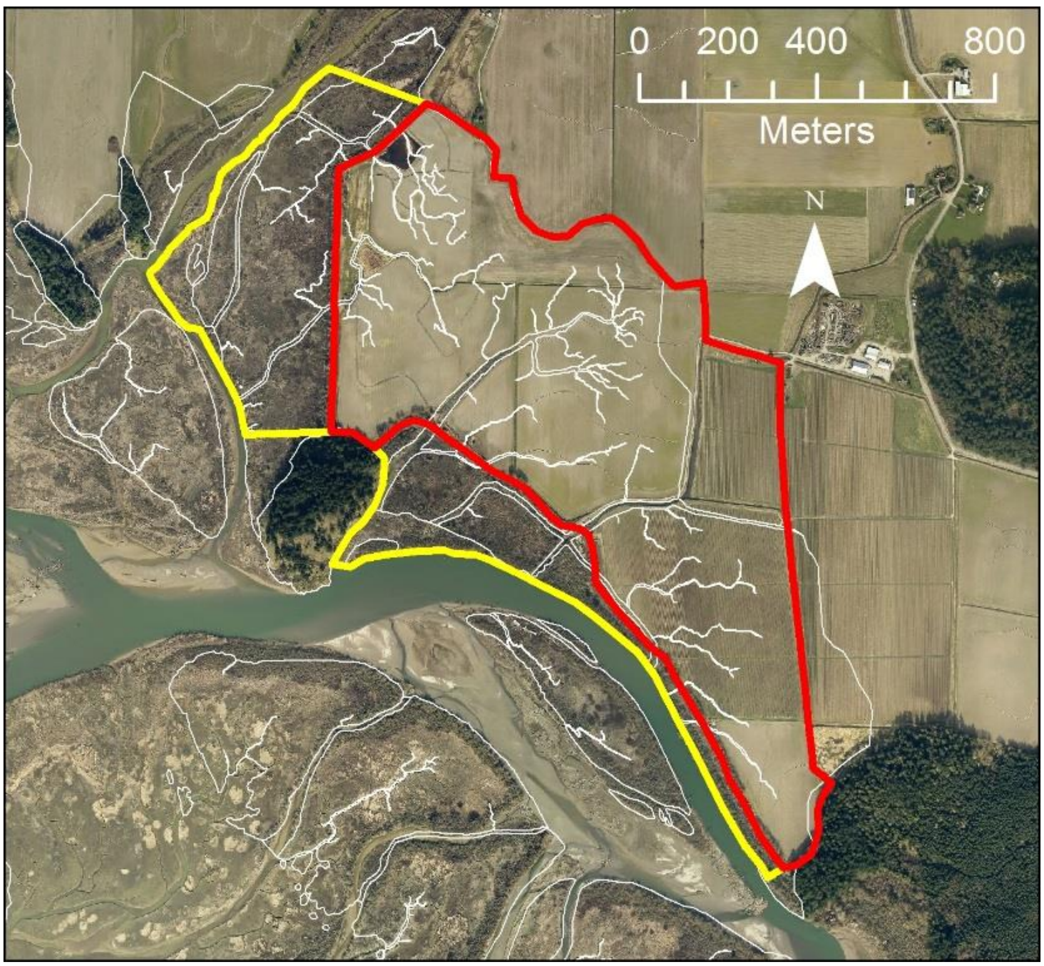

Figure 12. Sullivan Hacienda project site (red outline) and adjacent downstream marshes (yellow outline). The 1937 tidal channel network (white) is overlaid on the 2015 background photo.

Landscape connectivity and juvenile Chinook carrying capacity predictions

The Sullivan Hacienda project has an average midpoint carrying capacity estimate of approximately 220,000 juvenile Chinook per year (Table 16). The lowest and highest predicted carrying capacity for this project is approximately 67,000 and 619,000 fish per year, respectively. Predicted carrying capacity for this project varied by hundreds of thousands of fish per year as a function of predicted habitat amount. Variability in predicted carrying capacity due to landscape connectivity ranges from a few thousand to tens of thousands of fish per year (Table 16). The primary fish migration pathway point uses an existing large channel that branches off the North Fork Skagit River (Figure 13). Predicted carrying capacity is up to 40,000 fish per year lower if fish travel downstream from Bald Island and into the Sullivan Slough area to access the site.

This project is the same project footprint as described in the Skagit Chinook Recovery Plan (page 187). Our midpoint prediction for Sullivan Hacienda is 220,000 fish per year, whereas the Chinook Plan estimate is approximately 37,000 fish per year. The main reason for the increase in Chinook benefit is our inclusion of new channel area forming in adjacent downstream marshes caused by the increased tidal flushing due to the restoration project. The Skagit Chinook Recovery Plan did not account for this issue.

Table 16. Summary of channel habitat area (with 80% confidence limits in parentheses), landscape connectivity, and predicted Chinook carrying capacity for the Sullivan Hacienda project. Chinook carrying capacity estimates are for the habitat point estimate and habitat 80% confidence limits (in parentheses).

Candidate restoration project (from Table 15)		**Fish migration pathway used (from Figure 13)**			**Juvenile Chinook carrying capacity**
Site	**Predicted channel area (ha)**	**Point name**	**Point type**	**Landscape connectivity**	
Sullivan Hacienda + dwnstr	14.06 (5.67 – 34.86)	Sullivan Hacienda 18	secondary	0.035858	241,494 (97,388 - 598,754)
		Sullivan Hacienda 15	secondary	0.035289	237,627 (95,828 - 589,166)
		Sullivan Hacienda 14	primary	0.037064	249,696 (100,695 - 619,089)
		Sullivan Hacienda 16	secondary	0.030380	204,269 (82,376 - 506,458)
		Sullivan Hacienda 17	secondary	0.024826	166,596 (67,183 - 413,054)

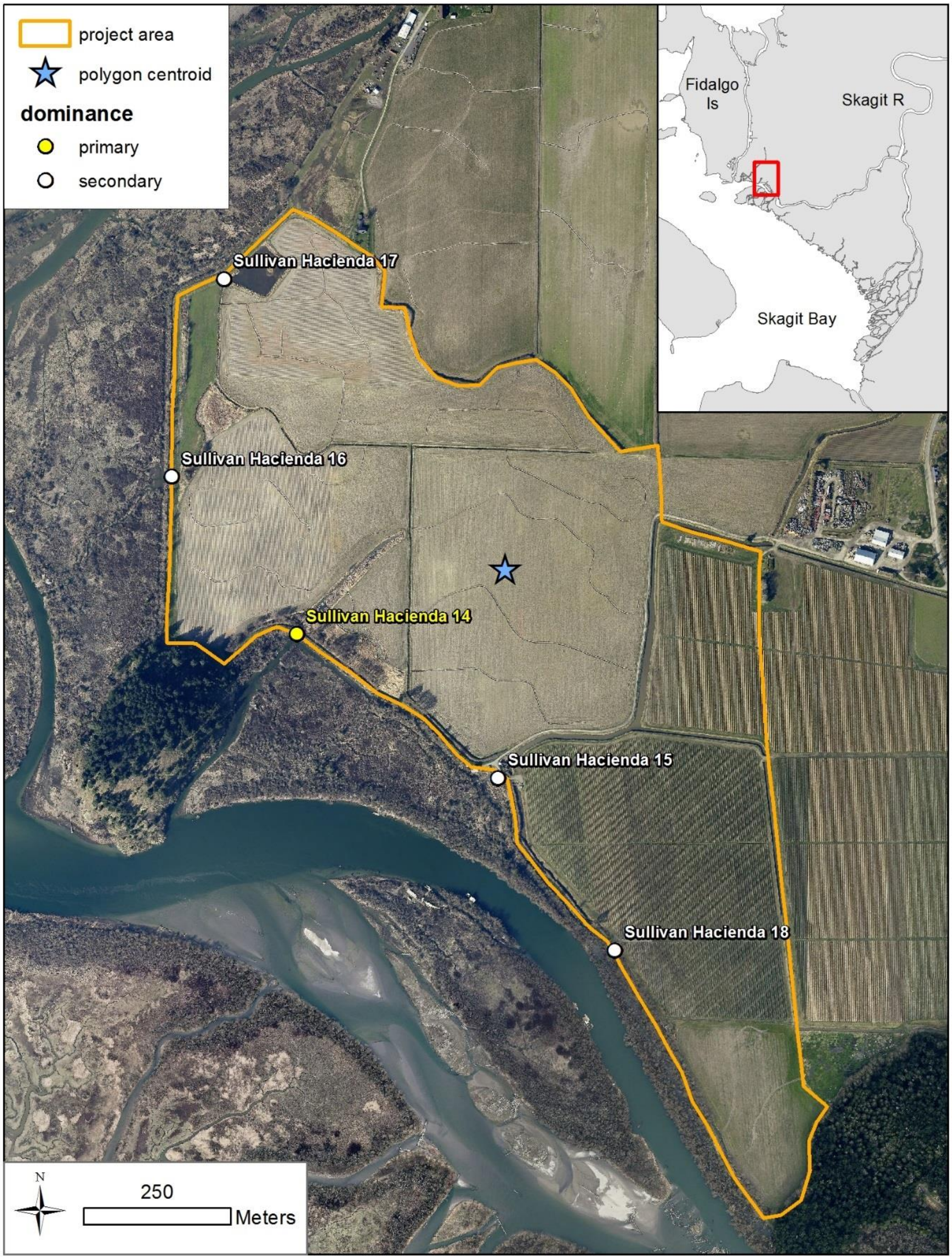

Figure 13. Location of fish migration pathway points used to estimate landscape connectivity for the Sullivan Hacienda project.

#11 Rawlins Road Distributary Channel

Habitat predictions

We evaluated the Rawlins Road Distributary Channel project for its value as new juvenile Chinook carrying capacity within the proposed excavated distributary channel. We did not evaluate this project for its influence on landscape connectivity for surrounding and downstream juvenile Chinook rearing habitats because its value as a new fish migration pathway is likely offset by the formation of the new distributary, which is much larger in size and located nearby. The influence of the newly formed North Fork tidal delta distributary on juvenile Chinook distribution is discussed in Beamer and Wolf (2016b).

Habitat estimates for the Rawlins Road Distributary Channel project were provided by the SHDM Project Team (2016). No range in habitat area or discussion of channel sustainability was provided. The project footprint is listed at 8 acres (3.24 ha) but the excavated distributary channel is 457 m long and 40 m wide, a 1.83 ha channel area.

Only the edges of distributary channels are consistently utilized by juvenile Chinook salmon (Beamer et al. 2005, see Appendix D.II starting on page 55). Average edge area suitable for juvenile Chinook rearing for distributary channels narrower than 50 m is 23% (Beamer et al. 2005, see Appendix D.III starting on page 60) so the habitat area used to calculate carrying capacity for this project is 0.42 ha.

<u>Offsite impacts</u>: The SHDM Project Team found no detectible offsite habitat changes due to this project.

Landscape connectivity and juvenile Chinook carrying capacity predictions

The Rawlins Road Distributary Channel project is estimated to create habitat for over 9,000 juvenile Chinook per year (Table 17). Estimated carrying capacity for this project is relatively high because of the high landscape connectivity value for this area compared to many other SHDM projects.

If the distributary channel is sustainable, we expect this project will improve fish access to marsh/channel habitats located approximately 0.8 km westward to Craft Island and southeasterly to the blind channel shown as the point ‘Hall Sl 2’ (Figure 9), approximately 0.75 km away from the mouth of the proposed distributary. We do not believe the proposed distributary will provide good access to Hall Slough proper or as far away as Browns Slough and Fir Island Farms because the water current direction is wrong for dispersing fry-sized juvenile Chinook salmon southeast along the bayfront (Beamer and Wolf 2016b).

We have concerns about two objectives for this project inferred to in SHDM Project Team (2016), specifically listed in the Rawlins Road Feasibility Study (Yang and Khangaonkar 2006), and listed below:

1. Increase Productivity of Chinook Salmon Rearing Habitat. This was described as: *Restore supply of freshwater from North Fork to provide brackish salinity for the emergent tidal marsh, scrub-shrub marsh and forested wetlands*.
2. Expand Migratory Opportunity between Skagit and Nearshore Marsh Habitats. This was described as: *Provide direct conveyance between the North Fork and the nearshore region west of the Fir Island dike*. (Direct conveyance presumably means conveyance of fish).

Objective 2 is consistent with the hypotheses presented in the Skagit Chinook Recovery Plan, but as a stand-alone objective, objective 1 is not. If objective 2 is achieved, it is true that objective 1 would be supported (i.e., salinity would also be reduced), but these should not be viewed as independent objectives. We do not believe reducing salinity along the bayfront is a valid stand-alone objective for Skagit Chinook recovery. Yang and Khangaonkar (2006) declare objective 1 as important but give no biological evidence to support it. Objective 1 is conceptually not wrong because juvenile salmon need to make the physiological transition from fresh to salt water, but fish and salinity data by habitat type and place within the greater Skagit estuary do not support bullet 1 as a stand-alone objective, except for the sudden change in salinity occurring at the Hole in the Wall located on the south end of Swinomish Channel (Yates 2001). Salinities in habitat along the bayfront (i.e., Browns Slough area) range from 0.4 to 18.2 ppt (SRSC unpublished data provided to Brian Williams for the Fir Island Farms Feasibility Study in 2008). These same areas support growth rates of juvenile Chinook salmon (average of 1.7 mm/day) consistent with other non-bayfront estuarine emergent marsh sites (SSC and USGS 1999). Moreover, juvenile Chinook salmon are known to rear (and grow) for extensive periods of time in non-natal pocket estuaries (Beamer et al. 2013), which are even more saline with salinities up to 25 ppt (Beamer et al. 2007). Having more fresh water will not necessarily make bayfront habitat more suitable for juvenile Chinook rearing. The bayfront already has salinities within the range that supports rearing juvenile Chinook salmon.

Table 17. Summary of channel habitat area, landscape connectivity, and predicted Chinook carrying capacity for the Rawlins Road Distributary Channel project.

Candidate restoration project		**Fish migration pathway used (from Figure 14)**			**Juvenile Chinook carrying capacity**
Site	**Predicted channel area (ha)**	**Point name**	**Point type**	**Landscape connectivity**	
Rawlins Road Distributary Channel	0.42	Rawlins distributary (centroid)	primary	0.045956	9,268*

* No range is predicted for juvenile Chinook carrying capacity because no habitat area range was provided.

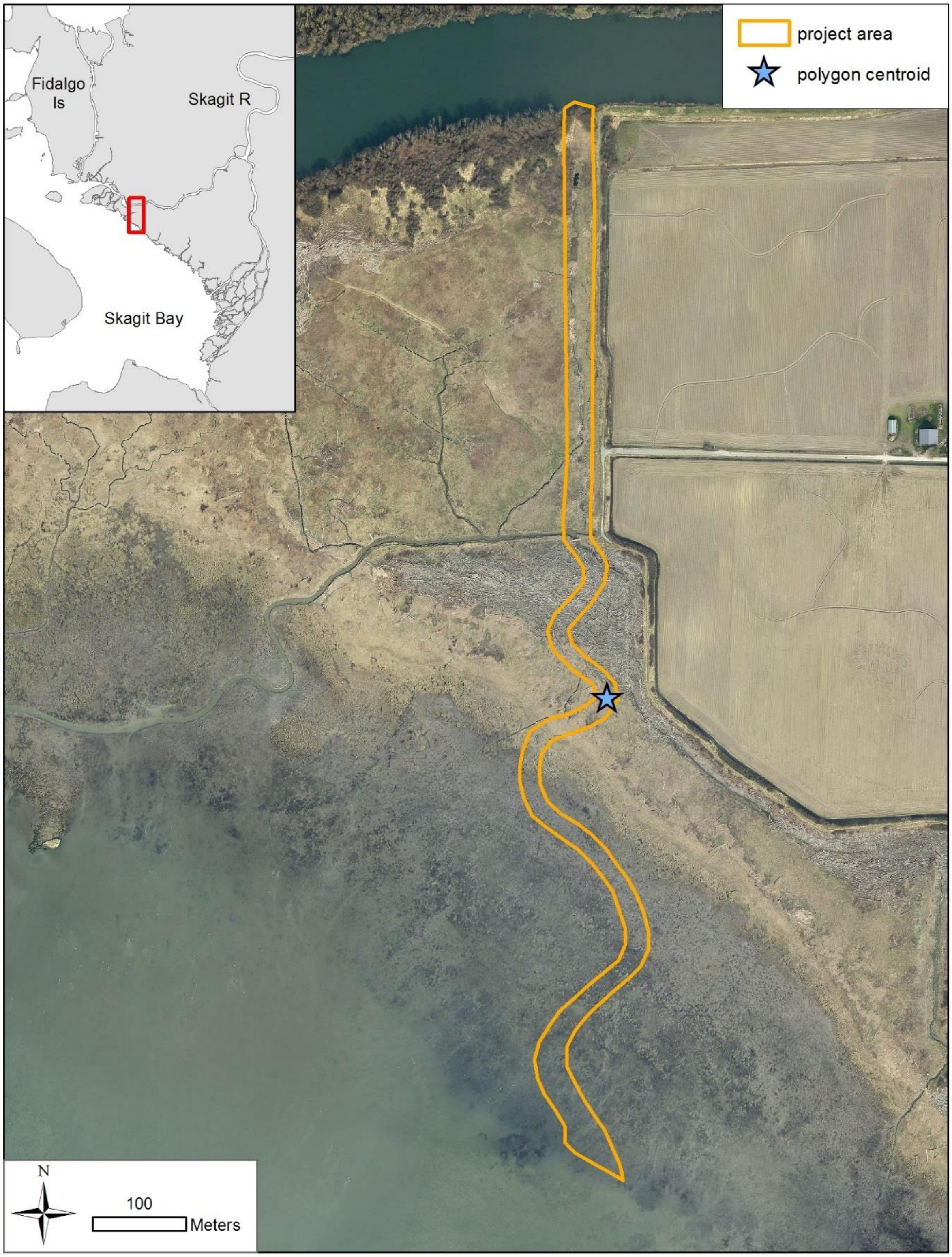

Figure 14. Location of fish migration pathway point (centroid) used to estimate landscape connectivity for the Rawlins Road Distributary Channel project.

#13 Avon-Swinomish Bypass

Habitat predictions

It was outside our scope of work to estimate habitat areas for the Avon-Swinomish Bypass project. However, limited project design elements for this project were provided by the SHDM Project Team (2016) and used to estimate preliminary habitat, landscape connectivity, and juvenile Chinook estimates.

The 1,293-acre (project footprint) Avon-Swinomish Bypass project runs from river mile 15.9 on the Skagit River near Avon to Swinomish Channel along the south side of Highway 20 (Figure 15). The project includes a 2,000-ft wide flood flow bypass with a low flow channel for continuous flow to allow fish use. The bypass channel's design drawing at the point of bifurcation with the mainstem Skagit River shows the channel's bankfull and low flow width at 500 and 100 feet, respectively. The Avon-Swinomish Bypass project connects to the Telegraph Slough 1 and 2 Project, so we used its habitat area estimates to predict juvenile Chinook carrying capacity estimates for this project (Table 18).

This project should create new juvenile Chinook habitat within the bypass area upstream of Telegraph Slough 1 & 2. Per the project's design, habitat within the bypass channel will likely function like a distributary channel, where only the channel edges are consistently used by juvenile Chinook salmon (Beamer et al. 2005, see Appendix D.II starting on page 55). Average edge area suitable for juvenile Chinook rearing for distributary channels is 23% for channels < 50 m and 5% for channels >100 m (Beamer et al. 2005, see Appendix D.III starting on page 60). Thus, fish rearing value of the bypass channel will depend on the actual channel width constructed (500 or 100 ft), and on flows observed. Without more information about the bypass channel we did not estimate its habitat area.

<u>Offsite impacts</u>: The SHDM Project Team estimated construction of the Avon-Swinomish Bypass would result in a reduction of 313 acres (126.7 hectares) of inundated floodplain habitat during a two-year flood event at low tide due to the lowered water levels downstream of the bypass. The losses are evenly distributed across the mainstem, North Fork, South Fork, and Steamboat Slough sub-areas, and include floodplain habitat along the edge of the river between the dikes as well as parts of Edgewater Park, East Cottonwood, Cottonwood Island, South Fork Dike Setback #1, Milltown Island and around the North Fork Bridge. Additional habitat may be affected upstream of the inlet to the Bypass, but this was not a part of the study area.

Landscape connectivity and juvenile Chinook carrying capacity predictions

We calculated landscape connectivity for this project based on design drawings showing channel width (500 or 100 ft). We used the design widths to calculate bifurcation order of the bypass channel relative to the mainstem Skagit River. However, we were not given a channel length value, only the footprint of the project area. The artist's rendition of channel form for the Avon-Swinomish Bypass Project likely over estimates channel length because of the very high sinuosity used. We measured sinuosity from two historic distributary channels located in the area of the proposed bypass channel (from Collins and Sheikh 2005; Collins and Montgomery 2001) in order to estimate the bypass channel's length for landscape connectivity calculation purposes. The two historic channels' sinuosity values are 1.24 and 1.27. Thus, the bypass channel would be 10.89 km long if its sinuosity was 1.26 over the 8.64 km length of the project footprint (i.e., split from the mainstem Skagit to the centroid of the Telegraph Slough 1 & 2 project footprint, see Figure 15). If the bypass channel is 500 or 100 ft wide, then landscape connectivity to the Telegraph Slough 1 & 2 area is 0.0459 and 0.0230, respectively (Table 18). Please note: landscape connectivity results for the bypass project are within the range observed for our monitored fish sampling sites but outside of the spatial range in which the rules were developed. Thus, the predictions of juvenile Chinook carrying capacity for the bypass project are based on some estimates outside of the model's dataset.

The Avon-Swinomish Bypass project is estimated to produce connectivity conditions for 70,000 to over 900,000 juvenile Chinook per year in the Telegraph Slough 1 & 2 area, depending on: 1) which channel width drives landscape connectivity; and 2) how much habitat is actually formed (Table 18). Assuming the project creates suitable and passable habitat within the bypass channel, it should increase juvenile Chinook values for all Telegraph Slough projects (Project #9, 13, and 18) and existing (or future) habitat within the north end of Swinomish Channel and southern Padilla Bay. However, these increases should be considered in the context of any offsite impact to fish migration pathways.

<u>Offsite impacts to fish migration pathways</u>: The Avon-Swinomish Bypass project will reduce juvenile Chinook use of habitat areas fed by fish traveling down the Skagit River downstream of the bypass channel's bifurcation point. If the bypass channel is 500 ft wide (bankfull channel condition), then the bypass project dramatically reduces landscape connectivity values downstream of the bifurcation. This is because the mainstem Skagit River becomes a bifurcation order of '2' starting at Avon (instead of at the fork), rather than remaining a first order channel. Under this scenario, half the fish outmigrating the Skagit River would theoretically take the bypass channel pathway, which would significantly increase fish seeding of habitats along the Swinomish Channel corridor and southern Padilla Bay. There are about 300 hectares of vegetated tidal delta footprint in these areas compared to the over 2,700 hectares present in the North Fork, South Fork, and bayfront tidal delta areas. If the 100-ft wide low flow channel is used for bifurcation ordering of the bypass channel, then the project does not mathematically reduce landscape connectivity values for all Skagit tidal delta habitat downstream of Avon. In reality, some fish will take the new bypass channel pathway. If this project receives significant traction toward actually happening, then we recommend its design for fish migration pathways be balanced with the amount of receiving water's habitat. It would be a bad idea for Skagit Chinook recovery to have half of the Skagit River's juvenile Chinook outmigrants connected to much less than half of the Skagit's total tidal delta habitat. If such a phenomenon occurred, it would likely result in exporting juvenile fish to exposed nearshore habitat before they are ready, similar to what was detected for the new distributary channel in the North Fork Skagit tidal delta (Beamer and Wolf 2016b).

<u>Prediction limitations</u>: The Avon-Swinomish Bypass project utilizes input variables that are outside the data range used to develop bifurcation ordering of channels used for calculating landscape connectivity which makes the juvenile Chinook salmon carrying capacity estimates suspect (likely biased high). Moreover, the project would have large negative offsite impacts to

inundation of the main Skagit tidal delta and could move many downstream migrating juvenile Chinook away from the majority of habitat in the Skagit estuary if constructed. We were unable to predict habitat areas for the bypass channel reach with the information provided. Nevertheless, we provided meaningful discussion (above) of some pros and cons to juvenile Chinook salmon for this project, which may be helpful to managers as they decide which suite of SHDM projects are pursued further. Because of the project's listed limitations, we do not recommend directly comparing carrying capacity estimates for this project with other SHDM projects.

Table 18. Summary of channel habitat area (with 80% confidence limits in parentheses), landscape connectivity, and predicted Chinook carrying capacity for the Avon-Swinomish Bypass project. Chinook carrying capacity estimates are for the habitat point estimate and habitat 80% confidence limits (in parentheses). The habitat area estimate is for the Telegraph Slough 1 & 2 project and landscape connectivity varies depending on bypass channel width.

Candidate restoration project		**Fish migration pathway used (from Figure 15)**			**Juvenile Chinook carrying capacity**
Site	**Predicted channel area (ha)**	**Point name**	**Point type**	**Landscape connectivity**	
500 ft wide bypass channel	16.70 (6.49 – 42.94)	Telegraph 1&2 centroid	primary	0.045914	368,167 (143,078 – 946,651)
100 ft wide bypass channel				0.022957	182,844 (71,057 – 470,139)

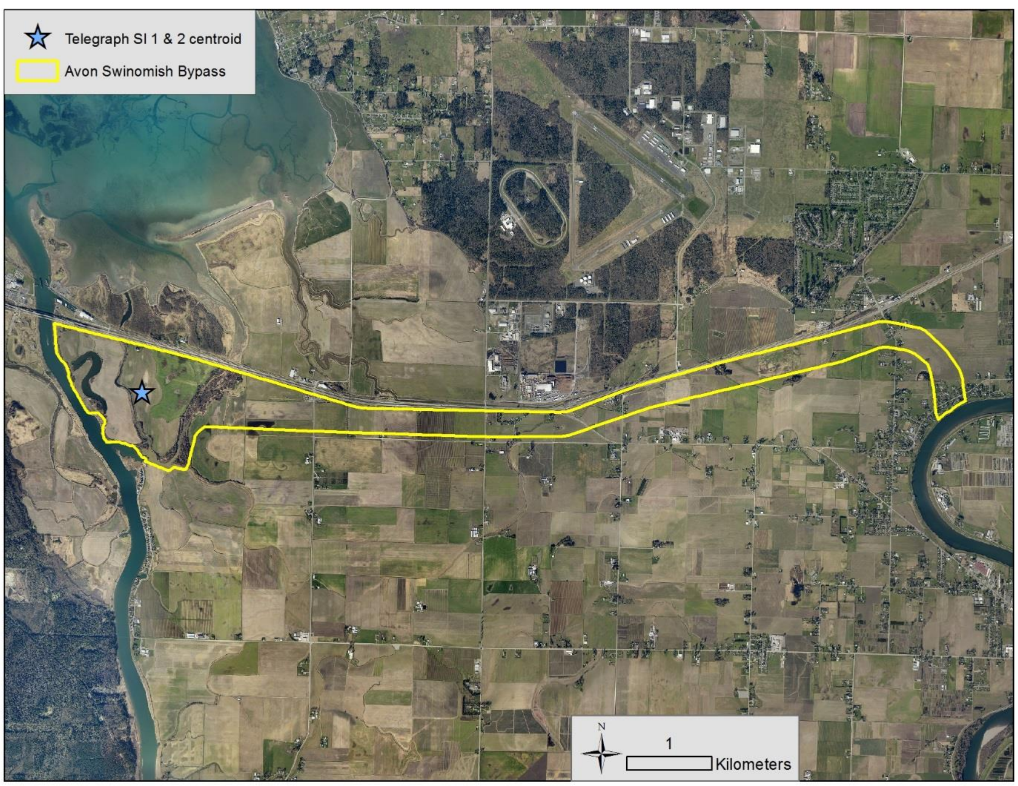

Figure 15. Location of fish migration pathway point (Telegraph Sl centroid) used to estimate landscape connectivity for the Avon-Swinomish Bypass project.

#14 North Fork Left Bank Levee Setback C

Habitat predictions

This site is bordered by adjacent existing tidal/riverine marsh; downstream effects of site restoration were considered for these adjacent marshes. This site was subdivided into three sites that were thought to likely act relatively independently of each other. The most upstream site was bounded by the road prism leading to the North Fork Skagit River bridge as well as the bridge abutment. The other border is further downstream at a comparatively narrow portion of the site (126 m compared to a maximum site width of 550 m).

The reference system for allometric prediction (Table 19) consisted a suite of tidal marshes in river deltas throughout Puget Sound, whose tidal ranges varied from 2.6 to 4.1 m (Hood 2015). This Puget Sound data was modeled through multiple regression to generate predictions, with marsh area and tide range as the independent variables. The tide range of the North Fork Left Bank Levee Setback C project was estimated to vary from 2.2 m at its upstream limit to 2.9 m at its downstream limit.

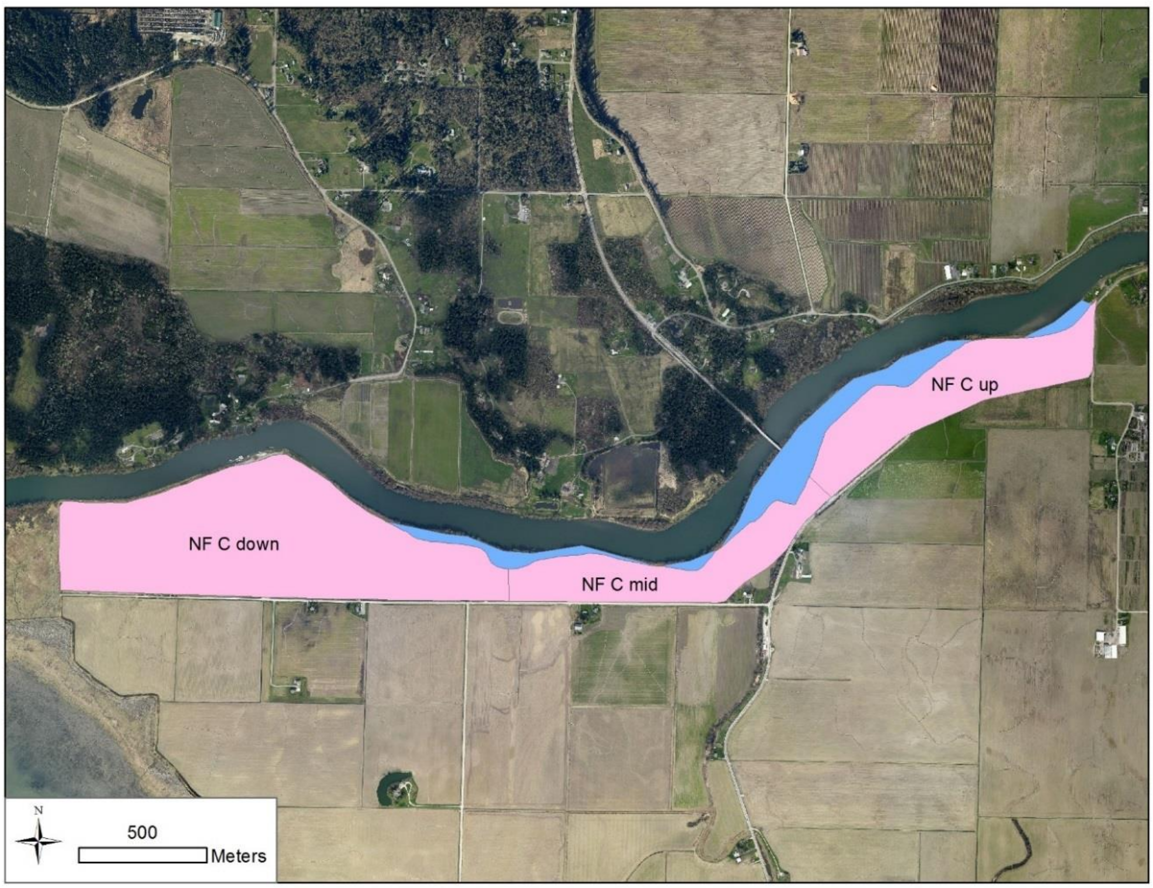

Figure 16. North Fork Left Bank Levee Setback C (pink polygons) and adjacent marsh (blue polygons).

Table 19. Allometric predictions of tidal channel geometry for North Fork Left Bank Levee Setback C, with 80% confidence limits of the prediction in parentheses. Rows labeled "Total – Upstr" show the difference between upstream project site plus downstream existing marsh ("Total") predictions and project site only ("Upstr") predictions (i.e., indirect or downstream effects of project site restoration), with currently observed channel metrics in the existing downstream marsh shown in brackets for comparison with indirect effects predictions.

Site	Site area (ha)	Predicted channel count	Predicted channel area (ha)	Predicted channel length (m)
North Fork Setback up	25.62	6 (3 – 13)	0.18 (0.06 – 0.56)	1,288 (555 – 2,992)
NF setback up + dwnstr	33.58	7 (3 – 15)	0.27 (0.09 – 0.82)	1,770 (762 – 4,112)
Total - Upstr	7.96	1 [2]	0.09 [0.08]	482 [190]
North Fork Setback mid	20.67	6 (3 – 13)	0.18 (0.06 – 0.55)	1,291 (560 – 2,979)
NF setback mid + dwnstr	26.64	7 (3 – 16)	0.26 (0.09 – 0.78)	1,742 (753 – 4,018)
Total - Upstr	5.97	1 [2]	0.08 [-]	451 [-]
North Fork Setback down	65.19	14 (6 - 32)	1.25 (0.41 – 3.77)	6,531 (2,831 – 15,066)
NF setback down + dwnstr	66.95	14 (7 - 32)	1.29 (0.43 – 3.91)	6,730 (2,917 – 15,524)
Total - Upstr	1.76	0 [0]	0.04 [0]	199 [0]

The tidal marsh/river floodplain adjacent to the project site has only one visible side channel, which appears to be a vestige of the historical Browns-Hall distributary that once diverged from the North Fork Skagit River to cross Fir Island. This broadly u-shaped side channel (in planform) has two connections to the river, so it was counted as two channels (i.e., two outlets) to maintain consistency with the definition of channel count in the reference marsh system. Two other small channels are known to be present but were not visible in the aerial photos, being obscured by forest canopy.

Offsite impacts: The SHDM Project Team estimated construction of the North Fork Left Bank Setback C had a negligible net change in habitat outside of the project footprint, estimated at 0.5 acres with some gains occurring around the North Fork Bridge and minor losses of less than an acre at Cottonwood Island as well as wetted floodplain habitat along the edge of the river in the South Fork.

Landscape connectivity and juvenile Chinook carrying capacity predictions

The North Fork Left Bank Levee Setback C project predicted juvenile Chinook carrying capacity midpoint estimate is approximately 53,000 fish per year with three separate sub-project polygons contributing to the total (Table 20). Predicted carrying capacity for this project varies from a low of 18,000 to a high of 162,000 fish per year as a function of predicted habitat amount.

We did not model variability in landscape connectivity within each of the sub-project polygons. However, variability in landscape connectivity ranges from a high of 0.085 in the upstream-most polygon to a low of 0.054 for the downstream-most polygon (Figure 17).

Table 20. Summary of channel habitat area (with 80% confidence limits in parentheses), landscape connectivity, and predicted Chinook carrying capacity for the North Fork Left Bank Levee Setback C project. Chinook carrying capacity estimates are for the habitat point estimate and habitat 80% confidence limits (in parentheses).

Candidate restoration project (from Table 19)		Fish migration pathway used (from Figure 17)			Juvenile Chinook carrying capacity
Site	**Predicted channel area (ha)**	**Point name**	**Point type**	**Landscape connectivity**	
NF setback up + dwnstr	0.27 (0.09 – 0.82)	NF Setback upstr 8	primary	0.084898	11,072 (3,691 - 33,628)
NF setback mid + dwnstr	0.26 (0.09 – 0.78)	NF Setback mid 7	primary	0.069531	8,716 (3,017 - 26,147)
NF setback down + dwnstr	1.29 (0.43 – 3.91)	NF Setback dwnstr 6	primary	0.054299	33,688 (11,229 - 102,108)

Figure 17. Location of fish migration pathway points used to estimate landscape connectivity for the North Fork Left Bank Levee Setback C project.

#15 North Fork Left Bank Levee Setback A

Habitat predictions

This site includes North Fork Left Bank Levee Setback C as well as an adjacent extension of the project site upstream (Figure 18). The upstream extension was divided into three sections that may behave differently and to which fish may respond differently due to river meandering. The most upstream sections are bordered by adjacent existing tidal/riverine marsh; downstream effects of site restoration were considered for this adjacent marsh.

The reference system for allometric prediction (Table 21) consisted a suite of tidal marshes in river deltas throughout Puget Sound, whose tidal ranges varied from 2.6 to 4.1 m (Hood 2015). This Puget Sound data was modeled through multiple regression to generate predictions, with marsh area and tide range as the independent variables. The tide range of all polygons in the North Fork Left Bank Levee Setback A project was estimated to vary from 1.8 m at its upstream limit to 2.9 m at its downstream limit.

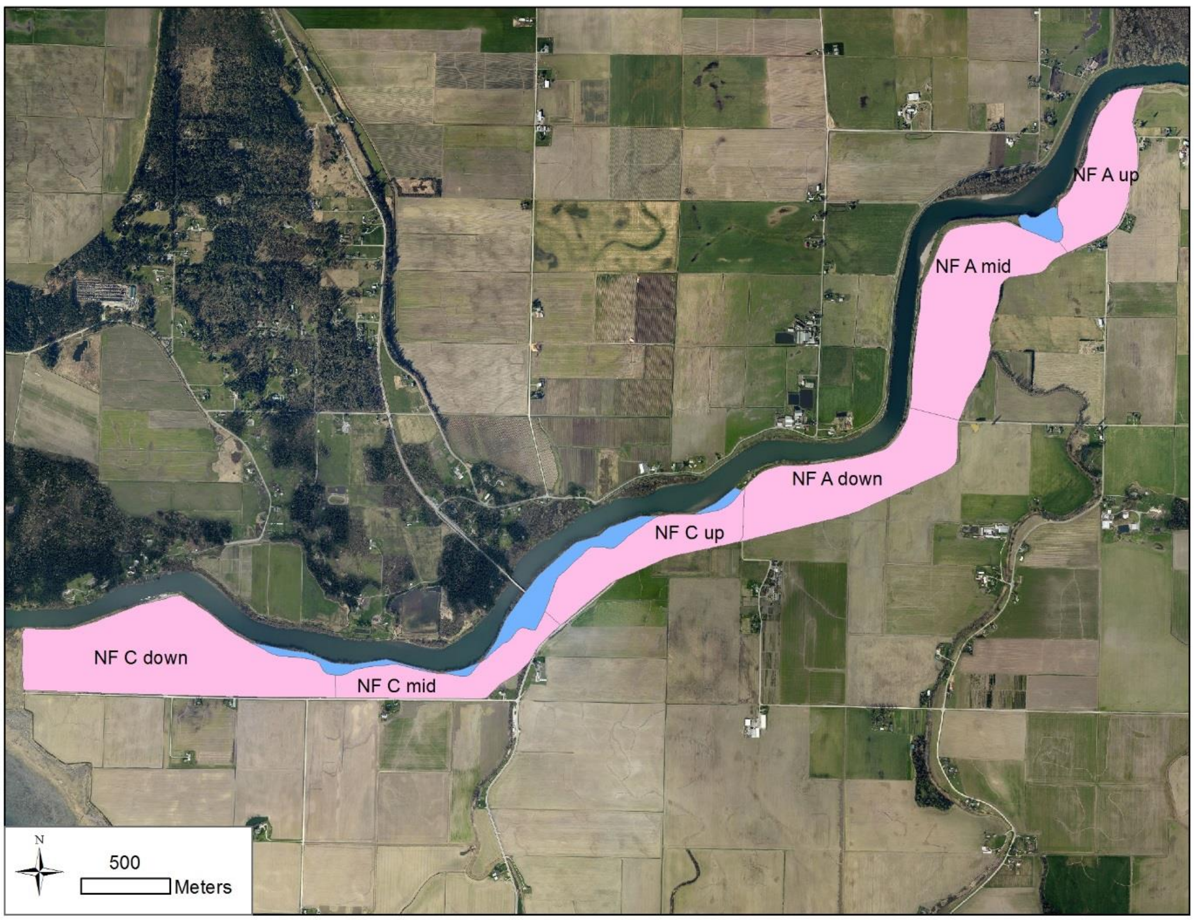

Figure 18. North Fork Left Bank Levee Setback A (pink polygons) and adjacent marsh (blue polygons). Note: The North Fork Left Bank Levee Setback A project also includes the North Fork Left Bank Levee Setback C project.

Table 21. Allometric predictions of tidal channel geometry for the North Fork Left Bank Levee Setback A project site, not including the portions identical to North Fork Left Bank Levee Setback C project (see Table 19), with 80% confidence limits of the prediction in parentheses. The rows labeled "Total – Upstr" shows the difference between upstream project site plus downstream existing marsh ("Total") predictions and project site only ("Upstr") predictions (i.e., indirect or downstream effects of project site restoration), with currently observed channel metrics in the existing downstream marsh shown in brackets for comparison with indirect effects predictions.

Site	Site area (ha)	Predicted channel count	Predicted channel area (ha)	Predicted channel length (m)
North Fork Setback A up	24.09	3 (1 – 8)	0.073 (0.023 – 0.23)	585 (245 – 1,396)
NF setback A up + dwnstr	26.92	4 (2 – 8)	0.086 (0.027 – 0.27)	670 (281 – 1,596)
Total - Upstr	2.83	1 [1]	0.013 [0.029]	85 [150]
North Fork Setback A mid	48.09	6 (3 – 15)	0.27 (0.086 – 0.82)	1,746 (745 – 4,083)
North Fork Setback A down	40.17	6 (3 - 14)	0.26 (0.084 – 0.81)	1,702 (719 – 4,018)

Offsite impacts: The SHDM Project Team estimated construction of the North Fork Left Bank Levee Setback A reduced wetted floodplain habitat in the study area by approximately 26 acres (10.5 hectares). There were some gains and minor losses of wetted habitat around the North Fork Bridge for a net increase in this area of 4 acres (1.6 hectares). There were losses of wetted floodplain around and just downstream of Edgewater Park, as well as Cottonwood Island, East Cottonwood, and floodplain habitat along the edge of the South Fork. The largest wetted floodplain reduction was at Milltown Island.

Landscape connectivity and juvenile Chinook carrying capacity predictions

The North Fork Left Bank Levee Setback A project predicted juvenile Chinook carrying capacity midpoint estimate is approximately 85,000 fish per year with six separate sub-project polygons contributing to the total (Figure 19). Predicted carrying capacity for this project varies from a low of 28,000 to a high of 260,000 fish per year as a function of predicted habitat amount (Table 22).

We did not model variability in landscape connectivity within each of the sub-project polygons. However, variability in landscape connectivity ranges from a high of 0.154 in the upstream-most polygon to a low of 0.054 for the downstream-most polygon (Figure 19).

The North Fork Left Bank Levee Setback A project has the same project footprint as the North Fork Levee Setback project[1] listed on page 191 of the Skagit Chinook Recovery Plan. Our analysis uses: 1) an improved habitat predictor method (Hood 2015) over what was used in the Chinook Plan; and 2) breaks the restoration area up into smaller, more realistic, hydrologic units for estimating channel formation, resulting in less predicted channel area than what is predicted by the Chinook Plan. Thus, our analysis of this project predicts significantly less Chinook benefit

[1] Figure 11.14 on page 192 of the Skagit Chinook Recovery Plan only shows a possible first phase of the North Fork Levee Setback project which is equivalent to the footprint of SHDM North Fork Left Bank Levee Setback C project.

compared to the Chinook Plan. The midpoint prediction for North Fork Left Bank Levee Setback A is approximately 85,000 fish per year, whereas the Chinook Plan estimated over 600,000 fish per year.

Table 22. Summary of channel habitat area (with 80% confidence limits in parentheses), landscape connectivity, and predicted Chinook carrying capacity for the North Fork Left Bank Levee Setback A project. Chinook carrying capacity estimates are for the habitat point estimate and habitat 80% confidence limits (in parentheses).

Candidate restoration project (from Table 21)		**Fish migration pathway used (from Figure 19)**			**Juvenile Chinook carrying capacity**
Site	**Predicted channel area (ha)**	**Point name**	**Point type**	**Landscape connectivity**	
All NF "C" polygons	1.82 (0.61 – 5.51)	See Table 20	primary	See Table 20	53,476 (17,937 – 161,883)
NF setback A up + dwnstr	0.086 (0.027 – 0.27)	NF Setback A up 44	primary	0.153623	6,419 (2,015 - 20,152)
North Fork Setback A mid	0.27 (0.086 – 0.82)	NF Setback A mid 45	primary	0.102192	13,352 (4,253 - 40,551)
North Fork Setback A down	0.26 (0.084 – 0.81)	NF Setback A down 46	primary	0.095376	11,992 (3,874 - 37,360)

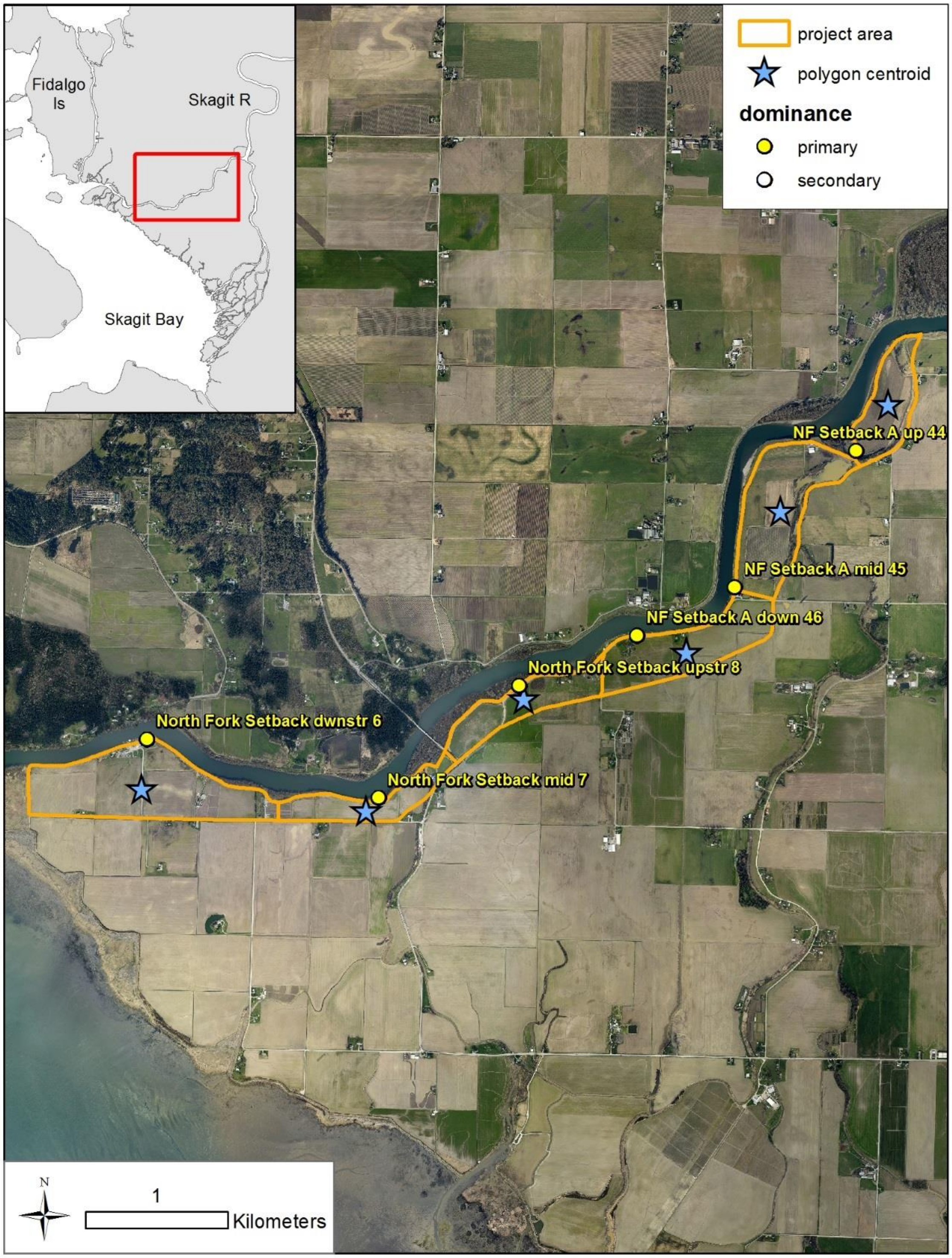

Figure 19. Location of fish migration pathway points used to estimate landscape connectivity for the North Fork Left Bank Levee Setback A project.

(not given) North Fork Left Bank Levee Setback B

Habitat predictions

This project consists of the same sites as North Fork Left Bank Levee Setback C, plus “NF A down” in Figure 6. The predicted channel geometries for these parcels are those in Table 19, plus the bottom line in Table 21.

Offsite impacts: The SHDM Project Team did not model offsite impacts for the North Fork Left Bank Levee Setback B project. It is expected that offsite impacts for this project are intermediate of those estimated for the North Fork C project (which were negligible) and the North Fork A project which reduced wetted floodplain habitat in the study area by approximately 26 acres (10.5 hectares).

Landscape connectivity and juvenile Chinook carrying capacity predictions

The North Fork Left Bank Levee Setback B project predicted juvenile Chinook carrying capacity midpoint estimate is approximately 65,000 fish per year with four separate sub-project polygons contributing to the total (Figure 20). Predicted carrying capacity for this project varies from a low of 22,000 to a high of 199,000 fish per year as a function of predicted habitat amount (Table 23).

We did not model variability in landscape connectivity within each of the sub-project polygons. However, variability in landscape connectivity ranges from a high of 0.095 in the upstream-most polygon to a low of 0.054 for the downstream-most polygon (Figure 20).

Table 23. Summary of channel habitat area (with 80% confidence limits in parentheses), landscape connectivity, and predicted Chinook carrying capacity for the North Fork Left Bank Levee Setback B project. Chinook carrying capacity estimates are for the habitat point estimate and habitat 80% confidence limits (in parentheses).

Candidate restoration project		**Fish migration pathway used (from Figure 20)**			**Juvenile Chinook carrying capacity**
Site	**Predicted channel area (ha)**	**Point name**	**Point type**	**Landscape connectivity**	
All NF “C” polygons	1.82 (0.61 – 5.51)	See Table 20	primary	See Table 20	53,476 (17,937 – 161,883)
North Fork Setback A down	0.26 (0.084 – 0.81)	NF Setback A down 46	primary	0.095376	11,992 (3,874 - 37,360)

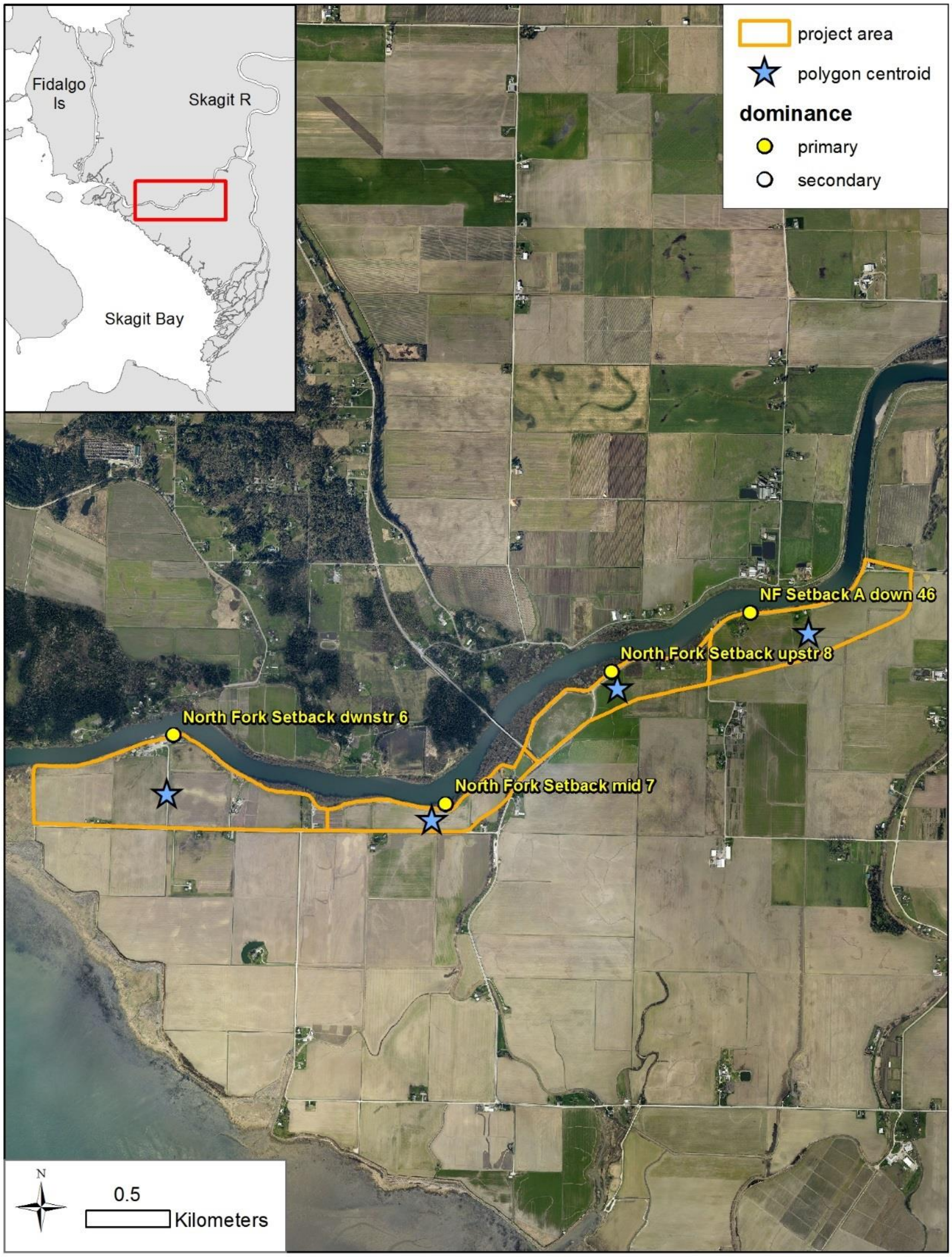

Figure 20. Location of fish migration pathway points used to estimate landscape connectivity for the North Fork Left Bank Levee Setback B project.

#16 North Fork Right Bank Levee Setback

Habitat predictions

This site (Figure 21) was bordered by adjacent existing tidal/riverine marsh at the most downstream portion of the project site; indirect, off-site effects of site restoration were considered for these adjacent marshes. This site was subdivided into two sites that were thought to likely act relatively independently of each other. The most upstream site is located on a concave bank of North Fork Skagit River and is separated from the downstream portion by a small narrowing in the site width. The downstream portion of the project site is along a generally straight reach of the river.

The reference system for allometric prediction (Table 24) consisted a suite of tidal marshes in river deltas throughout Puget Sound, whose tidal ranges varied from 2.6 to 4.1 m (Hood 2015). This Puget Sound data was modeled through multiple regression to generate predictions, with marsh area and tide range as the independent variables. The tide range of the North Fork Right Bank Levee Setback site was estimated to be approximately 2.25 m for the downstream portion of the project and 2.15 m for the upstream portion.

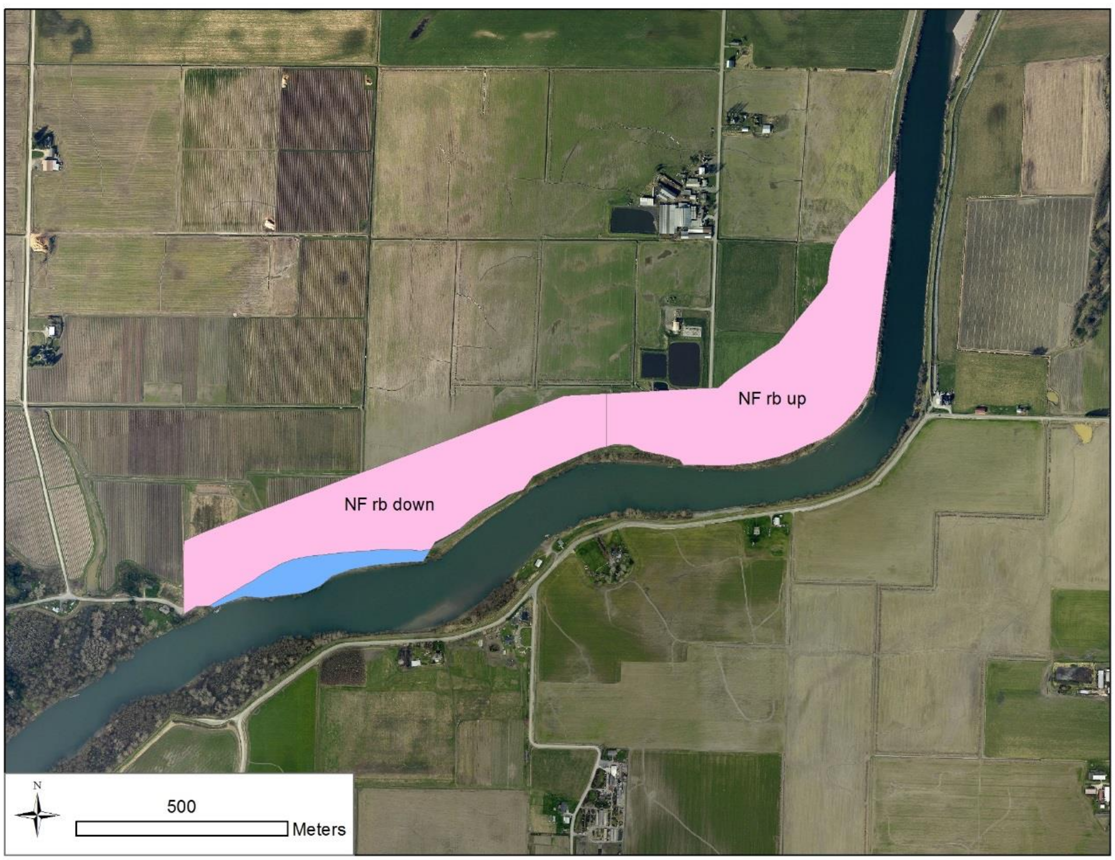

Figure 21. North Fork Right Bank levee setback (pink polygons) and adjacent marsh (blue polygons).

Table 24. Allometric predictions of tidal channel geometry for the North Fork Right Bank Levee Setback project site, with 80% confidence limits of the prediction in parentheses. The row labeled "Total – Upstr" shows the difference between upstream project site plus downstream existing marsh ("Total") predictions and project site only ("Upstr") predictions (i.e., indirect or downstream effects of project site restoration), with currently observed channel metrics in the existing downstream marsh shown in brackets for comparison with indirect effects predictions.

Site	Site area (ha)	Predicted channel count	Predicted channel area (ha)	Predicted channel length (m)
North Fork Right Bank down	17.81	4 (2 – 10)	0.097 (0.032 – 0.30)	755 (324 – 1,758)
NF RB down + dwnstr	20.29	5 (2 – 10)	0.116 (0.038 – 0.36)	879 (378 – 2,046)
Total - Upstr	2.48	1 [1]	0.019 [0.009]	124 [90]
North Fork Right Bank up	16.99	4 (2 – 9)	0.077 (0.025 – 0.24)	624 (267 – 1,459)

Offsite impacts: The SHDM Project Team estimated construction of the North Fork Right Bank Levee Setback Project would reduce wetted floodplain habitat across the study area by approximately 4 acres (1.6 hectares) total. These losses occur in small patches in the mainstem around Edgewater Park and just downstream of the park and along the edge of the river; in the North Fork around Cottonwood Island, the North Fork bridge and edges of the river; and in the South Fork in floodplain habitat along the edges of the river.

Landscape connectivity and juvenile Chinook carrying capacity predictions

The North Fork Right Bank Levee Setback project predicted juvenile Chinook carrying capacity midpoint estimate is approximately 8,000 fish per year with two separate sub-project polygons contributing to the total (Figure 22). Predicted carrying capacity for this project varies from a low of 2,650 to a high of 25,000 fish per year as a function of predicted habitat amount (Table 25). We did not model variability in landscape connectivity within each of the sub-project polygons. However, variability in landscape connectivity ranges from a high of 0.095 in the upstream-most polygon to a low of 0.082 for the downstream-most polygon (Figure 22).

Table 25. Summary of channel habitat area (with 80% confidence limits in parentheses), landscape connectivity, and predicted Chinook carrying capacity for the North Fork Right Bank Levee Setback project. Chinook carrying capacity estimates are for the habitat point estimate and habitat 80% confidence limits (in parentheses).

Candidate restoration project (from Table 24)		**Fish migration pathway used (from Figure 22)**			**Juvenile Chinook carrying capacity**
Site	**Predicted channel area (ha)**	**Point name**	**Point type**	**Landscape connectivity**	
NF RB down + dwnstr	0.116 (0.038 – 0.36)	NF rb down 47	primary	0.081739	4,578 (1,500 – 14,209)
North Fork Right Bank up	0.077 (0.025 – 0.24)	NF rb up 48	Primary	0.095089	3,541 (1,150 - 11,036)

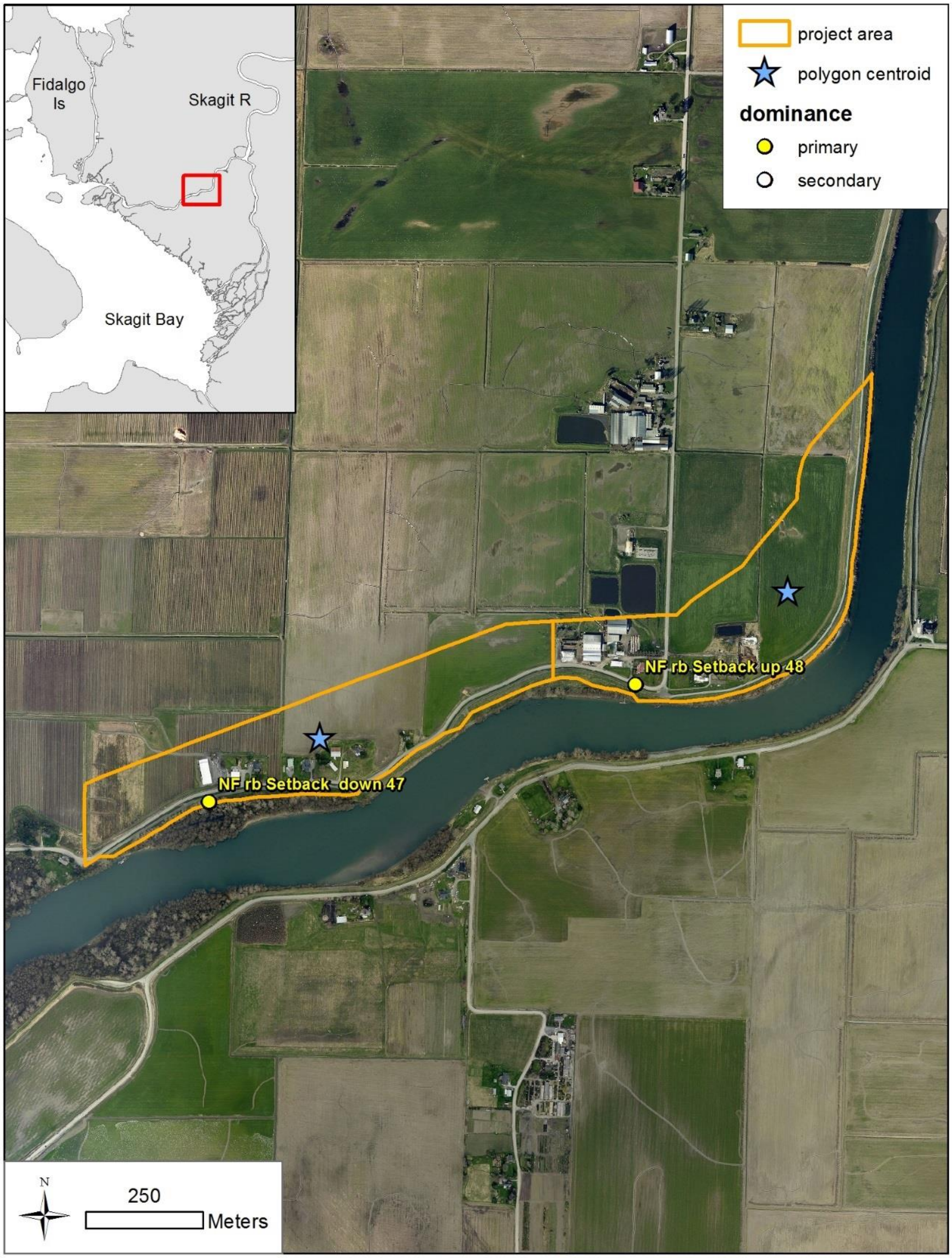

Figure 22. Location of fish migration pathway points used to estimate landscape connectivity for the North Fork Right Bank Levee Setback project.

#18 Telegraph Slough 1

Habitat predictions

This project consists of the westernmost third of Telegraph S polygon (Figure 23). As mentioned above for the Telegraph Slough Full project, the Skagit South Fork tidal marshes were used as the reference system for allometric prediction of tidal channel geometry, because of similar tide range and fetch.

The project site amounts to 74.86 ha. The predicted channel count is 27 with upper and lower 80% confidence limits (CLs) of the prediction ranging from 13 to 57; the predicted total tidal channel area is 3.74 ha (80% CLs: 1.49 – 9.37 ha); the predicted total channel length is 16,783 m (80% CLs: 6,747 – 41,746 m).

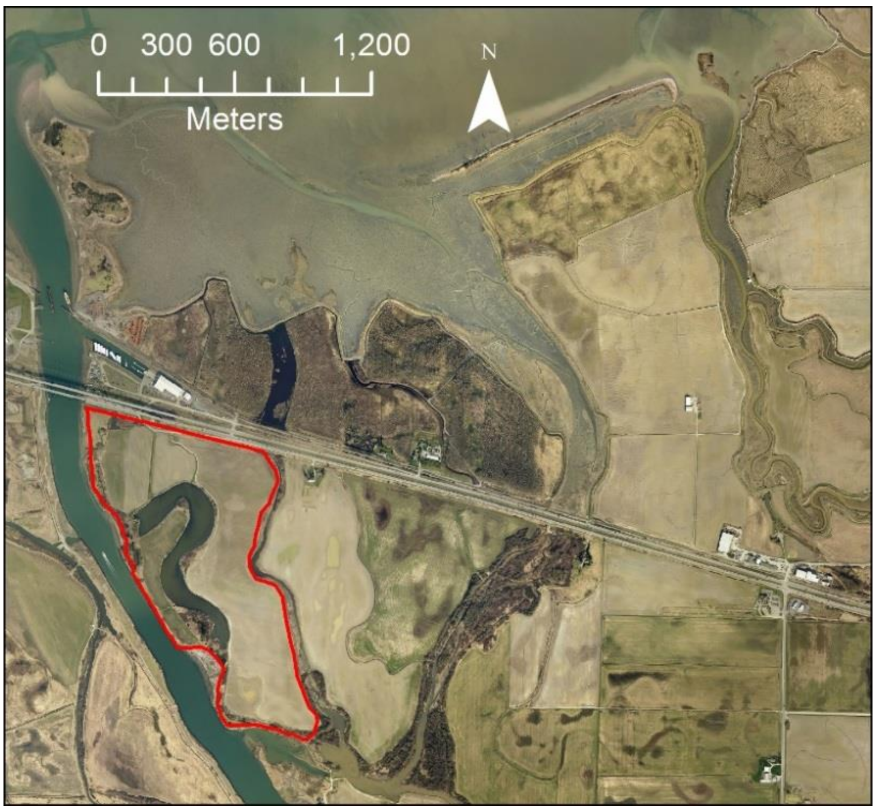

Figure 23. Telegraph Slough 1 project site (outlined in red). Note the large remnant historical Swinomish Channel meander in the project site.

The Telegraph 1 site contains a large remnant Swinomish Channel meander. This remnant channel is oversized as a blind tidal channel, so it will very likely fill in with sediment over time, the rate depending on sediment supply. The US Army Corps of Engineers currently dredges the existing Swinomish Channel for navigation on approximately a three-year schedule, depending on available funding, so sediment is not in short supply. Initially the restoration sites will have much more tidal channel area than predicted and perhaps less channel length. As the historical distributary remnants fill in, the channel area will decline and channel length will increase due to development of one or more meandering channels within the distributary footprint.

Offsite impacts: The SHDM Project Team found no detectible offsite habitat changes due to this project.

Landscape connectivity and juvenile Chinook carrying capacity predictions

The Telegraph Slough 1 project has an average midpoint carrying capacity estimate of approximately 14,000 juvenile Chinook per year (Table 26). The lowest and highest predicted carrying capacity for this project is approximately 5,400 and nearly 36,000 fish per year. Predicted carrying capacity for this project varied by approximately 30,000 fish per year as a function of predicted habitat amount. Variability in predicted carrying capacity due to landscape connectivity ranges from a few hundred to a thousand fish per year (Table 26).

This entire project is subject to fish migration pathways from the North Fork Skagit delta through the Swinomish Channel corridor in the area of McGlinn Island and its causeway. Improvement of connectivity through the McGlinn Causeway will improve connectivity to Telegraph Slough 1.

Prediction limitations: The Telegraph Slough 1 project utilizes input variables that are outside the data range used to develop the model for juvenile Chinook carrying capacity. However, the carrying capacity estimates for this project compared to fish monitoring data collected after the dataset used to create the juvenile Chinook carrying capacity model support the idea that predictions for this project are reasonable (see later section in this memo comparing predictions to existing fish monitoring results).

Table 26. Summary of channel habitat area (with 80% confidence limits in parentheses), landscape connectivity, and predicted Chinook carrying capacity for the Telegraph Slough 1 project. Chinook carrying capacity estimates are for the habitat point estimate and habitat 80% confidence limits (in parentheses).

Candidate restoration project		**Fish migration pathway used (from Figure 24)**			**Juvenile Chinook carrying capacity**
Site	**Predicted channel area (ha)**	**Point name**	**Point type**	**Landscape connectivity**	
Western-most third of Telegraph S	3.74 (1.49 – 9.37)	Telegraph S 1 29	primary	0.008101	14,304 (5,699 - 35,836)
		Telegraph S 1 30	primary	0.007710	13,607 (5,421 - 34,090)

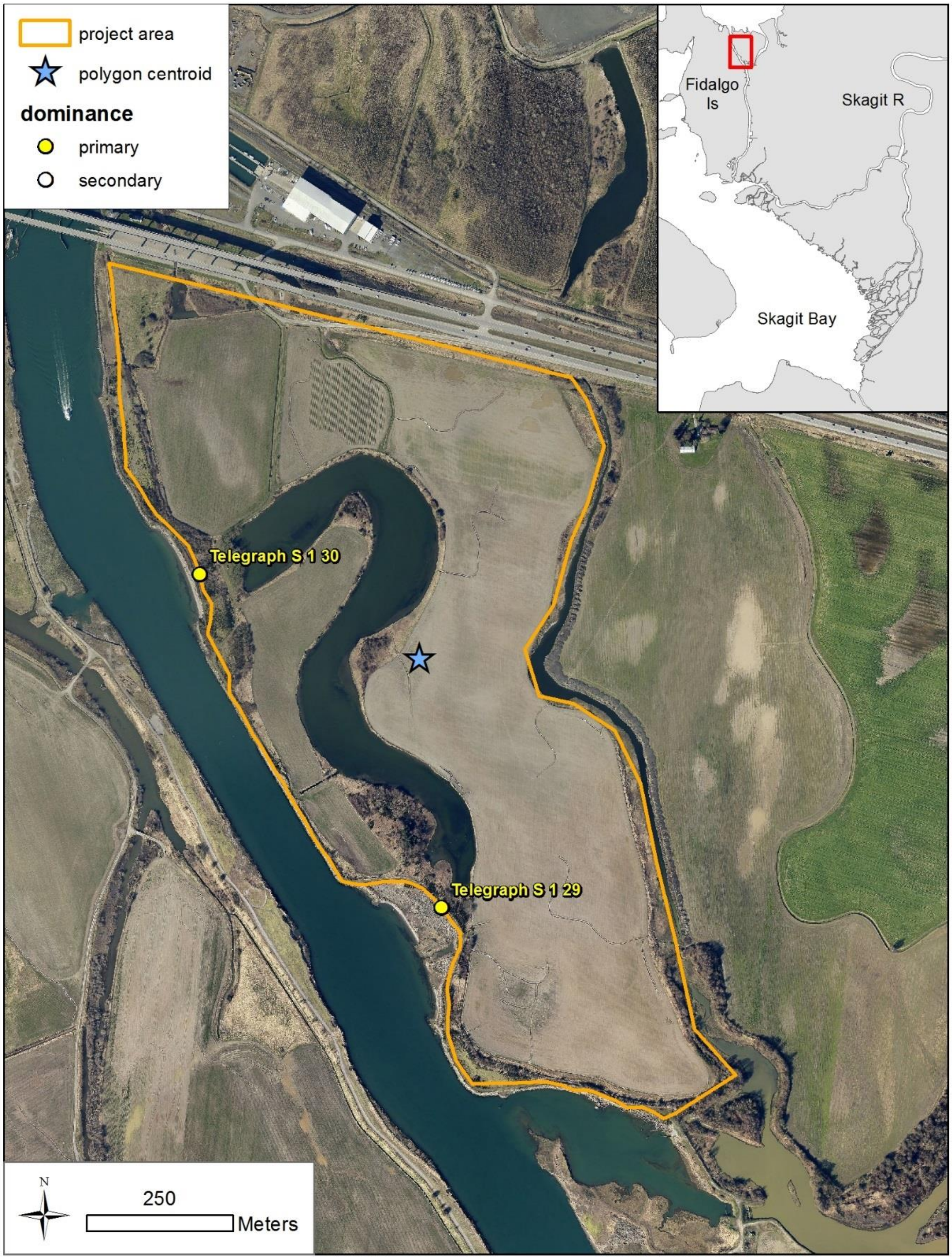

Figure 24. Location of fish migration pathway points used to estimate landscape connectivity for the Telegraph Slough 1 project.

#20 Deepwater Slough Phase 2

Habitat predictions

Two disjunct sites comprise Deepwater Slough Phase 2 (Figure 25); each has adjacent tidal marsh that consists principally of Deepwater Slough Phase 1, completed in the late summer of 2000. These adjacent marshes were evaluated for downstream, off-site restoration effects. The reference system for allometric prediction (Table 27) consisted of the South Fork tidal marshes, because the adjacent Deepwater Slough Phase 1 tidal channel networks generally conform to the geometry found in the reference tidal marshes of the South Fork Skagit delta.

Table 27. Allometric predictions of tidal channel geometry for Deepwater Slough Phase 2, with 80% confidence limits of the prediction in parentheses. Rows labeled "Total – Upstr" show the difference between upstream project site plus downstream existing marsh ("Total") predictions and project site only ("Upstr") predictions (i.e., indirect or downstream effects of project site restoration), with currently observed channel metrics in the existing downstream marsh shown in brackets for comparison with indirect effects predictions.

Site	Site area (ha)	Predicted channel count	Predicted channel area (ha)	Predicted channel length (m)
DW East	67.63	26 (12 – 54)	3.23 (1.29 – 8.07)	14,850 (5,983 – 36,857)
DW E + dwnstr	94.75	32 (15 – 66)	5.35 (2.13 – 13.49)	22,585 (9,030 – 56,488)
Total DW E - Upstr	27.12	6 [11]	2.12 [2.73]	7,735 [5,245]
DW West	40.94	19 (9 – 39)	1.50 (0.60 – 3.70)	7,846 (3,193 – 19,281)
DW W + dwnstr	74.99	27 (13 – 57)	3.75 (1.50 – 9.40)	16,820 (6,762 – 41,839)
Total DWW - Upstr	34.05	8 [9]	2.25 [2.09]	8,974 [6,250]

The new restoration actions are unlikely to increase channel number or length in the adjacent downstream marsh through off-site effects, but restoration is likely to increase the surface area of downstream channels which will have to accommodate increased tidal prism contributed by the new restoration project. The phase 1 restoration sites consist of many ponded areas that have been filling in on the western portion of the site; that has yet to occur in the eastern portion, but may do so in the future, somewhat off-setting the potential increase in channel area from off-site restoration effects.

<u>Offsite impacts</u>: The SHDM Project Team found no detectible offsite habitat changes due to this project.

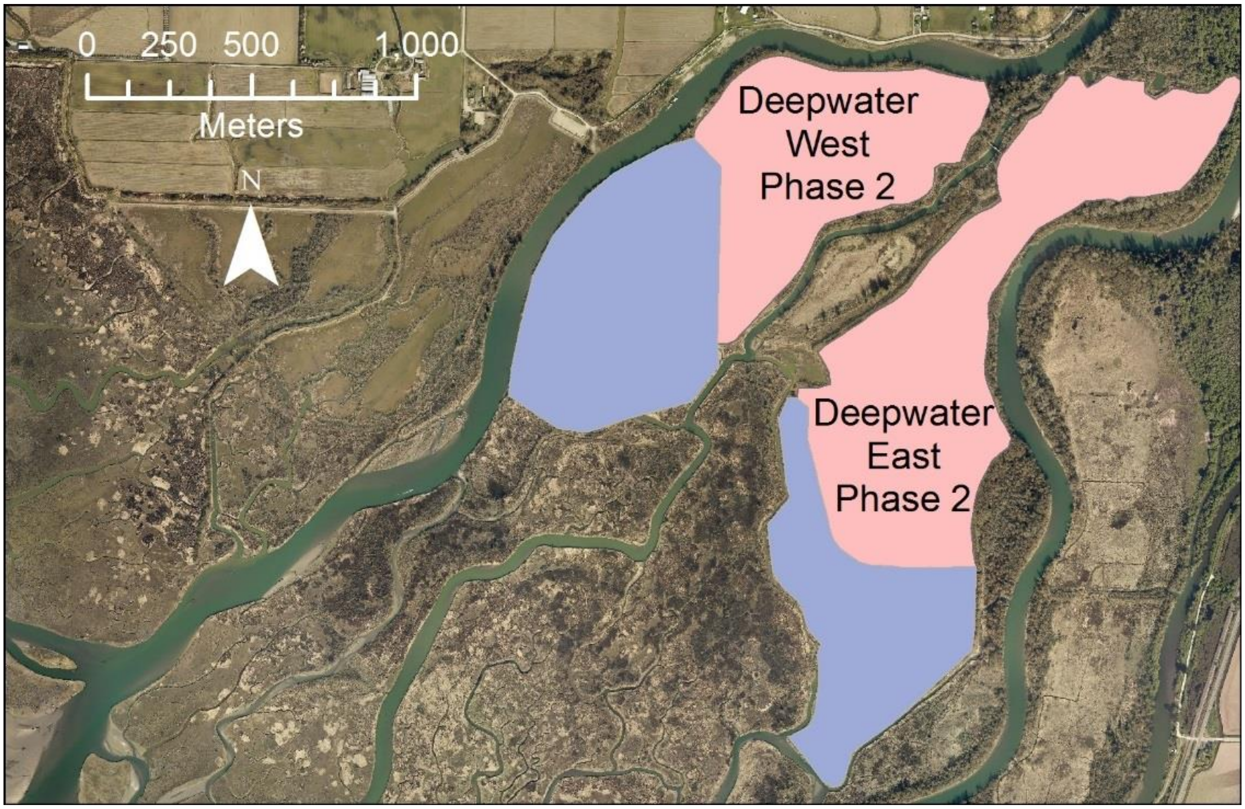

Figure 25. Deepwater Slough Phase 2 (pink polygons) and downstream-affected adjacent marsh (blue polygons).

Landscape connectivity and juvenile Chinook carrying capacity predictions

The Deepwater Slough Phase 2 project has an average midpoint carrying capacity estimate of approximately 160,000 juvenile Chinook per year (Table 28). The lowest and highest predicted carrying capacity for this project is approximately 52,000 and 477,000 fish per year. Predicted carrying capacity for this project varied by 300,000 fish per year as a function of predicted habitat amount. Predicted carrying capacity varied by over 50,000 fish per year as a function of landscape connectivity.

This project is the same project footprint as described in the Skagit Chinook Recovery Plan (page 189). Our midpoint prediction for Deepwater Slough Phase 2 is 160,000 fish per year, whereas the Chinook Plan estimate is approximately 96,000 fish per year. The main reason for the increase in Chinook benefit is our inclusion of new channel area forming in adjacent downstream marshes caused by the increased tidal flushing due to the restoration project. The Skagit Chinook Recovery Plan did not account for this issue.

Table 28. Summary of channel habitat area (with 80% confidence limits in parentheses), landscape connectivity, and predicted Chinook carrying capacity for the Deepwater Slough Phase 2 project. Chinook carrying capacity estimates are for the habitat point estimate and habitat 80% confidence limits (in parentheses).

Candidate restoration project (from Table 27)		Fish migration pathway used (from Figure 26)			Juvenile Chinook carrying capacity
Site	**Predicted channel area (ha)**	**Point came**	**Point type**	**Landscape connectivity**	
DW E + dwnstr	5.35 (2.13 – 13.49)	Deepwater E 37	primary	0.0375828	96,356 (38,362 - 242,961)
		Deepwater E 38	primary	0.028572	73,058 (29,087 - 184,216)
		Deepwater E 39	secondary	0.028465	72,782 (28,977 - 183,520)
		Deepwater E 40	secondary	0.033513	85,826 (34,170 - 216,409)
		Deepwater E 41	secondary	0.034031	87,165 (34,703 - 219,787)
		Deepwater E 42	secondary	0.040754	104,569 (41,632 - 263,670)
		Deepwater E 43	secondary	0.040676	104,367 (41,552 -263,160)
DW W + dwnstr	3.75 (1.50 – 9.40)	Deepwater W 31	primary	0.032273	57,911 (23,164 - 145,164)
		Deepwater W 32	primary	0.033263	59,705 (23,882 - 149,661)
		Deepwater W 33	secondary	0.039979	71,889 (28,755 - 180,201)
		Deepwater W 34	secondary	0.041236	74,171 (29,669 - 185,923)
		Deepwater W 35	secondary	0.043482	78,252 (31,301 - 196,151)
		Deepwater W 36	secondary	0.047257	85,114 (34,046 - 213,353)

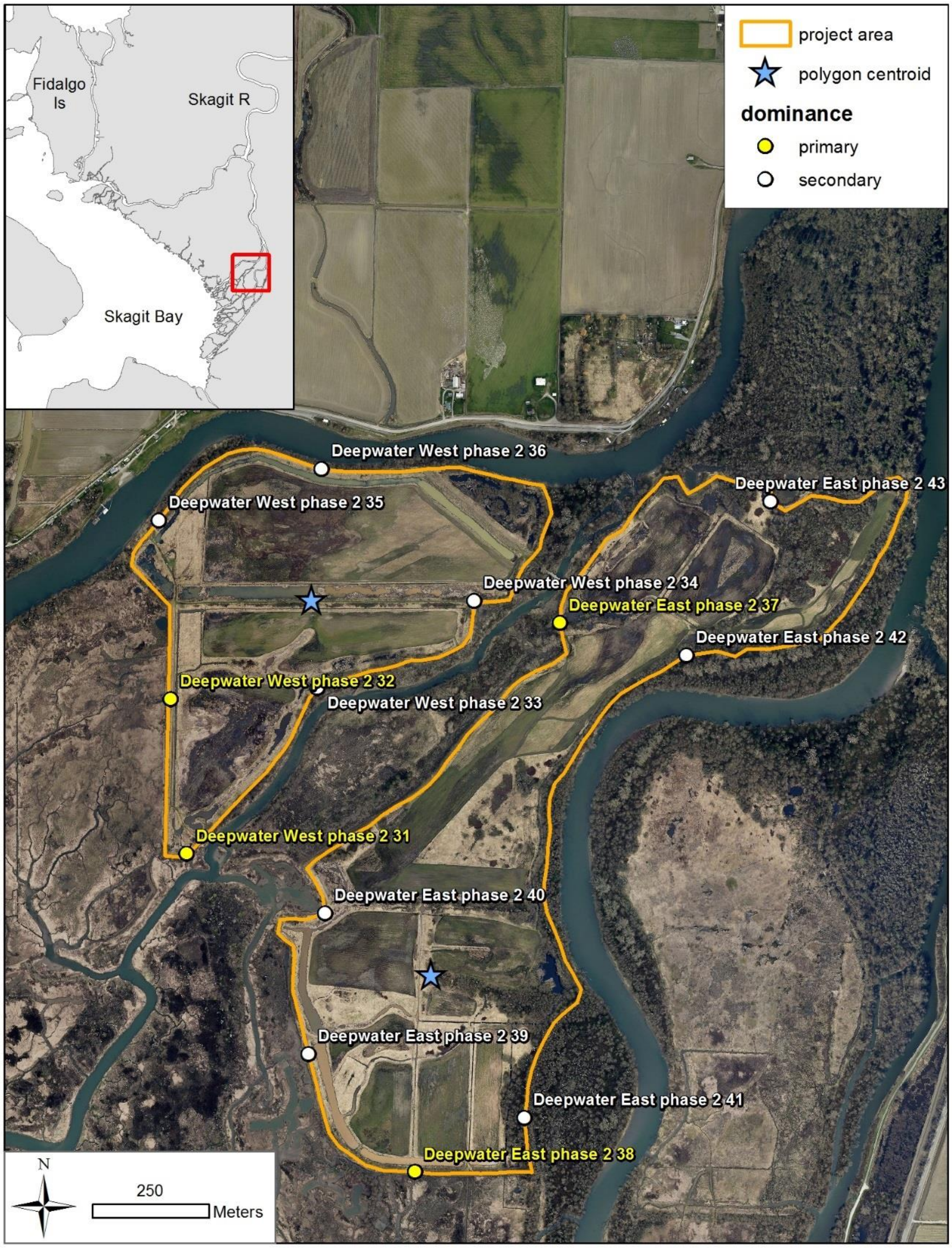

Figure 26. Location of fish migration pathway points used to estimate landscape connectivity for the Deepwater Slough Phase 2 project.

#21 Rawlins Road

Habitat predictions

This site (Figure 27) borders both the North Fork Skagit River and Skagit Bay. A portion of the site is within 650 m of Skagit Bay and can thus be considered windward marsh subject to southerly storm fetch across Skagit Bay. The remainder of the marsh is further from Skagit Bay and can be considered leeward marsh. Allometric predictions differ, depending on exposure to fetch. Additionally, because the restoration site is subsided by two to three feet relative to the adjacent North Fork marsh, the leeward portion of the marsh was assumed to drain primarily to the North Fork River. The smaller windward portion of the marsh, while also subsided, would have to have some channels excavated through bay-front dike to drain into Skagit Bay across remnant fringing marsh. There would be some downstream effect of marsh restoration on existing marsh channels to accommodate restored tidal prism (Table 29). It was assumed for the sake of simplicity that only the windward portion of the site would contribute to downstream effects on the adjacent remnant bay fringe marsh.

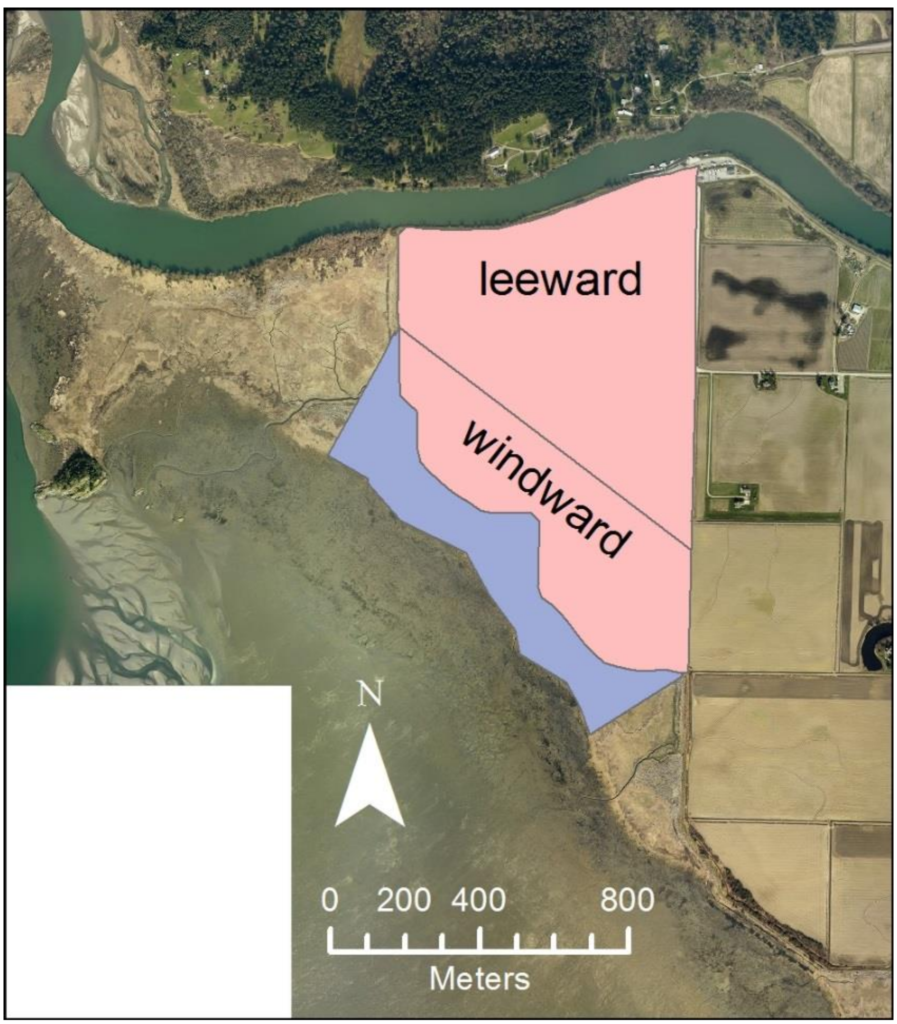

Figure 27. Location of Rawlins Road restoration site (pink polygons) and adjacent bay fringe marsh likely to be influenced by indirect, downstream effects of tidal prism restoration (blue polygon).

Table 29. Allometric predictions of tidal channel geometry for the Rawlins Road site, with 80% confidence limits of the prediction in parentheses. The rows labeled "Total – Upstr" shows the difference between upstream project site plus downstream existing marsh ("Total") predictions and project site only ("Upstr") predictions (i.e., indirect or downstream effects of project site restoration), with currently observed channel metrics in the existing downstream marsh shown in brackets for comparison with indirect effects predictions.

Site	Site area (ha)	Predicted channel count	Predicted channel area (ha)	Predicted channel length (m)
Rawlins Rd leeward	49.57	12 (7 – 22)	2.95 (1.12 – 7.81)	10,608 (5,192 – 21,674)
Rawlins Rd windward	28.00	7 (4 – 13)	0.35 (0.13 – 0.93)	2,062 (998 – 4,260)
Rawlins Rd windward + dwnstr	46.85	10 (5 – 18)	0.86 (0.31 – 2.39)	4,090 (1,920 – 8,711)
Total - Upstr	18.85	3 [3]	0.51 [0.35]	2,028 [1,465]

The adjacent bay fringe marsh is currently eroding as a result of exposure to southerly storm fetch (Hood et al. 2016). The 650 m distance to determine the shoreward limit of the windward marsh was measured from the lower edge of the eroding, low-elevation bay fringe marsh, which is characterized by the sedge, *Schoenoplectus pungens*. This may produce an underestimate of the extent of windward marsh and overpredict the amount of tidal channel habitat that may be restored here. A more conservative approach would have been to measure the 650 m distance from the edge of the higher-elevation, *Carex lyngbyei* marsh that has not yet been impacted by erosion. It is not clear which marsh edge should be used to determine the extent of windward marsh. The downstream effects of site restoration were limited only to the higher-elevation, *Carex* marsh, because tidal channels currently only exist in this portion of the marsh. The lower-elevation *Schoenoplectus* marsh is dominated by sheet flow rather than channelized flow because of its low elevation in the tidal frame.

<u>Offsite impacts</u>: The SHDM Project Team found no detectible offsite habitat changes due to this project.

Landscape connectivity and juvenile Chinook carrying capacity predictions

The Rawlins Road project has an average midpoint carrying capacity estimate of approximately 50,000 juvenile Chinook per year (Table 30). The lowest and highest predicted carrying capacity for this project is approximately 10,000 and 250,000 fish per year. Predicted carrying capacity for this project varied by 60,000 to over 200,000 fish per year as a function of predicted habitat amount. Predicted carrying capacity varied by over 60,000 fish per year as a function of landscape connectivity. This project has a large connectivity influence because one pathway fish could take to the site is directly off the North Fork (connectivity value is 0.051) whereas other pathways to the site are via the bayfront (connectivity values average 0.015).

Table 30. Summary of channel habitat area (with 80% confidence limits in parentheses), landscape connectivity, and predicted Chinook carrying capacity for the Rawlins Road project. Chinook carrying capacity estimates are for the habitat point estimate and habitat 80% confidence limits (in parentheses).

Candidate restoration project (from Table 29)		**Fish migration pathway used (from Figure 28)**			**Juvenile Chinook carrying capacity**
Site	**Predicted channel area (ha)**	**Point name**	**Point type**	**Landscape connectivity**	
Rawlins Rd leeward and Rawlins Rd windward + dwnstr (combined)	3.81 (1.43 – 10.2)	Rawlins Rd 49	primary	0.051075	93,533 (35,106 - 250,405)
		Rawlins Rd 50	primary	0.014827	26,827 (10,069 - 71,821)
		Rawlins Rd 51	primary	0.016260	29,447 (11,052 - 78,833)

Figure 28. Location of fish migration pathway points used to estimate landscape connectivity for the Rawlins Road project.

#22 Telegraph Slough 1 & 2

Habitat predictions

This site is the Telegraph Slough parcel south of Highway 20 (Telegraph S) mentioned in the preceding analysis. It is not bordered by any existing marsh fringe, so there are no indirect (downstream effects) of site restoration.

As mentioned above for previously discussed Telegraph Slough projects, the Skagit South Fork tidal marshes were used as the reference system for allometric prediction of tidal channel geometry, because of similar tide range and fetch.

The project site amounts to 200.25 ha. The predicted channel count is 51 with upper and lower 80% confidence limits (CLs) of the prediction ranging from 24 to 108; the predicted total tidal channel area is 16.70 ha (80% CLs: 6.49 – 42.94 ha); the predicted total channel length is 57,983 m (80% CLs: 22,710 – 148,045 m) (Table 31).

<u>Offsite impacts</u>: The SHDM Project Team found no detectible offsite habitat changes due to this project.

Table 31. Allometric predictions of tidal channel geometry for Telegraph Slough 1 & 2, with 80% confidence limits of the prediction in parentheses.

Site	Site area (ha)	Predicted channel count	Predicted channel area (ha)	Predicted channel length (m)
Telegraph S	200.25	51 (24 – 108)	16.70 (6.49 – 42.94)	57,983 (148,045 – 22,710)

Landscape connectivity and juvenile Chinook carrying capacity predictions

The Telegraph Slough 1 & 2 project has an average midpoint carrying capacity estimate of approximately 61,000 juvenile Chinook per year (Table 32). The lowest and highest predicted carrying capacity for this project is approximately 23,000 and over 160,000 fish per year. Predicted carrying capacity for this project varied by over 100,000 fish per year as a function of predicted habitat amount. Variability in predicted carrying capacity due to landscape connectivity is a few thousand fish per year (Table 32).

This entire project is subject to fish migration pathways from the North Fork Skagit delta through the Swinomish Channel corridor in the area of McGlinn Island and its causeway. Improvement of connectivity through the McGlinn Causeway will improve connectivity to Telegraph Slough 1 & 2.

Prediction limitations: The Telegraph Slough 1 & 2 project utilizes input variables that are outside the data range used to develop the model for juvenile Chinook carrying capacity. However, the carrying capacity estimates for this project compared to fish monitoring data collected after the dataset used to create the juvenile Chinook carrying capacity model support the idea that predictions for this project are reasonable (see later section in this memo comparing predictions to existing fish monitoring results).

Table 32. Summary of channel habitat area (with 80% confidence limits in parentheses), landscape connectivity, and predicted Chinook carrying capacity for the Telegraph Slough 1 & 2 project. Chinook carrying capacity estimates are for the habitat point estimate and habitat 80% confidence limits (in parentheses).

Candidate restoration project (from Table 31)		**Fish migration pathway used (from Figure 29)**			**Juvenile Chinook carrying capacity**
Site	**Predicted channel area (ha)**	**Point name**	**Point type**	**Landscape connectivity**	
Telegraph S	16.70 (6.49 – 42.94)	Telegraph S 1 28	primary	0.007967	62,804 (24,407 - 161,485)
		Telegraph S 1 29	primary	0.008011	63,155 (24,544 - 162,389)
		Telegraph S 2 30	primary	0.007381	58,137 (22,593 - 149,486)

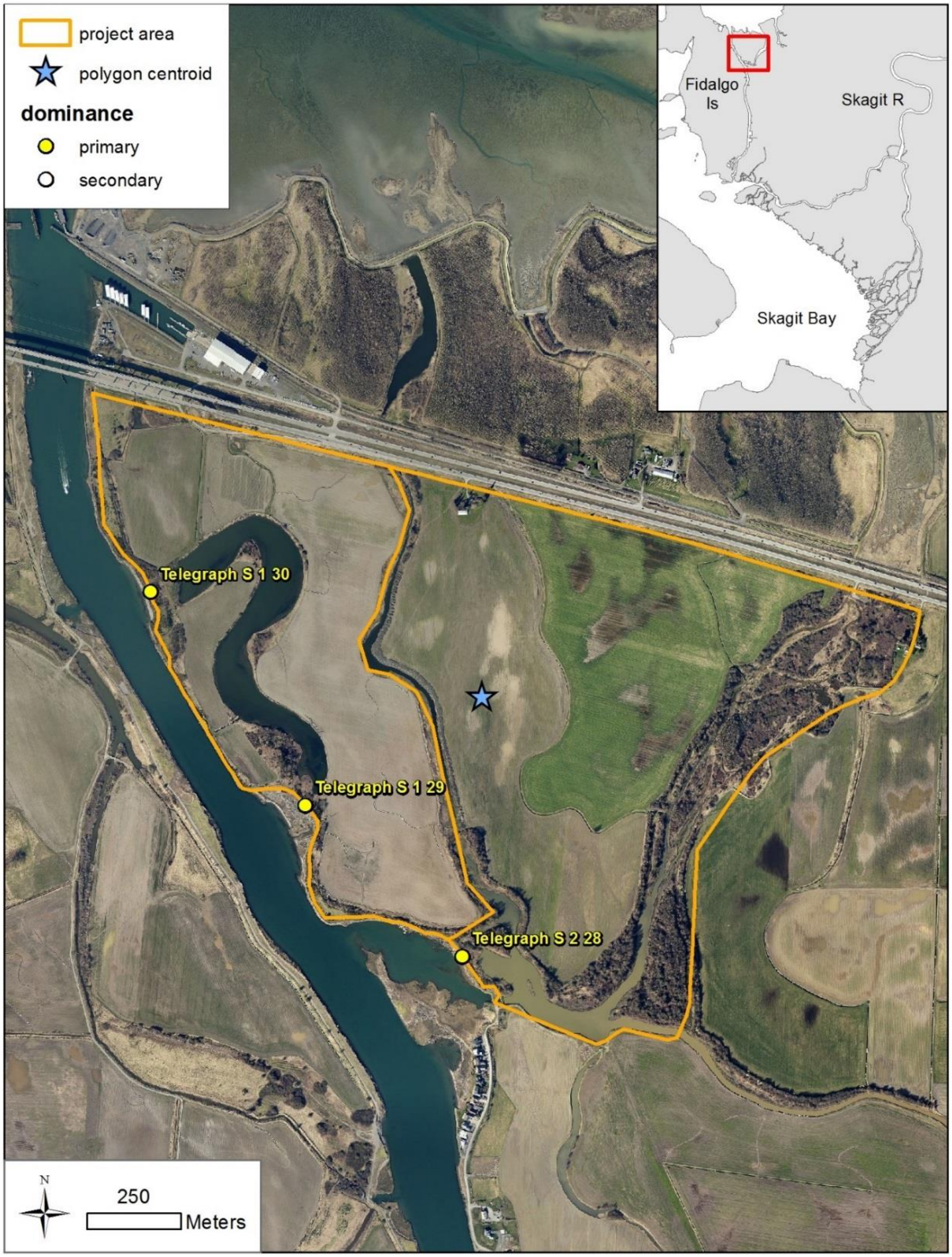

Figure 29. Location of fish migration pathway points used to estimate landscape connectivity for the Telegraph Slough 1 & 2 project.

Predictions compared to existing fish monitoring results

In general, observed monitoring results of cumulative Chinook salmon density are lower than point estimates of predicted juvenile Chinook carrying capacity (Figure 30). At least three possible reasons may explain why:

1. Monitoring of reference and restored sites occurred over varying juvenile Chinook outmigration sizes, while the prediction of SHDM project benefits are at carrying capacity. We elaborate on this subject in its own section below.
2. In some cases, we made predictions for areas with lower or higher landscape connectivity values than the dataset used to create the juvenile Chinook carrying capacity model. We elaborate on this subject in its own section below.
3. We are comparing the monitored point estimates against the predicted point estimates. Both monitored and predicted results have variability around their estimates so it is likely there is overlap between the two in some cases. It was beyond the scope of this project for us to update the carrying capacity model to include confidence limits.

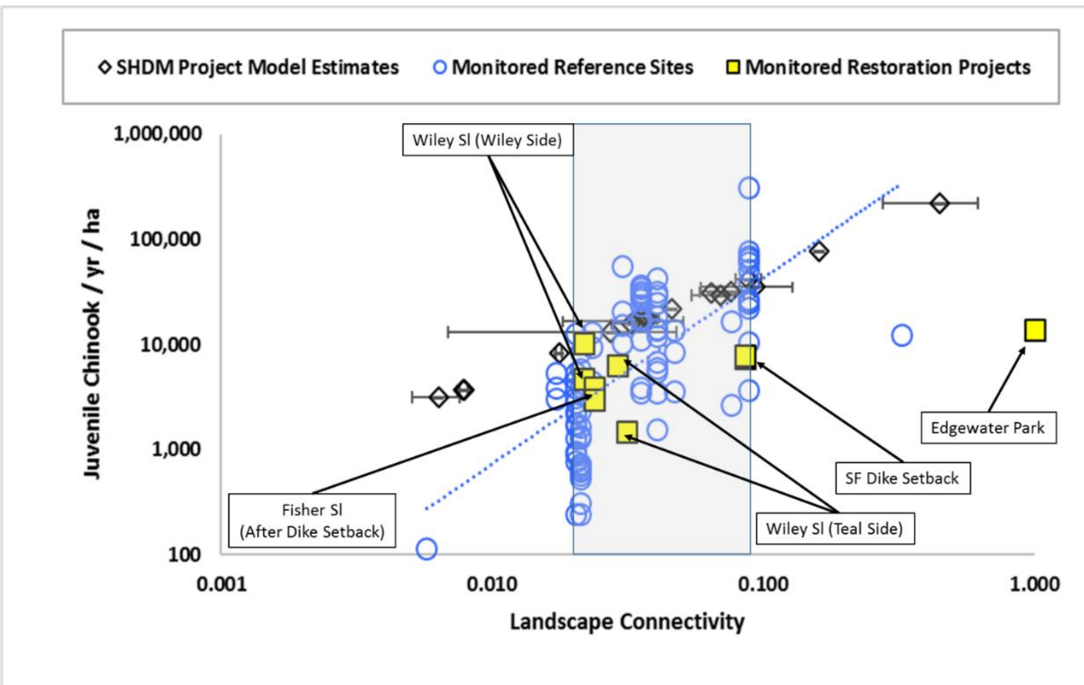

Figure 30. Juvenile Chinook carrying capacity predictions for SHDM projects and fish monitoring results standardized to one-hectare habitat size for direct comparison. For each SHDM project we show one value which is average midpoint carrying capacity and average landscape connectivity. The x-axis error bars on the SHDM project series reflect the landscape connectivity range possible for each project. Monitoring data are from 13 reference sites (n= 91 annually summarized observations) and 4 built restoration projects (n=9 annually summarized observations). See Figure 1 for site locations. The gray shaded box encompasses the landscape connectivity range [0.0234 (Tom Moore) to 0.0881 (Grain of Sand)] of the fish dataset used to create the juvenile Chinook carrying capacity model. The blue dashed trend line is for the reference site fish monitoring series using only landscape connectivity as the independent variable ($R^2 = 0.45$, $p < 0.00001$).

Effect of monitoring at varying juvenile Chinook outmigration sizes

Monitoring of reference and restored sites occurred over varying juvenile Chinook outmigration sizes, while the prediction of SHDM project benefits are at carrying capacity. Carrying capacity of Skagit tidal delta habitat is estimated to occur at a Skagit River wild Chinook fry outmigration of 3.9 million fish per year. Fifty-six of our 100 monitoring results occurred in years when less than 3.9 million wild Chinook fry out-migrated the Skagit River (Appendix 1 Table). We tested what influence varying outmigration levels and connectivity have on our monitoring results using regression analysis.

We created two linear regression models from the reference site monitoring results shown in Appendix 1 to predict juvenile Chinook density (fish/ha/yr) (Table 33). For each model, all independent variables were highly significant ($p < 0.001$). The trend line of Model 1 is shown in Figure 30. Model 1 uses only landscape connectivity as a predictor of juvenile Chinook density. Landscape connectivity alone accounts for 45% of the variation in juvenile Chinook density for all 91 reference site observations. By adding fry outmigration size to Model 2 we gain another 6% of explanatory power (Table 33). Landscape connectivity and outmigration size explain 51% of the variation in juvenile Chinook density. Using the equation for Model 2 and setting the fry outmigration variable to the Skagit tidal delta's carrying capacity for fry (i.e., 3.9 million) we compared whether the 91 monitoring observations are consistent with the carrying capacity model predictions. We found generally the carrying capacity model predictions and monitoring results are consistent for the range of landscape connectivity that was used to create the carrying capacity model, but not for landscape connectivity values lower or higher than the dataset used to create the carrying capacity model.

Table 33. Summary of regression models predicting juvenile Chinook density from Skagit tidal delta reference sites shown in Figure 1.

Model #	Equation	R^2, overall regression p-value, observations
1	Ln Chinook/yr/ha = (1.76492*Ln Landscape Connectivity) + 14.7279	R^2=0.45, p<0.0001, n=91
2	Ln Chinook/yr/ha = (0.000000272*fry outmigrants) + (1.856519*Ln Landscape Connectivity) + 14.24202	R^2=0.51, p<0.0001, n=91

Effect of making predictions outside of the values used to create the juvenile Chinook carrying capacity model

In some cases, we made predictions for areas with lower or higher landscape connectivity values than the dataset used to create the juvenile Chinook carrying capacity model. The shaded grey box in Figure 30 represents the range of landscape connectivity values that were used to create the carrying capacity model. Figure 30 shows that for areas outside of the grey shaded box, actual fish use is always lower than carrying capacity model predictions. Because of the logarithmic scaling of the data, over-prediction of the lower landscape connectivity areas is not as great as over-prediction of higher landscape connectivity value areas. We identify which SHDM projects are most influenced by carrying capacity prediction bias.

Sites with higher landscape connectivity: We had two observations from sites where landscape connectivity was higher than data used to create the carrying capacity model. The sites were monitored in 2012, a year with an outmigration higher than carrying capacity. Edgewater Park = 13,800 fish per hectare (1.38 fish /m^2). Cottonwood Pond = 12,500 fish per hectare (1.25 fish/m^2). These monitoring results support the idea that the carrying capacity model over-estimates carrying capacity for sites with landscape connectivity higher than 0.0881. The SHDM projects influenced by this over-prediction bias are: 3 TNC South Fork and 5 East Cottonwood. We suggest a more realistic carrying capacity for SHDM project sites upriver should be the average of the two sites, i.e., 13,150 fish per hectare per year.

Sites with lower landscape connectivity: We had 38 observations from four different reference sites (Telegraph A&B, Swin Ch Old Bridge Blind, Browns Sl Diked Side, and Browns Sl Barrow Channel) where landscape connectivity was lower than data used to create the carrying capacity model. These sites were monitored over a range of outmigration sizes, including some higher than carrying capacity. Monitoring results from these four sites support the idea that the carrying capacity model over-estimates carrying capacity for sites with landscape connectivity lower than 0.0234. The SHDM projects influenced by this over-prediction bias are: 9 Telegraph Slough Full, 22 Telegraph Slough 1 & 2, 18 Telegraph Slough 1, 7 Hall Slough, and 21 Rawlins Road (if the dominant fish migration pathway is via the bayfront rather than the North Fork Skagit River).

Comparison to restored sites

The Chinook carrying capacity model does not always over-predict fish benefit results. In fact, three Skagit tidal delta restoration projects have been evaluated for juvenile Chinook abundance after restoration. Two projects were found to have more fish than predicted (Fisher Slough - Beamer et al. 2014; Wiley Slough – Beamer et al. 2015) while one project had fewer fish than predicted (South Fork Dike Setback – Beamer 2015). The Fisher and Wiley Slough restoration projects were estimated to have more juvenile Chinook salmon using their restored habitat than predicted by the Chinook carrying capacity model largely because a) more wetted area was present in the restored areas than was predicted for the restored footprint area and b) juvenile Chinook were clearly using all the wetted areas. At the South Forth Dike Setback site fish had difficulty accessing the restored area due to sedimentation and small channel size. The site also had less than ideal dissolved oxygen levels during the two years of monitoring.

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Appendix 1. Juvenile Chinook monitoring results

Monitoring results are standardized to one-hectare habitat area for direct comparison to SHDM Projects.

Site type	Name	Year	fish/yr/ha	Skagit River Chinook fry outmigration size[1] (fish)	Landscape Connectivity	At carrying capacity outmigration[2]
Reference	Browns Sl Barrow Channel	2002	3,965	4,338,274	0.0212	yes
		2003	8,434	4,702,344	0.0212	yes
		2004	246	1,131,606	0.0212	no
		2005	1,632	3,160,558	0.0212	no
		2006	1,291	5,116,578	0.0212	yes
		2007	5,781	1,808,798	0.0212	no
		2008	2,349	914,161	0.0212	no
		2009	572	1,580,141	0.0212	no
		2010	312	801,677	0.0212	no
		2011	1,338	3,177,656	0.0212	no
		2012	690	3,900,019	0.0212	yes
		2013	711	4,603,262	0.0212	yes
		2014	730	3,416,943	0.0212	no
		2015	535	1,016,166	0.0212	no
		2011	1,373	3,177,656	0.0212	no
		2012	653	3,900,019	0.0212	yes
		2013	620	4,603,262	0.0212	yes
	Browns Sl Diked Side	2011	2,288	3,177,656	0.0203	no
		2012	1,313	3,900,019	0.0203	yes
		2013	3,886	4,603,262	0.0203	yes
		2002	933	4,338,274	0.0203	yes
		2003	5,433	4,702,344	0.0203	yes
		2004	247	1,131,606	0.0203	no
		2005	2,235	3,160,558	0.0203	no
		2006	2,291	5,116,578	0.0203	yes
		2007	12,643	1,808,798	0.0203	no
		2008	3,168	914,161	0.0203	no
		2009	906	1,580,141	0.0203	no
		2010	774	801,677	0.0203	no
		2011	1,689	3,177,656	0.0203	no
		2012	960	3,900,019	0.0203	yes
		2013	2,835	4,603,262	0.0203	yes
		2014	4,561	3,416,943	0.0203	no
		2015	1,804	1,016,166	0.0203	no
	Cattail	2003	25,329	4,702,344	0.0403	yes

		2004	3,485	1,131,606	0.0403	no
		2005	31,700	3,160,558	0.0403	no
		2006	18,617	5,116,578	0.0403	yes
		2007	5,475	1,808,798	0.0403	no
		2008	6,051	914,161	0.0403	no
		2009	11,970	1,580,141	0.0403	no
		2010	14,327	801,677	0.0403	no
		2011	13,670	3,177,656	0.0403	no
		2012	29,695	3,900,019	0.0403	yes
		2013	42,789	4,603,262	0.0403	yes
		2014	6,905	3,416,943	0.0403	no
		2015	1,581	1,016,166	0.0403	no
	Cottonwood Pond	2012	12,536	3,900,019	0.3228	yes
	DW Reference E Blind	2010	10,169	801,677	0.0302	no
		2011	20,630	3,177,656	0.0302	no
		2012	15,493	3,900,019	0.0302	yes
		2013	56,563	4,603,262	0.0302	yes
	Fisher Sl Blind Ch	2011	8,511	3,177,656	0.0472	no
		2012	3,574	3,900,019	0.0472	yes
		2013	13,665	4,603,262	0.0472	yes
	Grain of Sand	2003	308,851	4,702,344	0.0881	yes
		2004	3,752	1,131,606	0.0881	no
		2005	60,823	3,160,558	0.0881	no
		2006	25,167	5,116,578	0.0881	yes
		2007	39,915	1,808,798	0.0881	no
		2008	22,432	914,161	0.0881	no
		2009	26,923	1,580,141	0.0881	no
		2010	25,930	801,677	0.0881	no
		2011	51,162	3,177,656	0.0881	no
		2012	69,373	3,900,019	0.0881	yes
		2013	66,655	4,603,262	0.0881	yes
		2014	77,469	3,416,943	0.0881	no
		2015	10,593	1,016,166	0.0881	no
	Ika	2003	34,887	4,702,344	0.0353	yes
		2004	3,499	1,131,606	0.0353	no
		2005	27,358	3,160,558	0.0353	no
		2006	36,106	5,116,578	0.0353	yes
		2007	11,307	1,808,798	0.0353	no
		2008	17,334	914,161	0.0353	no
		2009	28,265	1,580,141	0.0353	no
		2010	29,910	801,677	0.0353	no
		2011	18,024	3,177,656	0.0353	no

		2012	23,844	3,900,019	0.0353	yes
		2013	36,312	4,603,262	0.0353	yes
		2014	32,089	3,416,943	0.0353	no
		2015	3,864	1,016,166	0.0353	no
	N Fork 1	1992	16,820	706,886	0.0762	no
		1993	2,663	474,055	0.0762	no
	Swin Ch Old Bridge Blind	2011	3,032	3,177,656	0.0172	no
		2012	5,377	3,900,019	0.0172	yes
		2013	3,963	4,603,262	0.0172	yes
	Telegraph A& B.	2003	116	4,702,344	0.0057	yes
	Tom Moore	2010	3,419	801,677	0.0234	no
		2011	4,517	3,177,656	0.0234	no
		2012	13,130	3,900,019	0.0234	yes
		2013	9,482	4,603,262	0.0234	yes
Restored	Edgewater Park Restoration	2012	13,796	3,900,019	1.0000	yes
	Fisher Sl Restoration (after dike setback)	2012	3,949	3,900,019	0.0239	yes
		2013	3,027	4,603,262	0.0239	yes
	SF Dike Setback	2012	7,487	3,900,019	0.0858	yes
		2014	7,868	3,416,943	0.0858	no
	Wiley Sl Restoration (Teal side)	2012	1,504	3,900,019	0.0312	yes
		2013	6,302	4,603,262	0.0291	yes
	Wiley Sl Restoration (Wiley side)	2012	4,728	3,900,019	0.0217	yes
		2013	10,165	4,603,262	0.0217	yes

[1]Wild Skagit River juvenile Chinook outmigration estimates 2003, 2011-2013 from Clayton Kinsel & Joe Anderson of WDFW, personal communication; 1992 and 1993 from Seiler et al. 1998.

[2] Skagit tidal delta juvenile Chinook carrying capacity is estimated to be achieved at an outmigration of 5.1 million total subyearling Chinook outmigrants (Beamer et al. 2005). Regression analysis of outmigration data by fry and parr life history types through 2015 suggests tidal delta carrying capacity is achieved at an outmigration of 3.9 million Chinook fry.

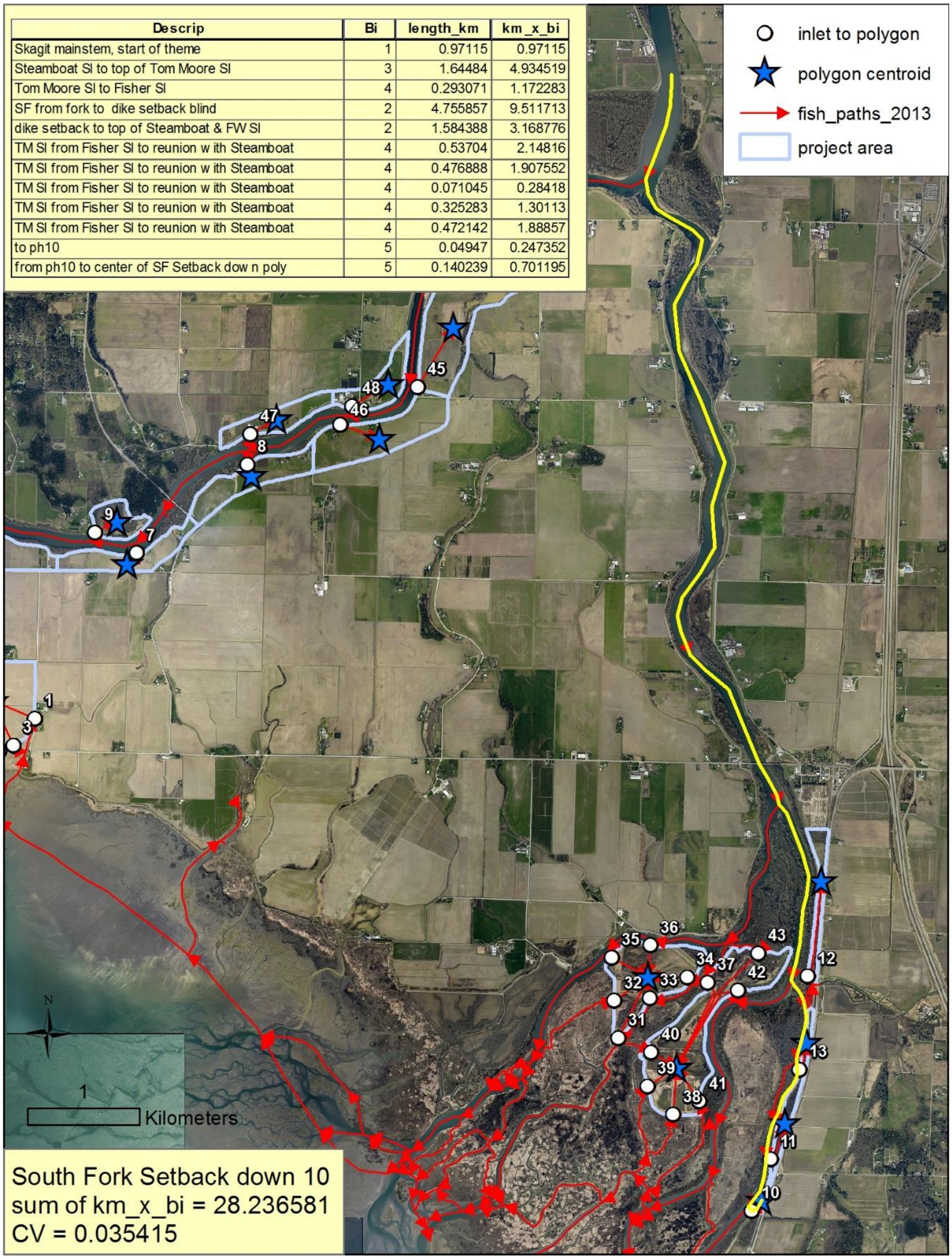
Appendix 1. Landscape Connectivity Figures

Table 1. List of figures.

HDM project(s)	GIS point	km_x_bi	Landscape connectivity (CV = connectivity value)	Figure number
#1	SF Setback down 10	28.236581	0.035415	1
#1	SF Setback mid 11	27.446409	0.036435	2
#1	SF Setback N 12 (long way)	52.320675	0.019113	3
#1	SF Setback N 12 (short cut)	26.937354	0.037123	4
#1	SF Setback up 13	23.379585	0.042772	5
#3	TNC South Fork 53	6.212585	0.160964	6
#5	East Cottonwood 52	1.750923	0.571127	7
#5	East Cottonwood 54	3.067179	0.326032	8
#6	Pleasant Ridge S 9	15.487607	0.064568	9
#7	Hall Sl 1	56.137105	0.017814	10
#7	Hall Sl 2	59.266968	0.016873	11
#7	Hall Sl 3	55.916919	0.017884	12
#7	Hall Sl 4	56.304664	0.017761	13
#7	Hall Sl 5	56.194482	0.017795	14
#9	Telegraph NE 19	180.190906	0.005550	15
#9	Telegraph NE 20	180.658189	0.005535	16
#9	Telegraph NE 21	183.568736	0.005448	17
#9	Telegraph NE 21 via Telegraph Sl	150.205266	0.006658	18
#9	Telegraph NE 22	196.000724	0.005102	19
#9	Telegraph NE 23	196.355512	0.005093	20
#9	Telegraph NE 24	206.639056	0.004839	21
#9	Telegraph NW 25	176.395246	0.005669	22
#9	Telegraph NW 26	176.327103	0.005671	23
#9	Telegraph NW 26 via Telegraph Sl	165.959924	0.006026	24
#9	Telegraph NW 27	173.62647	0.005759	25
#9, #22	Telegraph S 28	125.515808	0.007967	26
#9, #22	Telegraph S 29	124.824275	0.008011	27
#9, #22	Telegraph S 30	135.490117	0.007381	28
#10	Sullivan Hacienda 14	26.980526	0.037064	29
#10	Sullivan Hacienda 15	28.337305	0.035289	30
#10	Sullivan Hacienda 16	32.91686	0.030380	31
#10	Sullivan Hacienda 17	40.28107	0.024826	32
#10	Sullivan Hacienda 18	27.887848	0.035858	33

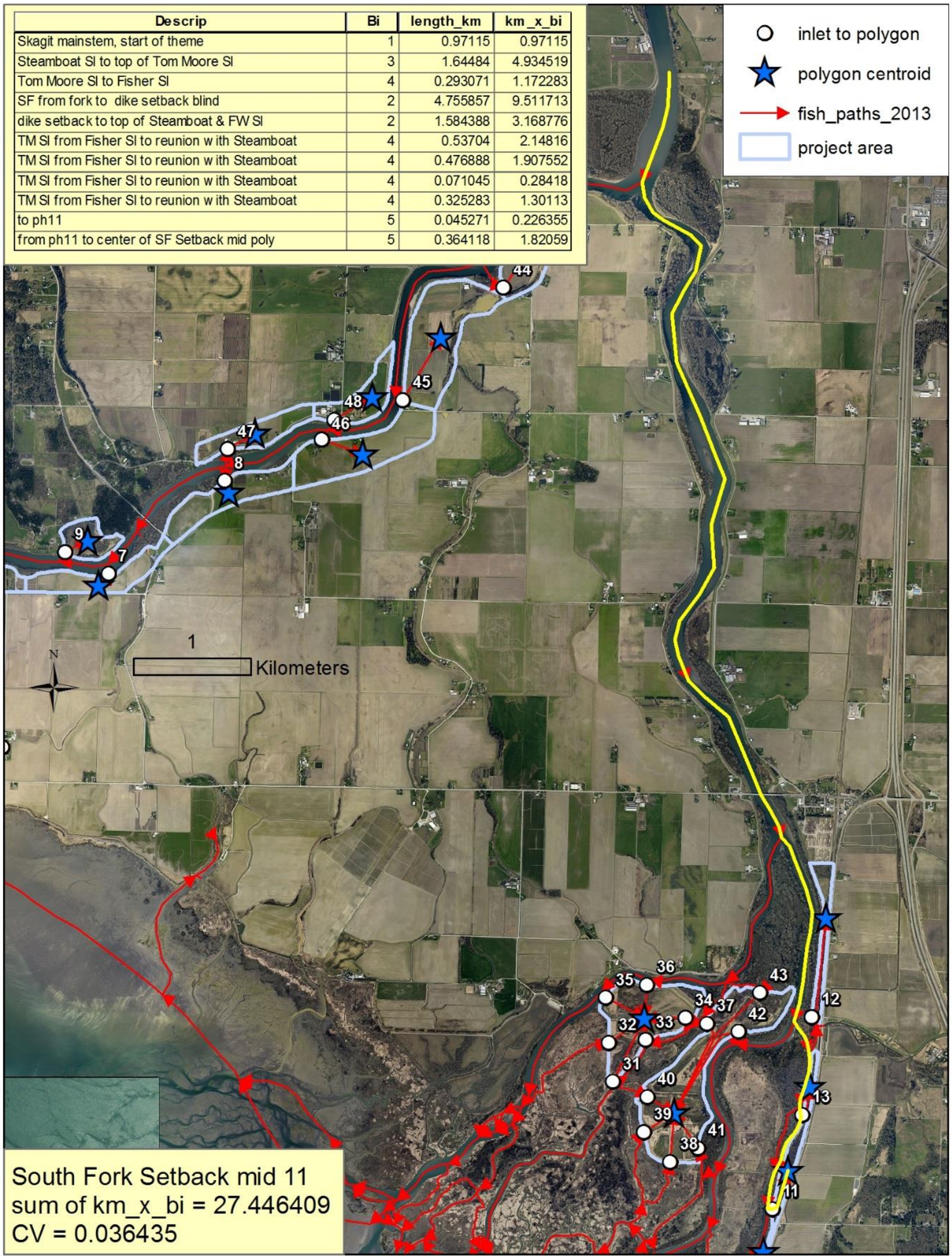
#11	Rawlins distributary (centroid)	21.760147	0.045956	34
#14, #15, #not given	NF Setback dwnstr 6	18.416672	0.054299	35
#14, #15, #not given	NF Setback mid 7	14.38201	0.069531	36
#14, #15, #not given	NF Setback upstr 8	11.676067	0.085645	37
#15	NF Setback A up 44	6.509427	0.153623	38
#15	NF Setback A mid 45	9.785455	0.102192	39
#15, #not given	NF Setback A down 46	10.48477	0.095376	40
#16	NF rb down 47	12.234105	0.081739	41
#16	NF rb up 48	10.516449	0.095089	42
#18	Telegraph S 29 (1)	123.43797	0.008101	43
#18	Telegraph S 30 (1)	129.709648	0.007710	44
#20	Deepwater W 31	30.985603	0.032273	45
#20	Deepwater W 32	30.063748	0.033263	46
#20	Deepwater W 33	25.01316	0.039979	47
#20	Deepwater W 34	24.250615	0.041236	48
#20	Deepwater W 35	22.998278	0.043482	49
#20	Deepwater W 36	21.160717	0.047257	50
#20	Deepwater E 37	26.607919	0.037583	51
#20	Deepwater E 38	34.999789	0.028572	52
#20	Deepwater E 39	35.130702	0.028465	53
#20	Deepwater E 40	29.838832	0.033513	54
#20	Deepwater E 41	29.384702	0.034031	55
#20	Deepwater E 42	24.537409	0.040754	56
#20	Deepwater E 43	24.584396	0.040676	57
#21	Rawlins Rd 49	19.579026	0.051075	58
#21	Rawlins Rd 50	67.446102	0.014827	59
#21	Rawlins Rd 51	61.502202	0.016260	60
fish monitored	Browns Sl Barrow Ch	47.127178	0.021219	61
fish monitored	Browns Sl Barrow Ch (Rawlins)	46.855487	0.021342	62
fish monitored	Browns Sl Diked Side	49.344342	0.020266	63
fish monitored	Browns Sl Diked Side (Rawlins)	49.072651	0.020378	64
fish monitored	Fisher Sl Blind Ch (long way)	46.57682	0.021470	65
fish monitored	Fisher Sl Blind Ch (shortcut)	21.193499	0.047184	66
fish monitored	N Fork 1	13.119021	0.076225	67
fish monitored	Swin Ch Old Bridge Blind	58.080655	0.017217	68

fish monitored	Swin Ch Site 65	106.04112	0.009430	69
fish monitored	Swin Ch Site 80	141.34767	0.007075	70
fish monitored	Telegraph A	174.418745	0.005733	71
fish monitored	Telegraph B	176.521002	0.005665	72



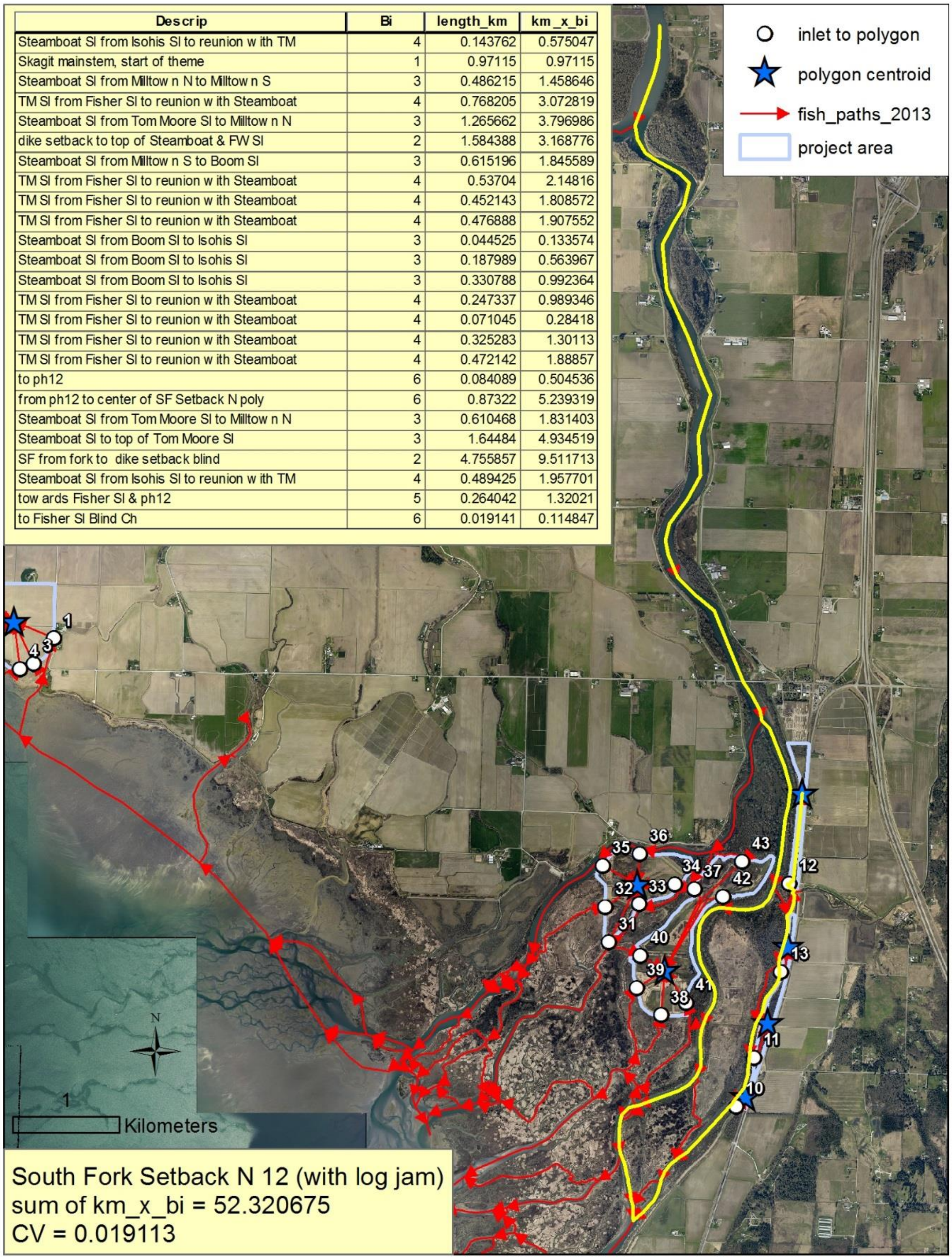
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Steamboat Sl to top of Tom Moore Sl	3	1.64484	4.934519
Tom Moore Sl to Fisher Sl	4	0.293071	1.172283
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
TM Sl from Fisher Sl to reunion w ith Steamboat	4	0.53704	2.14816
TM Sl from Fisher Sl to reunion w ith Steamboat	4	0.476888	1.907552
TM Sl from Fisher Sl to reunion w ith Steamboat	4	0.071045	0.28418
TM Sl from Fisher Sl to reunion w ith Steamboat	4	0.325283	1.30113
TM Sl from Fisher Sl to reunion w ith Steamboat	4	0.472142	1.88857
to ph10	5	0.04947	0.247352
from ph10 to center of SF Setback dow n poly	5	0.140239	0.701195

Figure 1



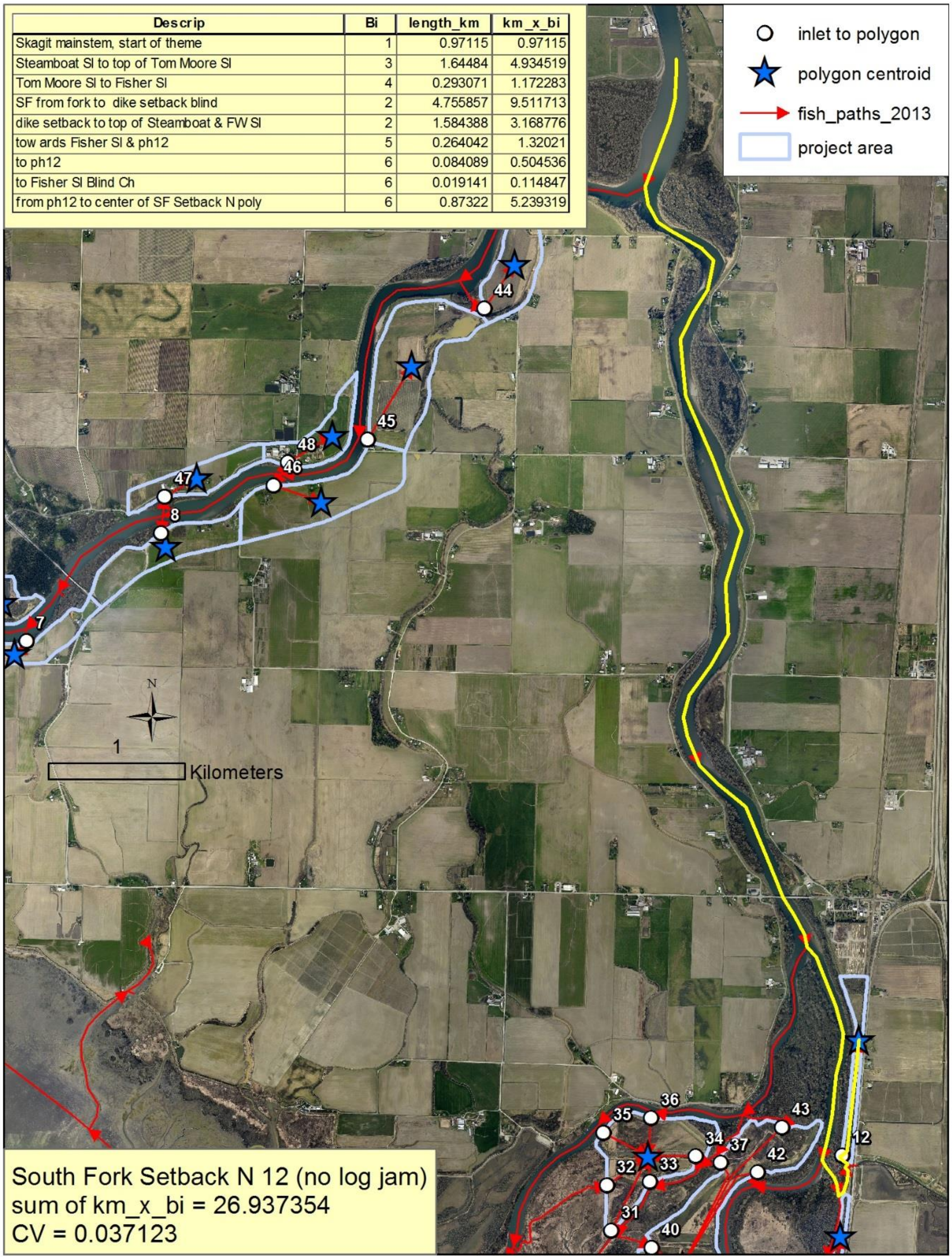
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Steamboat Sl to top of Tom Moore Sl	3	1.64484	4.934519
Tom Moore Sl to Fisher Sl	4	0.293071	1.172283
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
TM Sl from Fisher Sl to reunion w ith Steamboat	4	0.53704	2.14816
TM Sl from Fisher Sl to reunion w ith Steamboat	4	0.476888	1.907552
TM Sl from Fisher Sl to reunion w ith Steamboat	4	0.071045	0.28418
TM Sl from Fisher Sl to reunion w ith Steamboat	4	0.325283	1.30113
to ph11	5	0.045271	0.226355
from ph11 to center of SF Setback mid poly	5	0.364118	1.82059

Figure 2



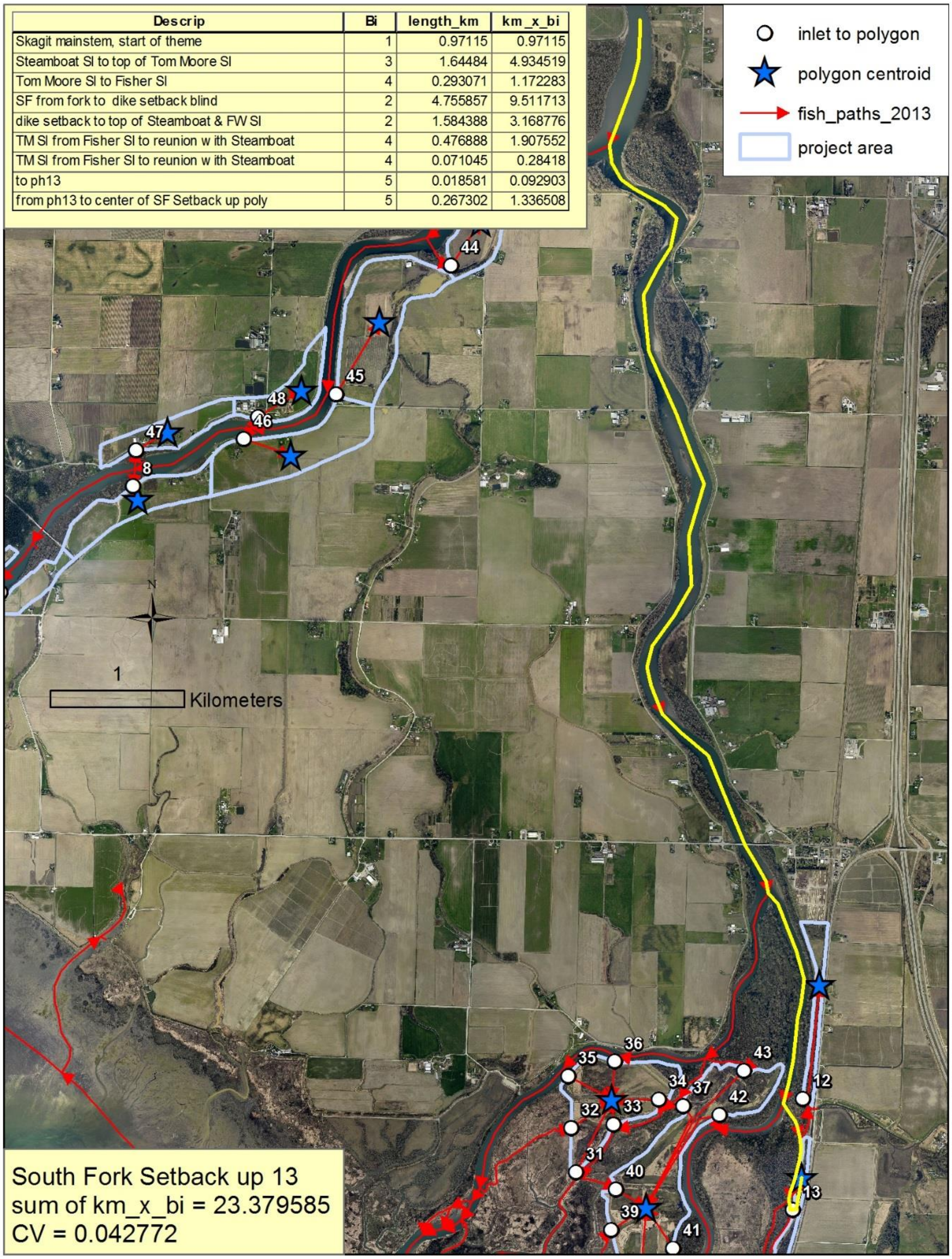
Descrip	Bi	length_km	km_x_bi
Steamboat Sl from Isohis Sl to reunion w ith TM	4	0.143762	0.575047
Skagit mainstem, start of theme	1	0.97115	0.97115
Steamboat Sl from Milltow n N to Milltow n S	3	0.486215	1.458646
TM Sl from Fisher Sl to reunion w ith Steamboat	4	0.768205	3.072819
Steamboat Sl from Tom Moore Sl to Milltow n N	3	1.265662	3.796986
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
Steamboat Sl from Milltow n S to Boom Sl	3	0.615196	1.845589
TM Sl from Fisher Sl to reunion w ith Steamboat	4	0.53704	2.14816
TM Sl from Fisher Sl to reunion w ith Steamboat	4	0.452143	1.808572
TM Sl from Fisher Sl to reunion w ith Steamboat	4	0.476888	1.907552
Steamboat Sl from Boom Sl to Isohis Sl	3	0.044525	0.133574
Steamboat Sl from Boom Sl to Isohis Sl	3	0.187989	0.563967
Steamboat Sl from Boom Sl to Isohis Sl	3	0.330788	0.992364
TM Sl from Fisher Sl to reunion w ith Steamboat	4	0.247337	0.989346
TM Sl from Fisher Sl to reunion w ith Steamboat	4	0.071045	0.28418
TM Sl from Fisher Sl to reunion w ith Steamboat	4	0.325283	1.30113
TM Sl from Fisher Sl to reunion w ith Steamboat	4	0.472142	1.88857
to ph12	6	0.084089	0.504536
from ph12 to center of SF Setback N poly	6	0.87322	5.239319
Steamboat Sl from Tom Moore Sl to Milltow n N	3	0.610468	1.831403
Steamboat Sl to top of Tom Moore Sl	3	1.64484	4.934519
SF from fork to dike setback blind	2	4.755857	9.511713
Steamboat Sl from Isohis Sl to reunion w ith TM	4	0.489425	1.957701
tow ards Fisher Sl & ph12	5	0.264042	1.32021
to Fisher Sl Blind Ch	6	0.019141	0.114847

Figure 3



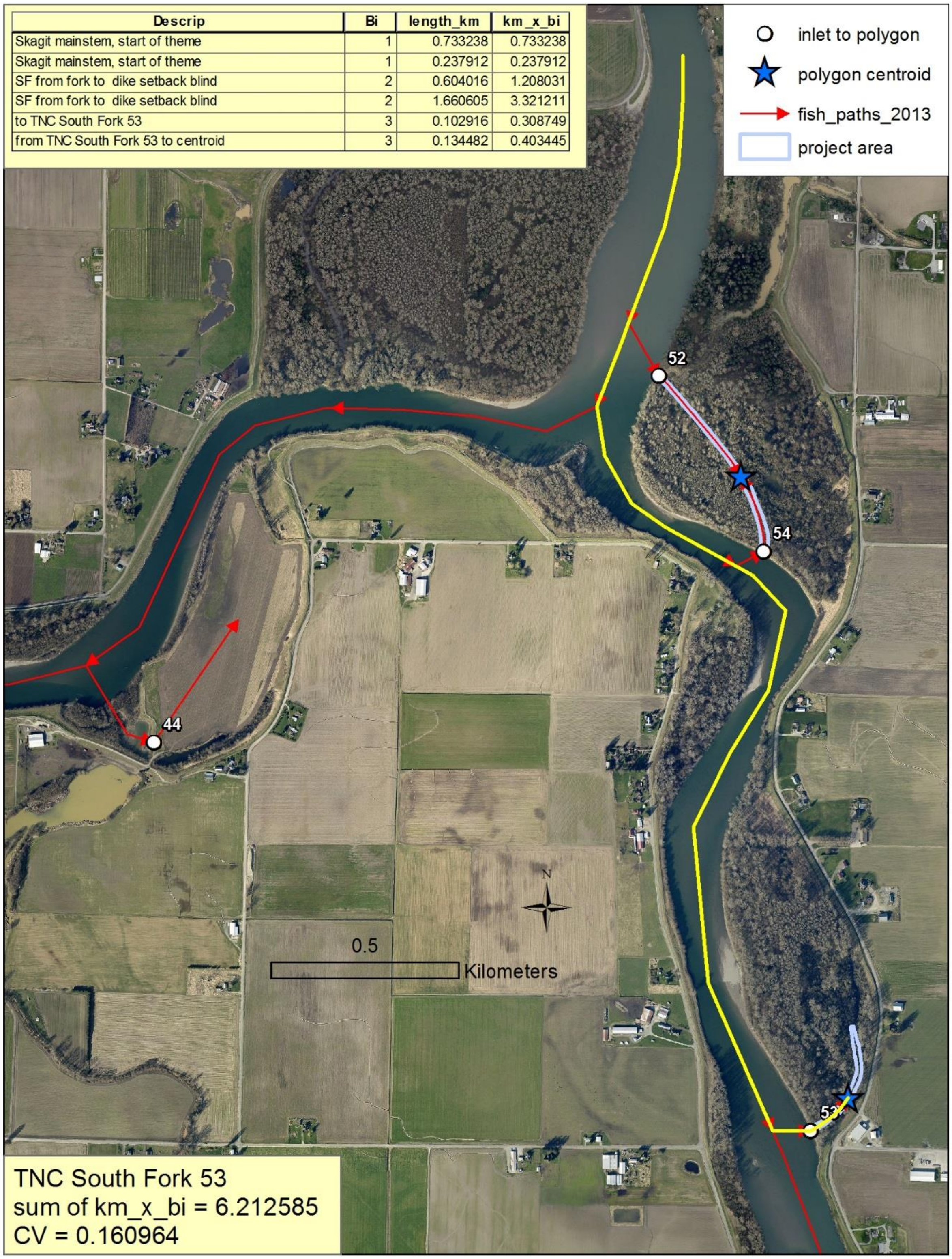
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Steamboat Sl to top of Tom Moore Sl	3	1.64484	4.934519
Tom Moore Sl to Fisher Sl	4	0.293071	1.172283
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
tow ards Fisher Sl & ph12	5	0.264042	1.32021
to ph12	6	0.084089	0.504536
to Fisher Sl Blind Ch	6	0.019141	0.114847
from ph12 to center of SF Setback N poly	6	0.87322	5.239319

Figure 4



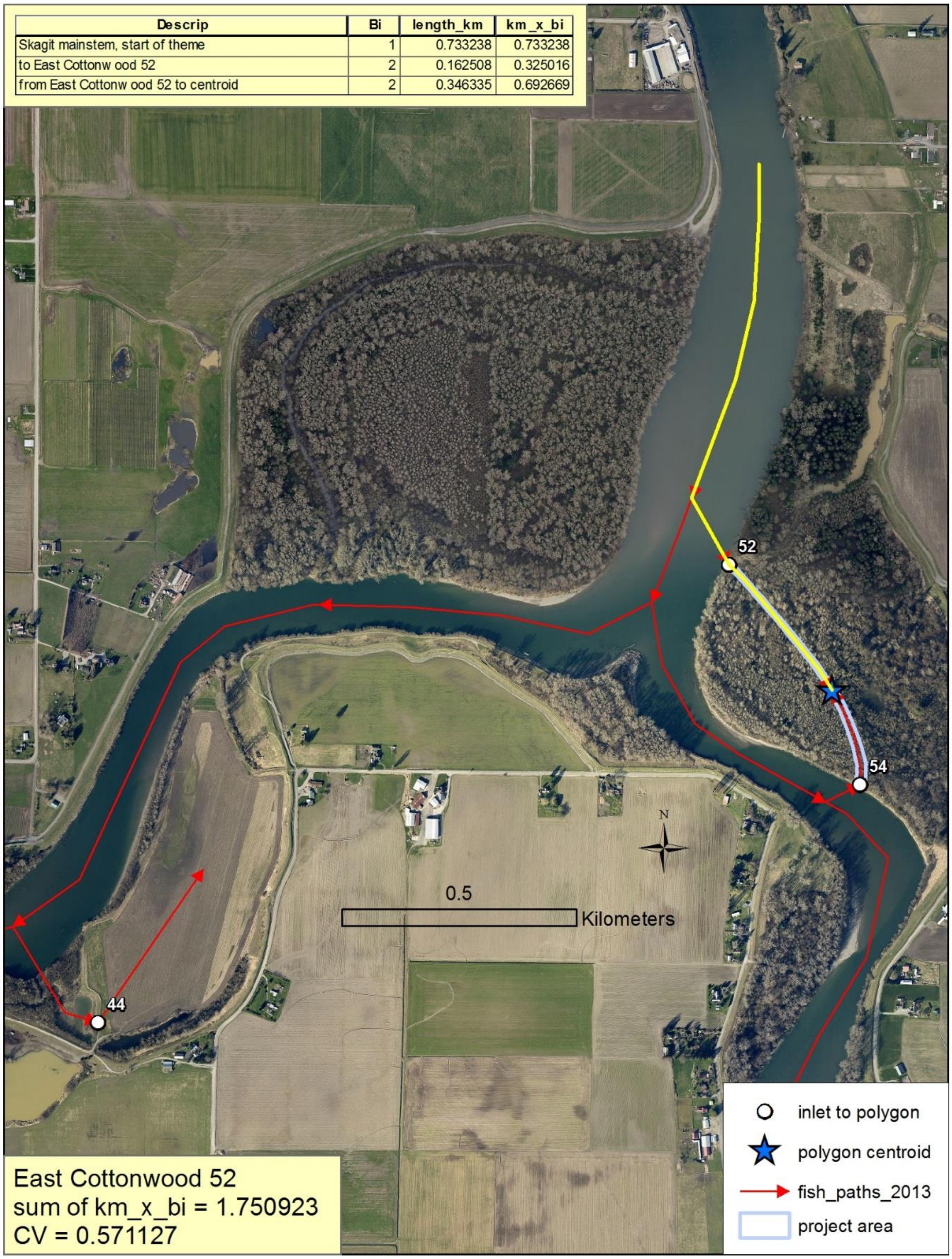
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Steamboat Sl to top of Tom Moore Sl	3	1.64484	4.934519
Tom Moore Sl to Fisher Sl	4	0.293071	1.172283
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
TM Sl from Fisher Sl to reunion w ith Steamboat	4	0.476888	1.907552
TM Sl from Fisher Sl to reunion w ith Steamboat	4	0.071045	0.28418
to ph13	5	0.018581	0.092903
from ph13 to center of SF Setback up poly	5	0.267302	1.336508

Figure 5



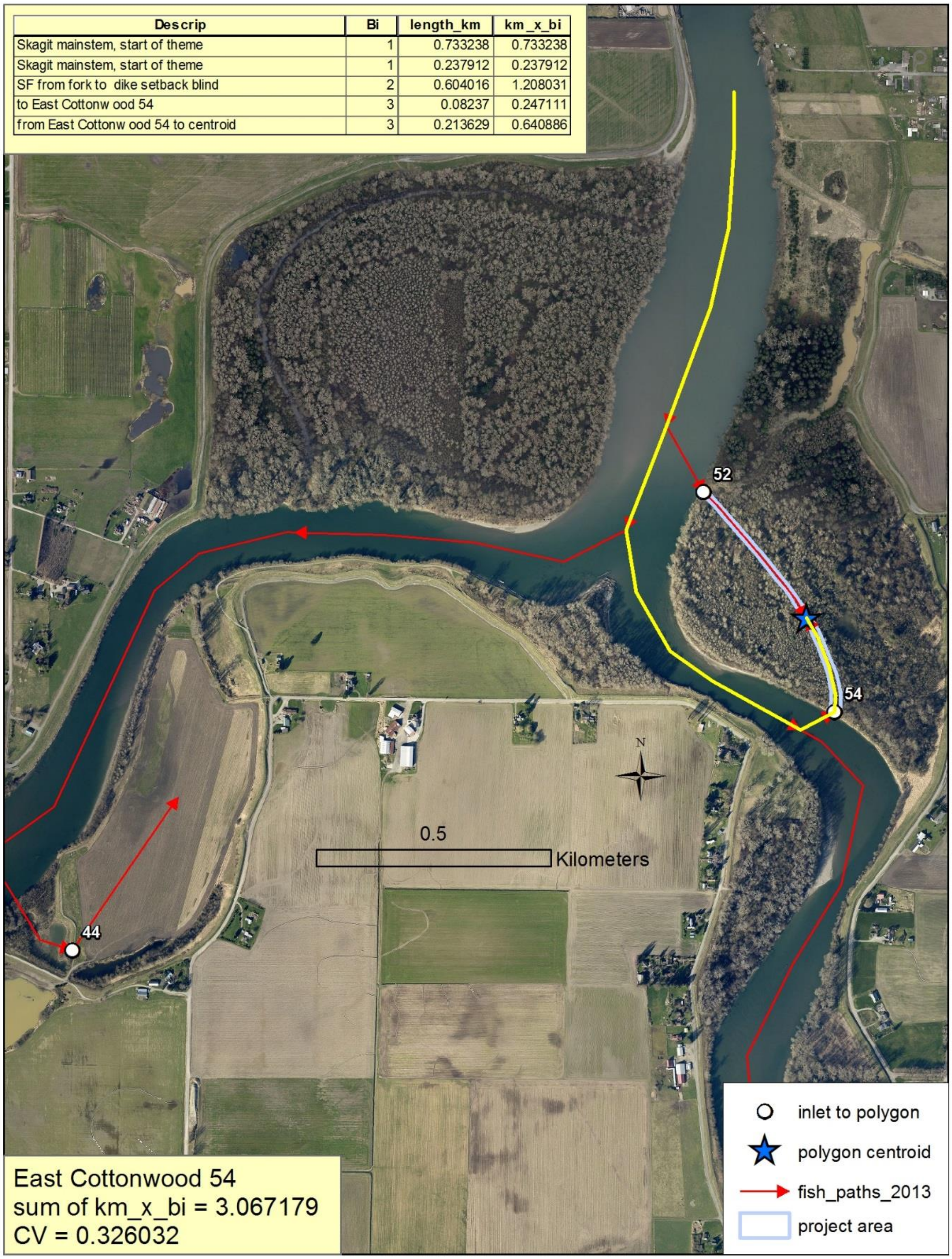
Descrip | Bi | length_km | km_x_bi
Skagit mainstem, start of theme | 1 | 0.733238 | 0.733238
Skagit mainstem, start of theme | 1 | 0.237912 | 0.237912
SF from fork to dike setback blind | 2 | 0.604016 | 1.208031
SF from fork to dike setback blind | 2 | 1.660605 | 3.321211
to TNC South Fork 53 | 3 | 0.102916 | 0.308749
from TNC South Fork 53 to centroid | 3 | 0.134482 | 0.403445
inlet to polygon
polygon centroid
fish_paths_2013
project area
52
54
44
N
0.5
Kilometers
TNC South Fork 53
sum of km_x_bi = 6.212585
CV = 0.160964

Figure 6



Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.733238	0.733238
to East Cottonw ood 52	2	0.162508	0.325016
from East Cottonw ood 52 to centroid	2	0.346335	0.692669

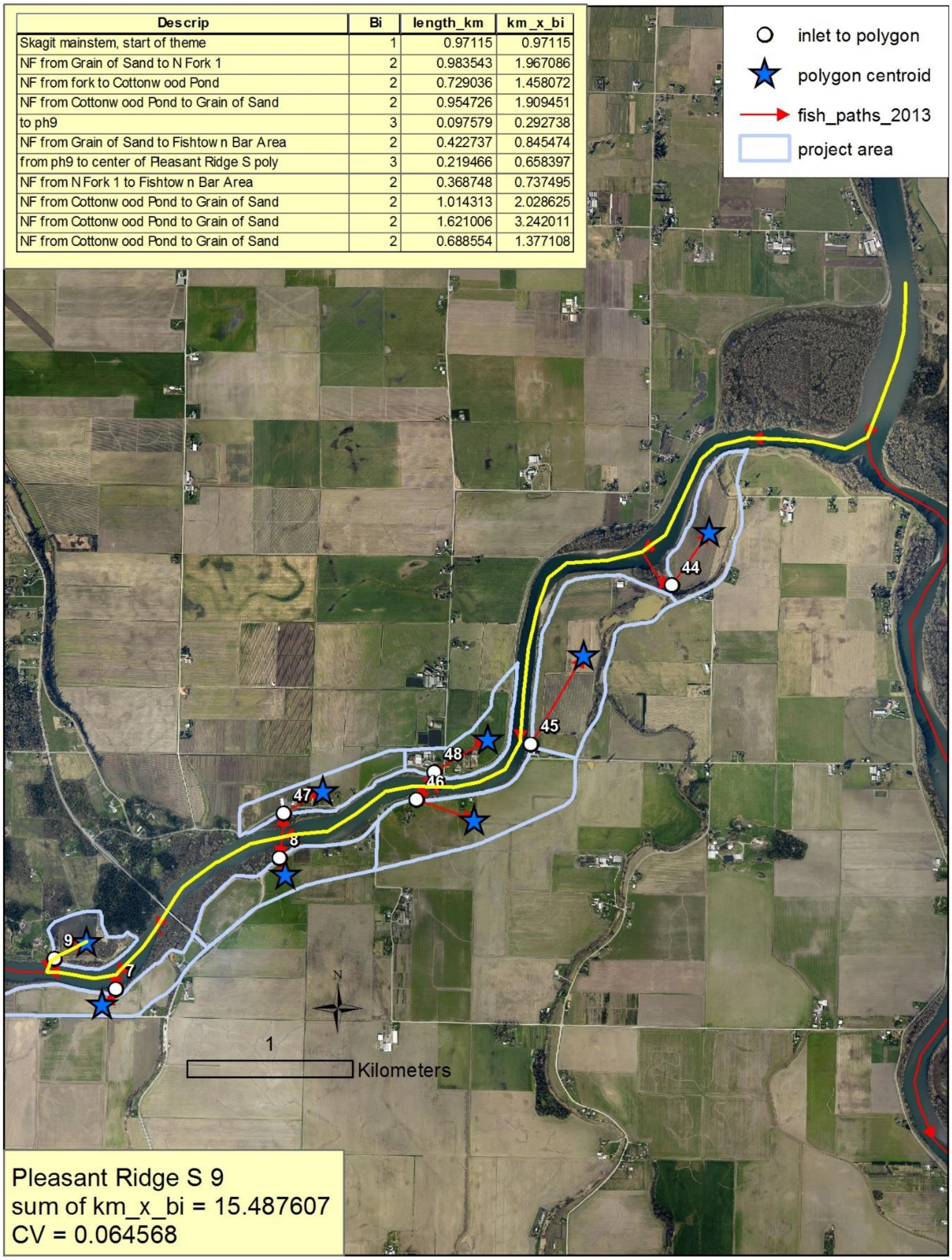
Figure 7



Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.733238	0.733238
Skagit mainstem, start of theme	1	0.237912	0.237912
SF from fork to dike setback blind	2	0.604016	1.208031
to East Cottonw ood 54	3	0.08237	0.247111
from East Cottonw ood 54 to centroid	3	0.213629	0.640886

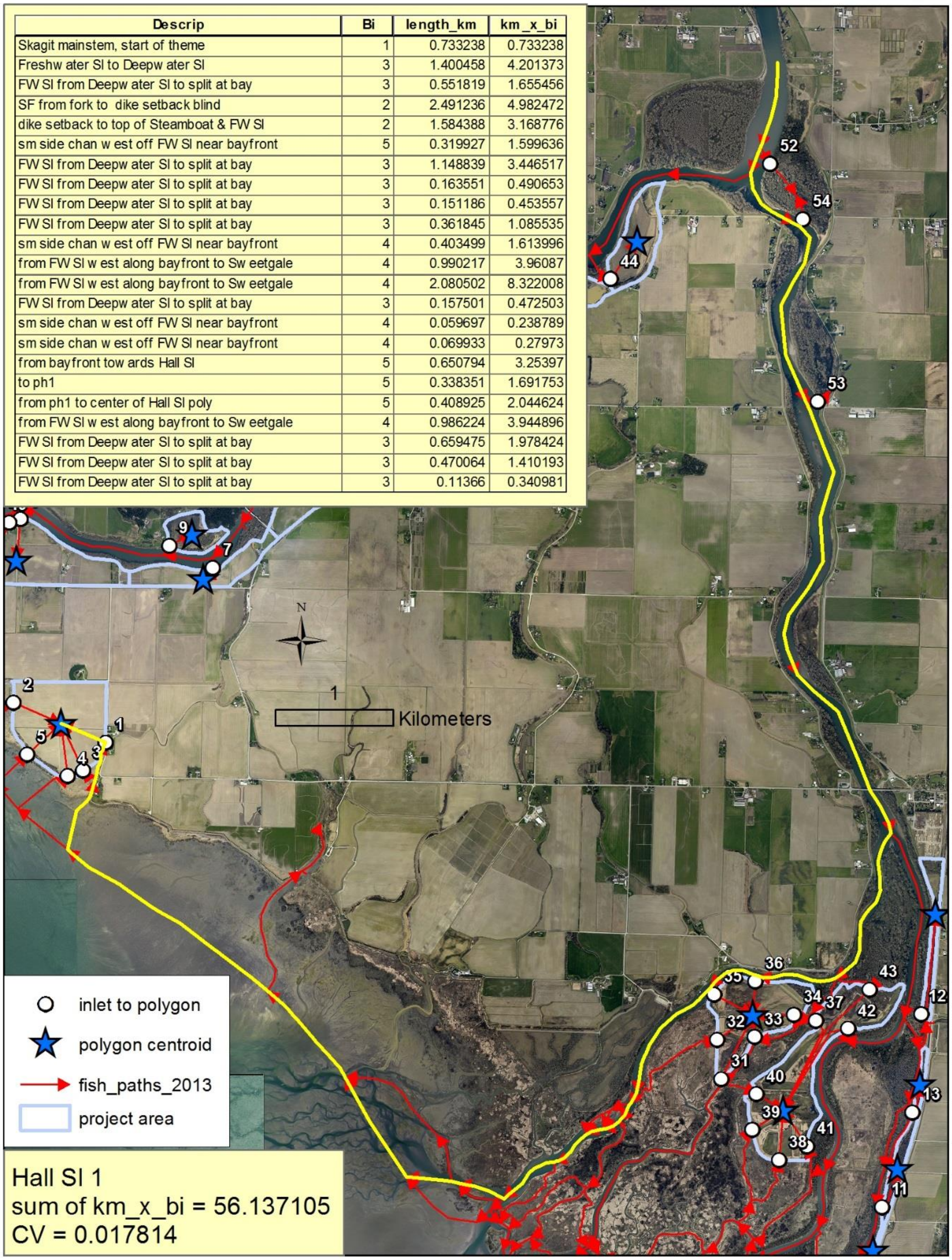
52
54
44
N
0.5
Kilometers
inlet to polygon
polygon centroid
fish_paths_2013
project area
East Cottonwood 54
sum of km_x_bi = 3.067179
CV = 0.326032

Figure 8



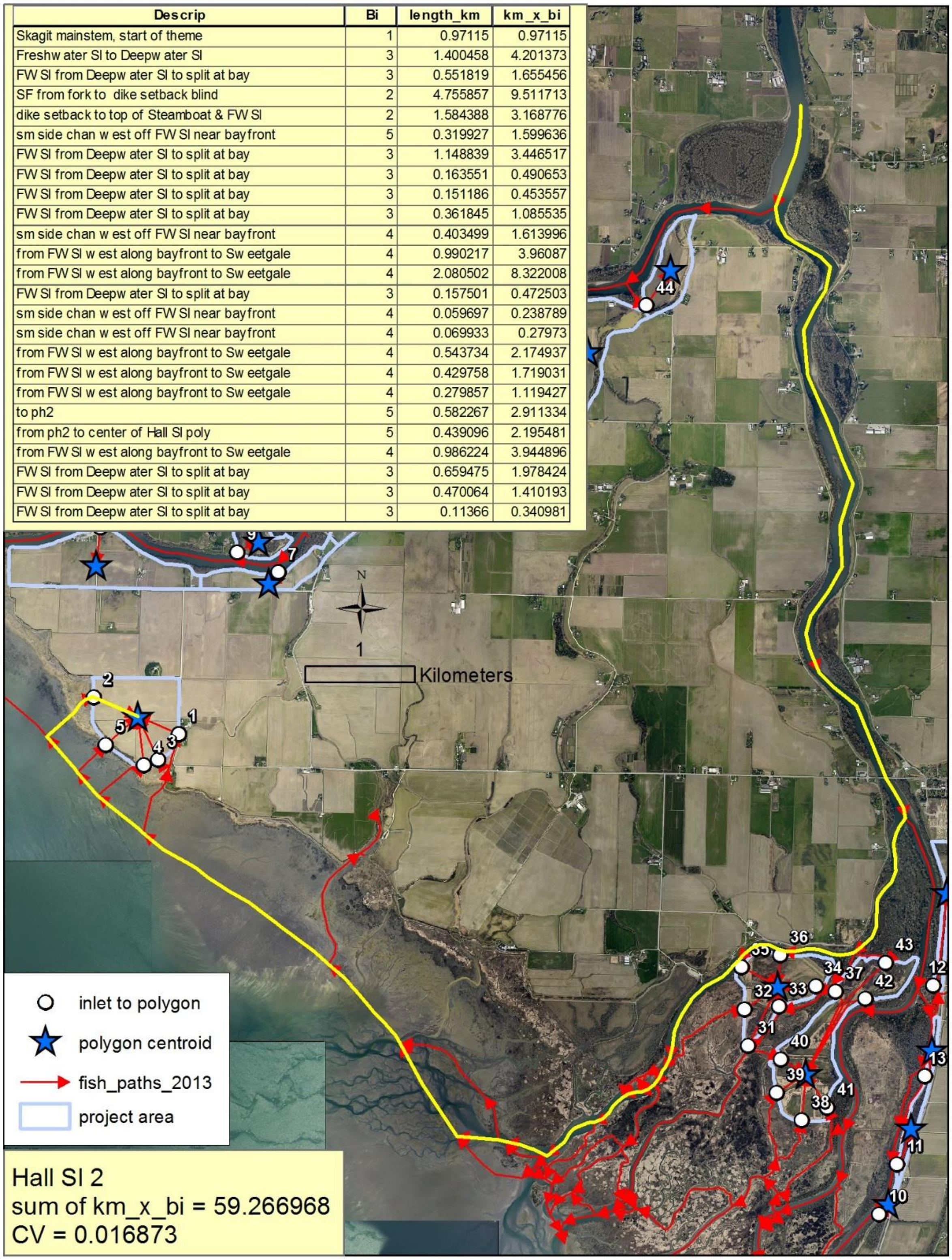
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
to ph9	3	0.097579	0.292738
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
from ph9 to center of Pleasant Ridge S poly	3	0.219466	0.658397
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 9



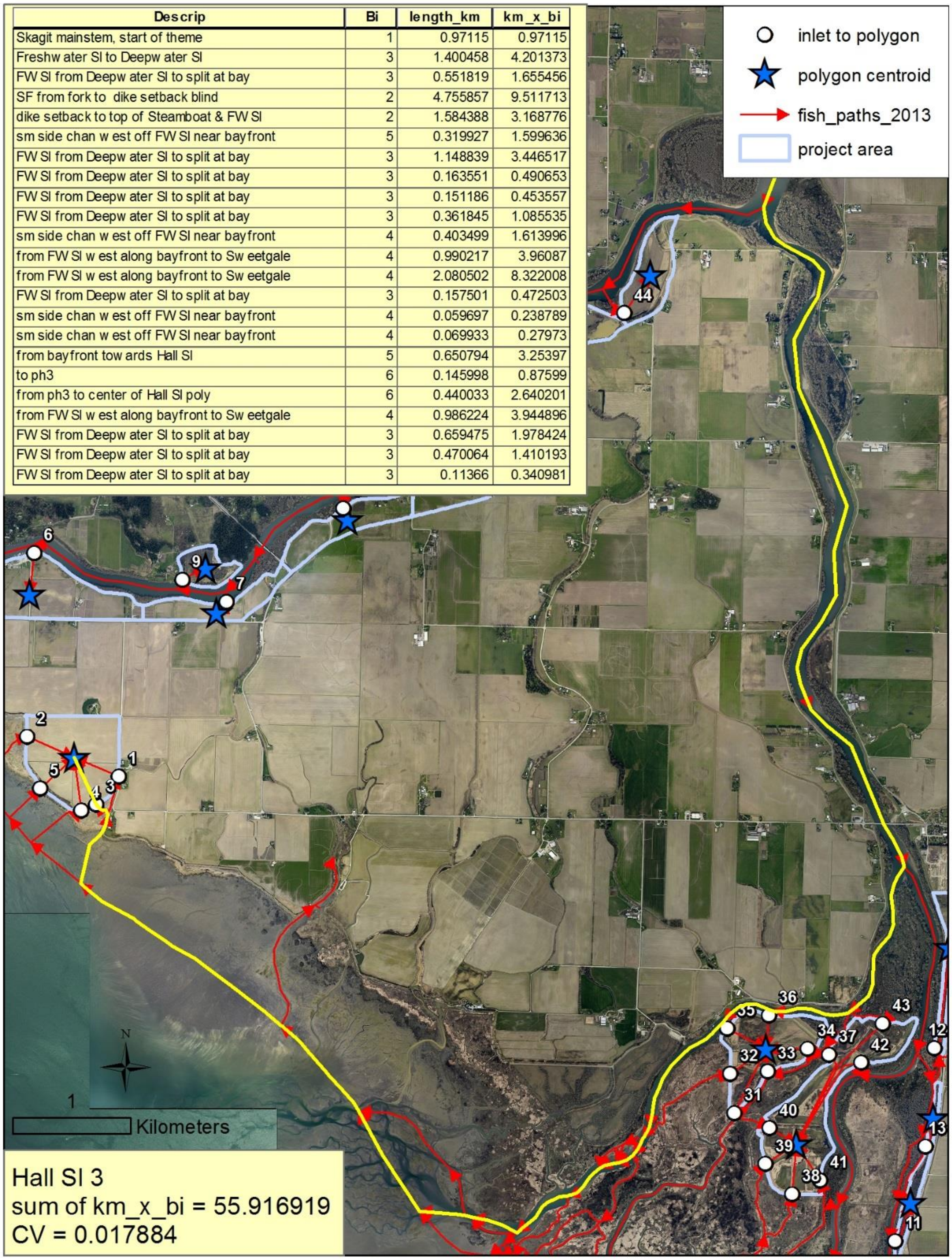
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.733238	0.733238
Freshw ater Sl to Deepw ater Sl	3	1.400458	4.201373
FW Sl from Deepw ater Sl to split at bay	3	0.551819	1.655456
SF from fork to dike setback blind	2	2.491236	4.982472
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
sm side chan w est off FW Sl near bayfront	5	0.319927	1.599636
FW Sl from Deepw ater Sl to split at bay	3	1.148839	3.446517
FW Sl from Deepw ater Sl to split at bay	3	0.163551	0.490653
FW Sl from Deepw ater Sl to split at bay	3	0.151186	0.453557
FW Sl from Deepw ater Sl to split at bay	3	0.361845	1.085535
sm side chan w est off FW Sl near bayfront	4	0.403499	1.613996
from FW Sl w est along bayfront to Sw eetgale	4	0.990217	3.96087
from FW Sl w est along bayfront to Sw eetgale	4	2.080502	8.322008
FW Sl from Deepw ater Sl to split at bay	3	0.157501	0.472503
sm side chan w est off FW Sl near bayfront	4	0.059697	0.238789
sm side chan w est off FW Sl near bayfront	4	0.069933	0.27973
from bayfront tow ards Hall Sl	5	0.650794	3.25397
to ph1	5	0.338351	1.691753
from ph1 to center of Hall Sl poly	5	0.408925	2.044624
from FW Sl w est along bayfront to Sw eetgale	4	0.986224	3.944896
FW Sl from Deepw ater Sl to split at bay	3	0.659475	1.978424
FW Sl from Deepw ater Sl to split at bay	3	0.470064	1.410193
FW Sl from Deepw ater Sl to split at bay	3	0.11366	0.340981

Figure 10



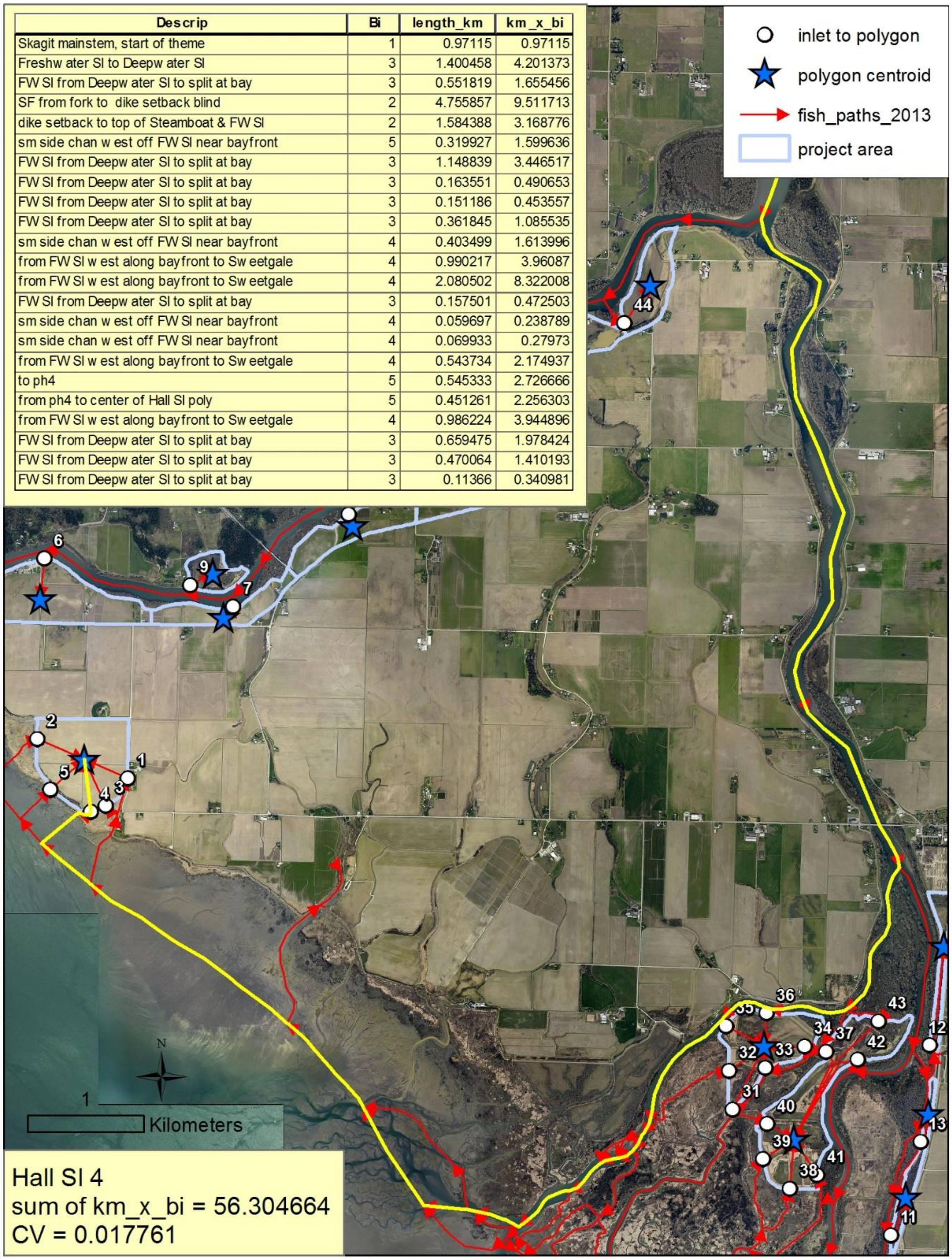
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Freshw ater Sl to Deepw ater Sl	3	1.400458	4.201373
FW Sl from Deepw ater Sl to split at bay	3	0.551819	1.655456
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
sm side chan w est off FW Sl near bayfront	5	0.319927	1.599636
FW Sl from Deepw ater Sl to split at bay	3	1.148839	3.446517
FW Sl from Deepw ater Sl to split at bay	3	0.163551	0.490653
FW Sl from Deepw ater Sl to split at bay	3	0.151186	0.453557
FW Sl from Deepw ater Sl to split at bay	3	0.361845	1.085535
sm side chan w est off FW Sl near bayfront	4	0.403499	1.613996
from FW Sl w est along bayfront to Sw eetgale	4	0.990217	3.96087
from FW Sl w est along bayfront to Sw eetgale	4	2.080502	8.322008
FW Sl from Deepw ater Sl to split at bay	3	0.157501	0.472503
sm side chan w est off FW Sl near bayfront	4	0.059697	0.238789
sm side chan w est off FW Sl near bayfront	4	0.069933	0.27973
from FW Sl w est along bayfront to Sw eetgale	4	0.543734	2.174937
from FW Sl w est along bayfront to Sw eetgale	4	0.429758	1.719031
from FW Sl w est along bayfront to Sw eetgale	4	0.279857	1.119427
to ph2	5	0.582267	2.911334
from ph2 to center of Hall Sl poly	5	0.439096	2.195481
from FW Sl w est along bayfront to Sw eetgale	4	0.986224	3.944896
FW Sl from Deepw ater Sl to split at bay	3	0.659475	1.978424
FW Sl from Deepw ater Sl to split at bay	3	0.470064	1.410193
FW Sl from Deepw ater Sl to split at bay	3	0.11366	0.340981

Figure 11



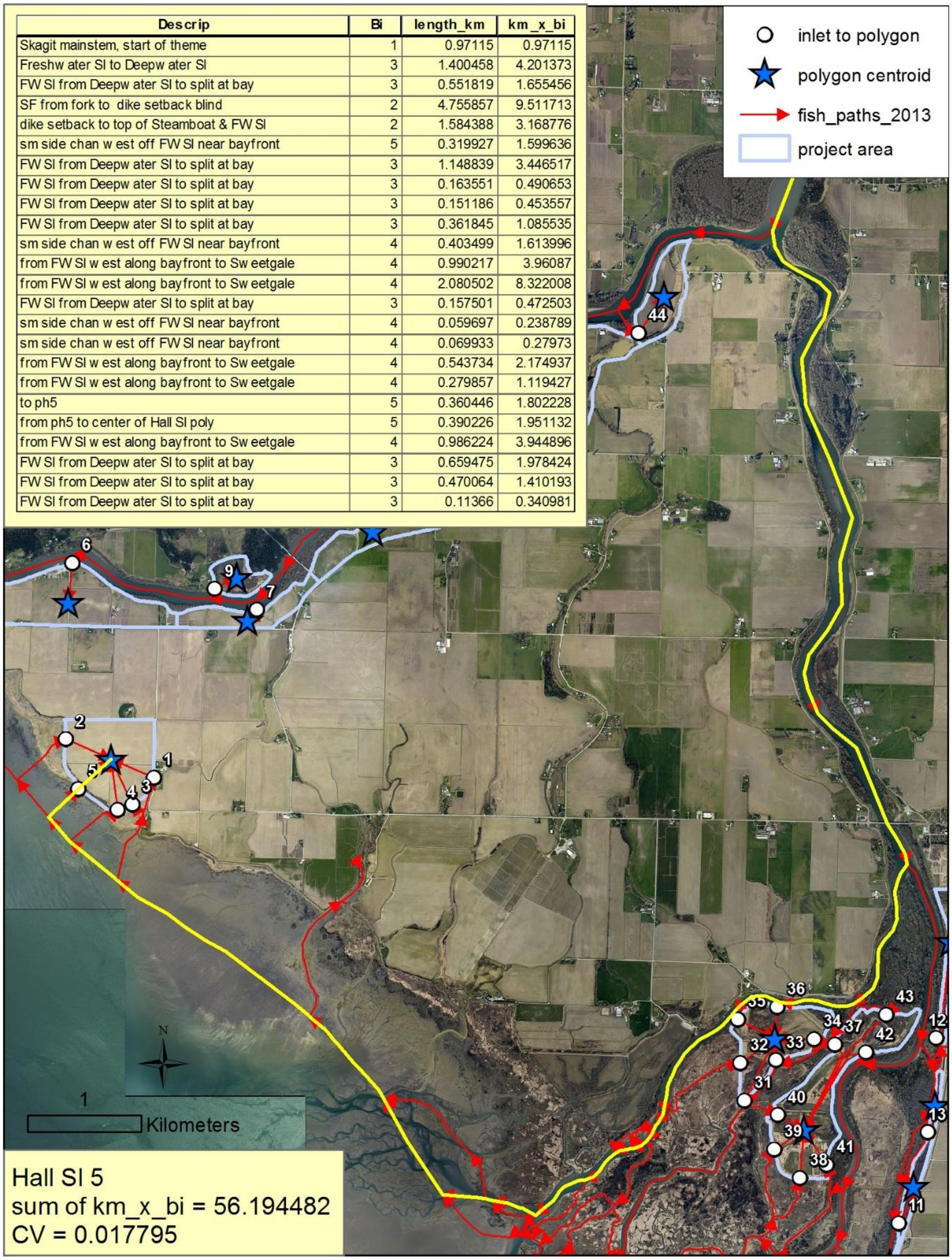
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Freshw ater Sl to Deepw ater Sl	3	1.400458	4.201373
FW Sl from Deepw ater Sl to split at bay	3	0.551819	1.655456
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
sm side chan w est off FW Sl near bayfront	5	0.319927	1.599636
FW Sl from Deepw ater Sl to split at bay	3	1.148839	3.446517
FW Sl from Deepw ater Sl to split at bay	3	0.163551	0.490653
FW Sl from Deepw ater Sl to split at bay	3	0.151186	0.453557
FW Sl from Deepw ater Sl to split at bay	3	0.361845	1.085535
sm side chan w est off FW Sl near bayfront	4	0.403499	1.613996
from FW Sl w est along bayfront to Sw eetgale	4	0.990217	3.96087
from FW Sl w est along bayfront to Sw eetgale	4	2.080502	8.322008
FW Sl from Deepw ater Sl to split at bay	3	0.157501	0.472503
sm side chan w est off FW Sl near bayfront	4	0.059697	0.238789
sm side chan w est off FW Sl near bayfront	4	0.069933	0.27973
from bayfront tow ards Hall Sl	5	0.650794	3.25397
to ph3	6	0.145998	0.87599
from ph3 to center of Hall Sl poly	6	0.440033	2.640201
from FW Sl w est along bayfront to Sw eetgale	4	0.986224	3.944896
FW Sl from Deepw ater Sl to split at bay	3	0.659475	1.978424
FW Sl from Deepw ater Sl to split at bay	3	0.470064	1.410193
FW Sl from Deepw ater Sl to split at bay	3	0.11366	0.340981

Figure 12



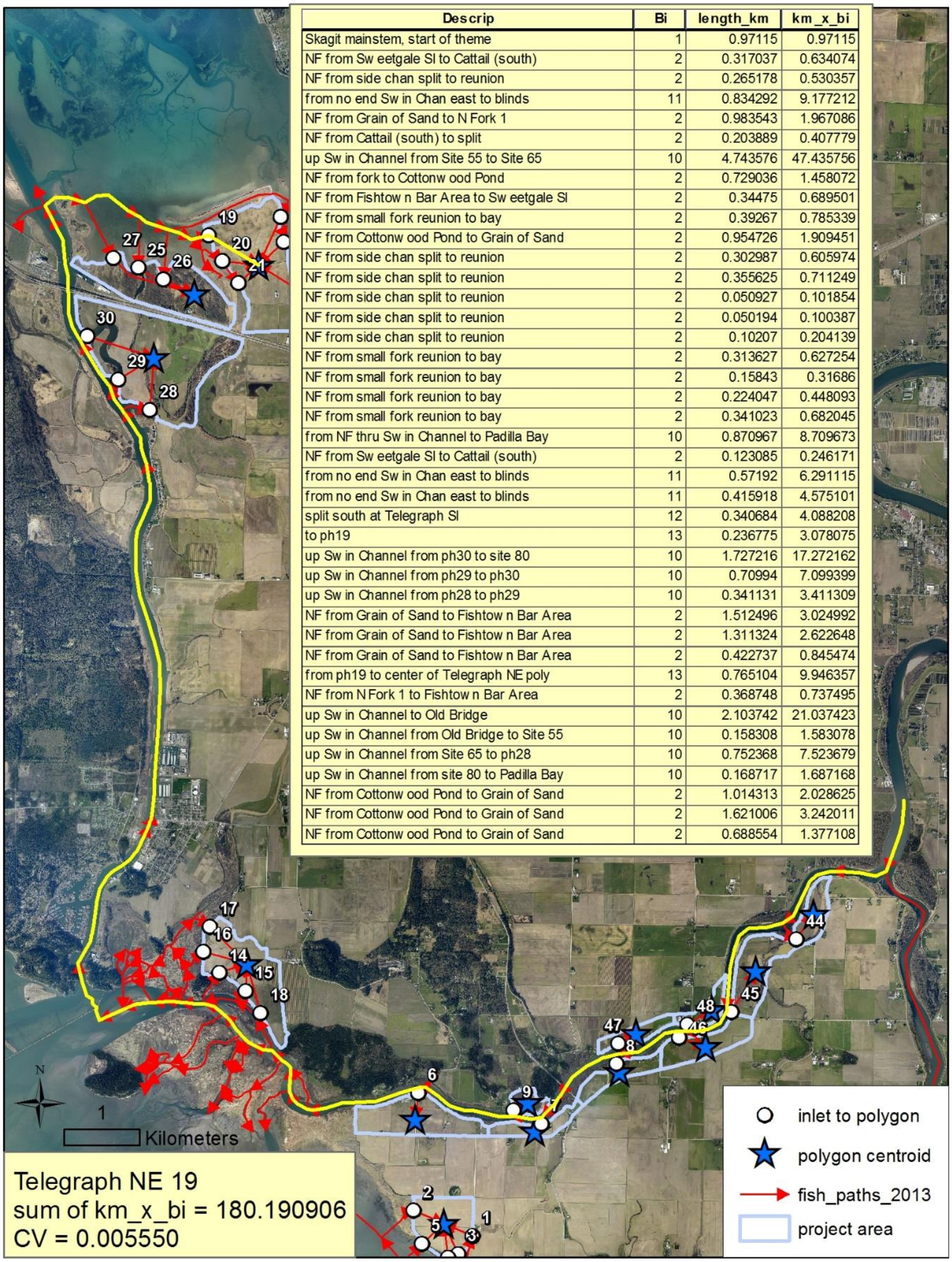
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Freshw ater Sl to Deepw ater Sl	3	1.400458	4.201373
FW Sl from Deepw ater Sl to split at bay	3	0.551819	1.655456
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
sm side chan w est off FW Sl near bayfront	5	0.319927	1.599636
FW Sl from Deepw ater Sl to split at bay	3	1.148839	3.446517
FW Sl from Deepw ater Sl to split at bay	3	0.163551	0.490653
FW Sl from Deepw ater Sl to split at bay	3	0.151186	0.453557
FW Sl from Deepw ater Sl to split at bay	3	0.361845	1.085535
sm side chan w est off FW Sl near bayfront	4	0.403499	1.613996
from FW Sl w est along bayfront to Sw eetgale	4	0.990217	3.96087
from FW Sl w est along bayfront to Sw eetgale	4	2.080502	8.322008
FW Sl from Deepw ater Sl to split at bay	3	0.157501	0.472503
sm side chan w est off FW Sl near bayfront	4	0.059697	0.238789
sm side chan w est off FW Sl near bayfront	4	0.069933	0.27973
from FW Sl w est along bayfront to Sw eetgale	4	0.543734	2.174937
to ph4	5	0.545333	2.726666
from ph4 to center of Hall Sl poly	5	0.451261	2.256303
from FW Sl w est along bayfront to Sw eetgale	4	0.986224	3.944896
FW Sl from Deepw ater Sl to split at bay	3	0.659475	1.978424
FW Sl from Deepw ater Sl to split at bay	3	0.470064	1.410193
FW Sl from Deepw ater Sl to split at bay	3	0.11366	0.340981

Figure 13



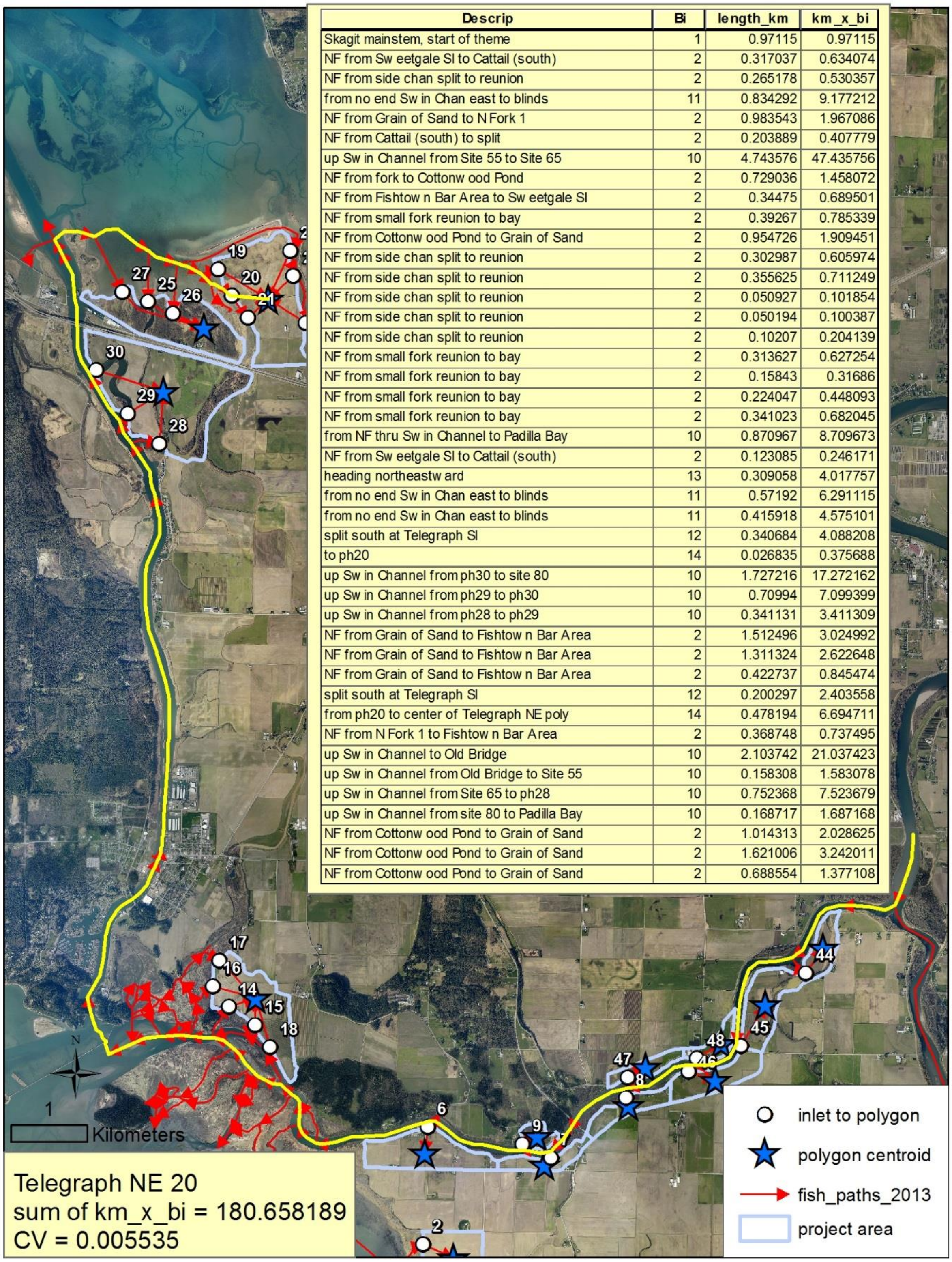
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Freshw ater Sl to Deepw ater Sl	3	1.400458	4.201373
FW Sl from Deepw ater Sl to split at bay	3	0.551819	1.655456
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
sm side chan w est off FW Sl near bayfront	5	0.319927	1.599636
FW Sl from Deepw ater Sl to split at bay	3	1.148839	3.446517
FW Sl from Deepw ater Sl to split at bay	3	0.163551	0.490653
FW Sl from Deepw ater Sl to split at bay	3	0.151186	0.453557
FW Sl from Deepw ater Sl to split at bay	3	0.361845	1.085535
sm side chan w est off FW Sl near bayfront	4	0.403499	1.613996
from FW Sl w est along bayfront to Sw eetgale	4	0.990217	3.96087
from FW Sl w est along bayfront to Sw eetgale	4	2.080502	8.322008
FW Sl from Deepw ater Sl to split at bay	3	0.157501	0.472503
sm side chan w est off FW Sl near bayfront	4	0.059697	0.238789
sm side chan w est off FW Sl near bayfront	4	0.069933	0.27973
from FW Sl w est along bayfront to Sw eetgale	4	0.543734	2.174937
from FW Sl w est along bayfront to Sw eetgale	4	0.279857	1.119427
to ph5	5	0.360446	1.802228
from ph5 to center of Hall Sl poly	5	0.390226	1.951132
from FW Sl w est along bayfront to Sw eetgale	4	0.986224	3.944896
FW Sl from Deepw ater Sl to split at bay	3	0.659475	1.978424
FW Sl from Deepw ater Sl to split at bay	3	0.470064	1.410193
FW Sl from Deepw ater Sl to split at bay	3	0.11366	0.340981

Figure 14



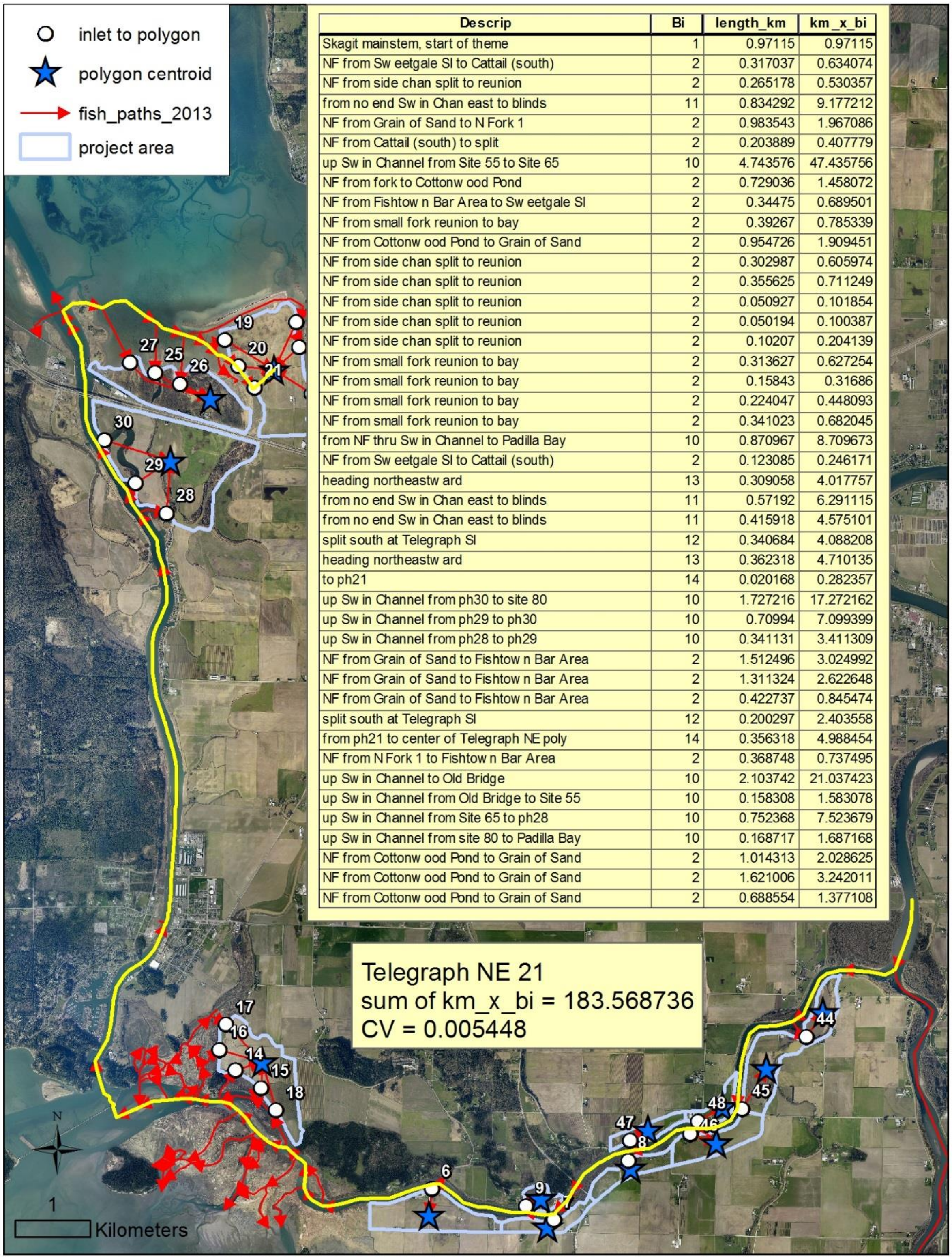
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Sweetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
from no end Sw in Chan east to blinds	11	0.834292	9.177212
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
up Sw in Channel from Site 55 to Site 65	10	4.743576	47.435756
NF from fork to Cottonwood Pond	2	0.729036	1.458072
NF from Fishtown Bar Area to Sweetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonwood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Channel to Padilla Bay	10	0.870967	8.709673
NF from Sweetgale Sl to Cattail (south)	2	0.123085	0.246171
from no end Sw in Chan east to blinds	11	0.57192	6.291115
from no end Sw in Chan east to blinds	11	0.415918	4.575101
split south at Telegraph Sl	12	0.340684	4.088208
to ph19	13	0.236775	3.078075
up Sw in Channel from ph30 to site 80	10	1.727216	17.272162
up Sw in Channel from ph29 to ph30	10	0.70994	7.099399
up Sw in Channel from ph28 to ph29	10	0.341131	3.411309
NF from Grain of Sand to Fishtown Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtown Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtown Bar Area	2	0.422737	0.845474
from ph19 to center of Telegraph NE poly	13	0.765104	9.946357
NF from N Fork 1 to Fishtown Bar Area	2	0.368748	0.737495
up Sw in Channel to Old Bridge	10	2.103742	21.037423
up Sw in Channel from Old Bridge to Site 55	10	0.158308	1.583078
up Sw in Channel from Site 65 to ph28	10	0.752368	7.523679
up Sw in Channel from site 80 to Padilla Bay	10	0.168717	1.687168
NF from Cottonwood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonwood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonwood Pond to Grain of Sand	2	0.688554	1.377108

Figure 15



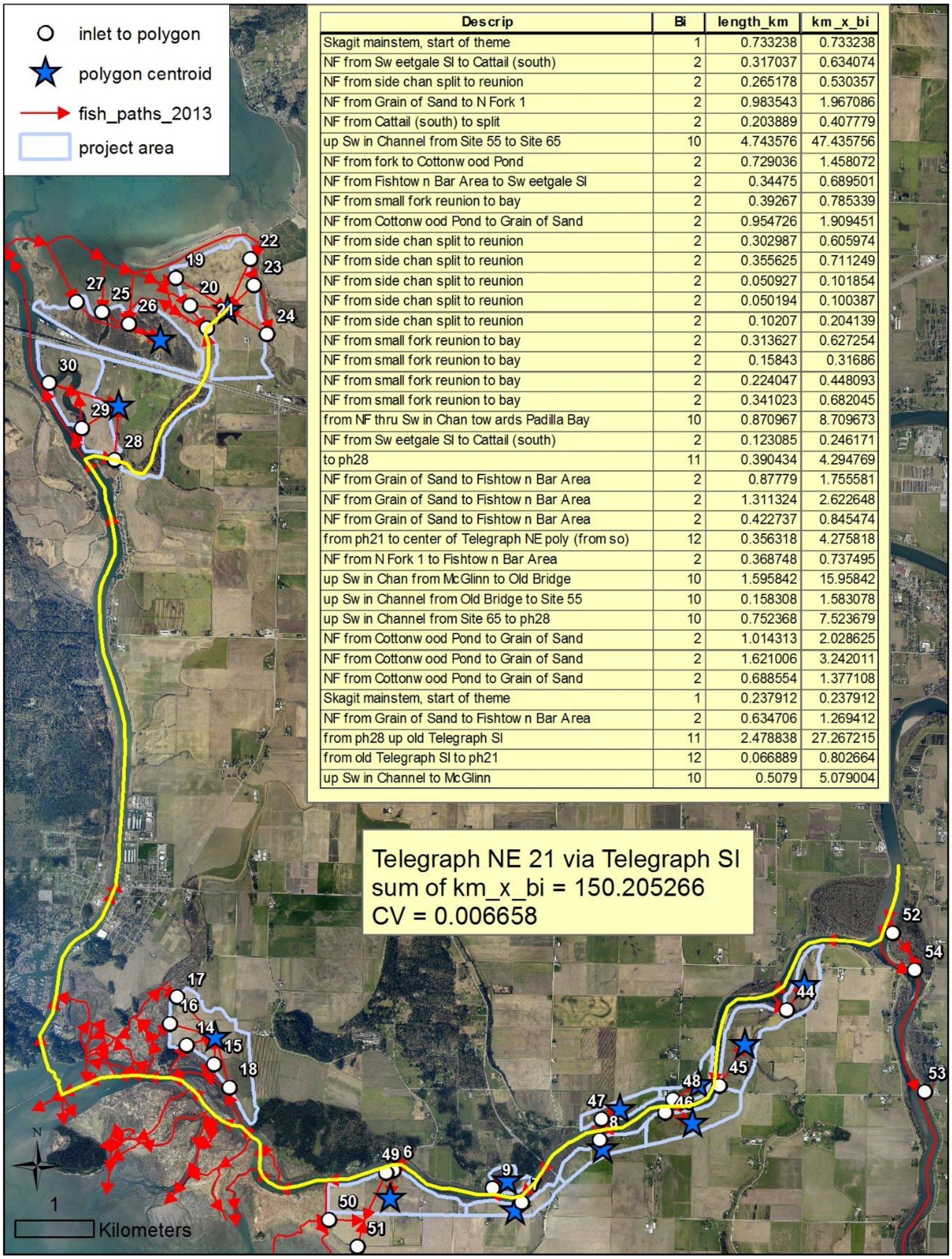
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
from no end Sw in Chan east to blinds	11	0.834292	9.177212
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
up Sw in Channel from Site 55 to Site 65	10	4.743576	47.435756
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Channel to Padilla Bay	10	0.870967	8.709673
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
heading northeastw ard	13	0.309058	4.017757
from no end Sw in Chan east to blinds	11	0.57192	6.291115
from no end Sw in Chan east to blinds	11	0.415918	4.575101
split south at Telegraph Sl	12	0.340684	4.088208
to ph20	14	0.026835	0.375688
up Sw in Channel from ph30 to site 80	10	1.727216	17.272162
up Sw in Channel from ph29 to ph30	10	0.70994	7.099399
up Sw in Channel from ph28 to ph29	10	0.341131	3.411309
NF from Grain of Sand to Fishtow n Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
split south at Telegraph Sl	12	0.200297	2.403558
from ph20 to center of Telegraph NE poly	14	0.478194	6.694711
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
up Sw in Channel to Old Bridge	10	2.103742	21.037423
up Sw in Channel from Old Bridge to Site 55	10	0.158308	1.583078
up Sw in Channel from Site 65 to ph28	10	0.752368	7.523679
up Sw in Channel from site 80 to Padilla Bay	10	0.168717	1.687168
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 16



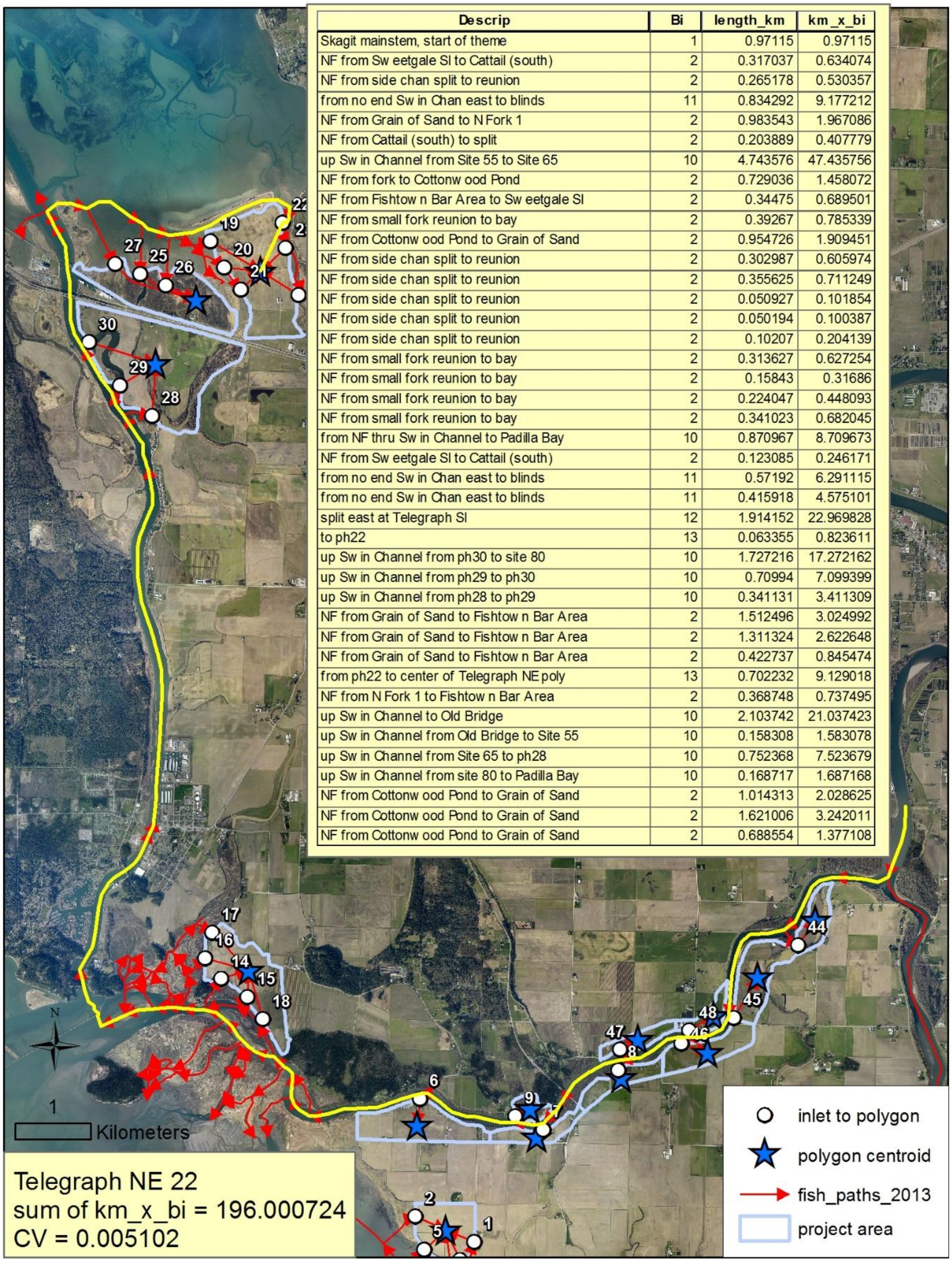
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
from no end Sw in Chan east to blinds	11	0.834292	9.177212
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
up Sw in Channel from Site 55 to Site 65	10	4.743576	47.435756
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Channel to Padilla Bay	10	0.870967	8.709673
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
heading northeastw ard	13	0.309058	4.017757
from no end Sw in Chan east to blinds	11	0.57192	6.291115
from no end Sw in Chan east to blinds	11	0.415918	4.575101
split south at Telegraph Sl	12	0.340684	4.088208
heading northeastw ard	13	0.362318	4.710135
to ph21	14	0.020168	0.282357
up Sw in Channel from ph30 to site 80	10	1.727216	17.272162
up Sw in Channel from ph29 to ph30	10	0.70994	7.099399
up Sw in Channel from ph28 to ph29	10	0.341131	3.411309
NF from Grain of Sand to Fishtow n Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
split south at Telegraph Sl	12	0.200297	2.403558
from ph21 to center of Telegraph NE poly	14	0.356318	4.988454
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
up Sw in Channel to Old Bridge	10	2.103742	21.037423
up Sw in Channel from Old Bridge to Site 55	10	0.158308	1.583078
up Sw in Channel from Site 65 to ph28	10	0.752368	7.523679
up Sw in Channel from site 80 to Padilla Bay	10	0.168717	1.687168
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 17



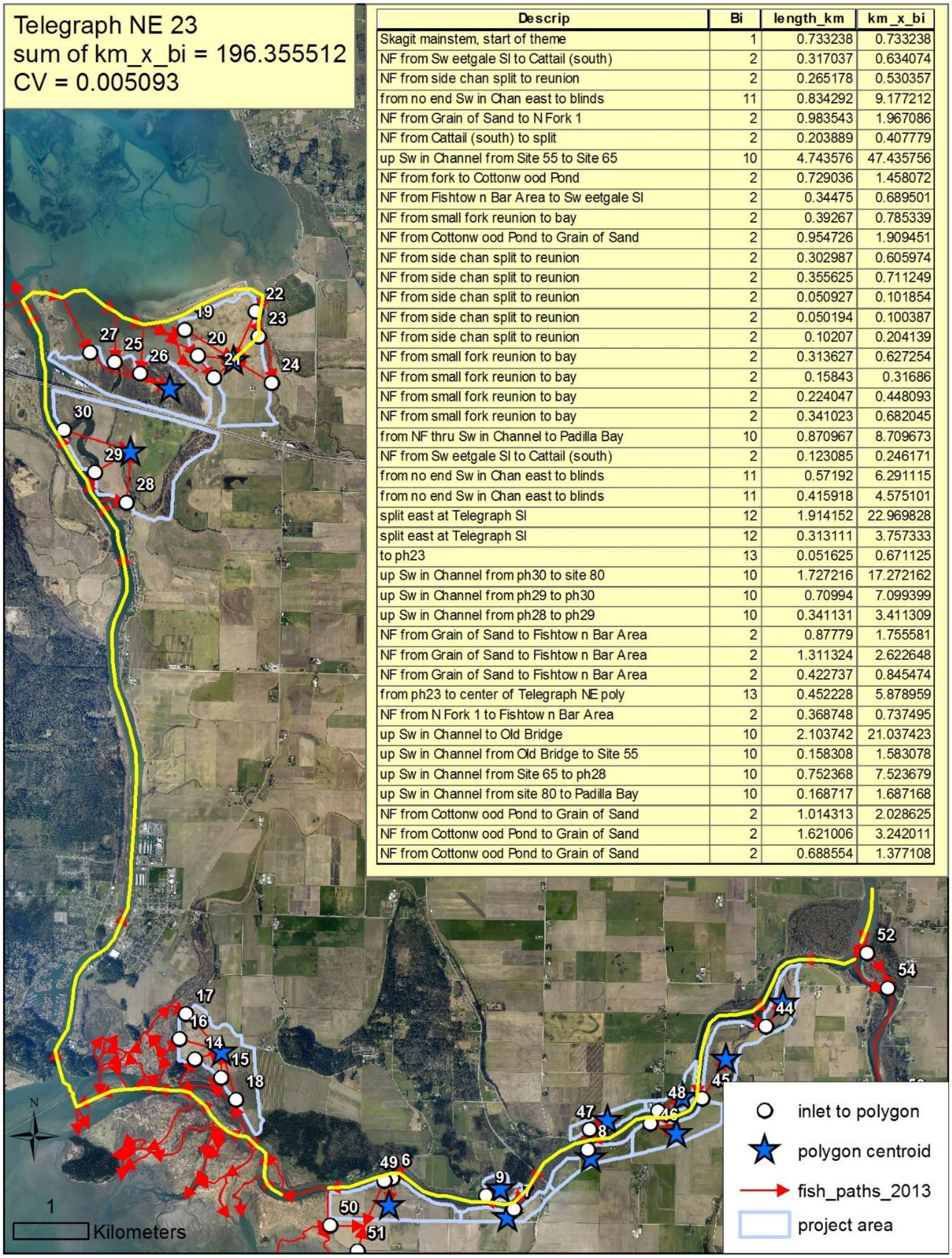
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.733238	0.733238
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
up Sw in Channel from Site 55 to Site 65	10	4.743576	47.435756
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Chan tow ards Padilla Bay	10	0.870967	8.709673
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
to ph28	11	0.390434	4.294769
NF from Grain of Sand to Fishtow n Bar Area	2	0.87779	1.755581
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
from ph21 to center of Telegraph NE poly (from so)	12	0.356318	4.275818
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
up Sw in Chan from McGlinn to Old Bridge	10	1.595842	15.95842
up Sw in Channel from Old Bridge to Site 55	10	0.158308	1.583078
up Sw in Channel from Site 65 to ph28	10	0.752368	7.523679
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108
Skagit mainstem, start of theme	1	0.237912	0.237912
NF from Grain of Sand to Fishtow n Bar Area	2	0.634706	1.269412
from ph28 up old Telegraph Sl	11	2.478838	27.267215
from old Telegraph Sl to ph21	12	0.066889	0.802664
up Sw in Channel to McGlinn	10	0.5079	5.079004

Figure 18



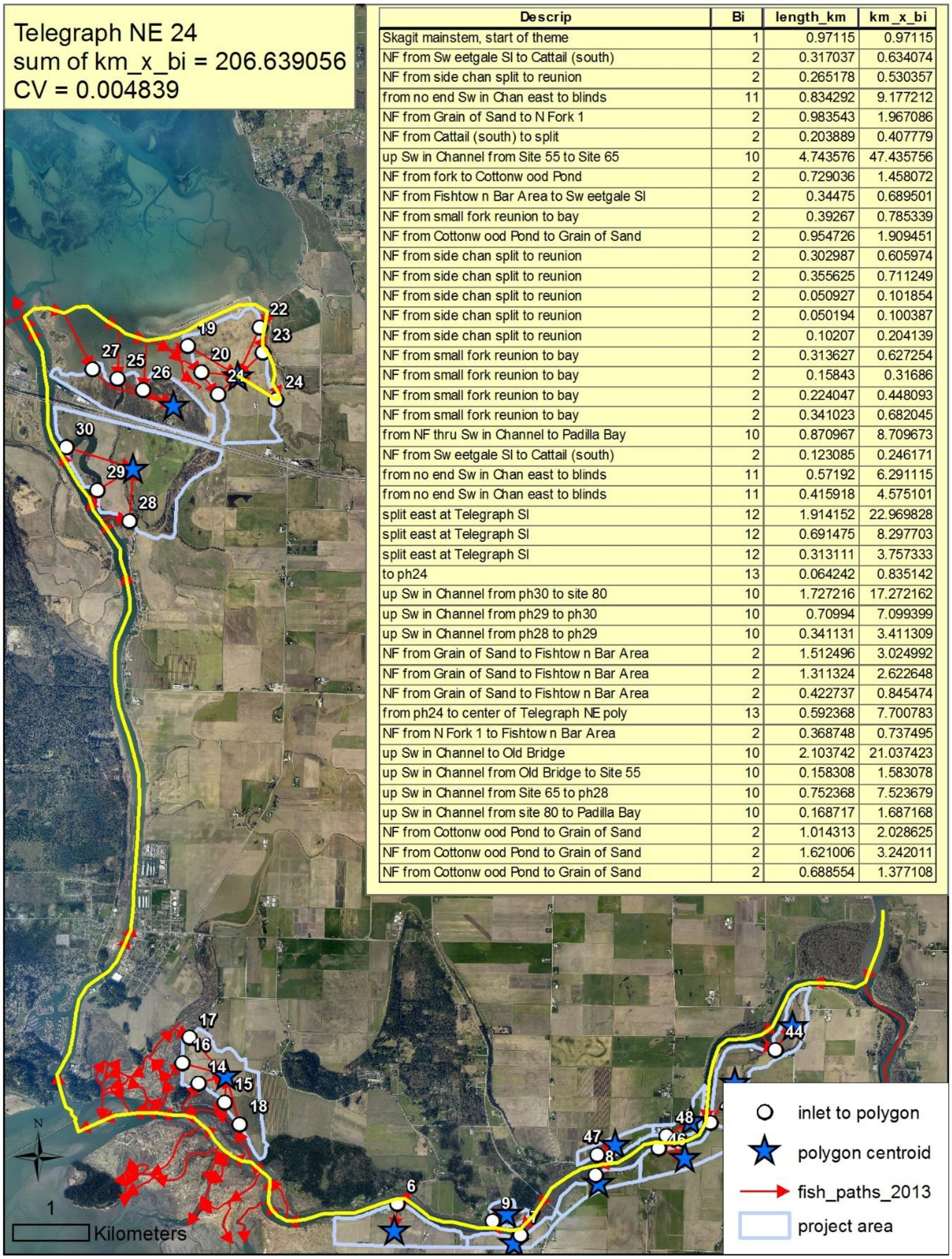
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
from no end Sw in Chan east to blinds	11	0.834292	9.177212
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
up Sw in Channel from Site 55 to Site 65	10	4.743576	47.435756
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Channel to Padilla Bay	10	0.870967	8.709673
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
from no end Sw in Chan east to blinds	11	0.57192	6.291115
from no end Sw in Chan east to blinds	11	0.415918	4.575101
split east at Telegraph Sl	12	1.914152	22.969828
to ph22	13	0.063355	0.823611
up Sw in Channel from ph30 to site 80	10	1.727216	17.272162
up Sw in Channel from ph29 to ph30	10	0.70994	7.099399
up Sw in Channel from ph28 to ph29	10	0.341131	3.411309
NF from Grain of Sand to Fishtow n Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
from ph22 to center of Telegraph NE poly	13	0.702232	9.129018
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
up Sw in Channel to Old Bridge	10	2.103742	21.037423
up Sw in Channel from Old Bridge to Site 55	10	0.158308	1.583078
up Sw in Channel from Site 65 to ph28	10	0.752368	7.523679
up Sw in Channel from site 80 to Padilla Bay	10	0.168717	1.687168
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 19



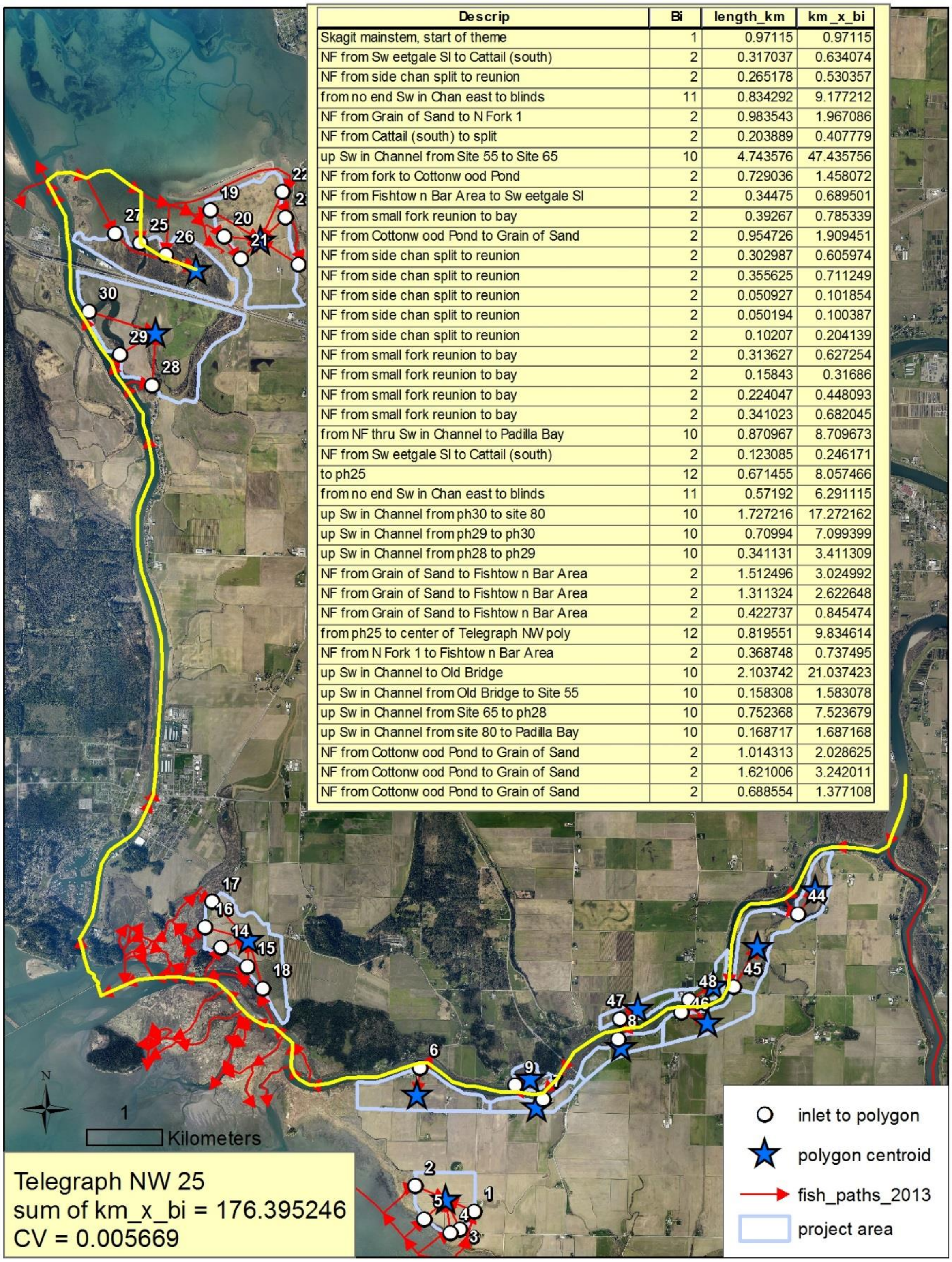
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.733238	0.733238
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
from no end Sw in Chan east to blinds	11	0.834292	9.177212
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
up Sw in Channel from Site 55 to Site 65	10	4.743576	47.435756
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Channel to Padilla Bay	10	0.870967	8.709673
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
from no end Sw in Chan east to blinds	11	0.57192	6.291115
from no end Sw in Chan east to blinds	11	0.415918	4.575101
split east at Telegraph Sl	12	1.914152	22.969828
split east at Telegraph Sl	12	0.313111	3.757333
to ph23	13	0.051625	0.671125
up Sw in Channel from ph30 to site 80	10	1.727216	17.272162
up Sw in Channel from ph29 to ph30	10	0.70994	7.099399
up Sw in Channel from ph28 to ph29	10	0.341131	3.411309
NF from Grain of Sand to Fishtow n Bar Area	2	0.87779	1.755581
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
from ph23 to center of Telegraph NE poly	13	0.452228	5.878959
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
up Sw in Channel to Old Bridge	10	2.103742	21.037423
up Sw in Channel from Old Bridge to Site 55	10	0.158308	1.583078
up Sw in Channel from Site 65 to ph28	10	0.752368	7.523679
up Sw in Channel from site 80 to Padilla Bay	10	0.168717	1.687168
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 20



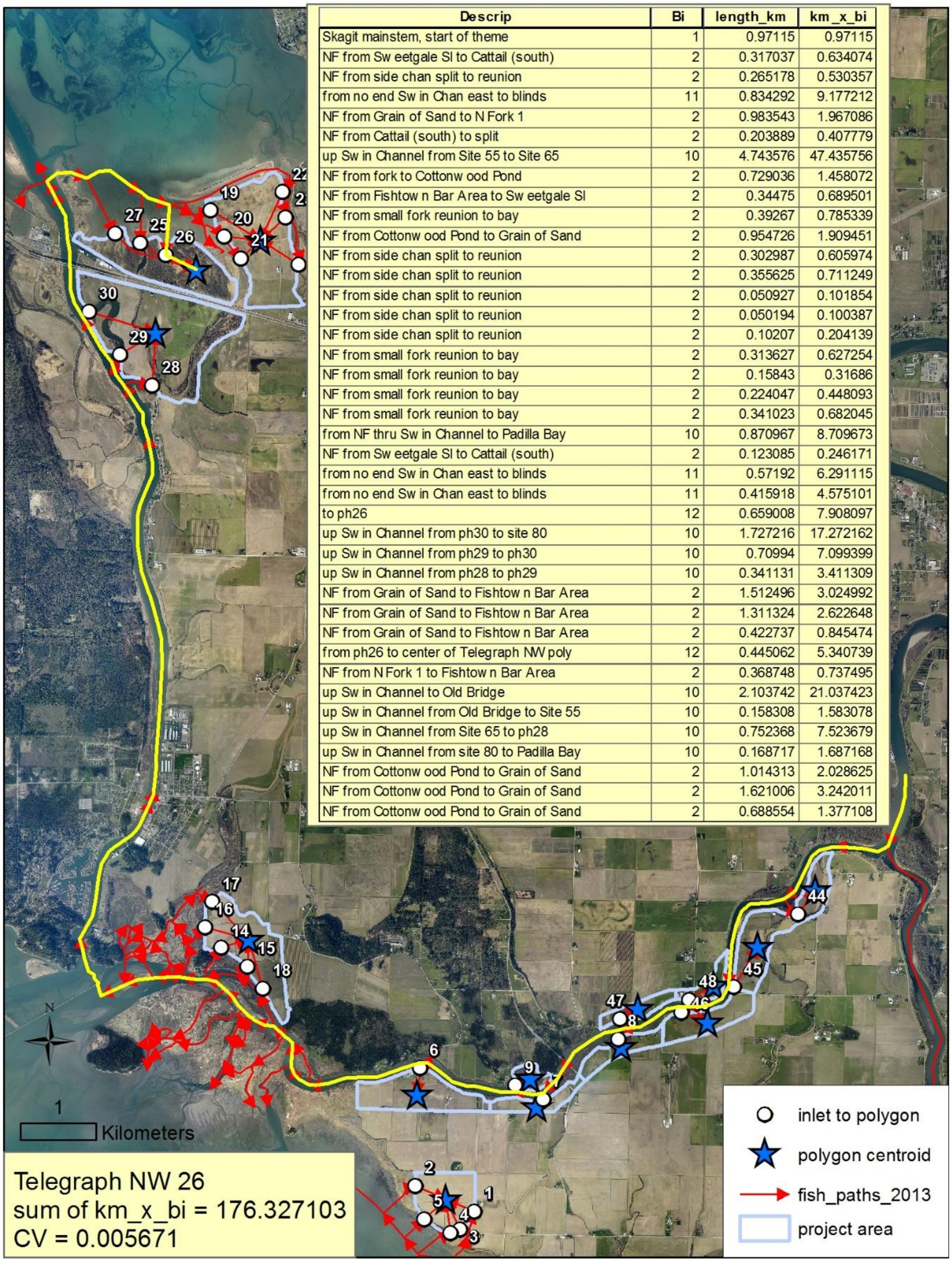
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
from no end Sw in Chan east to blinds	11	0.834292	9.177212
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
up Sw in Channel from Site 55 to Site 65	10	4.743576	47.435756
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Channel to Padilla Bay	10	0.870967	8.709673
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
from no end Sw in Chan east to blinds	11	0.57192	6.291115
from no end Sw in Chan east to blinds	11	0.415918	4.575101
split east at Telegraph Sl	12	1.914152	22.969828
split east at Telegraph Sl	12	0.691475	8.297703
split east at Telegraph Sl	12	0.313111	3.757333
to ph24	13	0.064242	0.835142
up Sw in Channel from ph30 to site 80	10	1.727216	17.272162
up Sw in Channel from ph29 to ph30	10	0.70994	7.099399
up Sw in Channel from ph28 to ph29	10	0.341131	3.411309
NF from Grain of Sand to Fishtow n Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
from ph24 to center of Telegraph NE poly	13	0.592368	7.700783
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
up Sw in Channel to Old Bridge	10	2.103742	21.037423
up Sw in Channel from Old Bridge to Site 55	10	0.158308	1.583078
up Sw in Channel from Site 65 to ph28	10	0.752368	7.523679
up Sw in Channel from site 80 to Padilla Bay	10	0.168717	1.687168
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 21



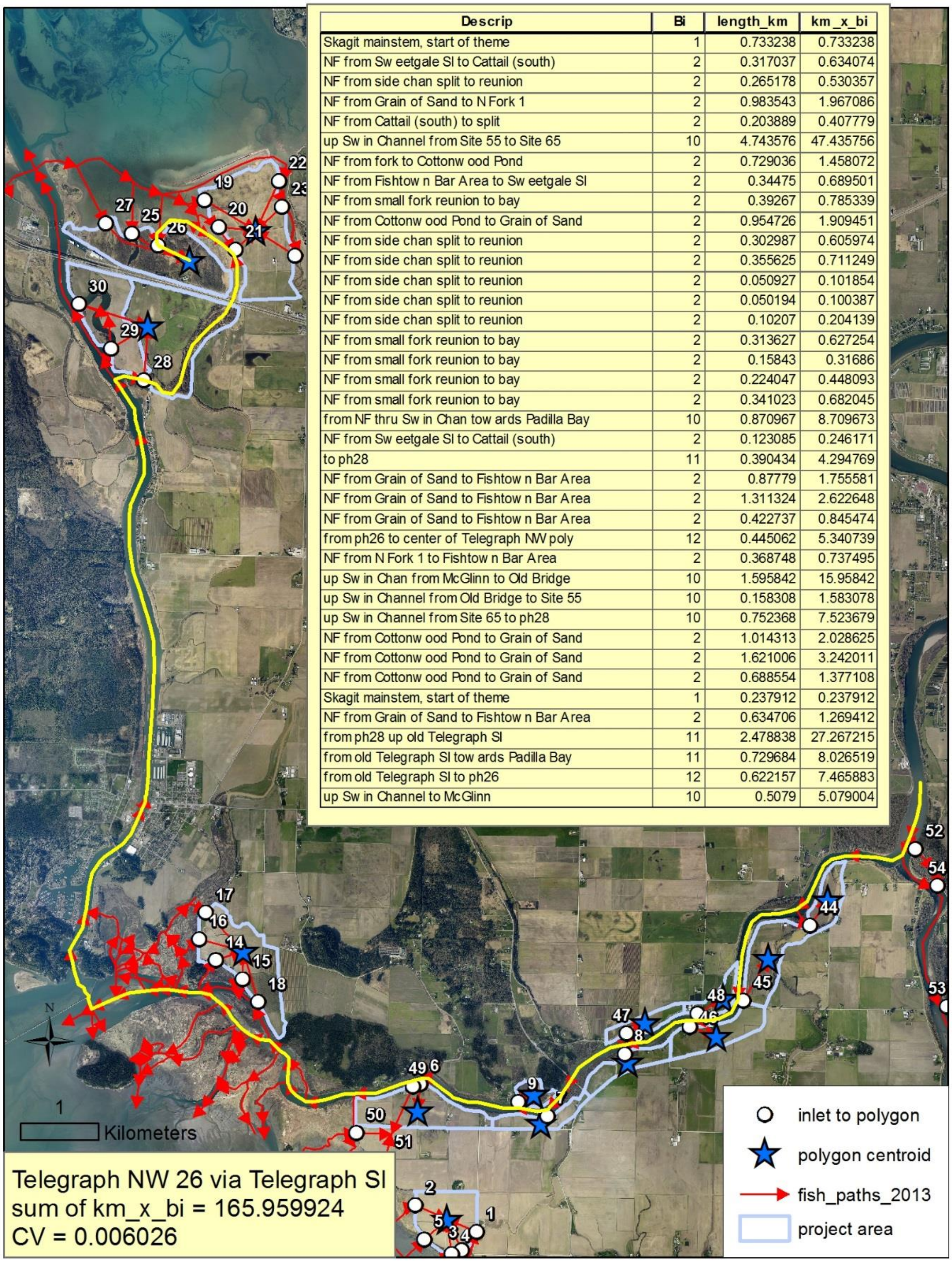
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
from no end Sw in Chan east to blinds	11	0.834292	9.177212
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
up Sw in Channel from Site 55 to Site 65	10	4.743576	47.435756
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Channel to Padilla Bay	10	0.870967	8.709673
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
to ph25	12	0.671455	8.057466
from no end Sw in Chan east to blinds	11	0.57192	6.291115
up Sw in Channel from ph30 to site 80	10	1.727216	17.272162
up Sw in Channel from ph29 to ph30	10	0.70994	7.099399
up Sw in Channel from ph28 to ph29	10	0.341131	3.411309
NF from Grain of Sand to Fishtow n Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
from ph25 to center of Telegraph NW poly	12	0.819551	9.834614
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
up Sw in Channel to Old Bridge	10	2.103742	21.037423
up Sw in Channel from Old Bridge to Site 55	10	0.158308	1.583078
up Sw in Channel from Site 65 to ph28	10	0.752368	7.523679
up Sw in Channel from site 80 to Padilla Bay	10	0.168717	1.687168
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 22



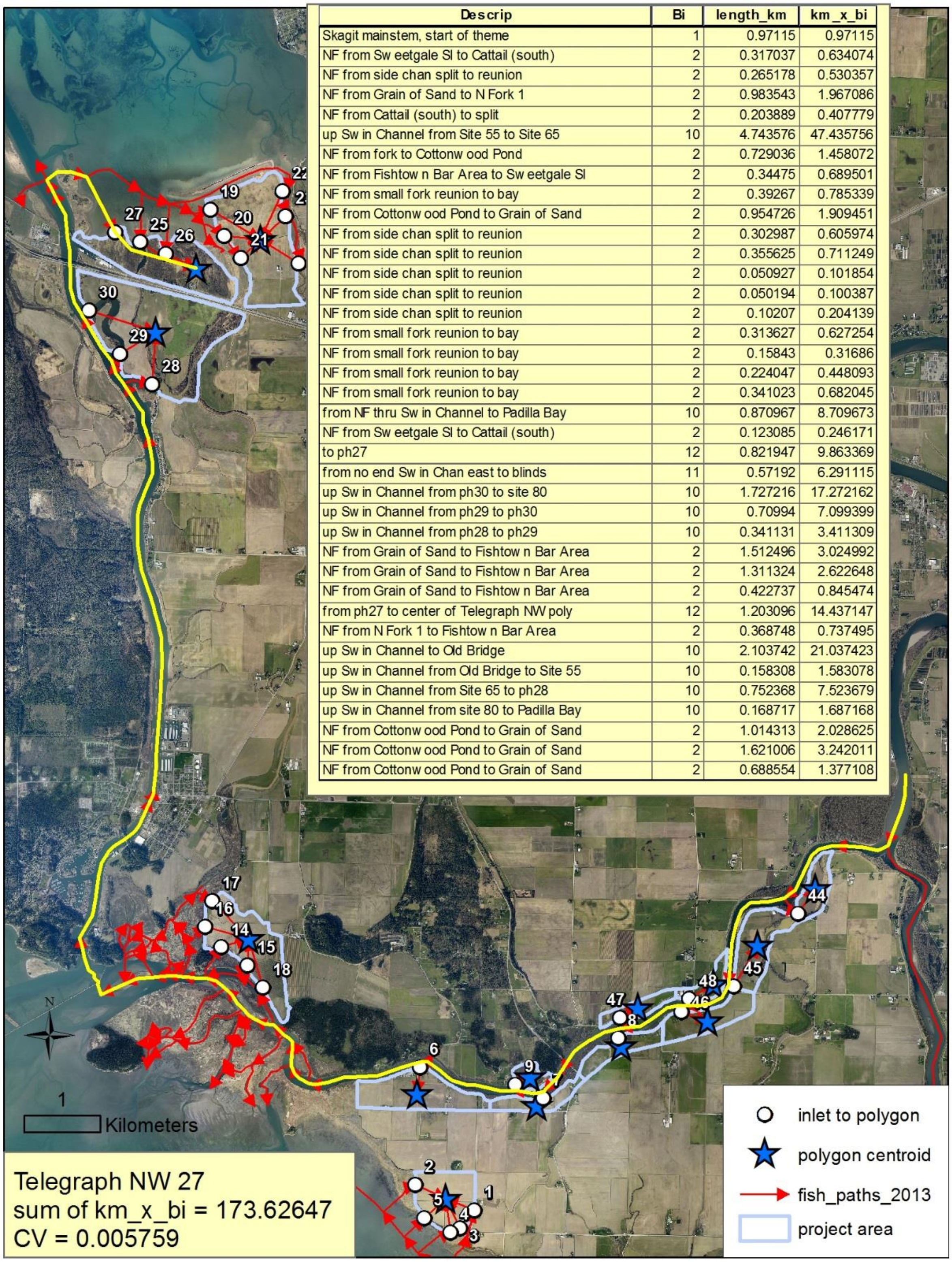
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
from no end Sw in Chan east to blinds	11	0.834292	9.177212
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
up Sw in Channel from Site 55 to Site 65	10	4.743576	47.435756
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Channel to Padilla Bay	10	0.870967	8.709673
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
from no end Sw in Chan east to blinds	11	0.57192	6.291115
from no end Sw in Chan east to blinds	11	0.415918	4.575101
to ph26	12	0.659008	7.908097
up Sw in Channel from ph30 to site 80	10	1.727216	17.272162
up Sw in Channel from ph29 to ph30	10	0.70994	7.099399
up Sw in Channel from ph28 to ph29	10	0.341131	3.411309
NF from Grain of Sand to Fishtow n Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
from ph26 to center of Telegraph NW poly	12	0.445062	5.340739
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
up Sw in Channel to Old Bridge	10	2.103742	21.037423
up Sw in Channel from Old Bridge to Site 55	10	0.158308	1.583078
up Sw in Channel from Site 65 to ph28	10	0.752368	7.523679
up Sw in Channel from site 80 to Padilla Bay	10	0.168717	1.687168
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 23



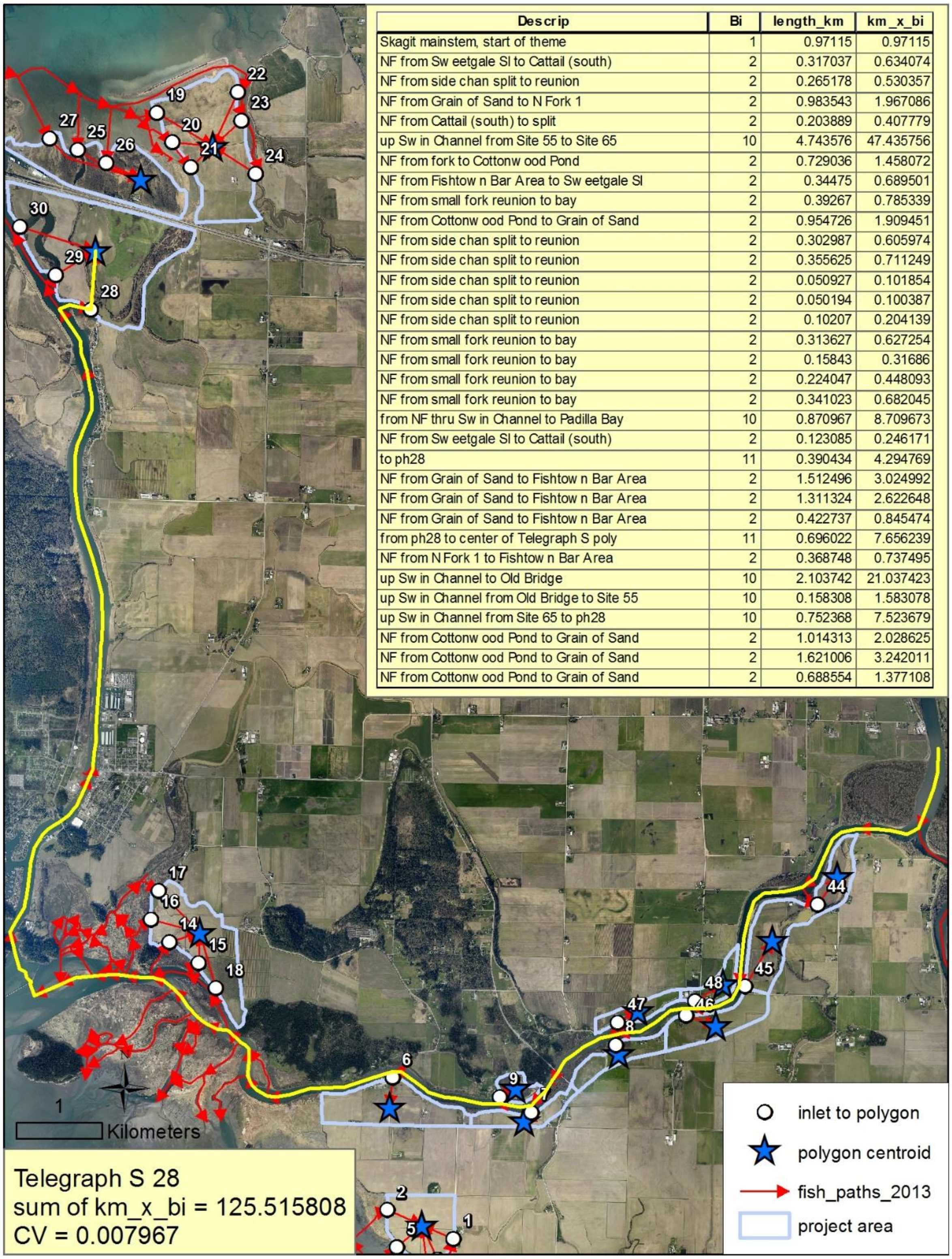
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.733238	0.733238
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
up Sw in Channel from Site 55 to Site 65	10	4.743576	47.435756
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Chan tow ards Padilla Bay	10	0.870967	8.709673
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
to ph28	11	0.390434	4.294769
NF from Grain of Sand to Fishtow n Bar Area	2	0.87779	1.755581
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
from ph26 to center of Telegraph NW poly	12	0.445062	5.340739
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
up Sw in Chan from McGlinn to Old Bridge	10	1.595842	15.95842
up Sw in Channel from Old Bridge to Site 55	10	0.158308	1.583078
up Sw in Channel from Site 65 to ph28	10	0.752368	7.523679
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108
Skagit mainstem, start of theme	1	0.237912	0.237912
NF from Grain of Sand to Fishtow n Bar Area	2	0.634706	1.269412
from ph28 up old Telegraph Sl	11	2.478838	27.267215
from old Telegraph Sl tow ards Padilla Bay	11	0.729684	8.026519
from old Telegraph Sl to ph26	12	0.622157	7.465883
up Sw in Channel to McGlinn	10	0.5079	5.079004

Figure 24



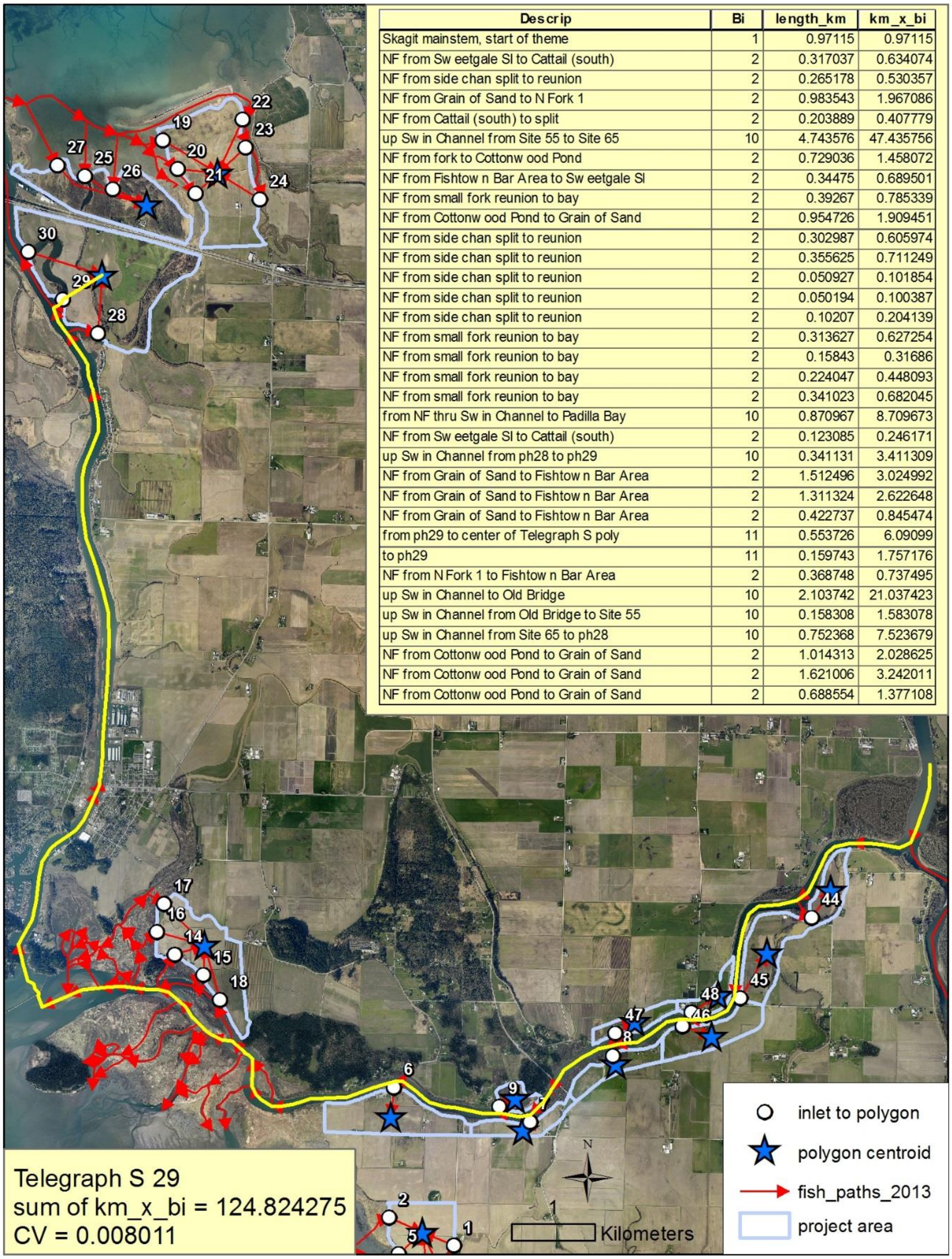
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
up Sw in Channel from Site 55 to Site 65	10	4.743576	47.435756
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Channel to Padilla Bay	10	0.870967	8.709673
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
to ph27	12	0.821947	9.863369
from no end Sw in Chan east to blinds	11	0.57192	6.291115
up Sw in Channel from ph30 to site 80	10	1.727216	17.272162
up Sw in Channel from ph29 to ph30	10	0.70994	7.099399
up Sw in Channel from ph28 to ph29	10	0.341131	3.411309
NF from Grain of Sand to Fishtow n Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
from ph27 to center of Telegraph NW poly	12	1.203096	14.437147
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
up Sw in Channel to Old Bridge	10	2.103742	21.037423
up Sw in Channel from Old Bridge to Site 55	10	0.158308	1.583078
up Sw in Channel from Site 65 to ph28	10	0.752368	7.523679
up Sw in Channel from site 80 to Padilla Bay	10	0.168717	1.687168
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 25



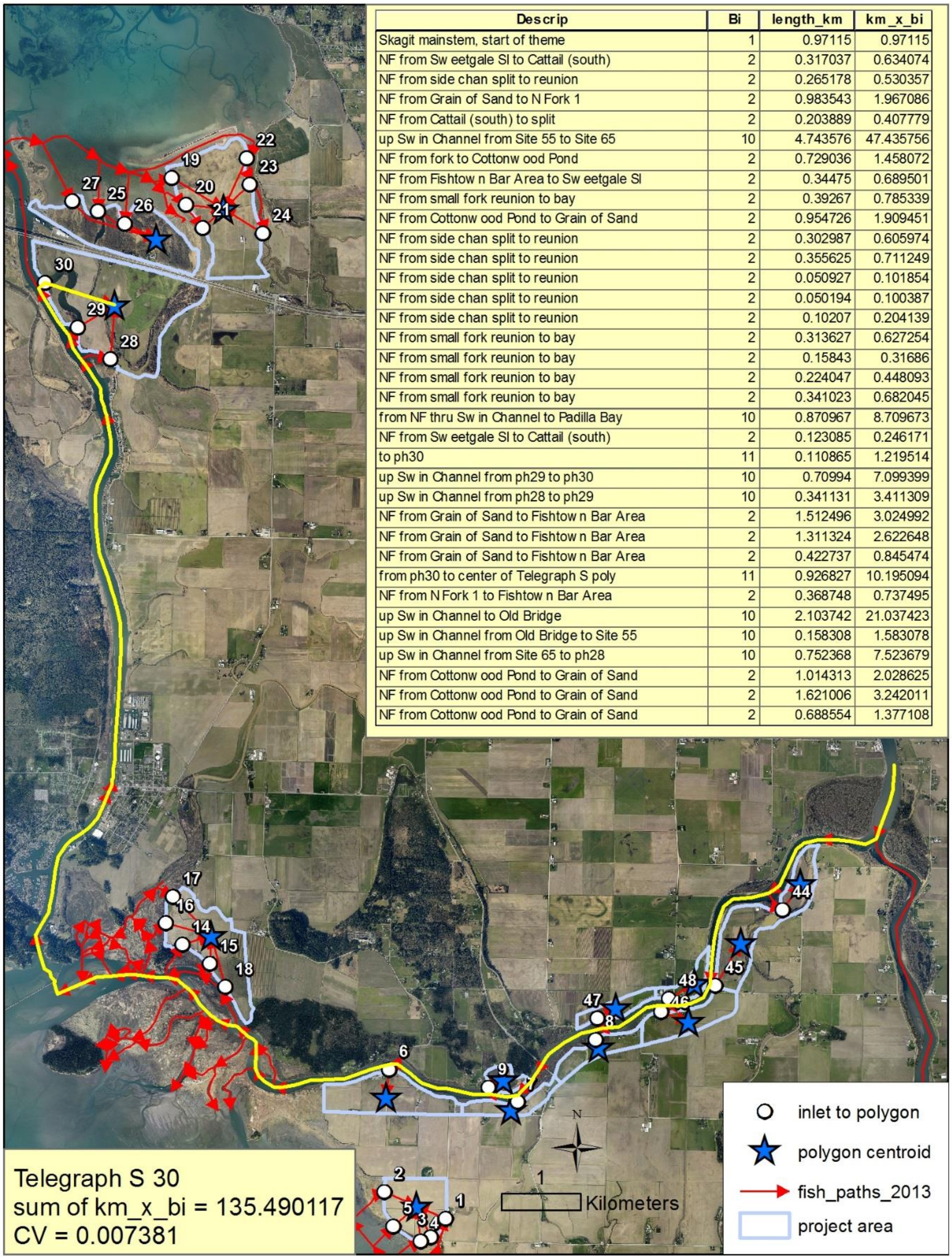
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Sweetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
up Sw in Channel from Site 55 to Site 65	10	4.743576	47.435756
NF from fork to Cottonwood Pond	2	0.729036	1.458072
NF from Fishtown Bar Area to Sweetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonwood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Channel to Padilla Bay	10	0.870967	8.709673
NF from Sweetgale Sl to Cattail (south)	2	0.123085	0.246171
to ph28	11	0.390434	4.294769
NF from Grain of Sand to Fishtown Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtown Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtown Bar Area	2	0.422737	0.845474
from ph28 to center of Telegraph S poly	11	0.696022	7.656239
NF from N Fork 1 to Fishtown Bar Area	2	0.368748	0.737495
up Sw in Channel to Old Bridge	10	2.103742	21.037423
up Sw in Channel from Old Bridge to Site 55	10	0.158308	1.583078
up Sw in Channel from Site 65 to ph28	10	0.752368	7.523679
NF from Cottonwood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonwood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonwood Pond to Grain of Sand	2	0.688554	1.377108

Figure 26



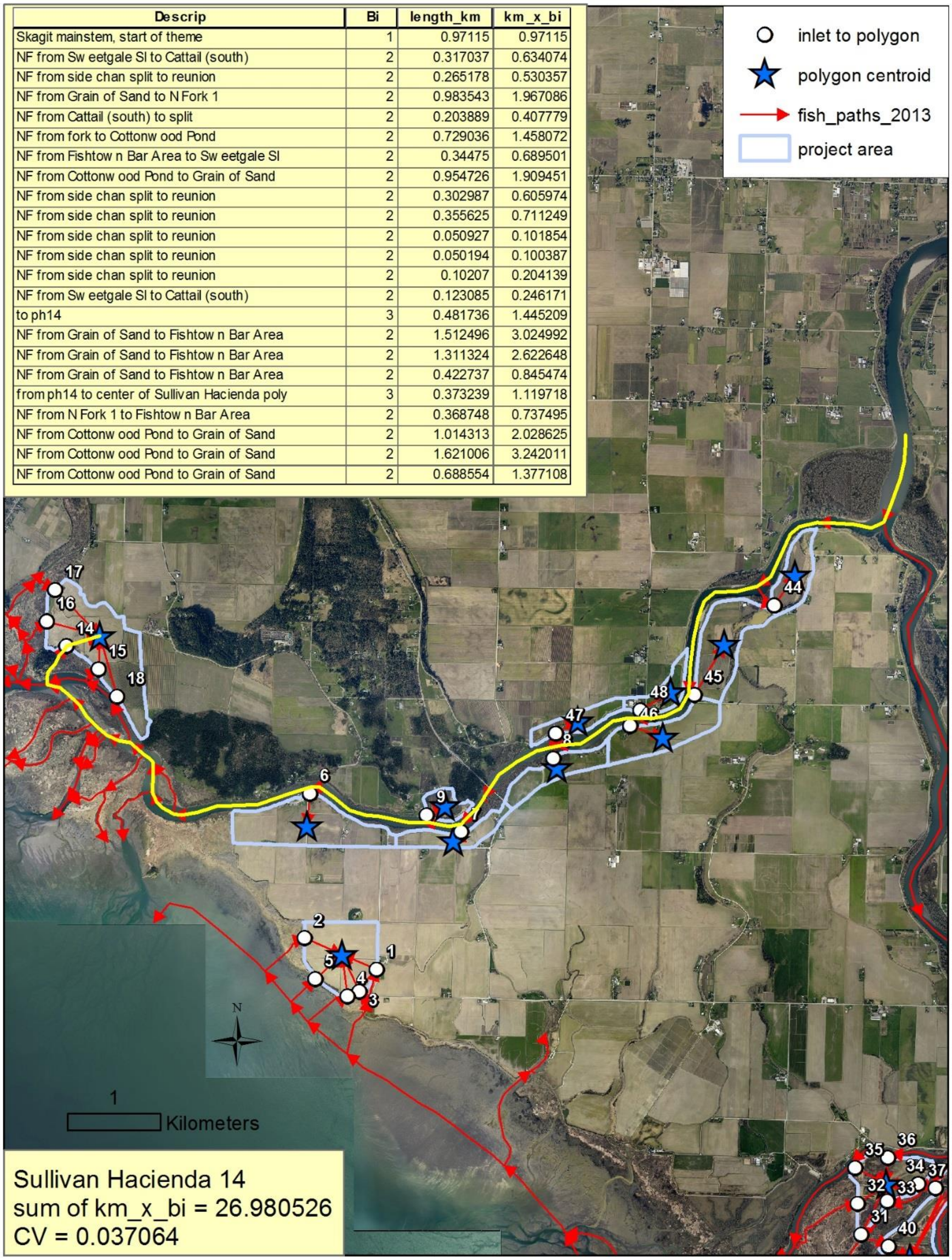
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
up Sw in Channel from Site 55 to Site 65	10	4.743576	47.435756
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Channel to Padilla Bay	10	0.870967	8.709673
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
up Sw in Channel from ph28 to ph29	10	0.341131	3.411309
NF from Grain of Sand to Fishtow n Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
from ph29 to center of Telegraph S poly	11	0.553726	6.09099
to ph29	11	0.159743	1.757176
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
up Sw in Channel to Old Bridge	10	2.103742	21.037423
up Sw in Channel from Old Bridge to Site 55	10	0.158308	1.583078
up Sw in Channel from Site 65 to ph28	10	0.752368	7.523679
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 27



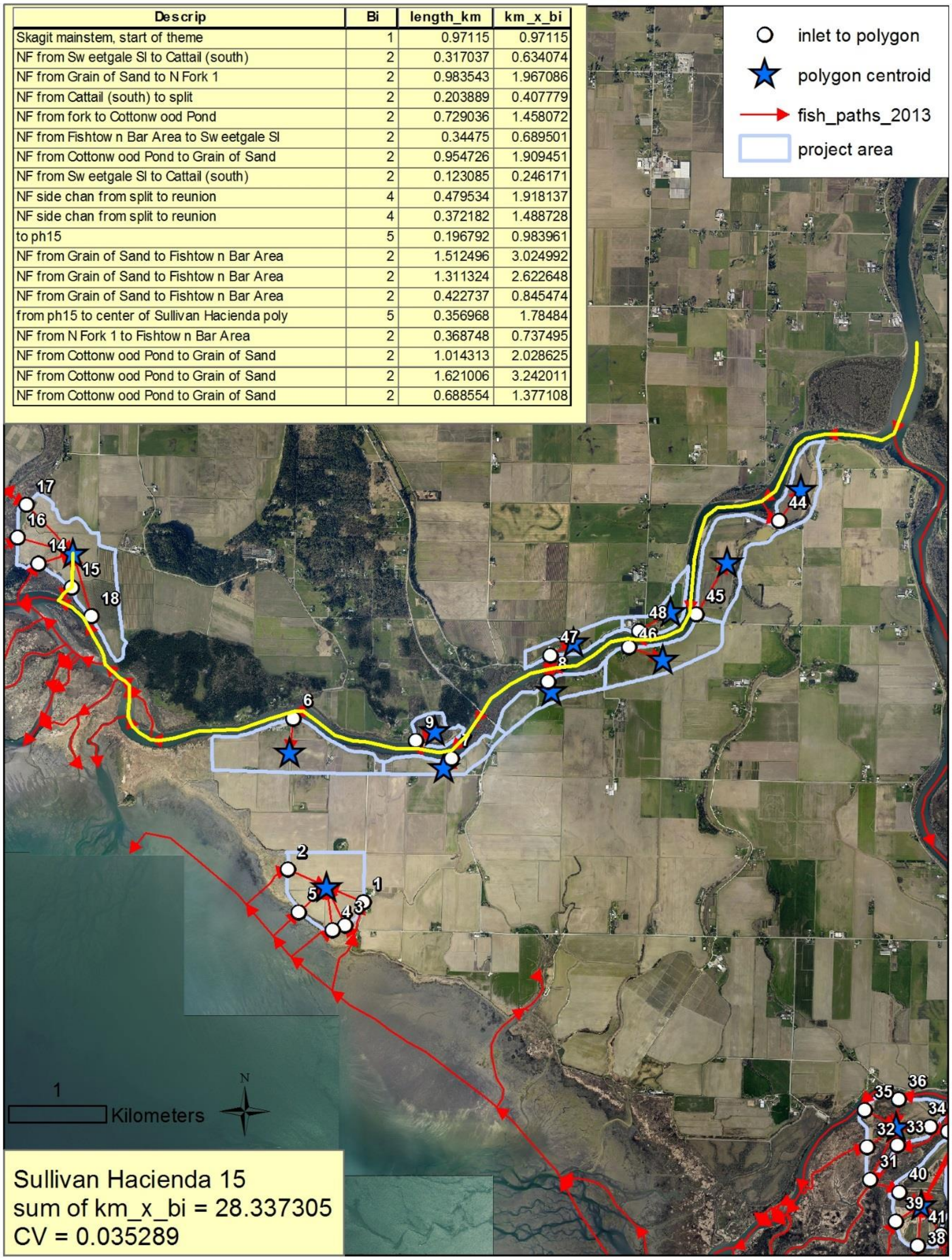
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
up Sw in Channel from Site 55 to Site 65	10	4.743576	47.435756
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Channel to Padilla Bay	10	0.870967	8.709673
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
to ph30	11	0.110865	1.219514
up Sw in Channel from ph29 to ph30	10	0.70994	7.099399
up Sw in Channel from ph28 to ph29	10	0.341131	3.411309
NF from Grain of Sand to Fishtow n Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
from ph30 to center of Telegraph S poly	11	0.926827	10.195094
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
up Sw in Channel to Old Bridge	10	2.103742	21.037423
up Sw in Channel from Old Bridge to Site 55	10	0.158308	1.583078
up Sw in Channel from Site 65 to ph28	10	0.752368	7.523679
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 28



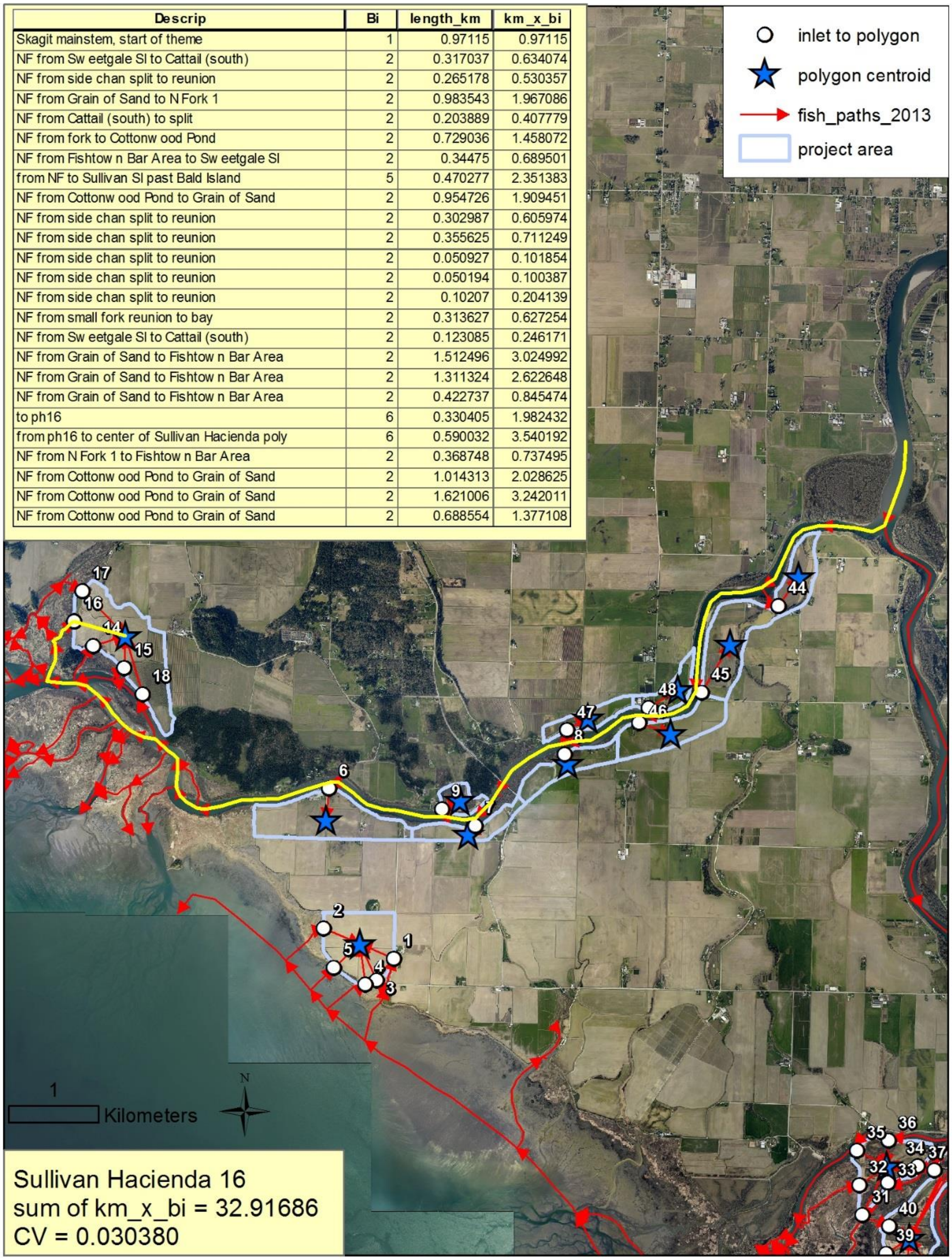
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
to ph14	3	0.481736	1.445209
NF from Grain of Sand to Fishtow n Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
from ph14 to center of Sullivan Hacienda poly	3	0.373239	1.119718
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 29



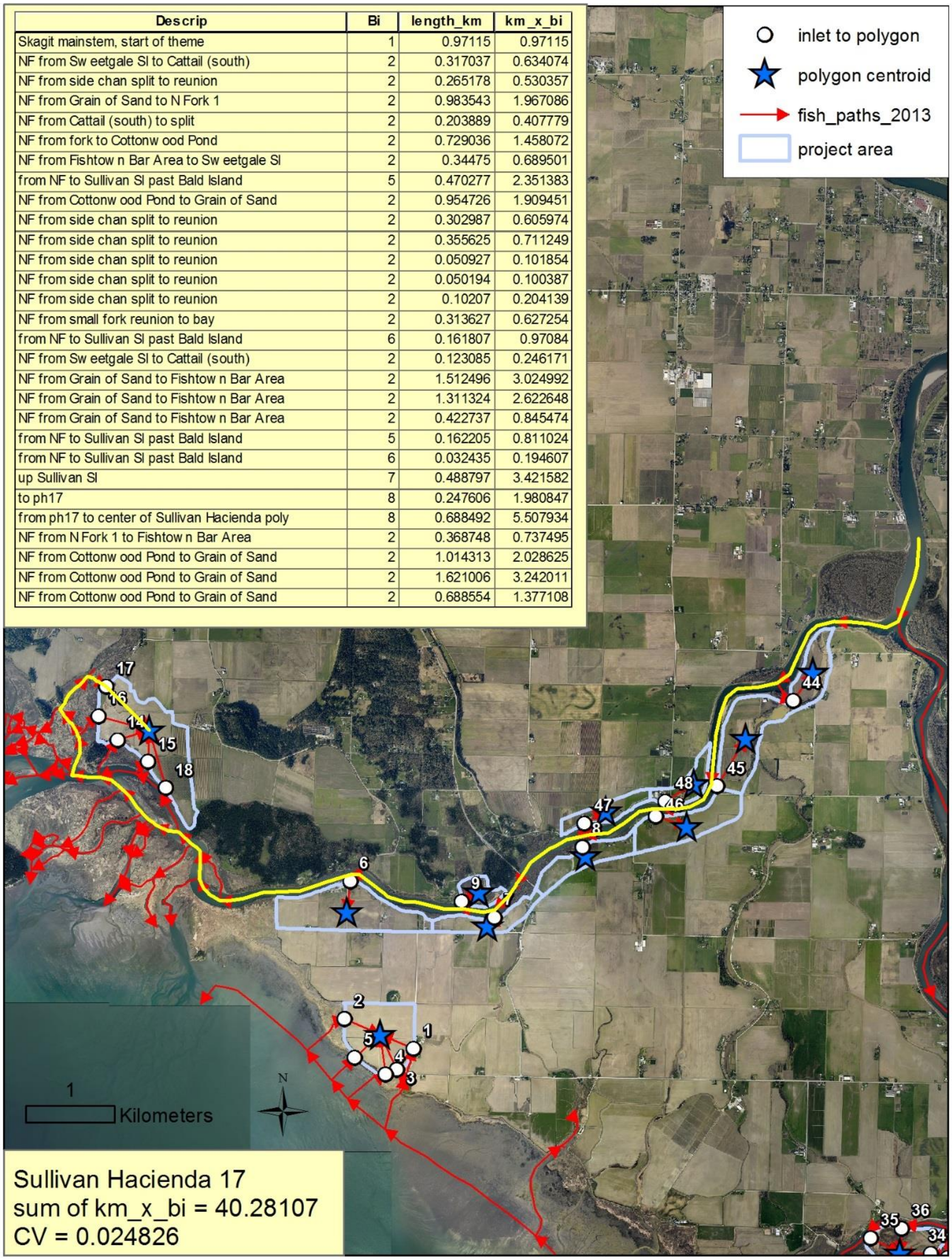
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
NF side chan from split to reunion	4	0.479534	1.918137
NF side chan from split to reunion	4	0.372182	1.488728
to ph15	5	0.196792	0.983961
NF from Grain of Sand to Fishtow n Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
from ph15 to center of Sullivan Hacienda poly	5	0.356968	1.78484
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 30



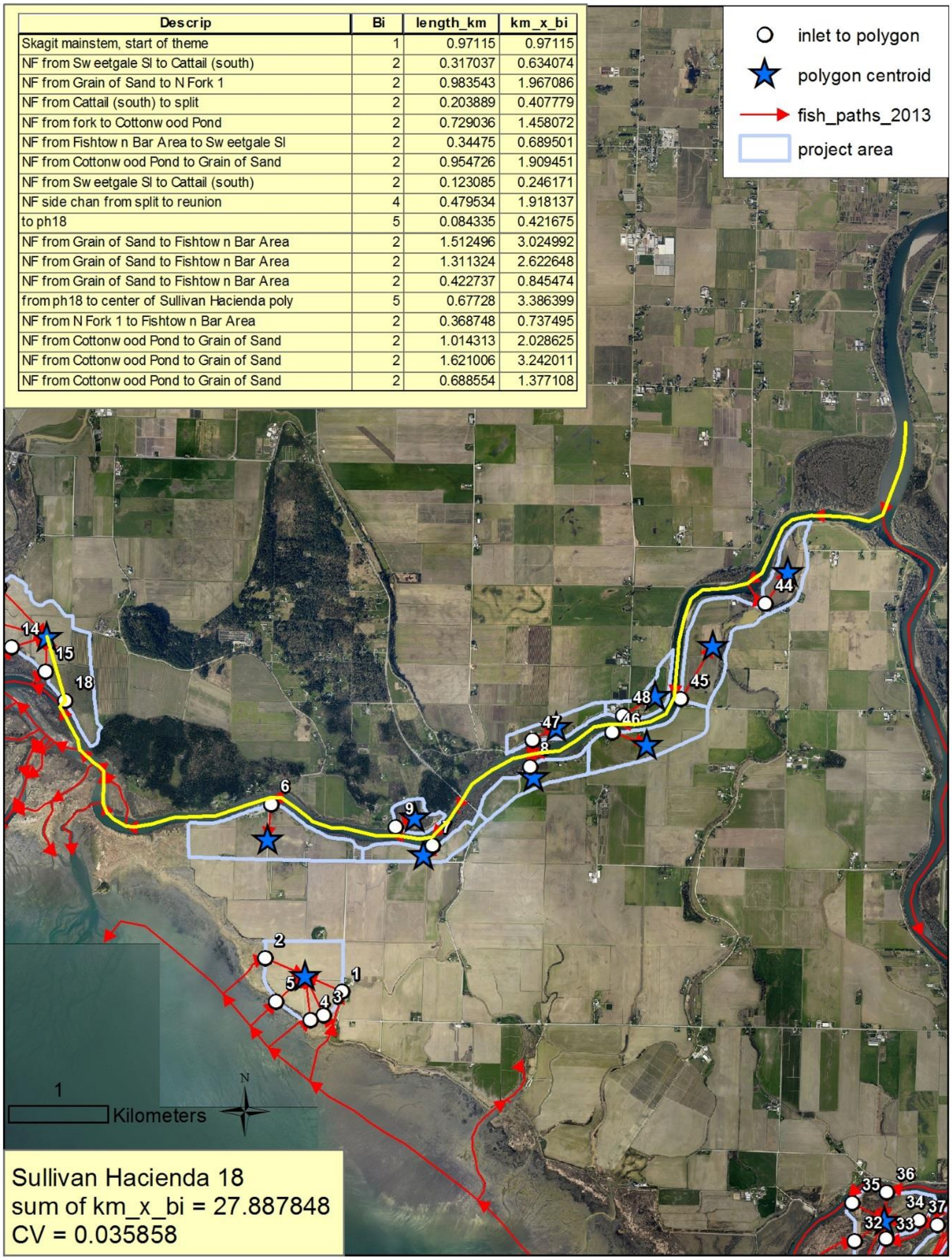
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
from NF to Sullivan Sl past Bald Island	5	0.470277	2.351383
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
NF from Grain of Sand to Fishtow n Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
to ph16	6	0.330405	1.982432
from ph16 to center of Sullivan Hacienda poly	6	0.590032	3.540192
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 31



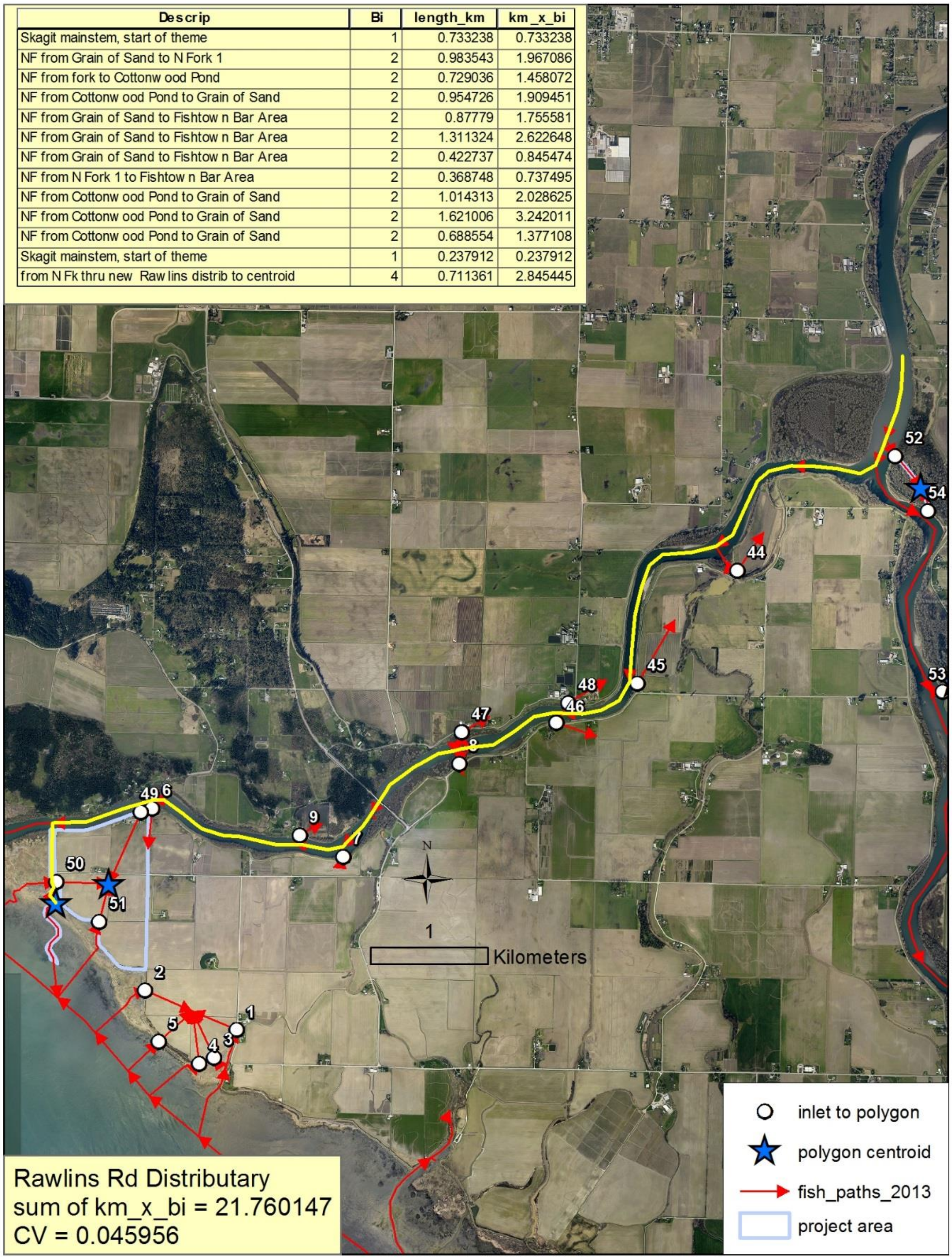
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
from NF to Sullivan Sl past Bald Island	5	0.470277	2.351383
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
from NF to Sullivan Sl past Bald Island	6	0.161807	0.97084
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
NF from Grain of Sand to Fishtow n Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
from NF to Sullivan Sl past Bald Island	5	0.162205	0.811024
from NF to Sullivan Sl past Bald Island	6	0.032435	0.194607
up Sullivan Sl	7	0.488797	3.421582
to ph17	8	0.247606	1.980847
from ph17 to center of Sullivan Hacienda poly	8	0.688492	5.507934
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 32



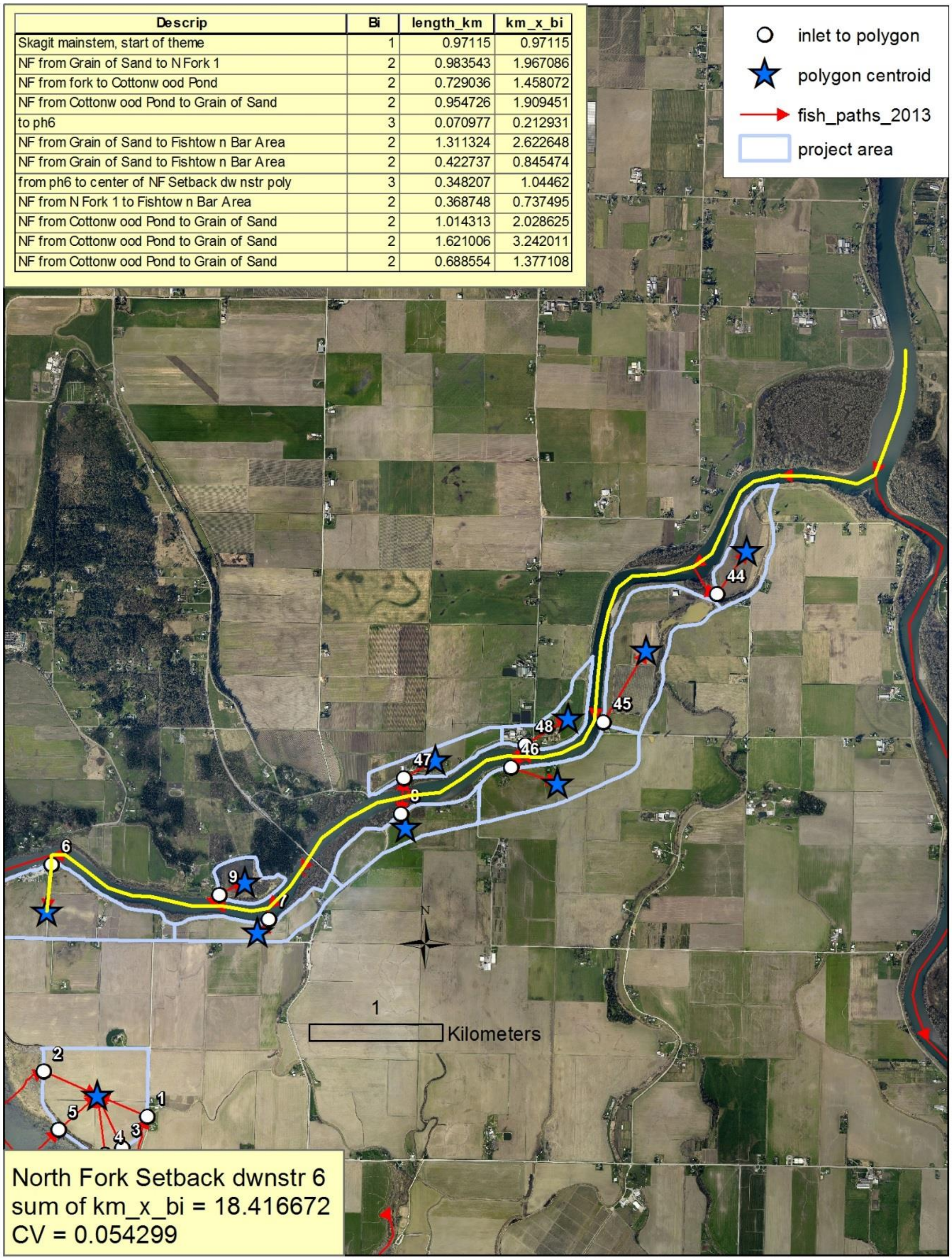
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
NF side chan from split to reunion	4	0.479534	1.918137
to ph18	5	0.084335	0.421675
NF from Grain of Sand to Fishtow n Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
from ph18 to center of Sullivan Hacienda poly	5	0.67728	3.386399
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 33



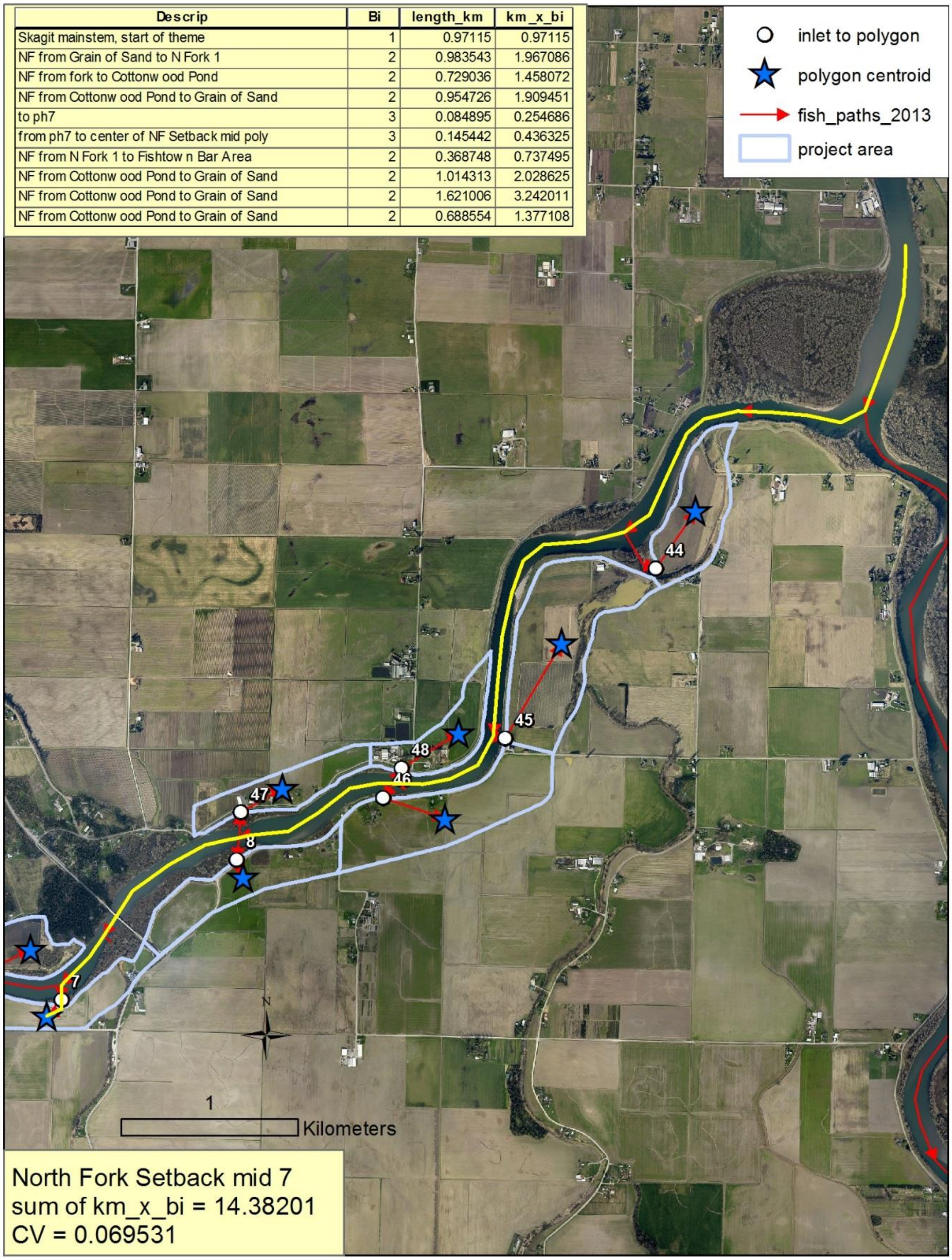
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.733238	0.733238
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from Grain of Sand to Fishtow n Bar Area	2	0.87779	1.755581
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108
Skagit mainstem, start of theme	1	0.237912	0.237912
from N Fk thru new Raw lins distrib to centroid	4	0.711361	2.845445

Figure 34



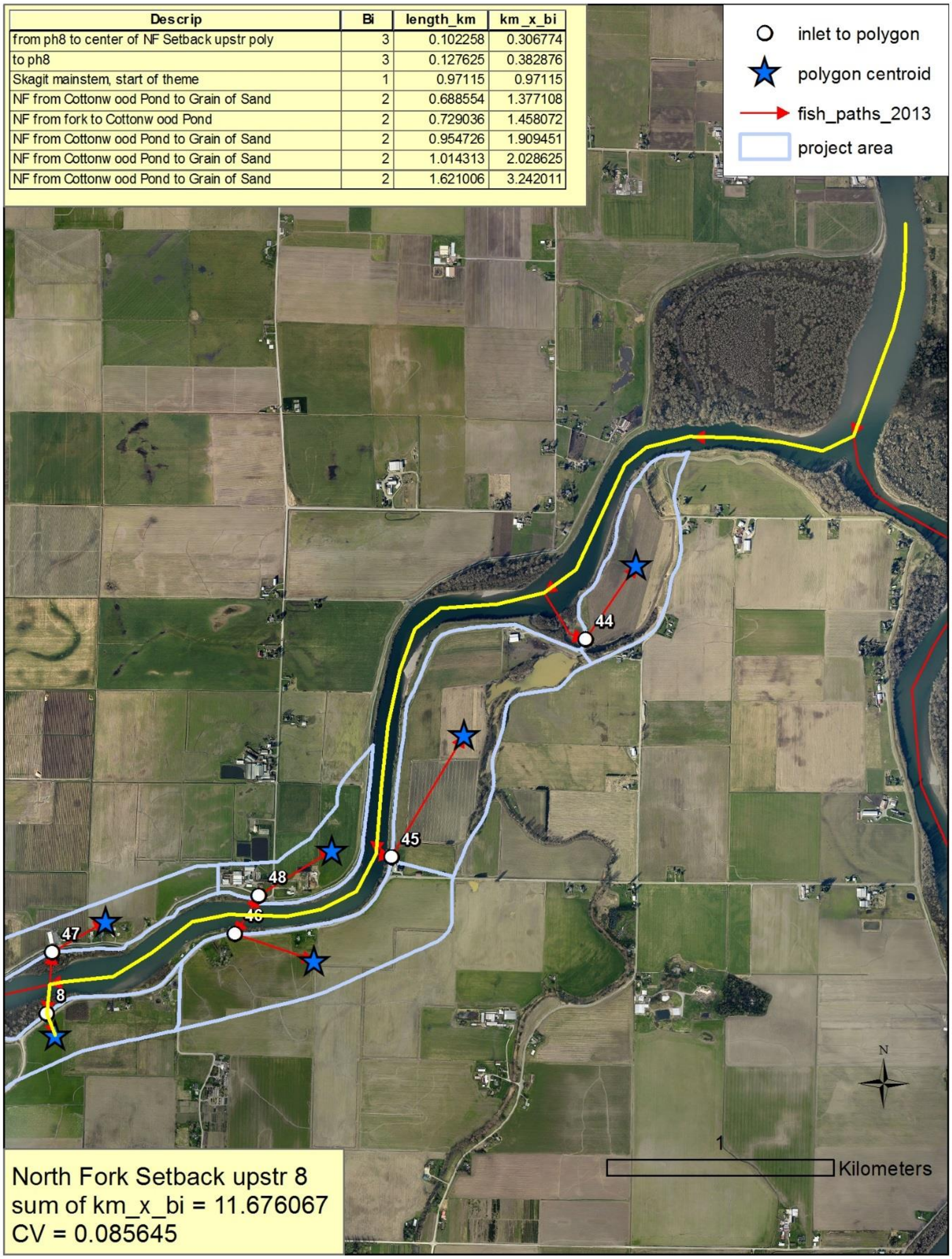
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
to ph6	3	0.070977	0.212931
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
from ph6 to center of NF Setback dw nstr poly	3	0.348207	1.04462
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 35



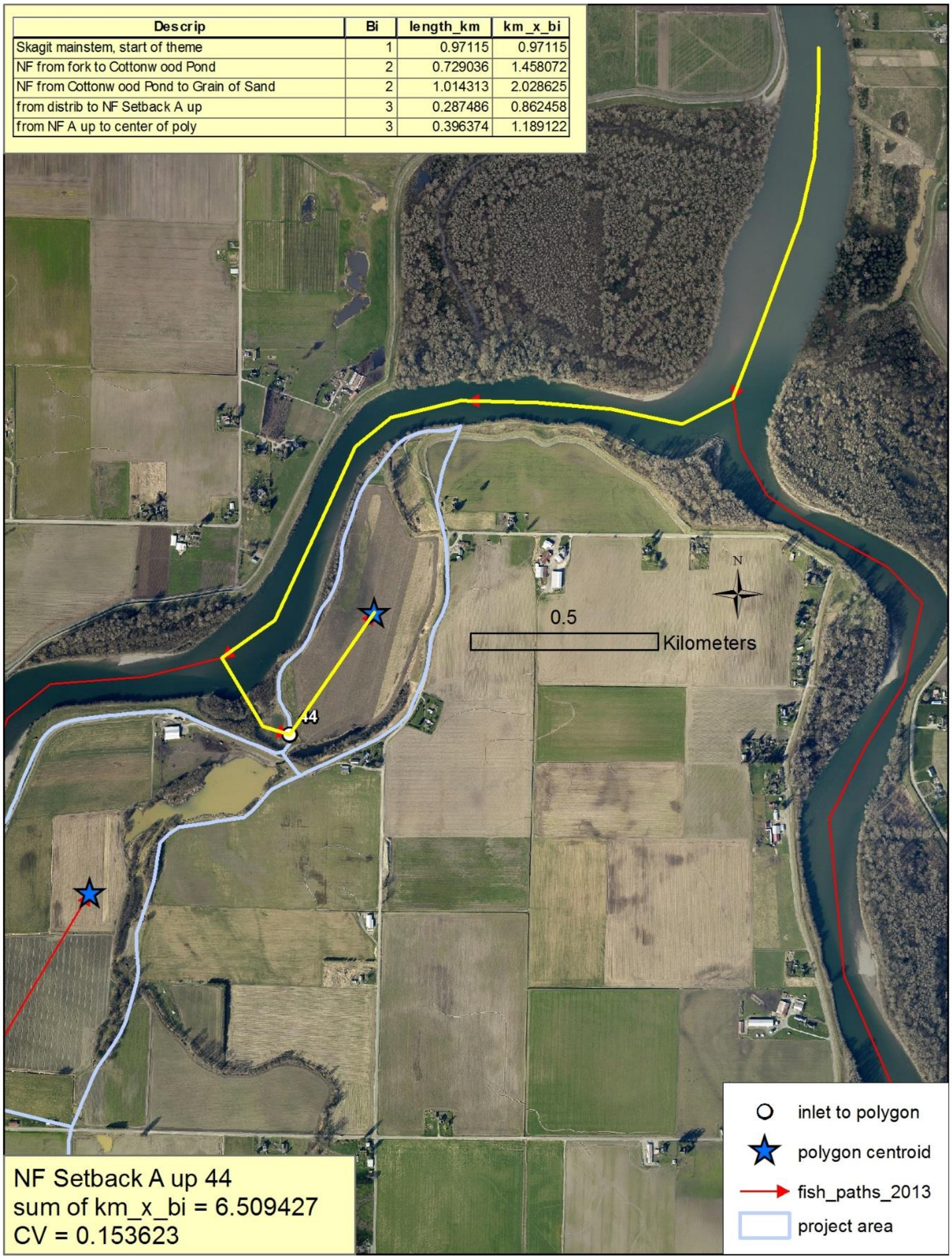
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
to ph7	3	0.084895	0.254686
from ph7 to center of NF Setback mid poly	3	0.145442	0.436325
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 36



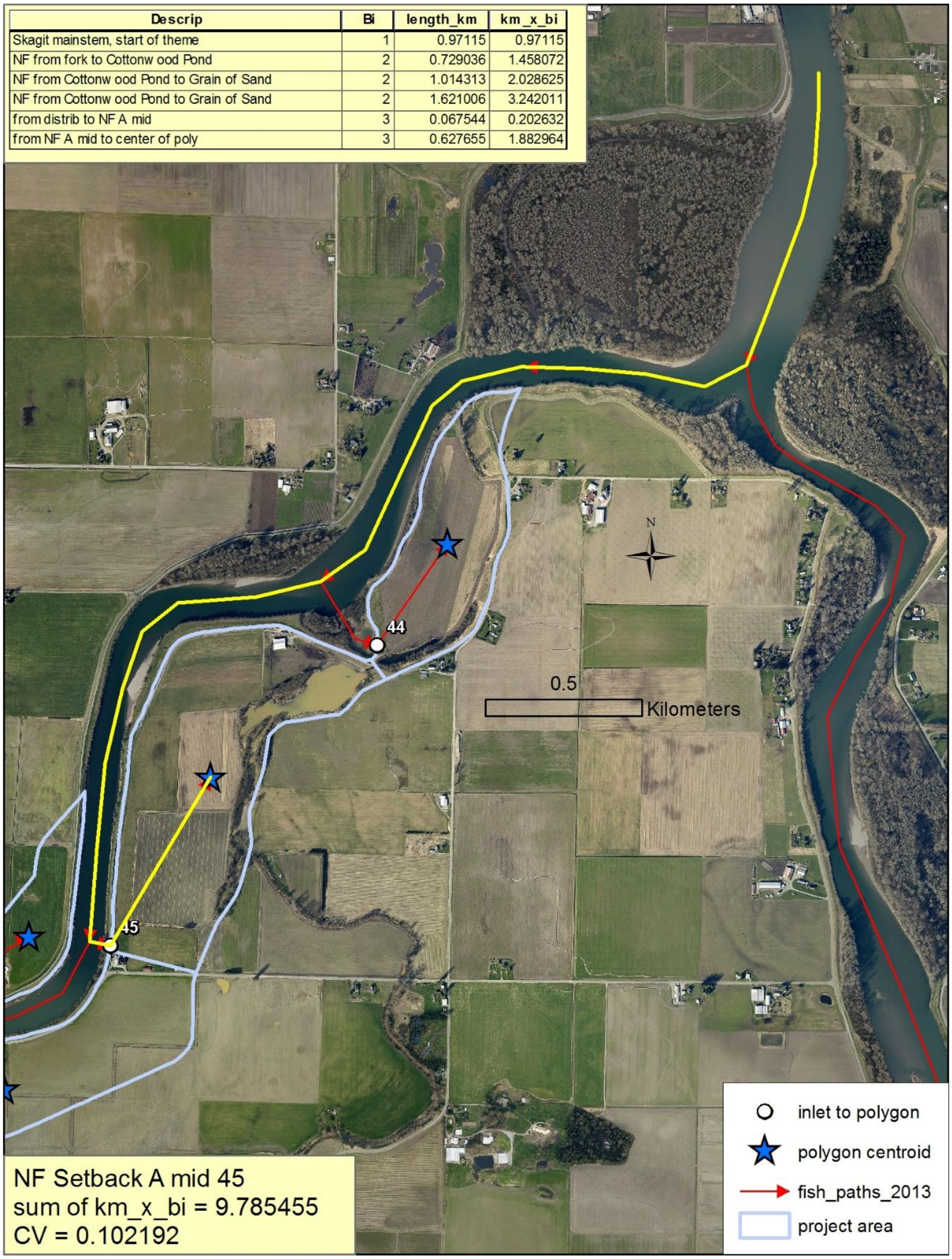
Descrip	Bi	length_km	km_x_bi
from ph8 to center of NF Setback upstr poly	3	0.102258	0.306774
to ph8	3	0.127625	0.382876
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011

Figure 37



Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
from distrib to NF Setback A up	3	0.287486	0.862458
from NF A up to center of poly	3	0.396374	1.189122

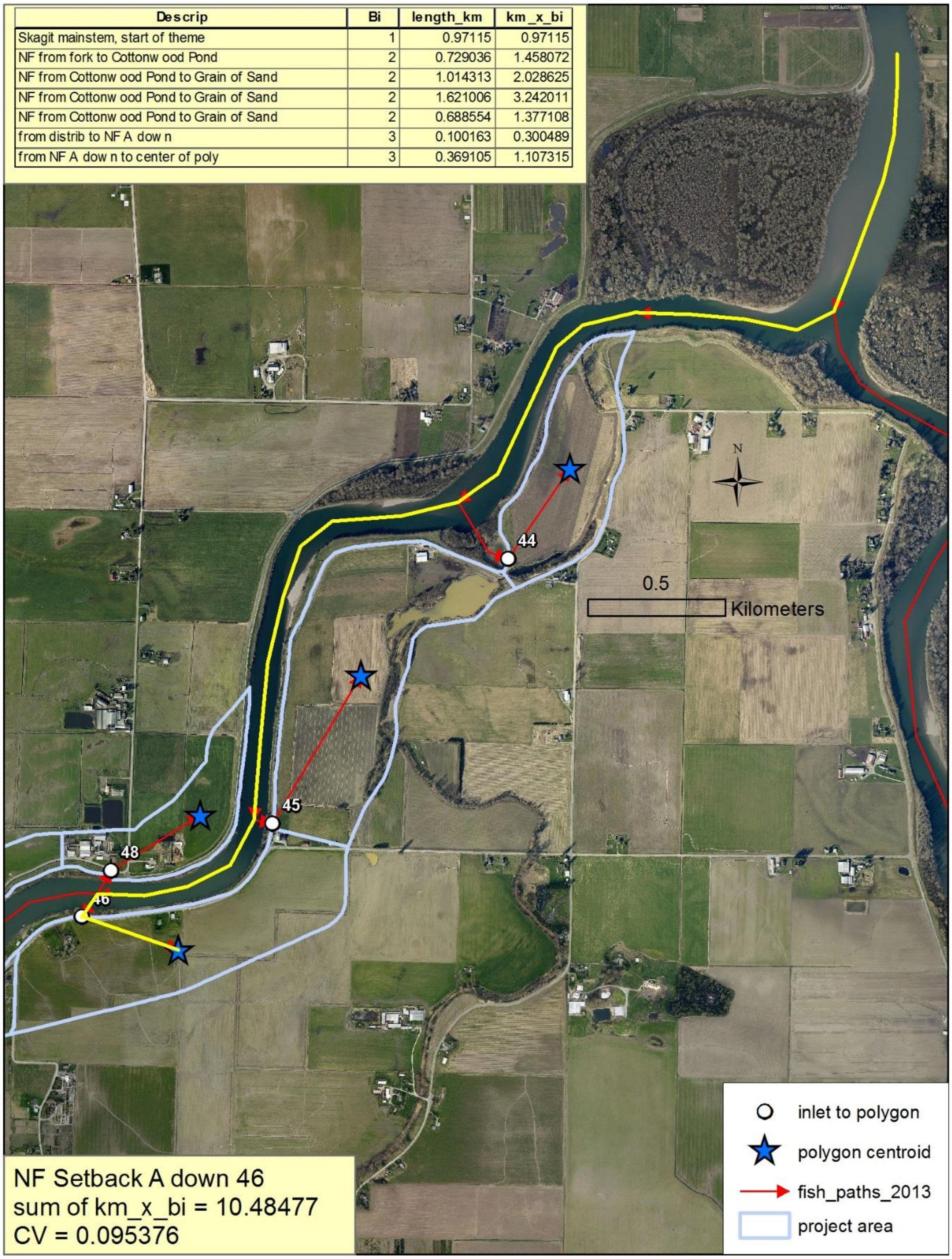
Figure 38



Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
from distrib to NF A mid	3	0.067544	0.202632
from NF A mid to center of poly	3	0.627655	1.882964

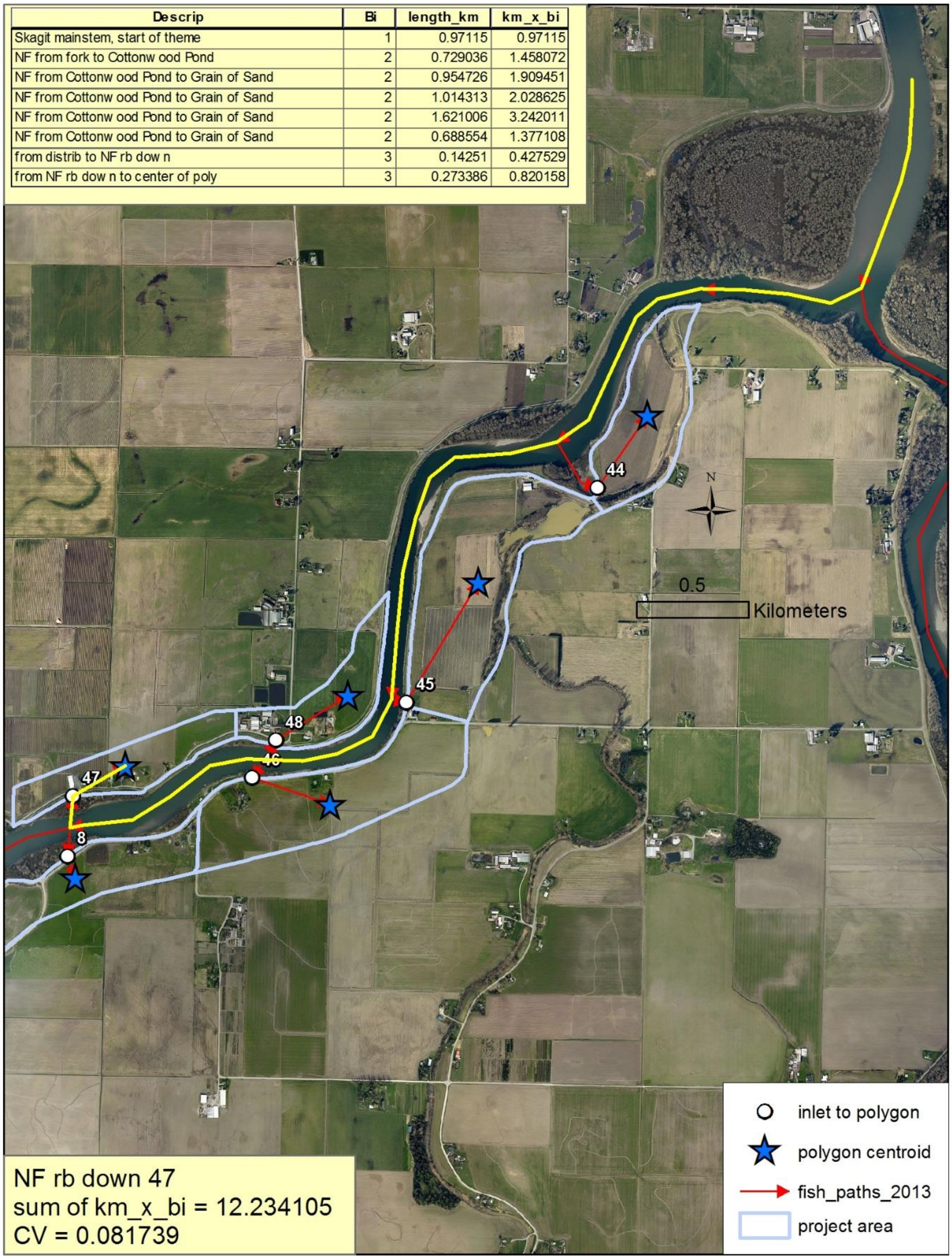
N
44
45
0.5
Kilometers
inlet to polygon
polygon centroid
fish_paths_2013
project area
NF Setback A mid 45
sum of km_x_bi = 9.785455
CV = 0.102192

Figure 39



Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108
from distrib to NF A dow n	3	0.100163	0.300489
from NF A dow n to center of poly	3	0.369105	1.107315

Figure 40



Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108
from distrib to NF rb dow n	3	0.14251	0.427529
from NF rb dow n to center of poly	3	0.273386	0.820158

Figure 41

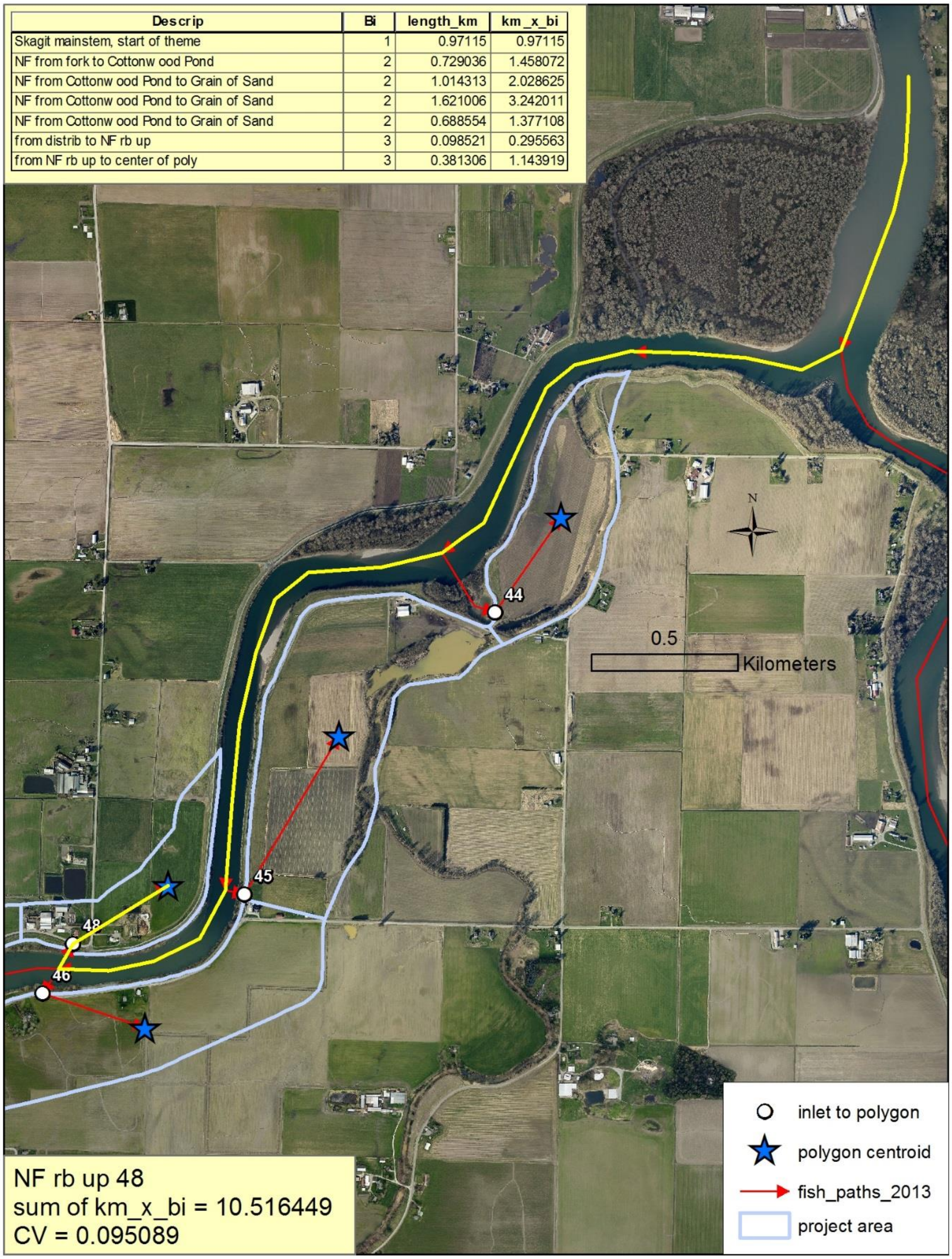
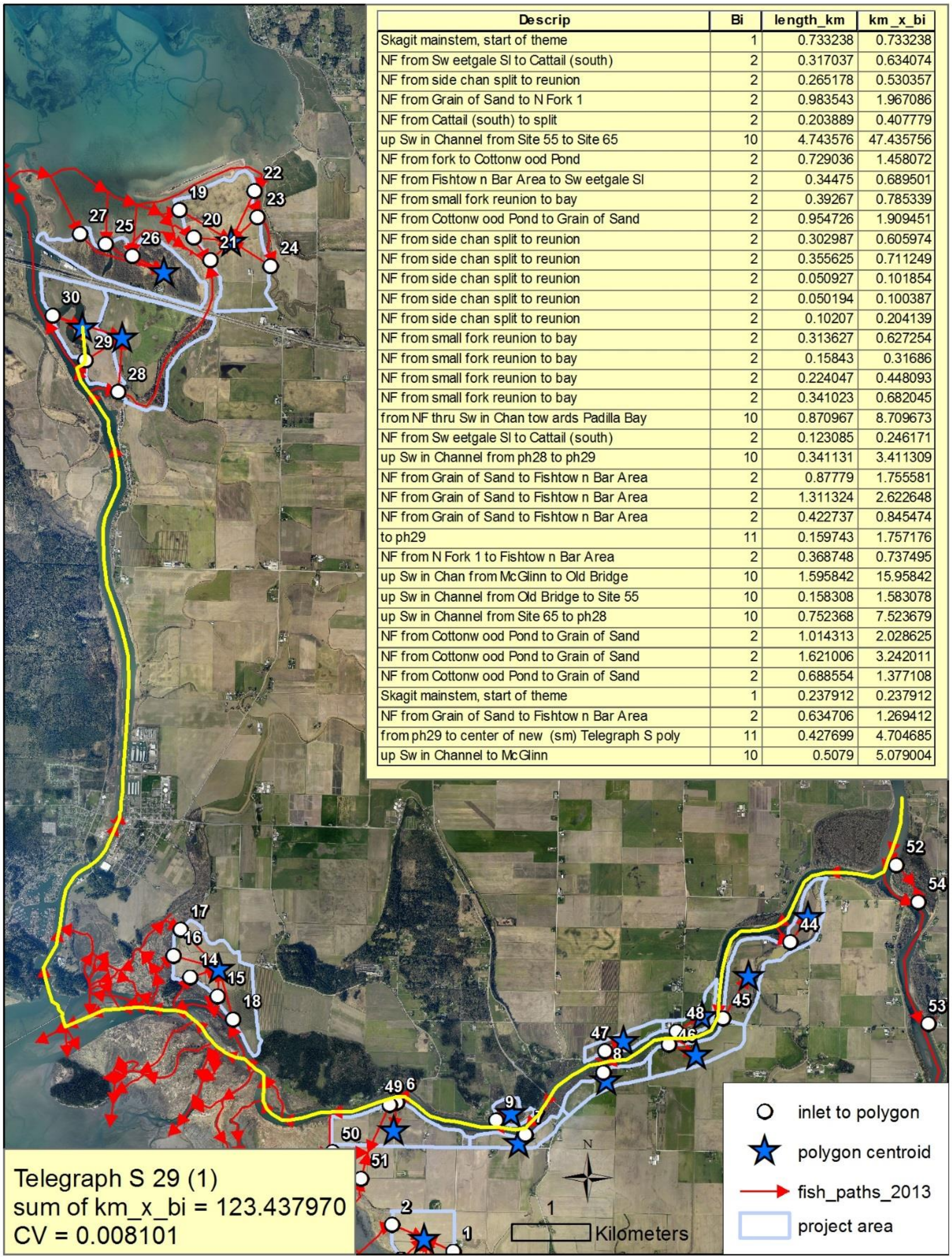
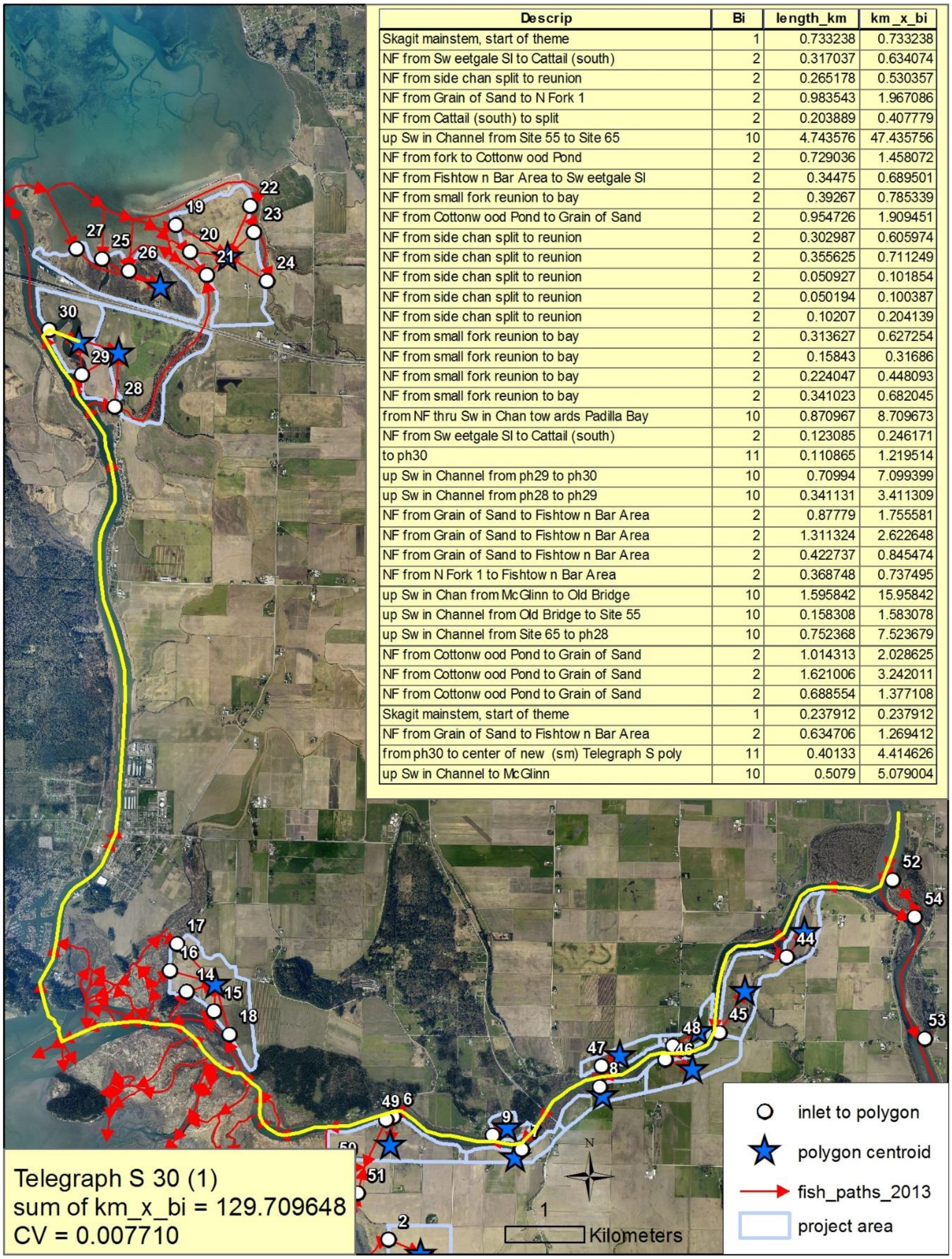

Descrip
Bi
length_km
km_x_bi
Skagit mainstem, start of theme
1
0.97115
0.97115
NF from fork to Cottonw ood Pond
2
0.729036
1.458072
NF from Cottonw ood Pond to Grain of Sand
2
1.014313
2.028625
NF from Cottonw ood Pond to Grain of Sand
2
1.621006
3.242011
NF from Cottonw ood Pond to Grain of Sand
2
0.688554
1.377108
from distrib to NF rb up
3
0.098521
0.295563
from NF rb up to center of poly
3
0.381306
1.143919
44
45
48
46
0.5
Kilometers
N
inlet to polygon
polygon centroid
fish_paths_2013
project area
NF rb up 48
sum of km_x_bi = 10.516449
CV = 0.095089

Figure 42



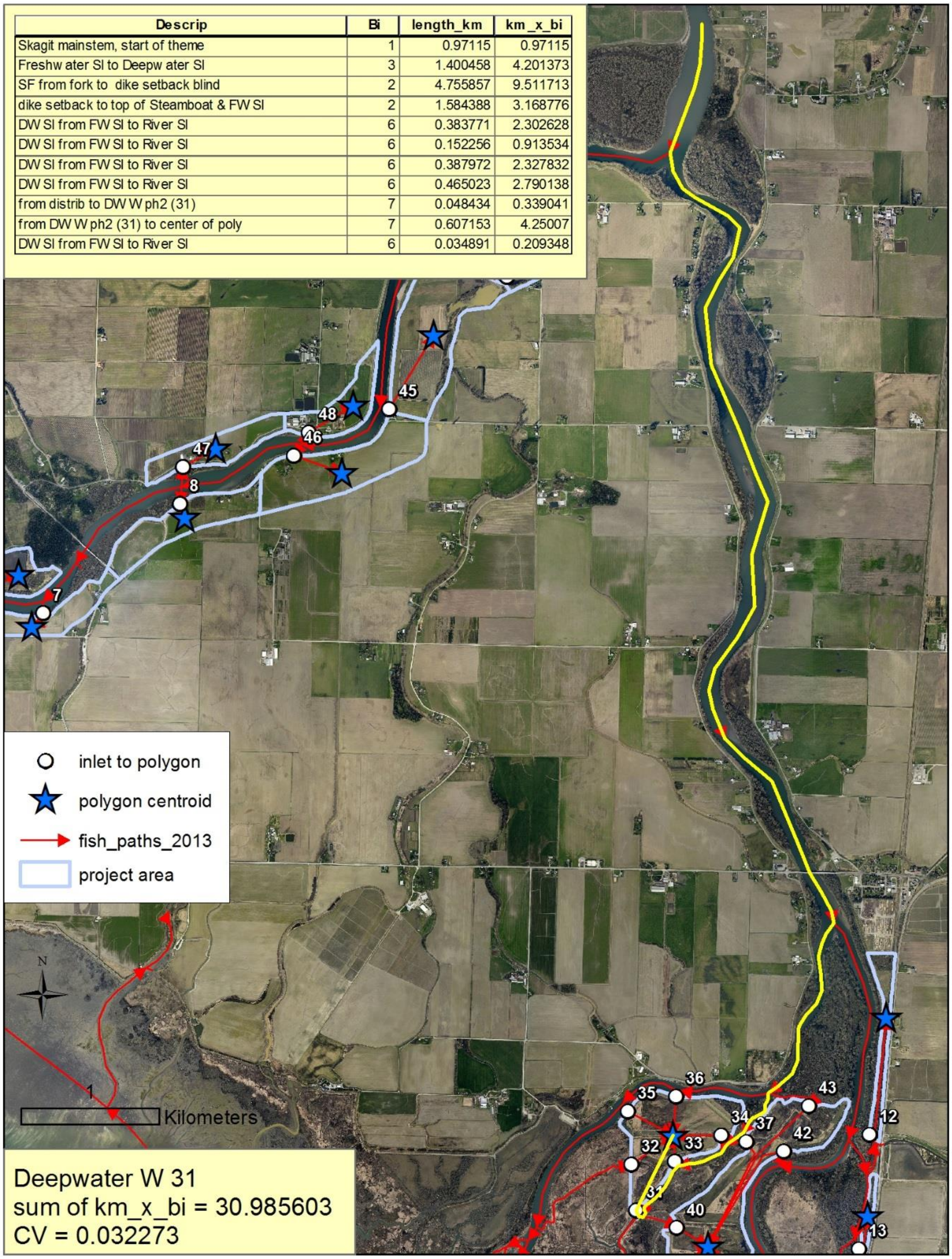
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.733238	0.733238
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
up Sw in Channel from Site 55 to Site 65	10	4.743576	47.435756
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Chan tow ards Padilla Bay	10	0.870967	8.709673
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
up Sw in Channel from ph28 to ph29	10	0.341131	3.411309
NF from Grain of Sand to Fishtow n Bar Area	2	0.87779	1.755581
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
to ph29	11	0.159743	1.757176
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
up Sw in Chan from McGlinn to Old Bridge	10	1.595842	15.95842
up Sw in Channel from Old Bridge to Site 55	10	0.158308	1.583078
up Sw in Channel from Site 65 to ph28	10	0.752368	7.523679
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108
Skagit mainstem, start of theme	1	0.237912	0.237912
NF from Grain of Sand to Fishtow n Bar Area	2	0.634706	1.269412
from ph29 to center of new (sm) Telegraph S poly	11	0.427699	4.704685
up Sw in Channel to McGlinn	10	0.5079	5.079004

Figure 43



Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.733238	0.733238
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
up Sw in Channel from Site 55 to Site 65	10	4.743576	47.435756
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Chan tow ards Padilla Bay	10	0.870967	8.709673
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
to ph30	11	0.110865	1.219514
up Sw in Channel from ph29 to ph30	10	0.70994	7.099399
up Sw in Channel from ph28 to ph29	10	0.341131	3.411309
NF from Grain of Sand to Fishtow n Bar Area	2	0.87779	1.755581
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
up Sw in Chan from McGlinn to Old Bridge	10	1.595842	15.95842
up Sw in Channel from Old Bridge to Site 55	10	0.158308	1.583078
up Sw in Channel from Site 65 to ph28	10	0.752368	7.523679
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108
Skagit mainstem, start of theme	1	0.237912	0.237912
NF from Grain of Sand to Fishtow n Bar Area	2	0.634706	1.269412
from ph30 to center of new (sm) Telegraph S poly	11	0.40133	4.414626
up Sw in Channel to McGlinn	10	0.5079	5.079004

Figure 44



Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Freshw ater Sl to Deepw ater Sl	3	1.400458	4.201373
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
DW Sl from FW Sl to River Sl	6	0.383771	2.302628
DW Sl from FW Sl to River Sl	6	0.152256	0.913534
DW Sl from FW Sl to River Sl	6	0.387972	2.327832
DW Sl from FW Sl to River Sl	6	0.465023	2.790138
from distrib to DW W ph2 (31)	7	0.048434	0.339041
from DW W ph2 (31) to center of poly	7	0.607153	4.25007
DW Sl from FW Sl to River Sl	6	0.034891	0.209348

Figure 45

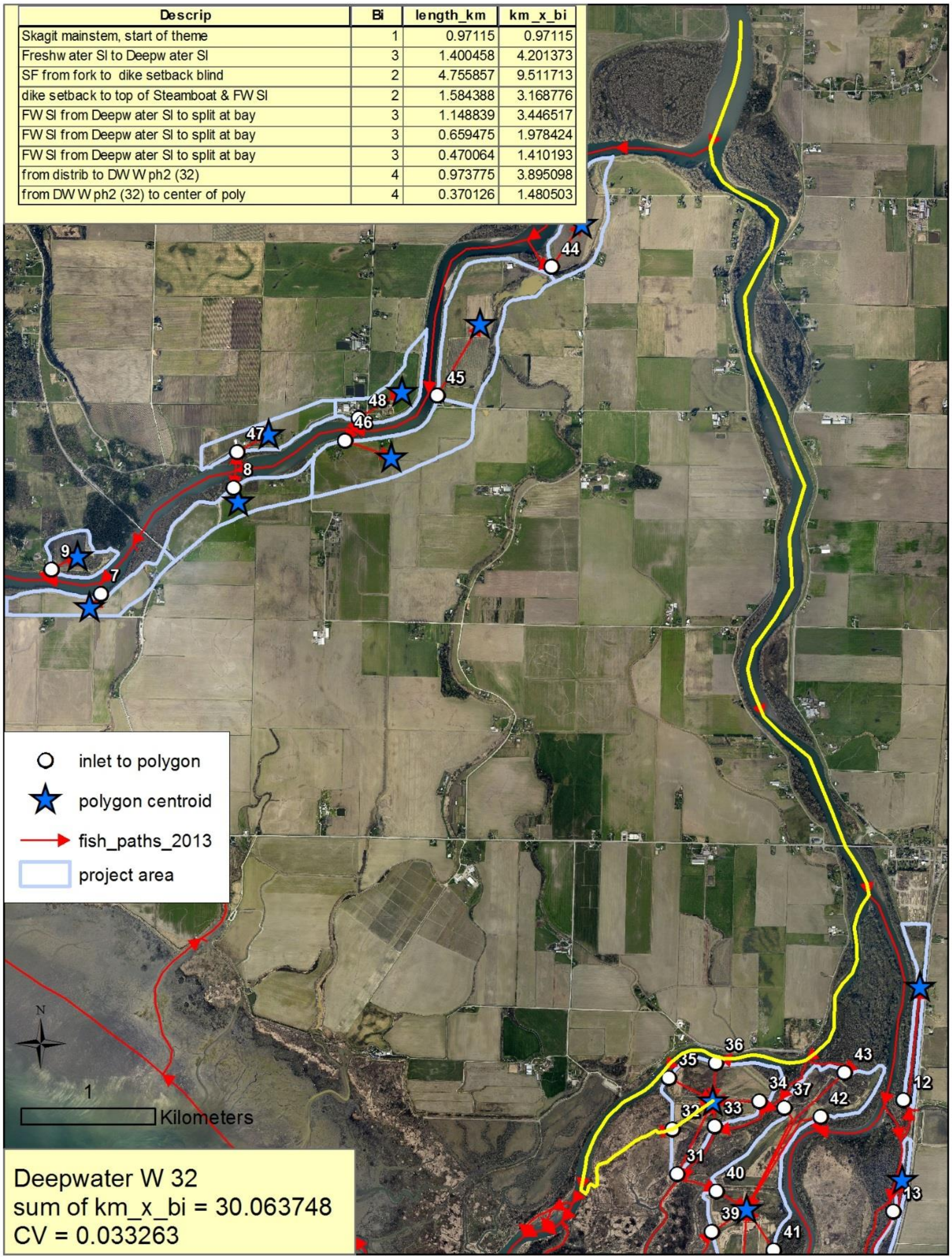
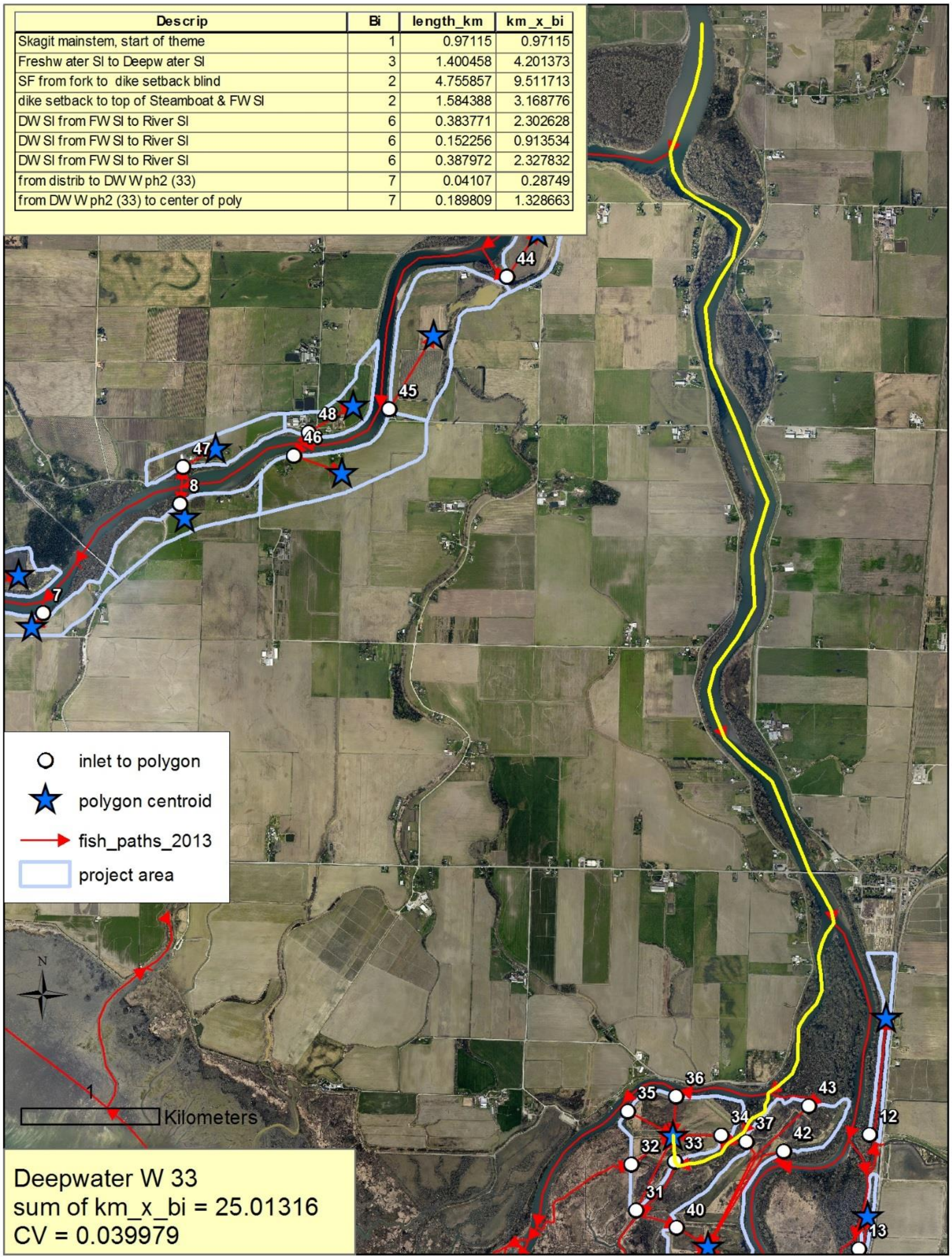
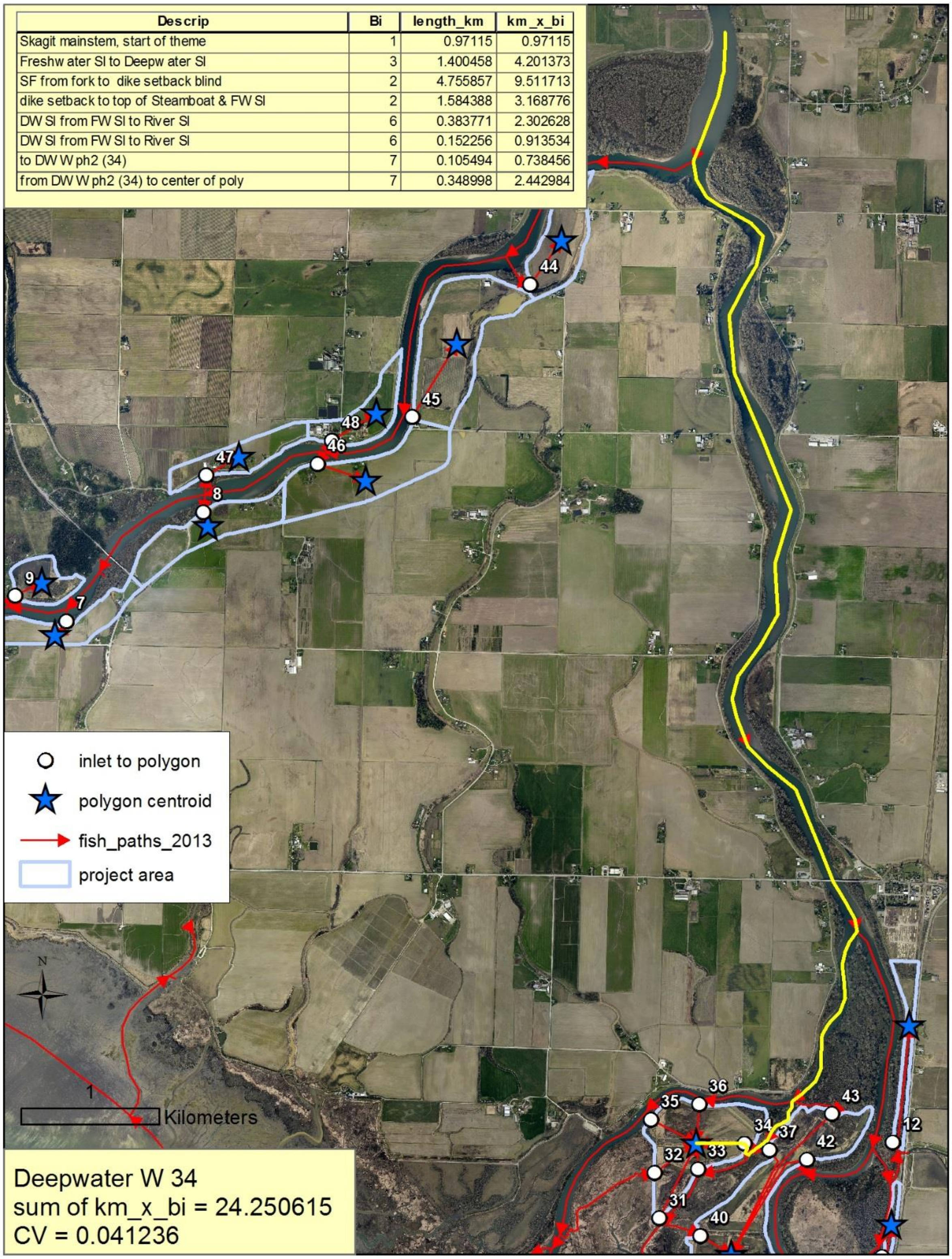

Descrip | Bi | length_km | km_x_bi
Skagit mainstem, start of theme | 1 | 0.97115 | 0.97115
Freshw ater Sl to Deepw ater Sl | 3 | 1.400458 | 4.201373
SF from fork to dike setback blind | 2 | 4.755857 | 9.511713
dike setback to top of Steamboat & FW Sl | 2 | 1.584388 | 3.168776
FW Sl from Deepw ater Sl to split at bay | 3 | 1.148839 | 3.446517
FW Sl from Deepw ater Sl to split at bay | 3 | 0.659475 | 1.978424
FW Sl from Deepw ater Sl to split at bay | 3 | 0.470064 | 1.410193
from distrib to DW W ph2 (32) | 4 | 0.973775 | 3.895098
from DW W ph2 (32) to center of poly | 4 | 0.370126 | 1.480503
44
45
48
46
47
8
9
7
inlet to polygon
polygon centroid
fish_paths_2013
project area
N
1
Kilometers
36
35
43
34
37
12
32
33
42
31
40
39
13
41
Deepwater W 32
sum of km_x_bi = 30.063748
CV = 0.033263

Figure 46



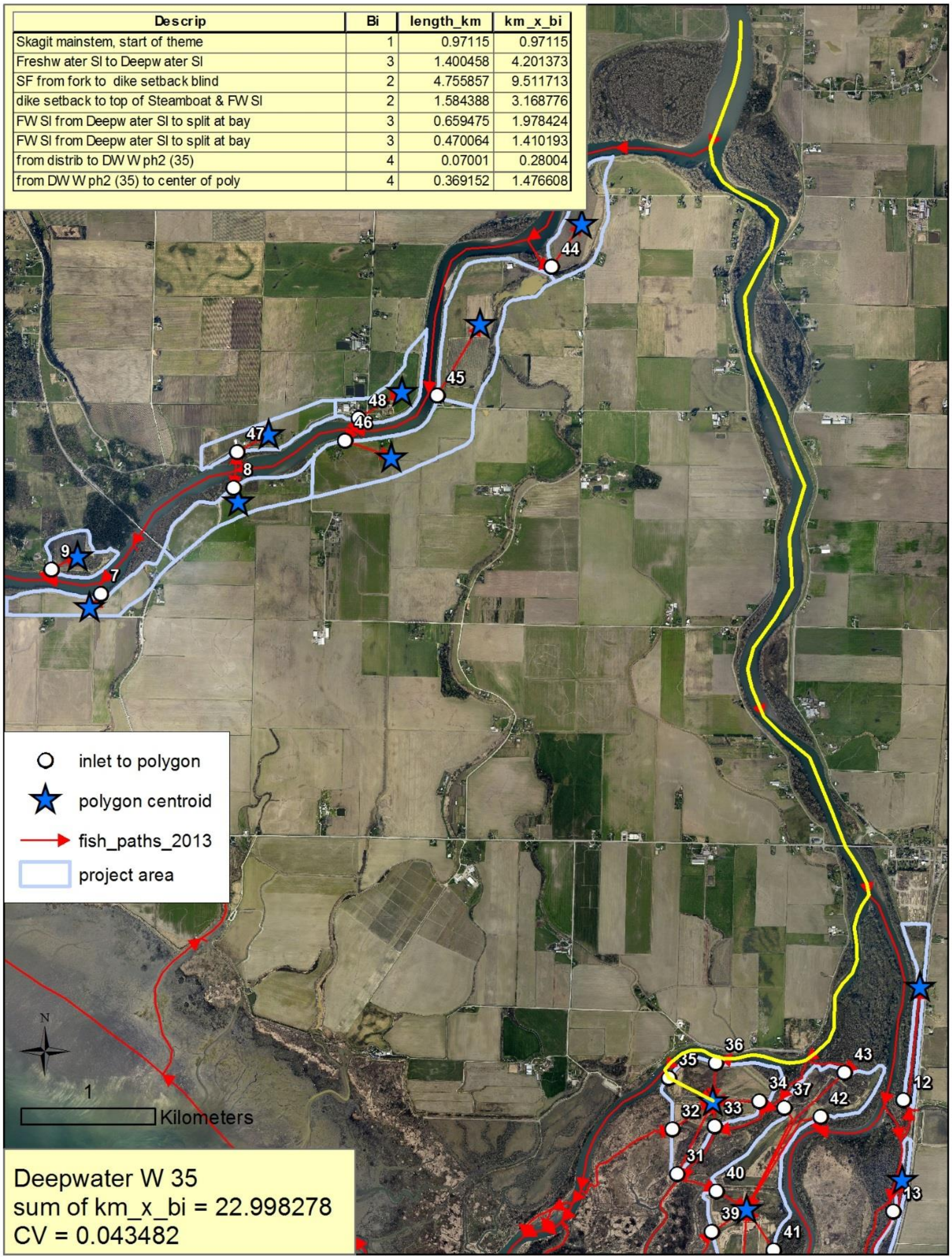
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Freshw ater Sl to Deepw ater Sl	3	1.400458	4.201373
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
DW Sl from FW Sl to River Sl	6	0.383771	2.302628
DW Sl from FW Sl to River Sl	6	0.152256	0.913534
DW Sl from FW Sl to River Sl	6	0.387972	2.327832
from distrib to DW W ph2 (33)	7	0.04107	0.28749
from DW W ph2 (33) to center of poly	7	0.189809	1.328663

Figure 47



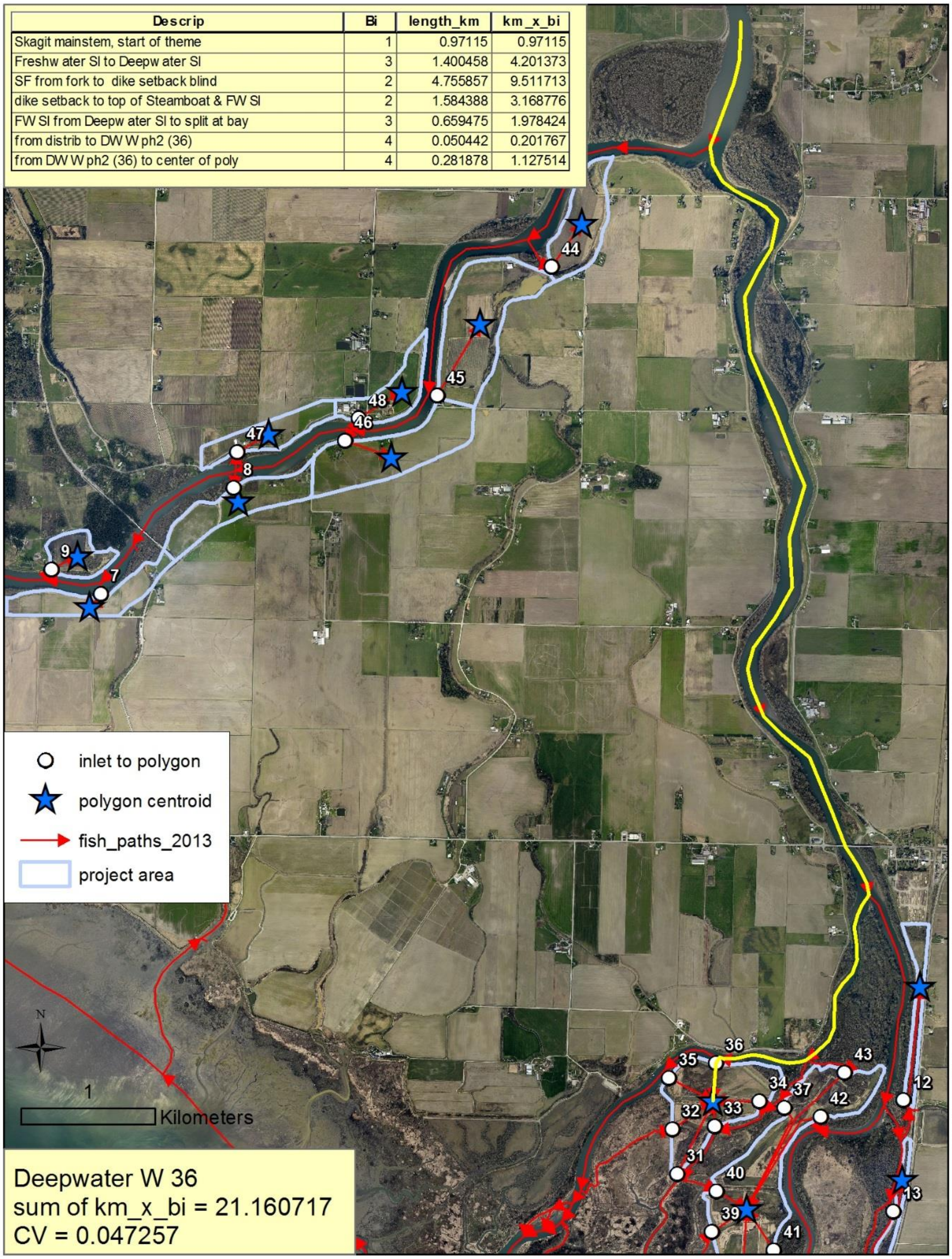
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Freshw ater Sl to Deepw ater Sl	3	1.400458	4.201373
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
DW Sl from FW Sl to River Sl	6	0.383771	2.302628
DW Sl from FW Sl to River Sl	6	0.152256	0.913534
to DW W ph2 (34)	7	0.105494	0.738456
from DW W ph2 (34) to center of poly	7	0.348998	2.442984

Figure 48



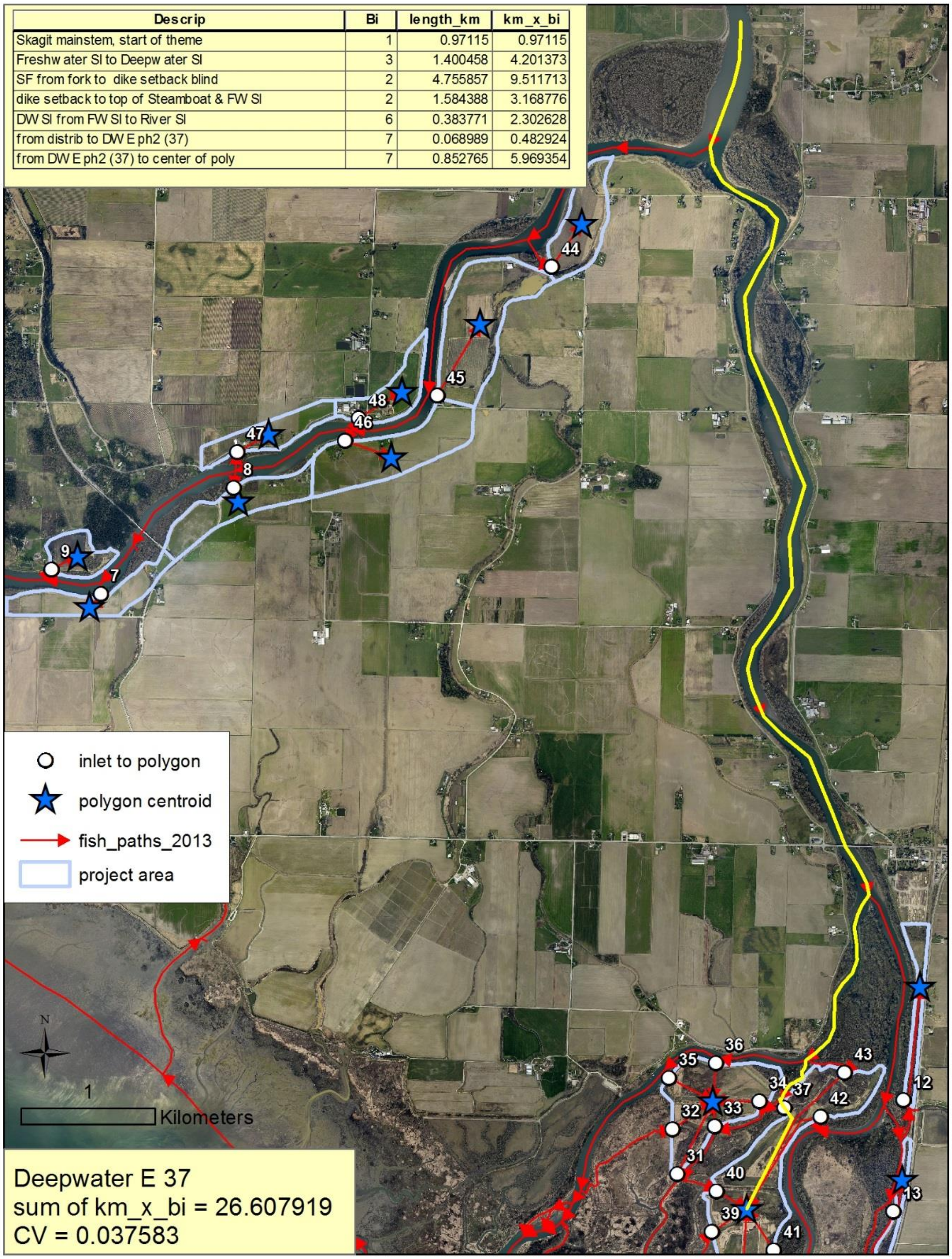
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Freshw ater Sl to Deepw ater Sl	3	1.400458	4.201373
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
FW Sl from Deepw ater Sl to split at bay	3	0.659475	1.978424
FW Sl from Deepw ater Sl to split at bay	3	0.470064	1.410193
from distrib to DW W ph2 (35)	4	0.07001	0.28004
from DW W ph2 (35) to center of poly	4	0.369152	1.476608

Figure 49



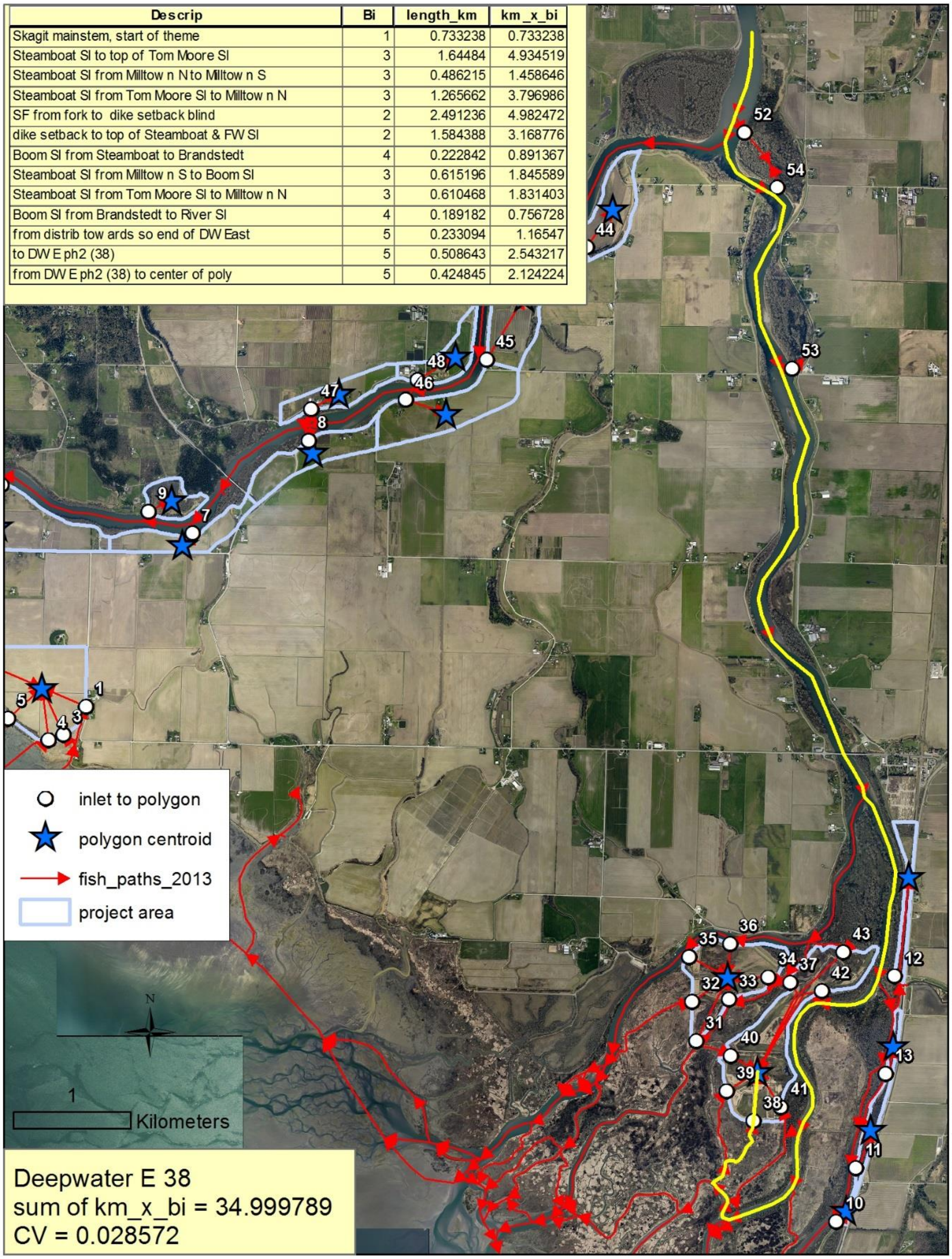
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Freshw ater Sl to Deepw ater Sl	3	1.400458	4.201373
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
FW Sl from Deepw ater Sl to split at bay	3	0.659475	1.978424
from distrib to DW W ph2 (36)	4	0.050442	0.201767
from DW W ph2 (36) to center of poly	4	0.281878	1.127514

Figure 50



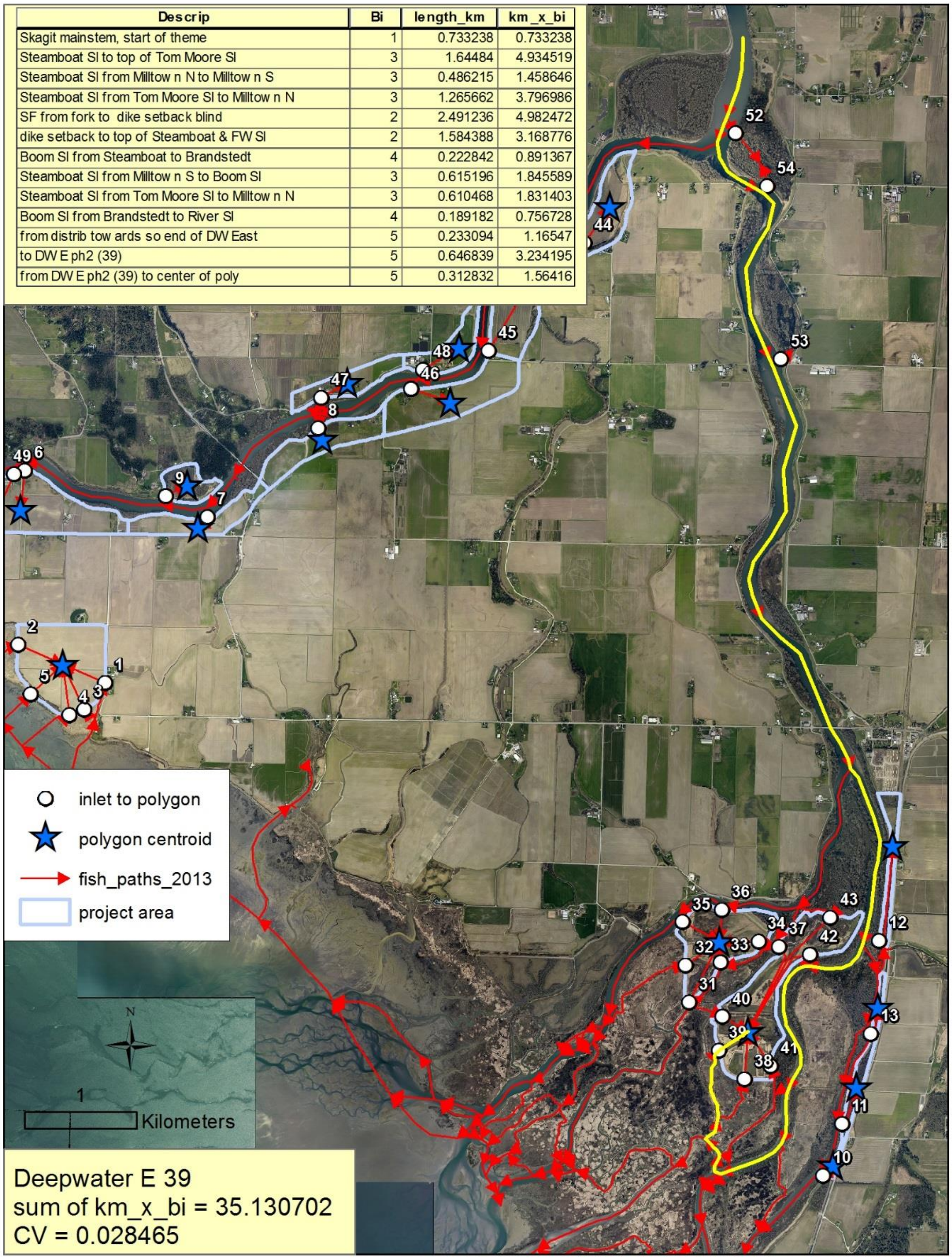
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Freshw ater Sl to Deepw ater Sl	3	1.400458	4.201373
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
DW Sl from FW Sl to River Sl	6	0.383771	2.302628
from distrib to DW E ph2 (37)	7	0.068989	0.482924
from DW E ph2 (37) to center of poly	7	0.852765	5.969354

Figure 51



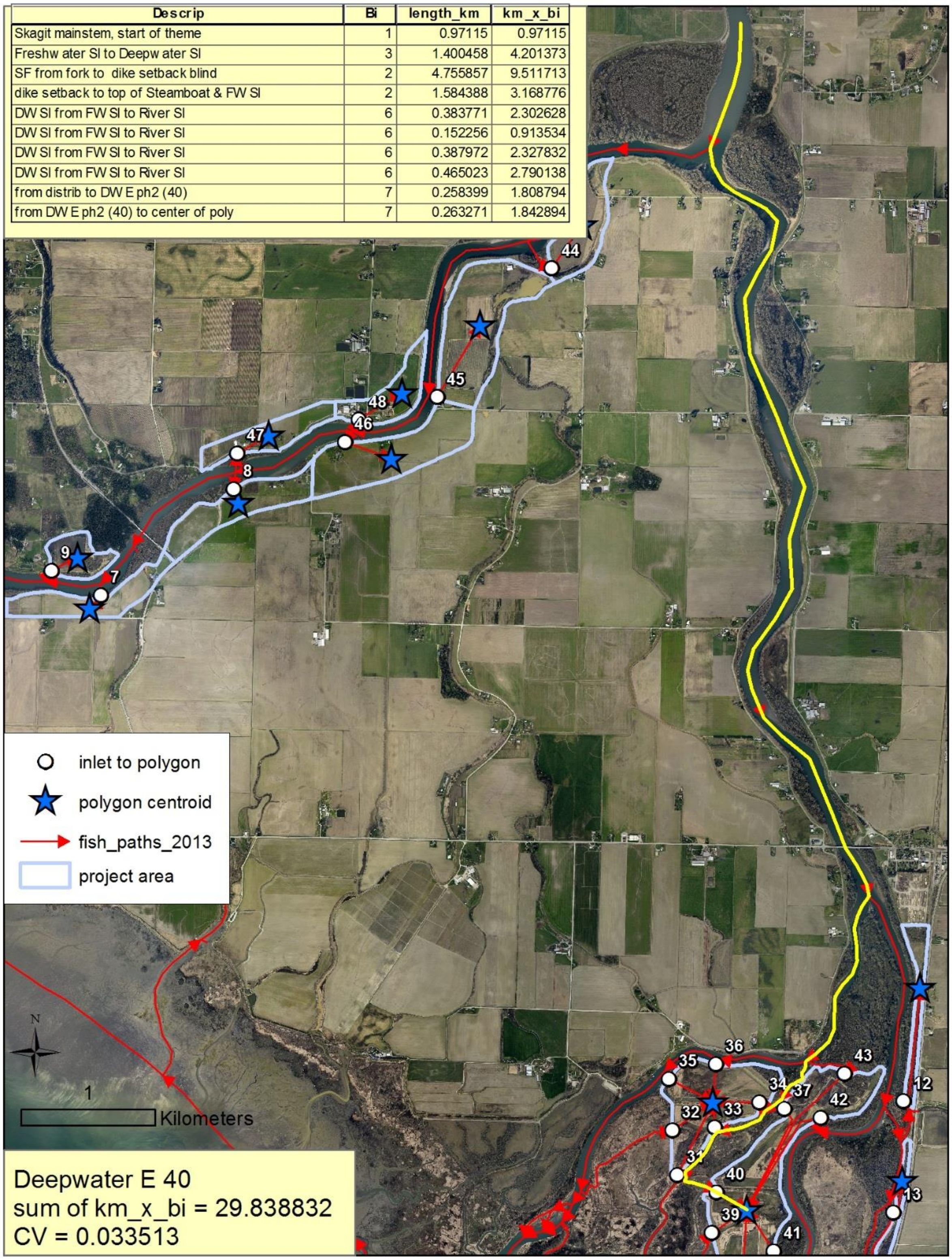
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.733238	0.733238
Steamboat Sl to top of Tom Moore Sl	3	1.64484	4.934519
Steamboat Sl from Milltow n N to Milltow n S	3	0.486215	1.458646
Steamboat Sl from Tom Moore Sl to Milltow n N	3	1.265662	3.796986
SF from fork to dike setback blind	2	2.491236	4.982472
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
Boom Sl from Steamboat to Brandstedt	4	0.222842	0.891367
Steamboat Sl from Milltow n S to Boom Sl	3	0.615196	1.845589
Steamboat Sl from Tom Moore Sl to Milltow n N	3	0.610468	1.831403
Boom Sl from Brandstedt to River Sl	4	0.189182	0.756728
from distrib tow ards so end of DW East	5	0.233094	1.16547
to DW E ph2 (38)	5	0.508643	2.543217
from DW E ph2 (38) to center of poly	5	0.424845	2.124224

Figure 52



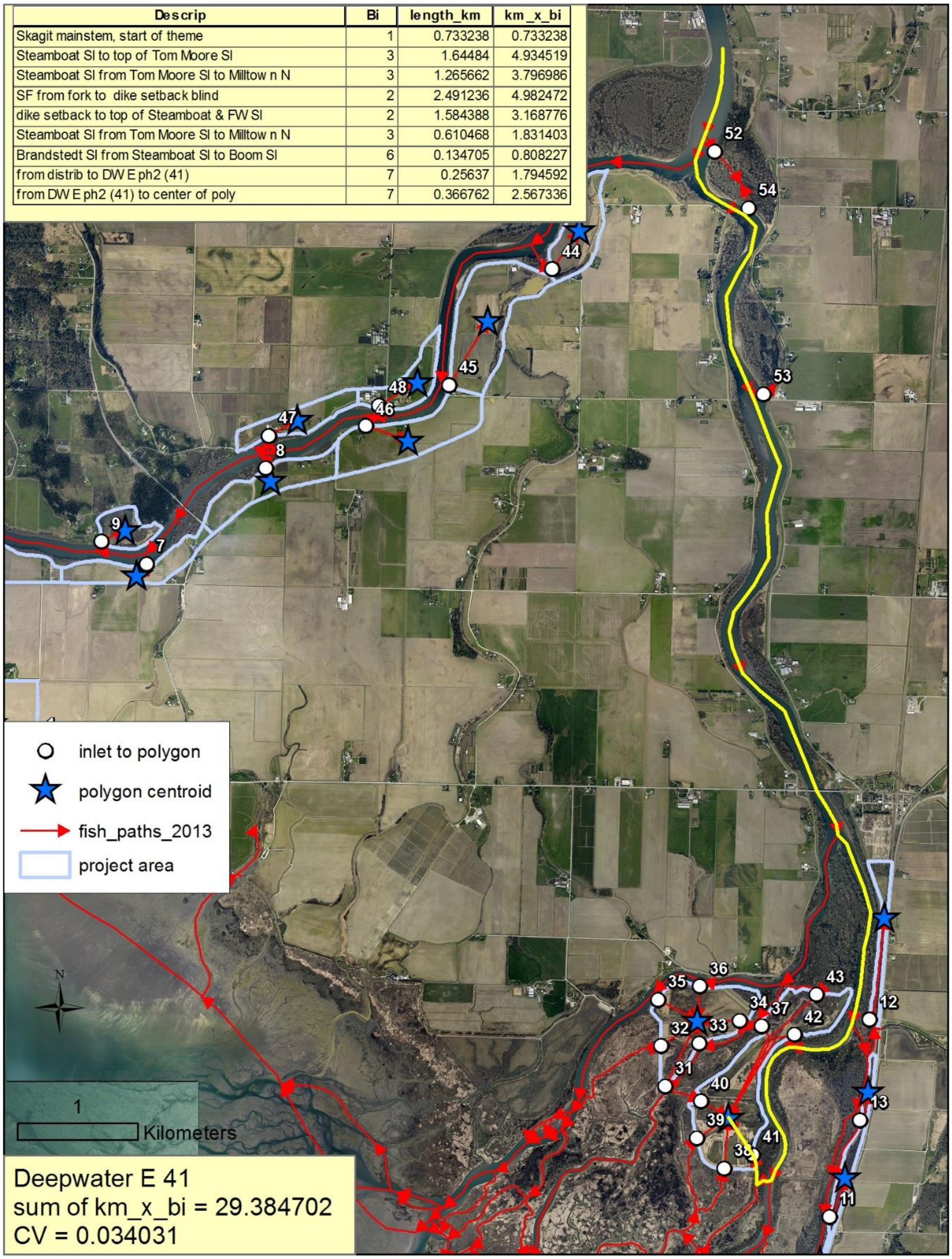
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.733238	0.733238
Steamboat Sl to top of Tom Moore Sl	3	1.64484	4.934519
Steamboat Sl from Milltow n N to Milltow n S	3	0.486215	1.458646
Steamboat Sl from Tom Moore Sl to Milltow n N	3	1.265662	3.796986
SF from fork to dike setback blind	2	2.491236	4.982472
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
Boom Sl from Steamboat to Brandstedt	4	0.222842	0.891367
Steamboat Sl from Milltow n S to Boom Sl	3	0.615196	1.845589
Steamboat Sl from Tom Moore Sl to Milltow n N	3	0.610468	1.831403
Boom Sl from Brandstedt to River Sl	4	0.189182	0.756728
from distrib tow ards so end of DW East	5	0.233094	1.16547
to DW E ph2 (39)	5	0.646839	3.234195
from DW E ph2 (39) to center of poly	5	0.312832	1.56416

Figure 53



Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Freshw ater Sl to Deepw ater Sl	3	1.400458	4.201373
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
DW Sl from FW Sl to River Sl	6	0.383771	2.302628
DW Sl from FW Sl to River Sl	6	0.152256	0.913534
DW Sl from FW Sl to River Sl	6	0.387972	2.327832
DW Sl from FW Sl to River Sl	6	0.465023	2.790138
from distrib to DW E ph2 (40)	7	0.258399	1.808794
from DW E ph2 (40) to center of poly	7	0.263271	1.842894

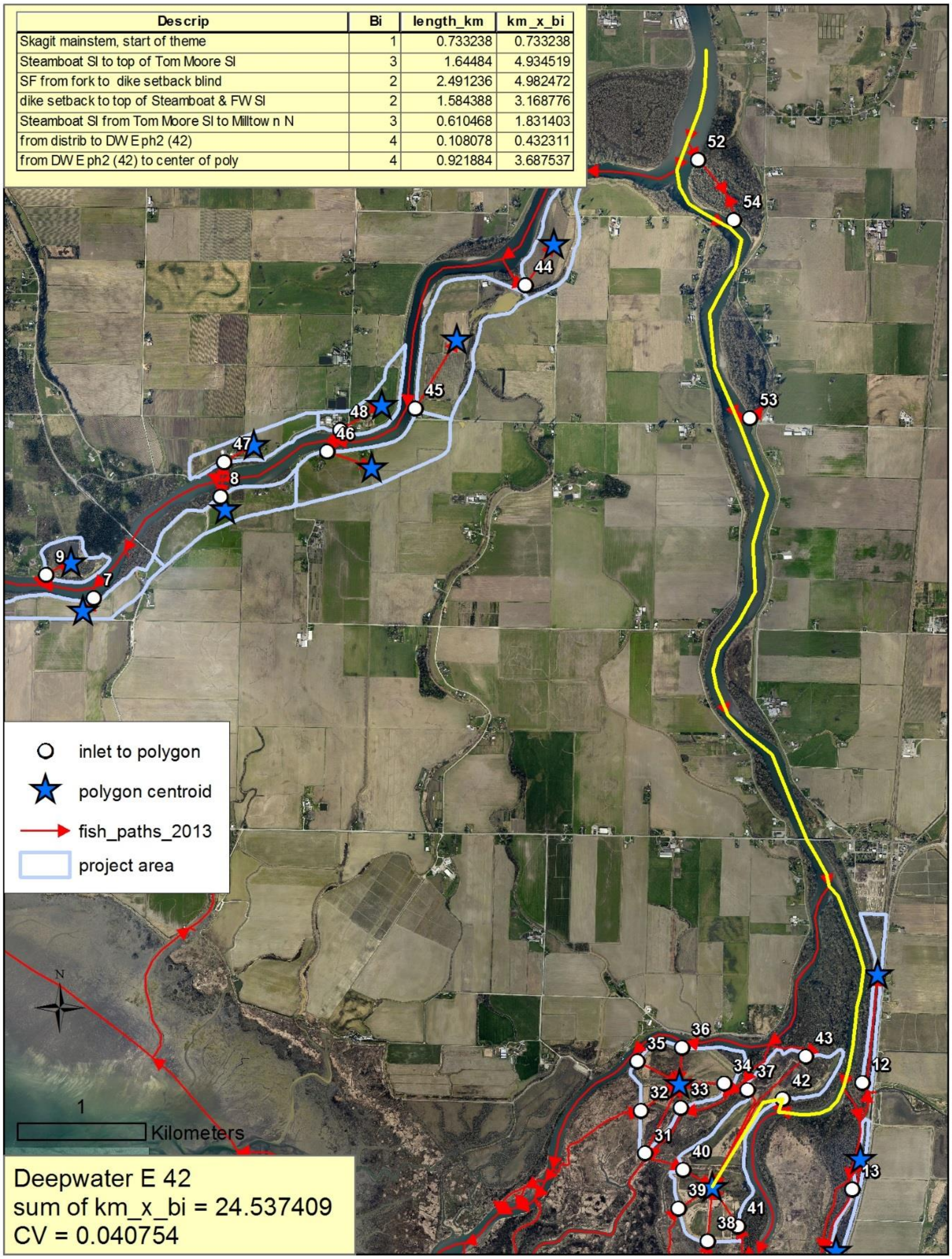
Figure 54



Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.733238	0.733238
Steamboat Sl to top of Tom Moore Sl	3	1.64484	4.934519
Steamboat Sl from Tom Moore Sl to Milltow n N	3	1.265662	3.796986
SF from fork to dike setback blind	2	2.491236	4.982472
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
Steamboat Sl from Tom Moore Sl to Milltow n N	3	0.610468	1.831403
Brandstedt Sl from Steamboat Sl to Boom Sl	6	0.134705	0.808227
from distrib to DW E ph2 (41)	7	0.25637	1.794592
from DW E ph2 (41) to center of poly	7	0.366762	2.567336

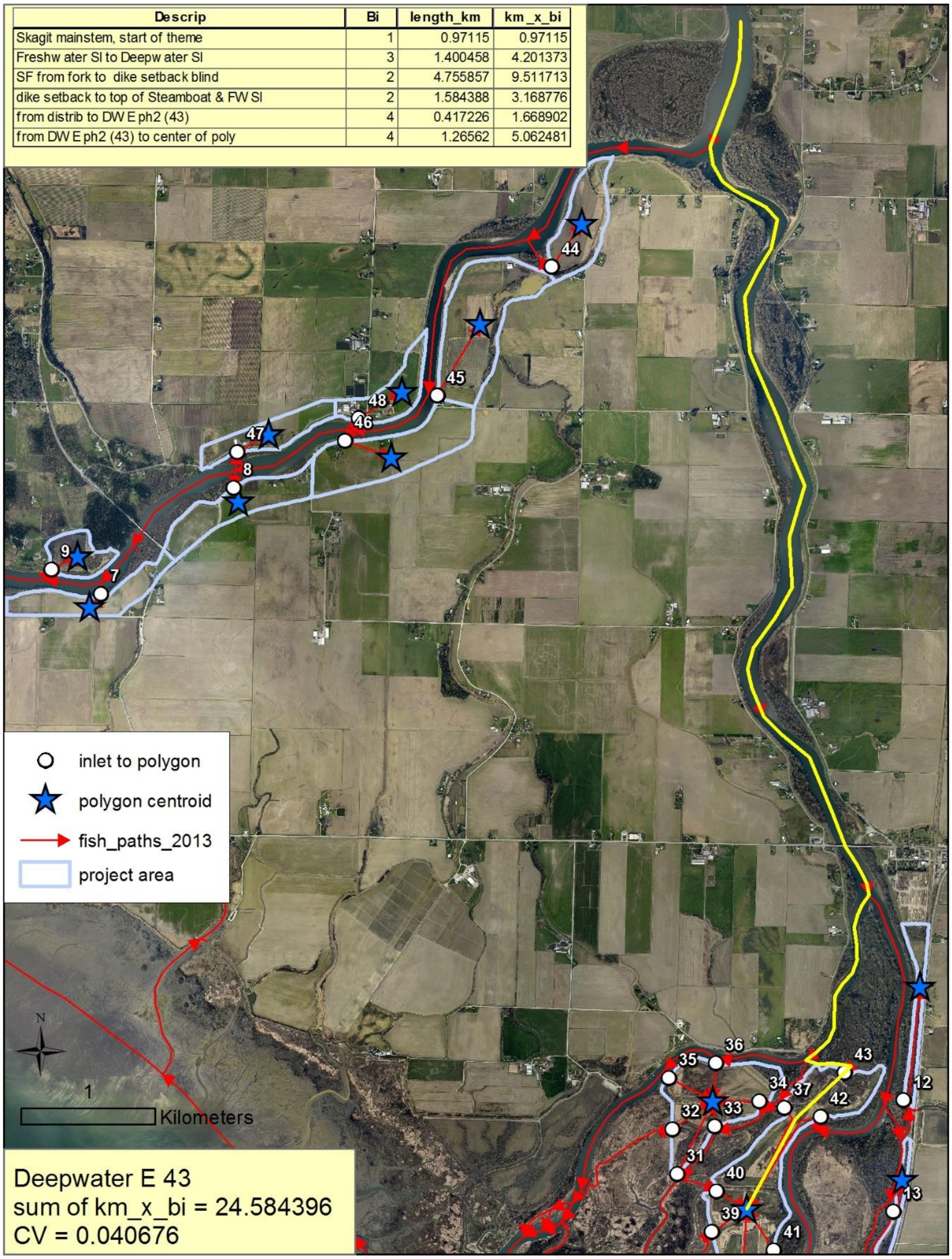
inlet to polygon
polygon centroid
fish_paths_2013
project area
N
1
Kilometers
Deepwater E 41
sum of km_x_bi = 29.384702
CV = 0.034031

Figure 55



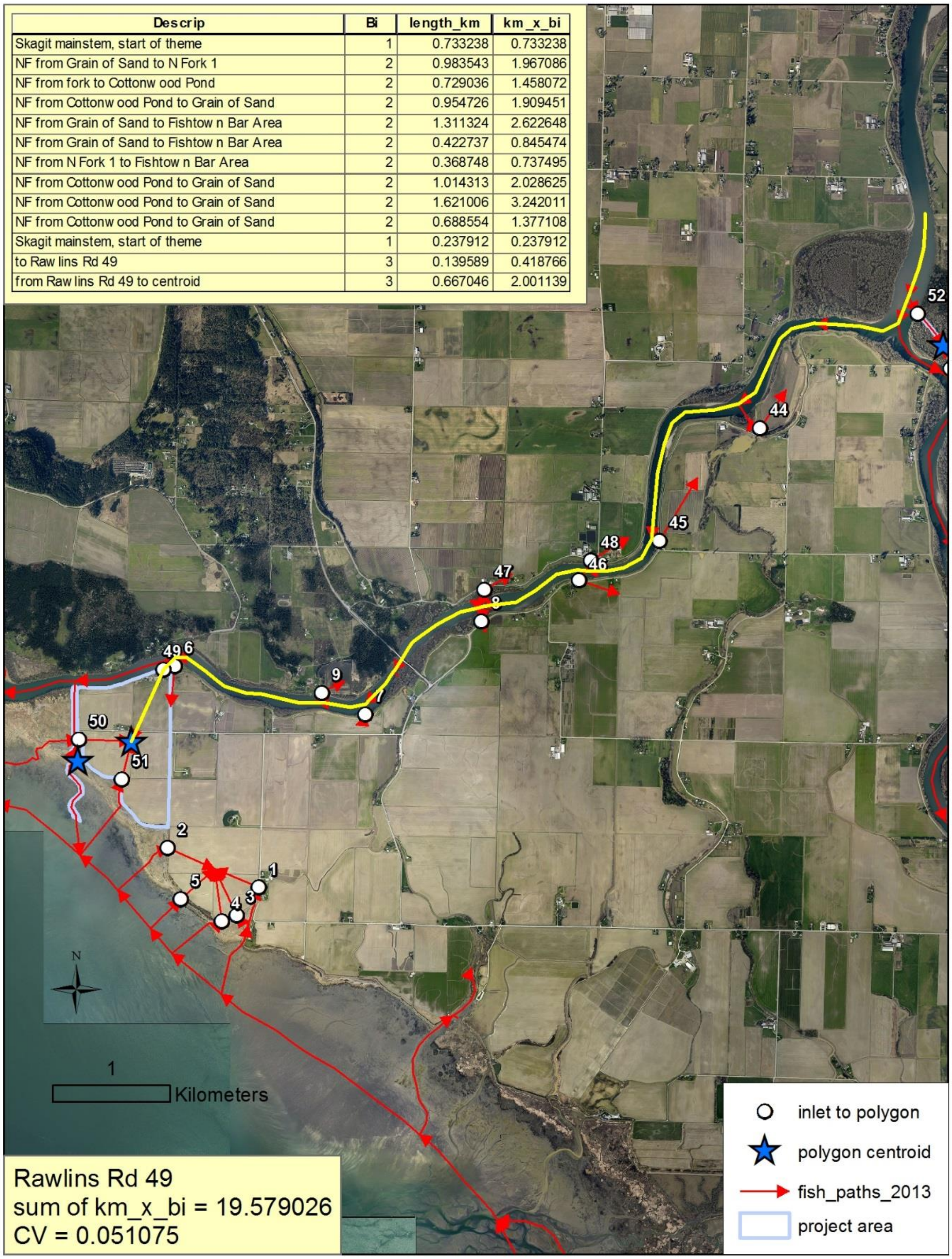
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.733238	0.733238
Steamboat Sl to top of Tom Moore Sl	3	1.64484	4.934519
SF from fork to dike setback blind	2	2.491236	4.982472
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
Steamboat Sl from Tom Moore Sl to Milltow n N	3	0.610468	1.831403
from distrib to DW E ph2 (42)	4	0.108078	0.432311
from DW E ph2 (42) to center of poly	4	0.921884	3.687537

Figure 56



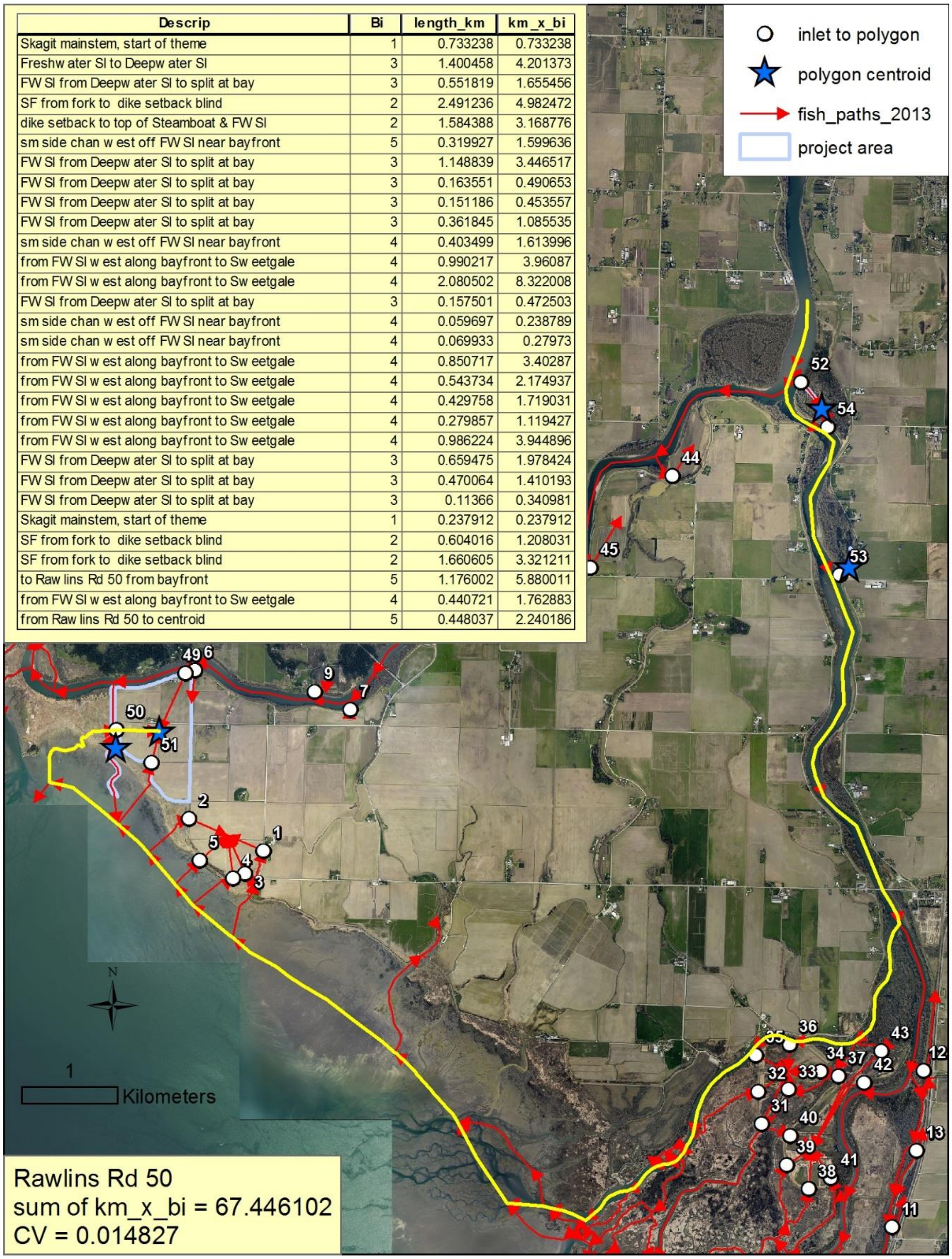
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Freshw ater Sl to Deepw ater Sl	3	1.400458	4.201373
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
from distrib to DW E ph2 (43)	4	0.417226	1.668902
from DW E ph2 (43) to center of poly	4	1.26562	5.062481

Figure 57



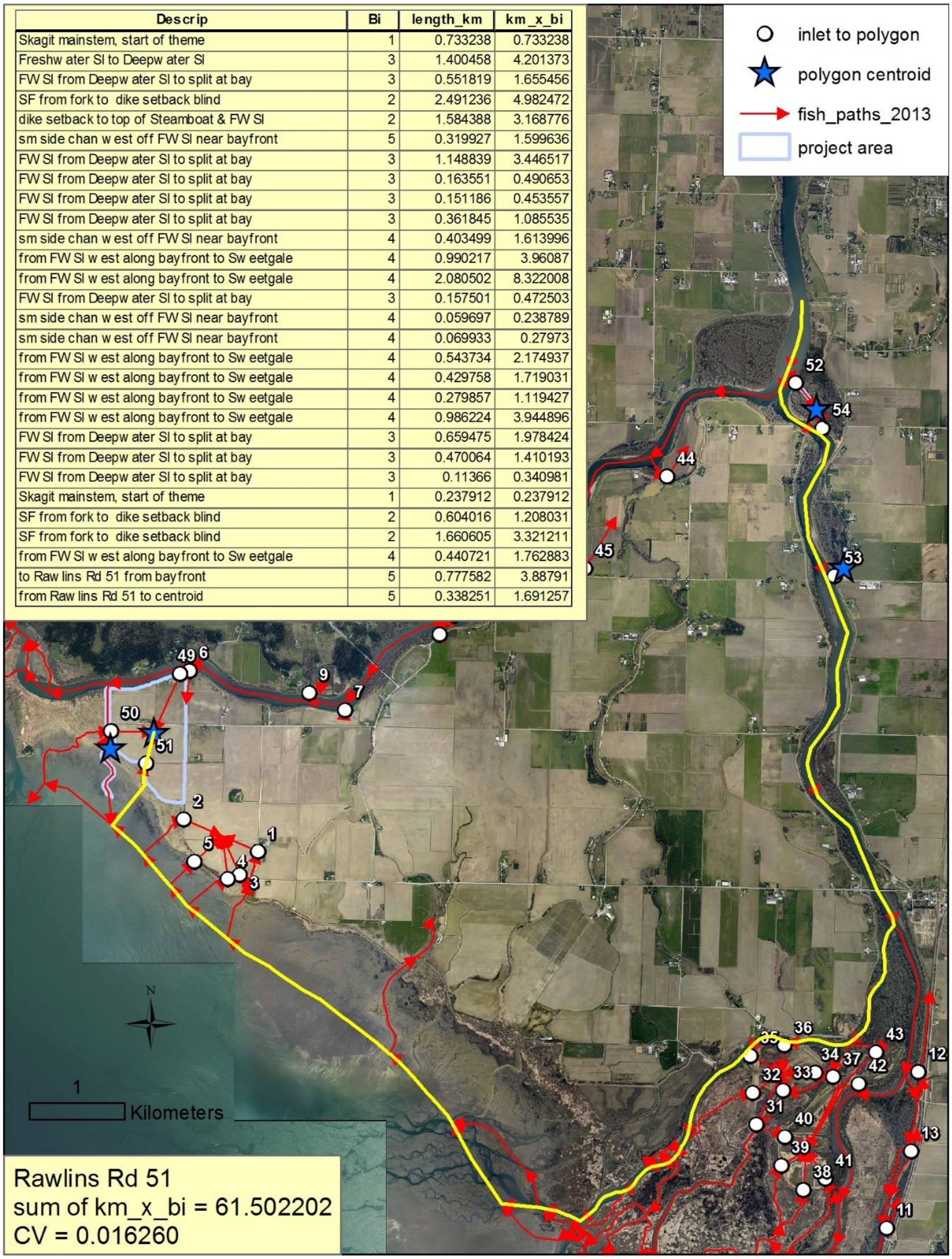
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.733238	0.733238
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108
Skagit mainstem, start of theme	1	0.237912	0.237912
to Raw lins Rd 49	3	0.139589	0.418766
from Raw lins Rd 49 to centroid	3	0.667046	2.001139

Figure 58



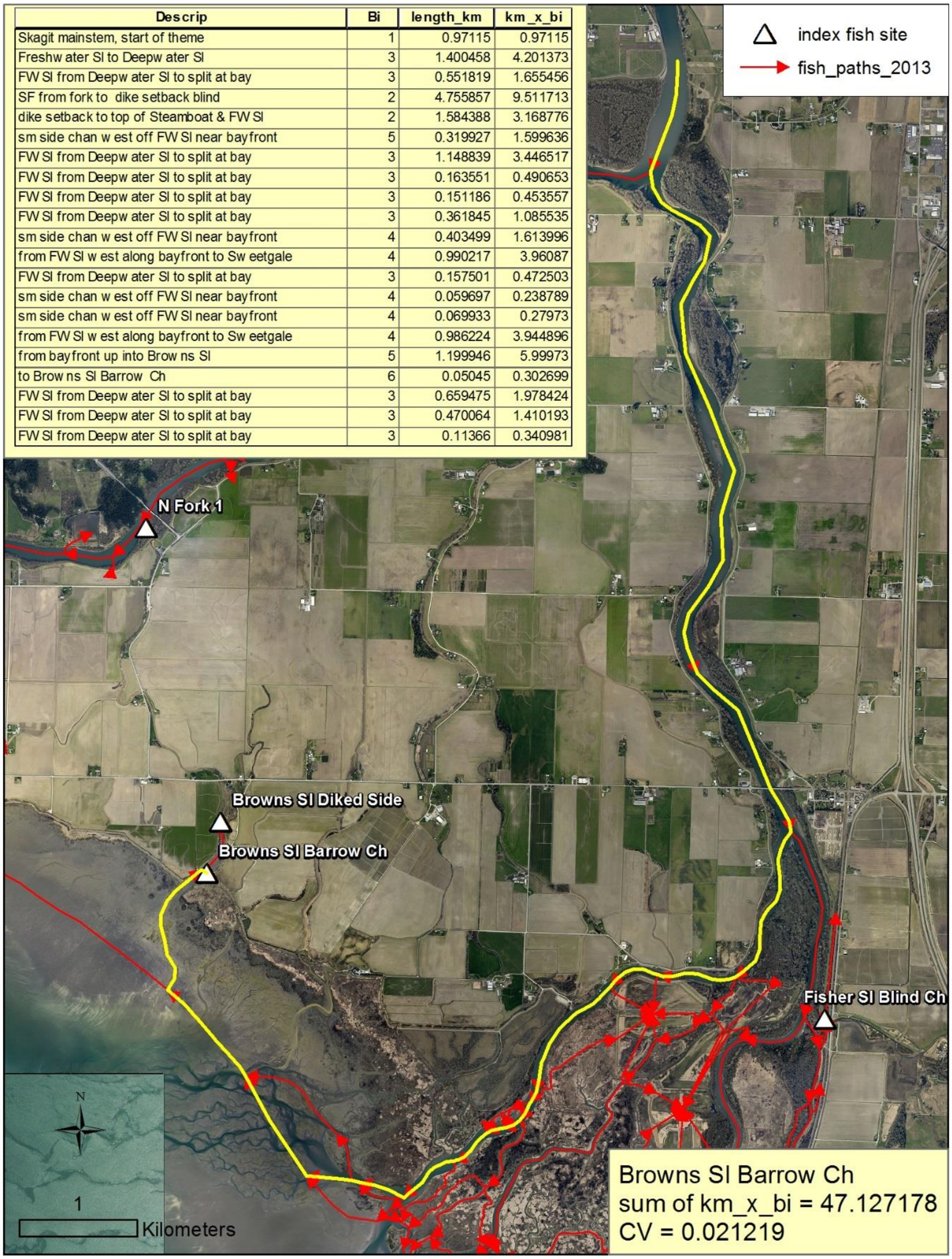
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.733238	0.733238
Freshw ater Sl to Deepw ater Sl	3	1.400458	4.201373
FW Sl from Deepw ater Sl to split at bay	3	0.551819	1.655456
SF from fork to dike setback blind	2	2.491236	4.982472
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
sm side chan w est off FW Sl near bayfront	5	0.319927	1.599636
FW Sl from Deepw ater Sl to split at bay	3	1.148839	3.446517
FW Sl from Deepw ater Sl to split at bay	3	0.163551	0.490653
FW Sl from Deepw ater Sl to split at bay	3	0.151186	0.453557
FW Sl from Deepw ater Sl to split at bay	3	0.361845	1.085535
sm side chan w est off FW Sl near bayfront	4	0.403499	1.613996
from FW Sl w est along bayfront to Sw eetgale	4	0.990217	3.96087
from FW Sl w est along bayfront to Sw eetgale	4	2.080502	8.322008
FW Sl from Deepw ater Sl to split at bay	3	0.157501	0.472503
sm side chan w est off FW Sl near bayfront	4	0.059697	0.238789
sm side chan w est off FW Sl near bayfront	4	0.069933	0.27973
from FW Sl w est along bayfront to Sw eetgale	4	0.850717	3.40287
from FW Sl w est along bayfront to Sw eetgale	4	0.543734	2.174937
from FW Sl w est along bayfront to Sw eetgale	4	0.429758	1.719031
from FW Sl w est along bayfront to Sw eetgale	4	0.279857	1.119427
from FW Sl w est along bayfront to Sw eetgale	4	0.986224	3.944896
FW Sl from Deepw ater Sl to split at bay	3	0.659475	1.978424
FW Sl from Deepw ater Sl to split at bay	3	0.470064	1.410193
FW Sl from Deepw ater Sl to split at bay	3	0.11366	0.340981
Skagit mainstem, start of theme	1	0.237912	0.237912
SF from fork to dike setback blind	2	0.604016	1.208031
SF from fork to dike setback blind	2	1.660605	3.321211
to Raw lins Rd 50 from bayfront	5	1.176002	5.880011
from FW Sl w est along bayfront to Sw eetgale	4	0.440721	1.762883
from Raw lins Rd 50 to centroid	5	0.448037	2.240186

Figure 59



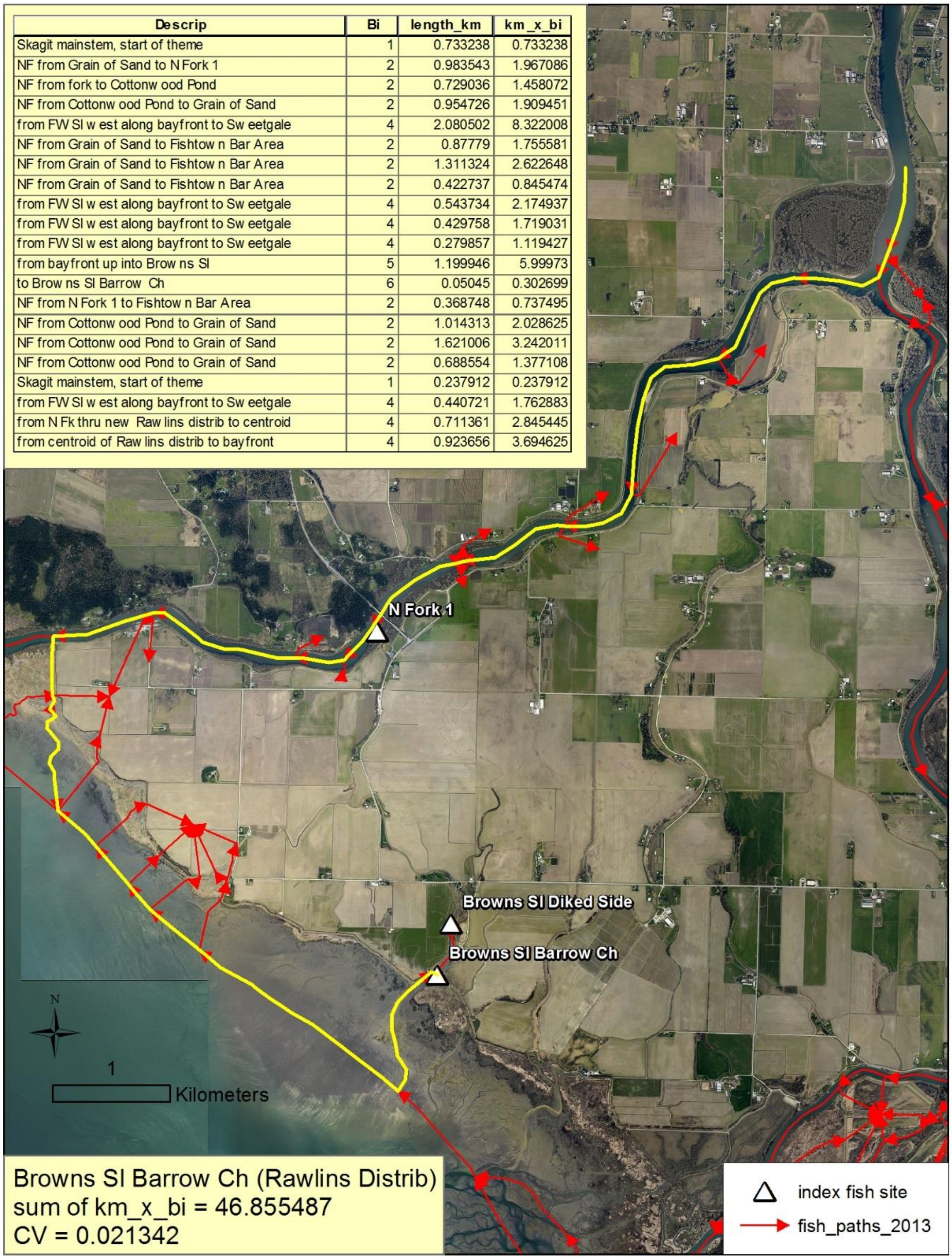
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.733238	0.733238
Freshwater Sl to Deepwater Sl	3	1.400458	4.201373
FW Sl from Deepwater Sl to split at bay	3	0.551819	1.655456
SF from fork to dike setback blind	2	2.491236	4.982472
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
sm side chan west off FW Sl near bayfront	5	0.319927	1.599636
FW Sl from Deepwater Sl to split at bay	3	1.148839	3.446517
FW Sl from Deepwater Sl to split at bay	3	0.163551	0.490653
FW Sl from Deepwater Sl to split at bay	3	0.151186	0.453557
FW Sl from Deepwater Sl to split at bay	3	0.361845	1.085535
sm side chan west off FW Sl near bayfront	4	0.403499	1.613996
from FW Sl west along bayfront to Sweetgale	4	0.990217	3.96087
from FW Sl west along bayfront to Sweetgale	4	2.080502	8.322008
FW Sl from Deepwater Sl to split at bay	3	0.157501	0.472503
sm side chan west off FW Sl near bayfront	4	0.059697	0.238789
sm side chan west off FW Sl near bayfront	4	0.069933	0.27973
from FW Sl west along bayfront to Sweetgale	4	0.543734	2.174937
from FW Sl west along bayfront to Sweetgale	4	0.429758	1.719031
from FW Sl west along bayfront to Sweetgale	4	0.279857	1.119427
from FW Sl west along bayfront to Sweetgale	4	0.986224	3.944896
FW Sl from Deepwater Sl to split at bay	3	0.659475	1.978424
FW Sl from Deepwater Sl to split at bay	3	0.470064	1.410193
FW Sl from Deepwater Sl to split at bay	3	0.11366	0.340981
Skagit mainstem, start of theme	1	0.237912	0.237912
SF from fork to dike setback blind	2	0.604016	1.208031
SF from fork to dike setback blind	2	1.660605	3.321211
from FW Sl west along bayfront to Sweetgale	4	0.440721	1.762883
to Rawlins Rd 51 from bayfront	5	0.777582	3.88791
from Rawlins Rd 51 to centroid	5	0.338251	1.691257

Figure 60



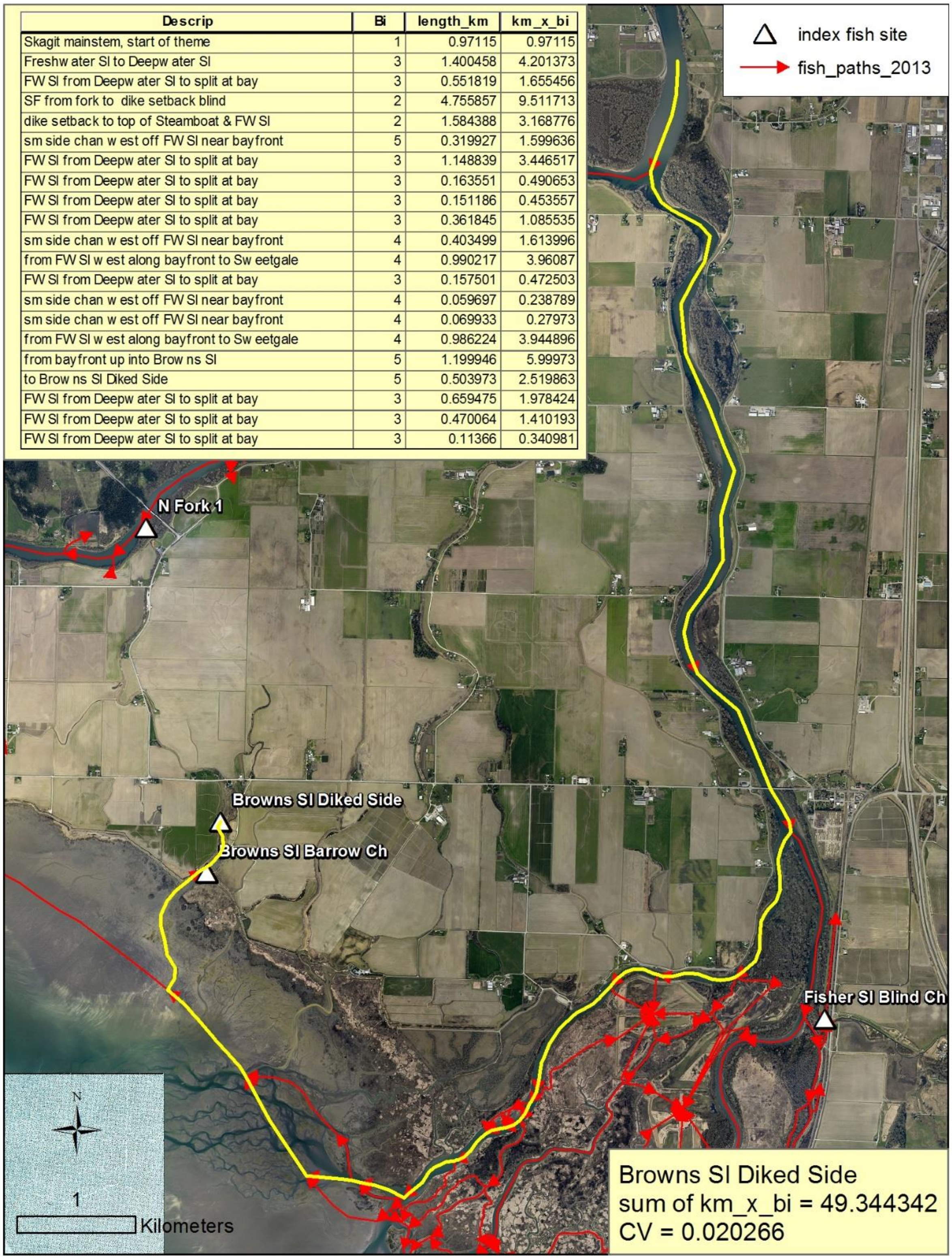
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Freshw ater Sl to Deepw ater Sl	3	1.400458	4.201373
FW Sl from Deepw ater Sl to split at bay	3	0.551819	1.655456
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
sm side chan w est off FW Sl near bayfront	5	0.319927	1.599636
FW Sl from Deepw ater Sl to split at bay	3	1.148839	3.446517
FW Sl from Deepw ater Sl to split at bay	3	0.163551	0.490653
FW Sl from Deepw ater Sl to split at bay	3	0.151186	0.453557
FW Sl from Deepw ater Sl to split at bay	3	0.361845	1.085535
sm side chan w est off FW Sl near bayfront	4	0.403499	1.613996
from FW Sl w est along bayfront to Sw eetgale	4	0.990217	3.96087
FW Sl from Deepw ater Sl to split at bay	3	0.157501	0.472503
sm side chan w est off FW Sl near bayfront	4	0.059697	0.238789
sm side chan w est off FW Sl near bayfront	4	0.069933	0.27973
from FW Sl w est along bayfront to Sw eetgale	4	0.986224	3.944896
from bayfront up into Brow ns Sl	5	1.199946	5.99973
to Brow ns Sl Barrow Ch	6	0.05045	0.302699
FW Sl from Deepw ater Sl to split at bay	3	0.659475	1.978424
FW Sl from Deepw ater Sl to split at bay	3	0.470064	1.410193
FW Sl from Deepw ater Sl to split at bay	3	0.11366	0.340981

Figure 61



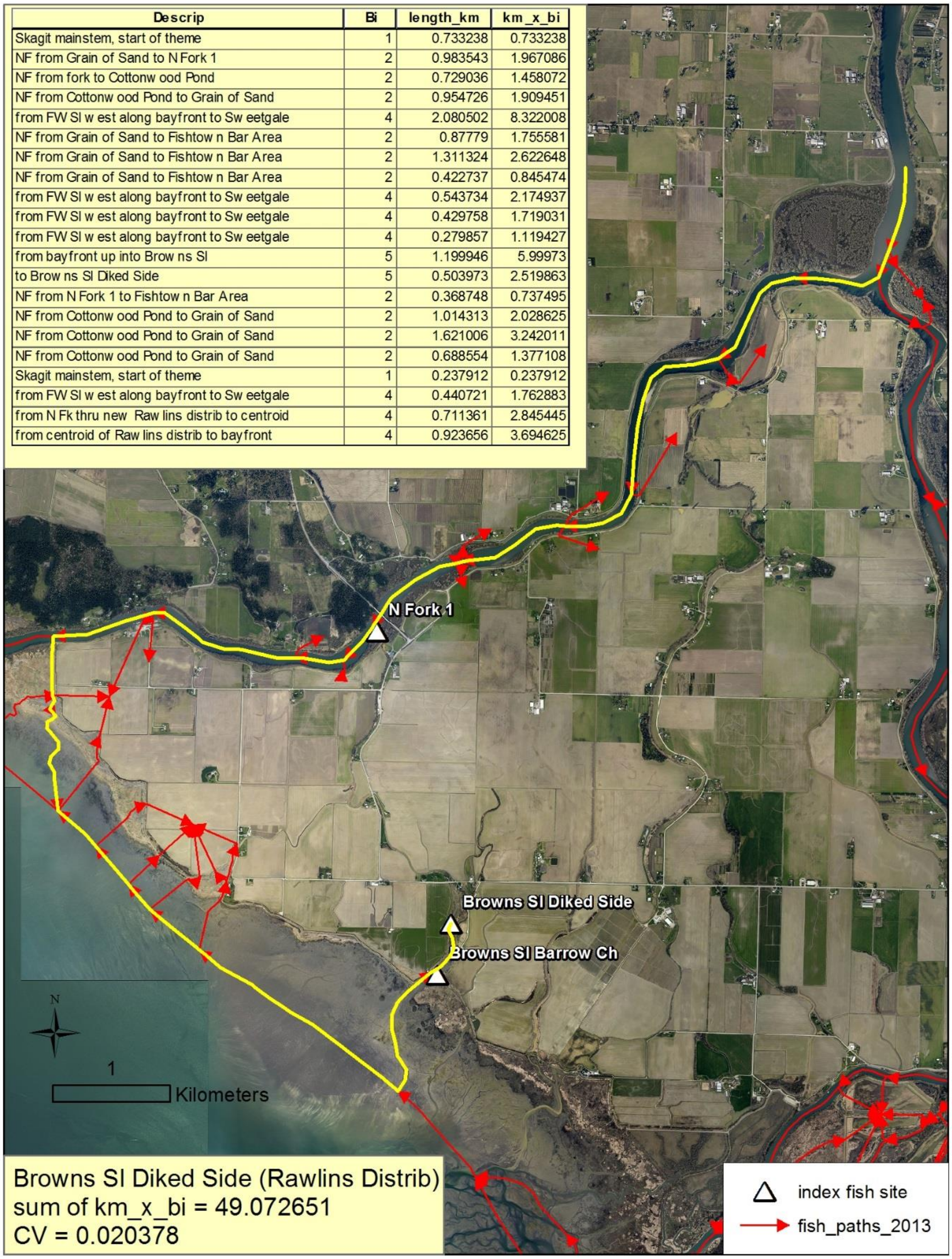
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.733238	0.733238
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
from FW Sl w est along bayfront to Sw eetgale	4	2.080502	8.322008
NF from Grain of Sand to Fishtow n Bar Area	2	0.87779	1.755581
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
from FW Sl w est along bayfront to Sw eetgale	4	0.543734	2.174937
from FW Sl w est along bayfront to Sw eetgale	4	0.429758	1.719031
from FW Sl w est along bayfront to Sw eetgale	4	0.279857	1.119427
from bayfront up into Brow ns Sl	5	1.199946	5.99973
to Brow ns Sl Barrow Ch	6	0.05045	0.302699
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108
Skagit mainstem, start of theme	1	0.237912	0.237912
from FW Sl w est along bayfront to Sw eetgale	4	0.440721	1.762883
from N Fk thru new Raw lins distrib to centroid	4	0.711361	2.845445
from centroid of Raw lins distrib to bayfront	4	0.923656	3.694625

Figure 62



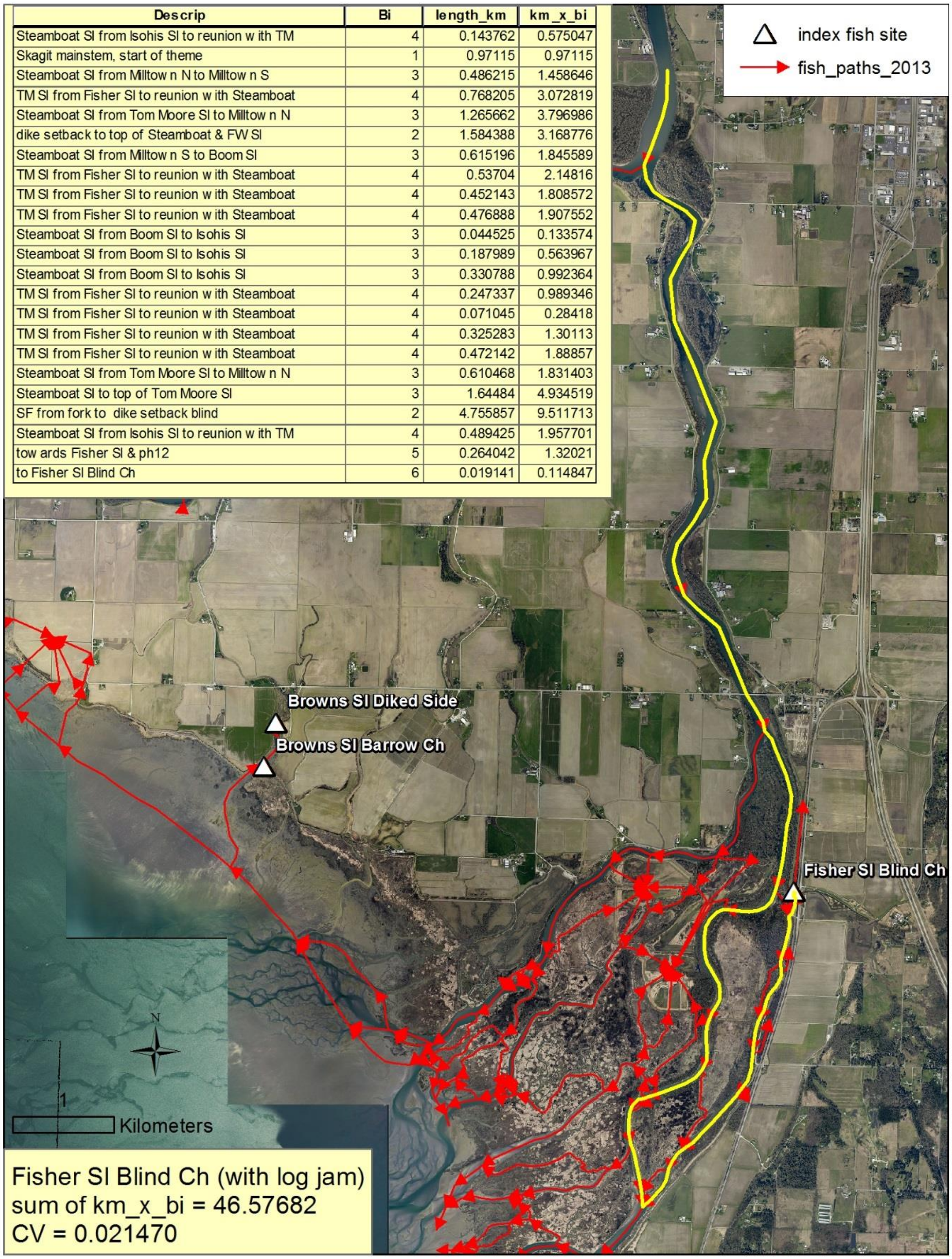
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Freshw ater Sl to Deepw ater Sl	3	1.400458	4.201373
FW Sl from Deepw ater Sl to split at bay	3	0.551819	1.655456
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
sm side chan w est off FW Sl near bayfront	5	0.319927	1.599636
FW Sl from Deepw ater Sl to split at bay	3	1.148839	3.446517
FW Sl from Deepw ater Sl to split at bay	3	0.163551	0.490653
FW Sl from Deepw ater Sl to split at bay	3	0.151186	0.453557
FW Sl from Deepw ater Sl to split at bay	3	0.361845	1.085535
sm side chan w est off FW Sl near bayfront	4	0.403499	1.613996
from FW Sl w est along bayfront to Sw eetgale	4	0.990217	3.96087
FW Sl from Deepw ater Sl to split at bay	3	0.157501	0.472503
sm side chan w est off FW Sl near bayfront	4	0.059697	0.238789
sm side chan w est off FW Sl near bayfront	4	0.069933	0.27973
from FW Sl w est along bayfront to Sw eetgale	4	0.986224	3.944896
from bayfront up into Brow ns Sl	5	1.199946	5.99973
to Brow ns Sl Diked Side	5	0.503973	2.519863
FW Sl from Deepw ater Sl to split at bay	3	0.659475	1.978424
FW Sl from Deepw ater Sl to split at bay	3	0.470064	1.410193
FW Sl from Deepw ater Sl to split at bay	3	0.11366	0.340981

Figure 63



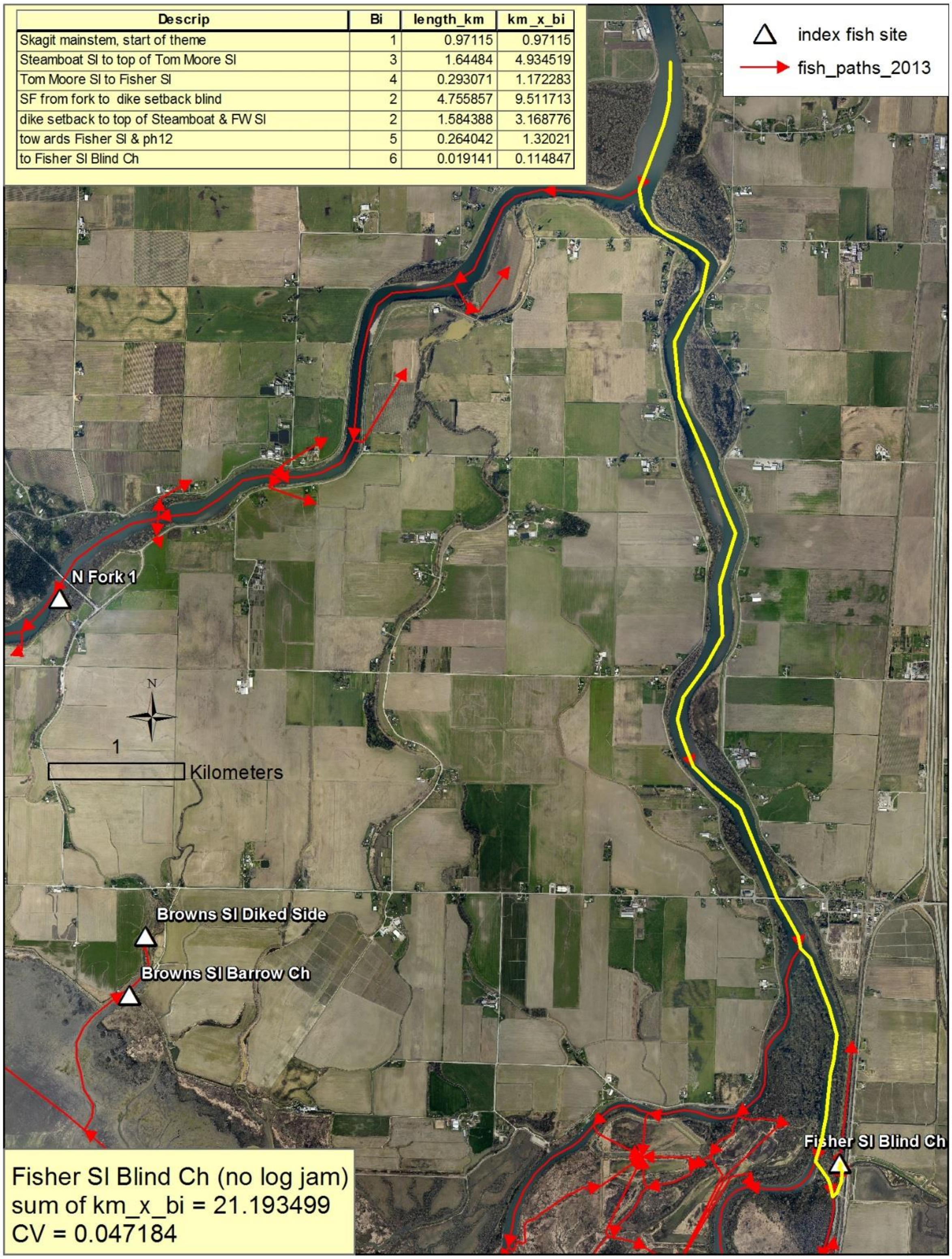
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.733238	0.733238
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
from FW Sl w est along bayfront to Sw eetgale	4	2.080502	8.322008
NF from Grain of Sand to Fishtow n Bar Area	2	0.87779	1.755581
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
from FW Sl w est along bayfront to Sw eetgale	4	0.543734	2.174937
from FW Sl w est along bayfront to Sw eetgale	4	0.429758	1.719031
from FW Sl w est along bayfront to Sw eetgale	4	0.279857	1.119427
from bayfront up into Brow ns Sl	5	1.199946	5.99973
to Brow ns Sl Diked Side	5	0.503973	2.519863
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108
Skagit mainstem, start of theme	1	0.237912	0.237912
from FW Sl w est along bayfront to Sw eetgale	4	0.440721	1.762883
from N Fk thru new Raw lins distrib to centroid	4	0.711361	2.845445
from centroid of Raw lins distrib to bayfront	4	0.923656	3.694625

Figure 64



Descrip	Bi	length_km	km_x_bi
Steamboat Sl from Isohis Sl to reunion with TM	4	0.143762	0.575047
Skagit mainstem, start of theme	1	0.97115	0.97115
Steamboat Sl from Milltown N to Milltown S	3	0.486215	1.458646
TM Sl from Fisher Sl to reunion with Steamboat	4	0.768205	3.072819
Steamboat Sl from Tom Moore Sl to Milltown N	3	1.265662	3.796986
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
Steamboat Sl from Milltown S to Boom Sl	3	0.615196	1.845589
TM Sl from Fisher Sl to reunion with Steamboat	4	0.53704	2.14816
TM Sl from Fisher Sl to reunion with Steamboat	4	0.452143	1.808572
TM Sl from Fisher Sl to reunion with Steamboat	4	0.476888	1.907552
Steamboat Sl from Boom Sl to Isohis Sl	3	0.044525	0.133574
Steamboat Sl from Boom Sl to Isohis Sl	3	0.187989	0.563967
Steamboat Sl from Boom Sl to Isohis Sl	3	0.330788	0.992364
TM Sl from Fisher Sl to reunion with Steamboat	4	0.247337	0.989346
TM Sl from Fisher Sl to reunion with Steamboat	4	0.071045	0.28418
TM Sl from Fisher Sl to reunion with Steamboat	4	0.325283	1.30113
TM Sl from Fisher Sl to reunion with Steamboat	4	0.472142	1.88857
Steamboat Sl from Tom Moore Sl to Milltown N	3	0.610468	1.831403
Steamboat Sl to top of Tom Moore Sl	3	1.64484	4.934519
SF from fork to dike setback blind	2	4.755857	9.511713
Steamboat Sl from Isohis Sl to reunion with TM	4	0.489425	1.957701
towards Fisher Sl & ph12	5	0.264042	1.32021
to Fisher Sl Blind Ch	6	0.019141	0.114847

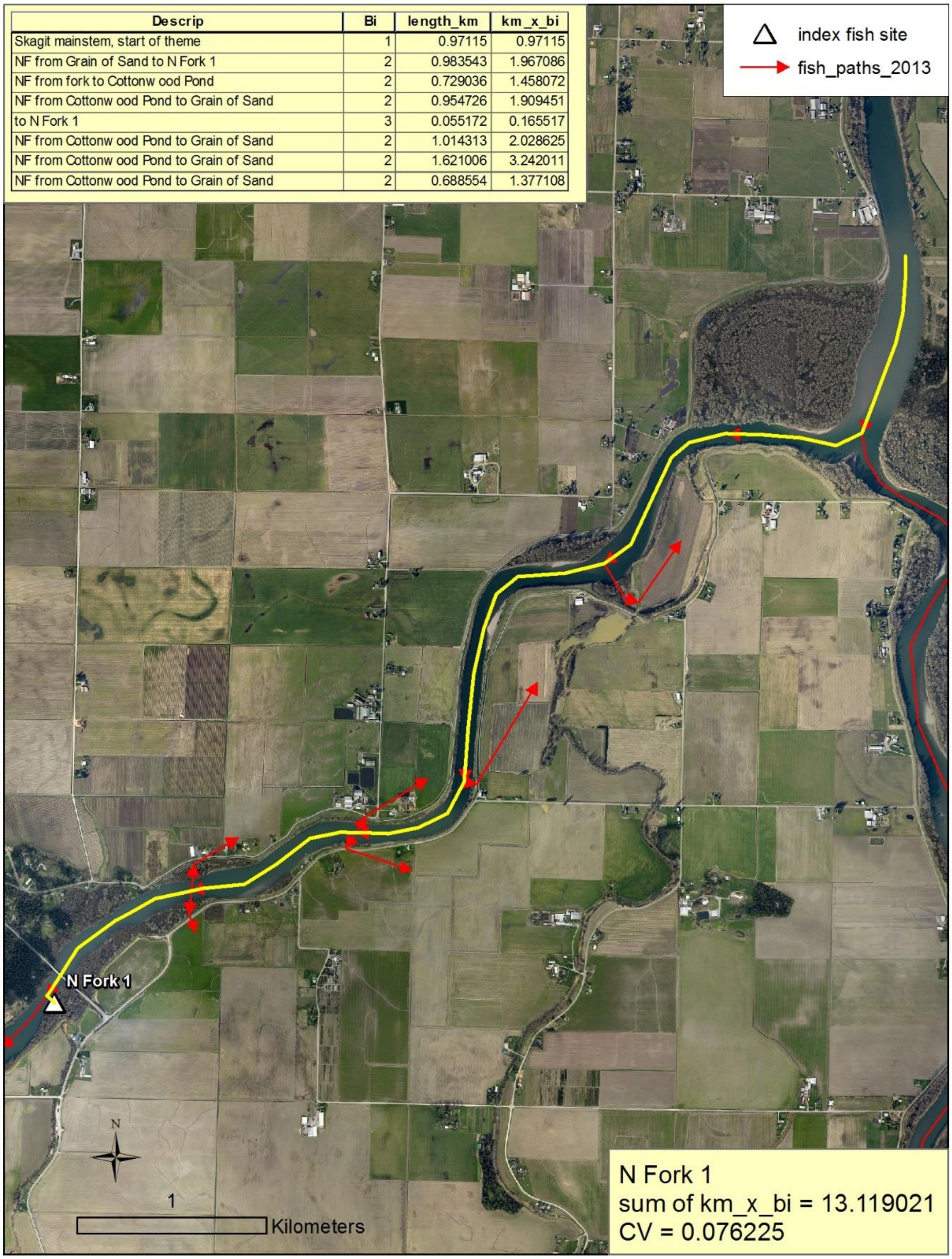
Figure 65



Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
Steamboat Sl to top of Tom Moore Sl	3	1.64484	4.934519
Tom Moore Sl to Fisher Sl	4	0.293071	1.172283
SF from fork to dike setback blind	2	4.755857	9.511713
dike setback to top of Steamboat & FW Sl	2	1.584388	3.168776
tow ards Fisher Sl & ph12	5	0.264042	1.32021
to Fisher Sl Blind Ch	6	0.019141	0.114847

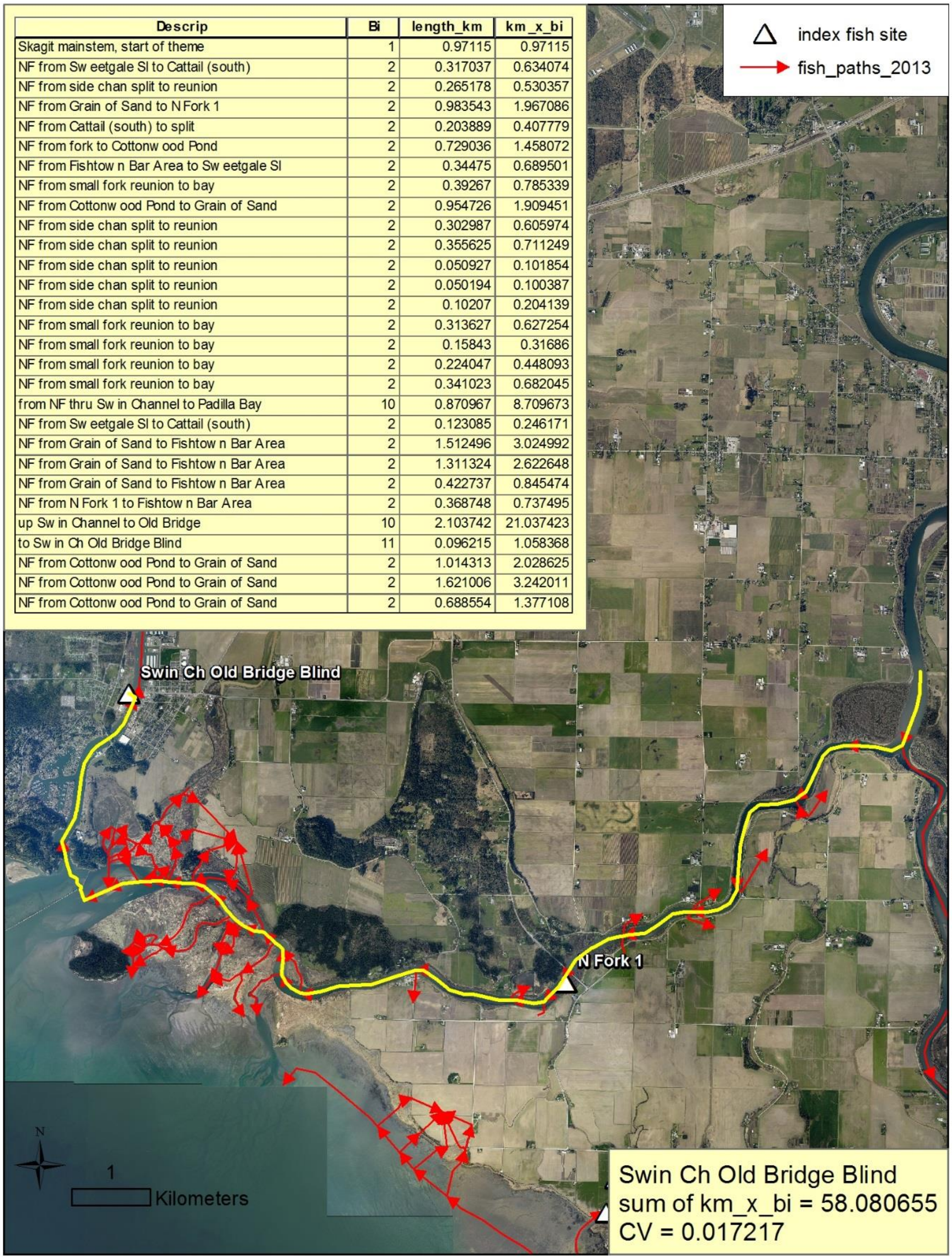
index fish site
fish_paths_2013
N Fork 1
N
1
Kilometers
Browns Sl Diked Side
Browns Sl Barrow Ch
Fisher Sl Blind Ch
Fisher Sl Blind Ch (no log jam)
sum of km_x_bi = 21.193499
CV = 0.047184

Figure 66



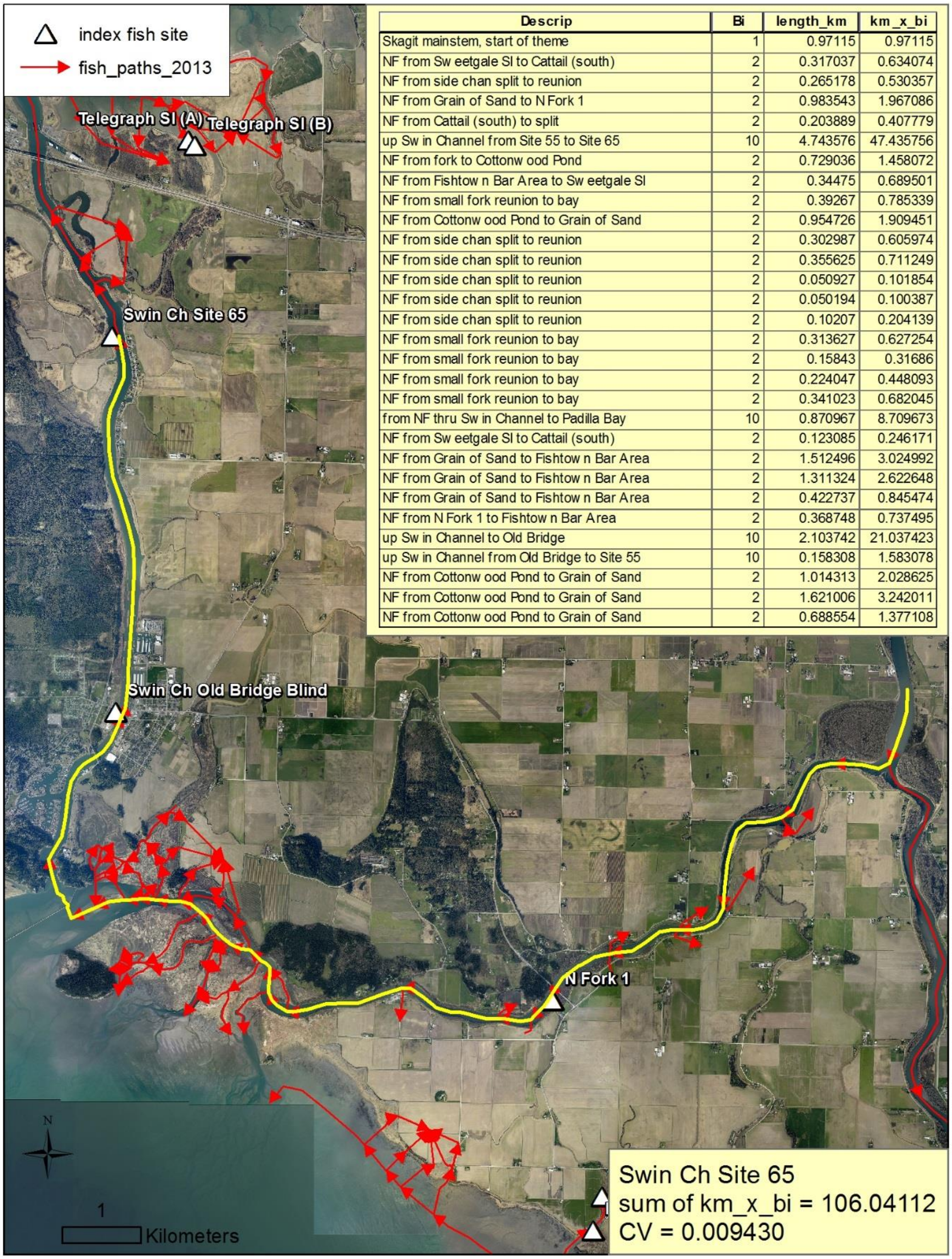
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
to N Fork 1	3	0.055172	0.165517
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 67



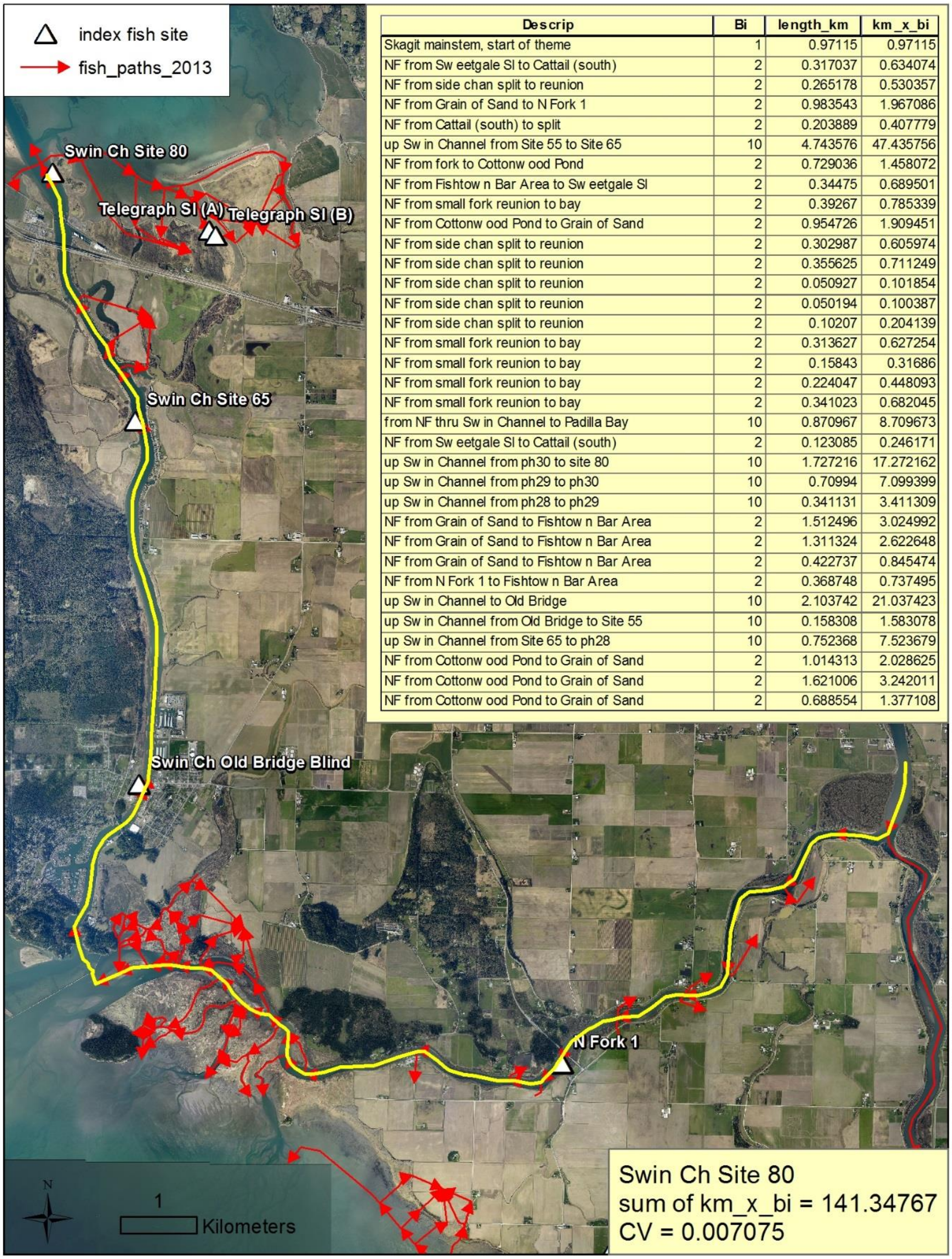
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Channel to Padilla Bay	10	0.870967	8.709673
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
NF from Grain of Sand to Fishtow n Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
up Sw in Channel to Old Bridge	10	2.103742	21.037423
to Sw in Ch Old Bridge Blind	11	0.096215	1.058368
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 68



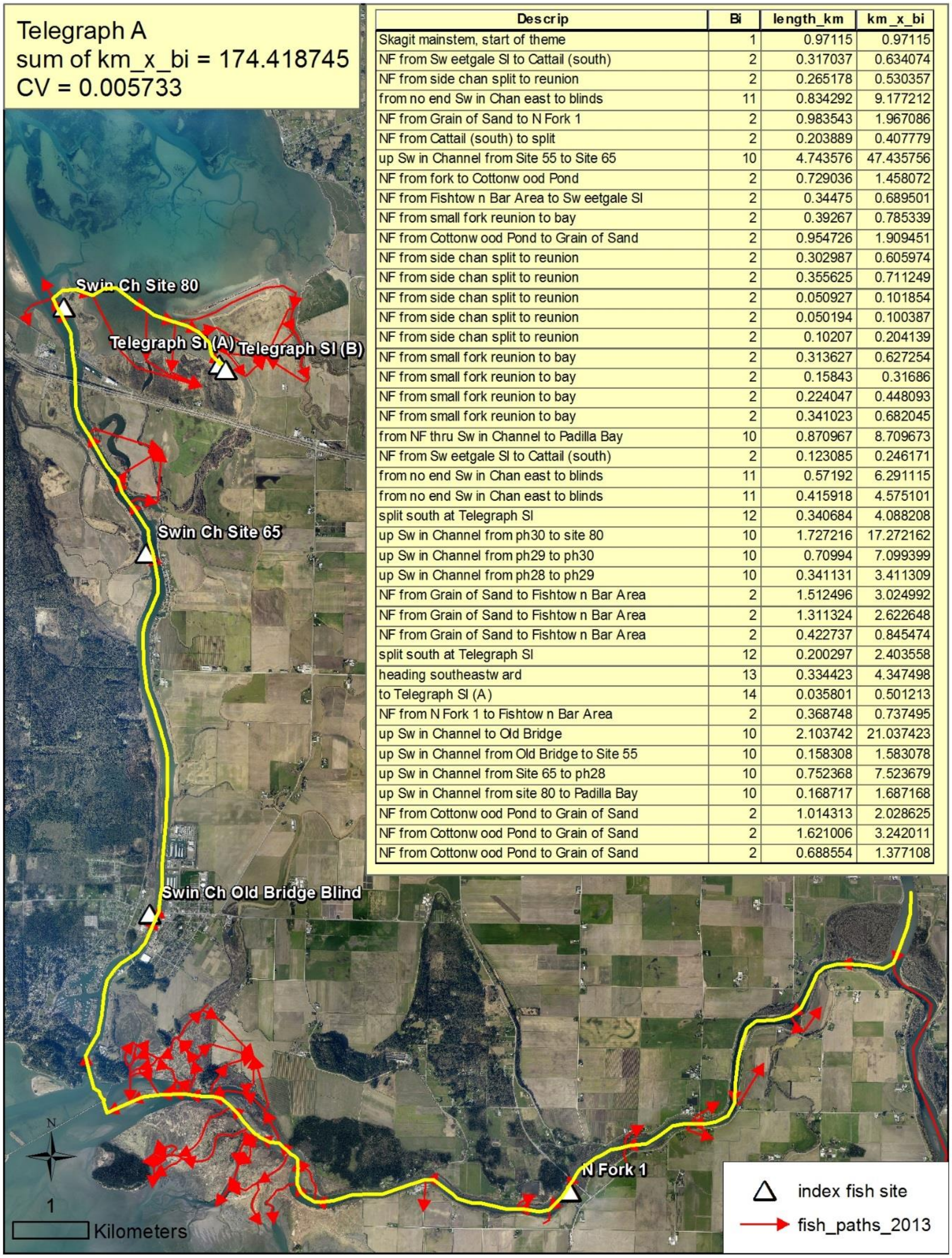
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
up Sw in Channel from Site 55 to Site 65	10	4.743576	47.435756
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Channel to Padilla Bay	10	0.870967	8.709673
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
NF from Grain of Sand to Fishtow n Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
up Sw in Channel to Old Bridge	10	2.103742	21.037423
up Sw in Channel from Old Bridge to Site 55	10	0.158308	1.583078
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 69



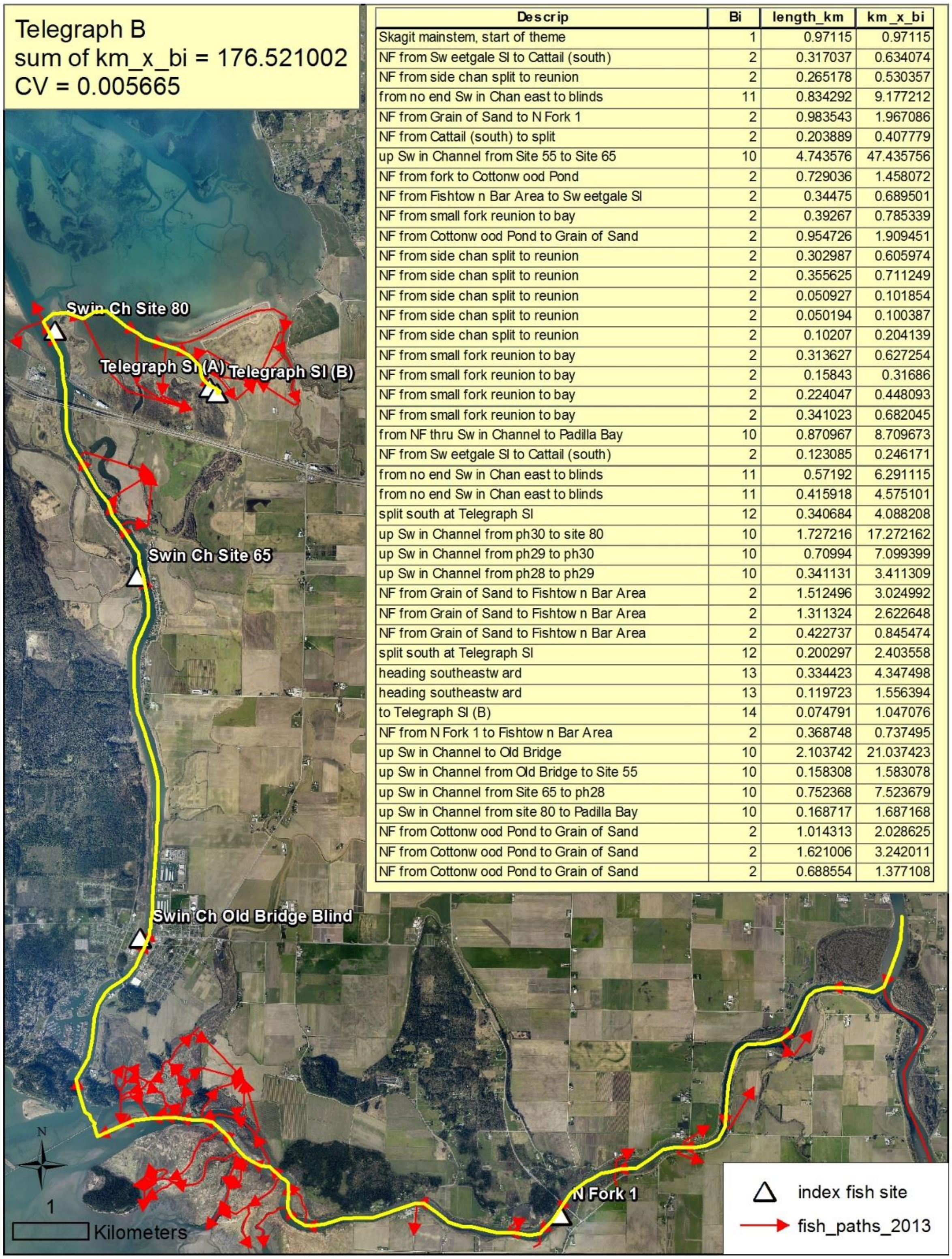
Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
up Sw in Channel from Site 55 to Site 65	10	4.743576	47.435756
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Channel to Padilla Bay	10	0.870967	8.709673
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
up Sw in Channel from ph30 to site 80	10	1.727216	17.272162
up Sw in Channel from ph29 to ph30	10	0.70994	7.099399
up Sw in Channel from ph28 to ph29	10	0.341131	3.411309
NF from Grain of Sand to Fishtow n Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
up Sw in Channel to Old Bridge	10	2.103742	21.037423
up Sw in Channel from Old Bridge to Site 55	10	0.158308	1.583078
up Sw in Channel from Site 65 to ph28	10	0.752368	7.523679
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 70



Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
NF from Sw eetgale Sl to Cattail (south)	2	0.317037	0.634074
NF from side chan split to reunion	2	0.265178	0.530357
from no end Sw in Chan east to blinds	11	0.834292	9.177212
NF from Grain of Sand to N Fork 1	2	0.983543	1.967086
NF from Cattail (south) to split	2	0.203889	0.407779
up Sw in Channel from Site 55 to Site 65	10	4.743576	47.435756
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Channel to Padilla Bay	10	0.870967	8.709673
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
from no end Sw in Chan east to blinds	11	0.57192	6.291115
from no end Sw in Chan east to blinds	11	0.415918	4.575101
split south at Telegraph Sl	12	0.340684	4.088208
up Sw in Channel from ph30 to site 80	10	1.727216	17.272162
up Sw in Channel from ph29 to ph30	10	0.70994	7.099399
up Sw in Channel from ph28 to ph29	10	0.341131	3.411309
NF from Grain of Sand to Fishtow n Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
split south at Telegraph Sl	12	0.200297	2.403558
heading southeastw ard	13	0.334423	4.347498
to Telegraph Sl (A)	14	0.035801	0.501213
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
up Sw in Channel to Old Bridge	10	2.103742	21.037423
up Sw in Channel from Old Bridge to Site 55	10	0.158308	1.583078
up Sw in Channel from Site 65 to ph28	10	0.752368	7.523679
up Sw in Channel from site 80 to Padilla Bay	10	0.168717	1.687168
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 71



Descrip	Bi	length_km	km_x_bi
Skagit mainstem, start of theme	1	0.97115	0.97115
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up Sw in Channel from Site 55 to Site 65	10	4.743576	47.435756
NF from fork to Cottonw ood Pond	2	0.729036	1.458072
NF from Fishtow n Bar Area to Sw eetgale Sl	2	0.34475	0.689501
NF from small fork reunion to bay	2	0.39267	0.785339
NF from Cottonw ood Pond to Grain of Sand	2	0.954726	1.909451
NF from side chan split to reunion	2	0.302987	0.605974
NF from side chan split to reunion	2	0.355625	0.711249
NF from side chan split to reunion	2	0.050927	0.101854
NF from side chan split to reunion	2	0.050194	0.100387
NF from side chan split to reunion	2	0.10207	0.204139
NF from small fork reunion to bay	2	0.313627	0.627254
NF from small fork reunion to bay	2	0.15843	0.31686
NF from small fork reunion to bay	2	0.224047	0.448093
NF from small fork reunion to bay	2	0.341023	0.682045
from NF thru Sw in Channel to Padilla Bay	10	0.870967	8.709673
NF from Sw eetgale Sl to Cattail (south)	2	0.123085	0.246171
from no end Sw in Chan east to blinds	11	0.57192	6.291115
from no end Sw in Chan east to blinds	11	0.415918	4.575101
split south at Telegraph Sl	12	0.340684	4.088208
up Sw in Channel from ph30 to site 80	10	1.727216	17.272162
up Sw in Channel from ph29 to ph30	10	0.70994	7.099399
up Sw in Channel from ph28 to ph29	10	0.341131	3.411309
NF from Grain of Sand to Fishtow n Bar Area	2	1.512496	3.024992
NF from Grain of Sand to Fishtow n Bar Area	2	1.311324	2.622648
NF from Grain of Sand to Fishtow n Bar Area	2	0.422737	0.845474
split south at Telegraph Sl	12	0.200297	2.403558
heading southeastw ard	13	0.334423	4.347498
heading southeastw ard	13	0.119723	1.556394
to Telegraph Sl (B)	14	0.074791	1.047076
NF from N Fork 1 to Fishtow n Bar Area	2	0.368748	0.737495
up Sw in Channel to Old Bridge	10	2.103742	21.037423
up Sw in Channel from Old Bridge to Site 55	10	0.158308	1.583078
up Sw in Channel from Site 65 to ph28	10	0.752368	7.523679
up Sw in Channel from site 80 to Padilla Bay	10	0.168717	1.687168
NF from Cottonw ood Pond to Grain of Sand	2	1.014313	2.028625
NF from Cottonw ood Pond to Grain of Sand	2	1.621006	3.242011
NF from Cottonw ood Pond to Grain of Sand	2	0.688554	1.377108

Figure 72

Appendix E: GIS Tech Notes and Maps

GIS Technical Notes

Jamie Robertson, Conservation Geographer, The Nature Conservancy

Indicator: Farm 1 - Acres of Skagit County zoned AG-NRL or OSRSI and has a history of farming that would be converted

GIS Method: Overlay project concepts with land zoned by Skagit County as AG-NRL, Rrv or ORSRI and that have a history of farming and calculate area

Data used: Skagit County Comprehensive Plan and Zoning District shape file

Steps:

1. Comprehensive Plan Zoning Categories
   i) Use Tabulate Intersection too to calculate area of each Skagit County Comprehensive Plan Zoning Category within each Concept Area.

Indicator: Farm 4 - Acres of public land per project concept

GIS Method: Overlay project concepts and Skagit County parcel maps and calculate areas in public vs. private ownership

Data used: Skagit County Parcel Map and data

Steps:

1. Ownership
   i) Using Skagit County parcel data, manually categorize owners into four categories of ownership (as determined from attribute data):
      (1) Private
      (2) District
      (3) Public
      (4) Water
   ii) Use Tabulate Intersection tool to calculate area of each category within each Concept Area

Indicator: Farm 5 - Acres of farmland protection easements

GIS Method: Overlay project concepts with farmland preservation easements and calculate area within easements

Data used: Skagit County Database Consortium (agricultural easements map and data)

Steps:

1. SCDC Agriculture Easements

i) Write custom Python script to run ArcGIS Tabulate Area tool on each. (See attached script.)
ii) The script runs the Tabulate Area tool for each polygon individually. Two steps are taken to speed up the processing:
    (1) concept areas which do not overlap agriculture easements are excluded from analysis.
    (2) agriculture easements are converted to a raster file to be used as input to the Tabulate Area tool rather than the tool having to convert to raster for each iteration of concept area run.
iii) Processing spatial reference and output units match those of the input layers. In this case, the projection is UTM Zone 10 NAD83 with units of meters.
iv) Processing cell size is set to 1-meter.
v) Input Zones: Concept Areas
    (1) Spatial Query: Select only those Concept Areas which intersect Agriculture easements
vi) Input Classes: SCDC 2016 parcels of type "Agriculture" only
    (1) Attribute Query: "ResTargNam" = 'Agriculture'

Indicator: Fish 1 – Within project increases in wetted area during a high tide or 2-year flow.

GIS Method: for the three backwater channels (TNC South Fork, Cottonwood Island, and East Cottonwood) that were too narrow to be accurately predicted by PNNL's output, calculate additional area inundated

Data used: PNNL world files for inundation depth

Steps:

1. Calculate minimum value (cell statistics) of the combination of the three bands making up input HDM raster (*.png with World Files) to get a single band raster. Do for both Baseline and Small Project Q2 Low Tide Depth.
    ii) Baseline output: gridMINIMUM_Baseline_Q2_LowTideDepth
    iii) Small Proj output: gridMINIMUM_SmallProjects_Q2_LowTideDepth
2. Convert above outputs to polygons.
    i) Baseline output fc: hdmBaseline_Q2_LowTide_Depth_poly
    ii) Small Proj output fc: hdmSmallProjects_Q2_LowTide_Depth_poly
3. Tabulate Intersection of baseline and small project HDM polygons with Concept Area polygons
    i) Baseline output: TabInt_Concept_hdmBaselineQ2LowTideDepth
    ii) Small Proj output: TabInt_Concept_hdmSmallProjectsQ2LowTideDepth
4. Join outputs to Concept Area attribute table and export to Excel where the necessary concept areas will be extracted. The necessary concept areas are: TNC South Fork, Cottonwood Island, and East Cottonwood.

Indicator: Fish 2 – Decreases in wetted area during a 2-year flow outside the project concept.

GIS Method: calculate areas outside the project concepts where increases or decreases in wetted area occurred

Data used: PNNL world files for inundation depth

Steps:

1. Convert each Lowtide-Depth WorldFile png to a single band raster using "Cell Statistics" tool, where Sum is the statistic used.
   ii) 5 outputs: [name].tif
2. Create binary raster from above output using "Raster Calculator" tool, where 1 is wet and 0 is not.
   ii) Conditional statement: [input] != 765 (Note: 765 is the maximum possible value of the summed total Red-Green-Blue bands of the png files. The max value of each band is 255, which are white space representing dry areas. All values less than 765 indicate some amount of water is present.)
   iii) 5 outputs: [name]_bin.tif
3. Create analysis masks for each area tabulation.
   i) Select relevant project concept polygons for the particular run, mouse over "Selection" and click "Create Layer from Selected Features". (Note: selection isn't needed when calculating for all projects at once.)
   ii) For each selection layer (project concept polygons), use the Erase tool to delete those polygon areas from the Riverine Area polygon provided by Jenna Friebel (WDFW), so there will be a total of 5 new layers created.
   iii) Re-project each of the 5 new layers to the same projection as the HDM rasters, so NAD 1983, UTM Zone 10.
4. Run area tabulations for each scenario with the Tabulate Area tool
   i) Zone input: Baseline-Q2-LowTide-Depth_bin.tif (Field: Value)
   ii) Class inputs: each of the 5 binary rasters (Field: Value)
   iii) Environment|Raster Analysis|Analysis Mask: use mask layers for respective Class inputs
   iv) 5 output tables: tabarea_Baseline_[run]_Lowtide_Depth
5. Copy output tables to Excel. Values are square meters and are converted to acres in final table deliverable. Rows are the Baseline values where 0=dry and 1=wet, and the column header values are the LowTide Depth runs where Value_0=dry and Value_1=wet. The change from Wet to Dry area is the combo [Baseline=1 and Run=0], and the change from Dry to Wet is the combo [Baseline=0 and Run=1]. The Net Change is the difference, i.e. [Wet to Dry] – [Dry to Wet].
6. Create layers representing the changes
   i) Raster Calculator (Map Algebra): Use Conditional statement to assign output values to the four combinations of the baseline wet/dry and scenario wet/dry cells. Use the following statement, where the first input raster is the baseline and second input raster is the scenario.
      (1) Con(("Baseline-Q2-LowTide-Depth_bin.tif" == 1) & ("R8-Q2-LowTide-Depth_bin.tif" == 1), 0, Con(("Baseline-Q2-LowTide-Depth_bin.tif" == 0) & ("R8-Q2-LowTide-Depth_bin.tif" == 0), 0, Con(("Baseline-Q2-LowTide-Depth_bin.tif" == 1) & ("R8-Q2-LowTide-Depth_bin.tif" == 0), 1, Con(("Baseline-Q2-LowTide-Depth_bin.tif" == 0) & ("R8-Q2-LowTide-Depth_bin.tif" == 1), -1))))
      (2) Output rasters: input name plus "_wetdry.tif", e.g. "R8-Q2-LowTide-Depth_wetdry.tif"
      (3) Output values
         (a) -1 = Change from Wet to Dry
         (b) 0 = No Change (Stays wet or stays dry)
         (c) 1 = Change from Dry to Wet
   ii) Set Null (tool) for changing the 0 (No Change) value to null and to clip the output to the appropriate analysis mask used in prior steps.

(1) Expression: “Value” = 0
(2) Input false raster: same as input conditional raster, e.g. *wetdry.tif
(3) Output raster: input raster name plus clpnull.tif
(4) Output values:
    (a) -1 = Change from Wet to Dry
    (b) 1 = Change from Dry to Wet

Indicator: Fish 6 – Diversity metric of predicted habitat types within project area based on elevation.

GIS Method: Calculate the area within each project concept that falls within each 1-foot elevation bin (NAVD 88)

Data used: Elevation data created from XYZ coordinates of the PNNL surface model

Steps:

1. Create new field [Z_feet] and convert elevation grid metric Z values to feet.
2. Convert “gridline” surface line vectors to polygons
   i) Output: pnnl_sufrace_gridlinepoly_jr
3. Dissolve polygons above
   i) Output: pnnl_sufrace_gridlinepoly_dslv_jr
4. Buffer dissolved polygons above by 1 meter to ensure border of elevation model is outside concept area boundaries
   i) Output: pnnl_surface_gridlinepoly_dslv_buf1m
5. Use “Spline with Barriers” tool to interpolate elevation grid points to a continuous raster. Use above buffered surface as barriers.
   i) Output: dem1m_zfeet_pnnlHDM
6. Convert the elevation fractional values to 1-foot elevation range categories by rounding positive numbers up and negative numbers down. No exact 0 (zero) values exist.
   i) Int(Con("dem1m_zfeet_pnnlHDM" > 0, RoundUp("dem1m_zfeet_pnnlHDM"), RoundDown("dem1m_zfeet_pnnlHDM")))
   ii) Output: dem1m_zfeet_pnnlHDM_rounded
7. Clip rounded raster to concept areas
   i) Output: dem1m_zfeet_pnnlHDM_rounded_clpConcAreas
8. Tabulate Area of 1-ft bins by concept area (using “Tabulate Area 2” script tool in “Spatial Analyst Supplemental Tools” toolbox).
   i) Output: tabarea_projareas_elevbin1ft_20160816
   ii) Copy to Excel file and convert square meters to acres for delivery. (Output units are sq meters, so conversion multiplies sq meter values by 0.000247105 to get acres.)

Indicator: Flood 1 – Length of river with reduced water surface elevation during a flood event

GIS Method: Create map products for Shear Stress (indicator not used) and Water Surface Elevation, and calculate length of reduced water surface elevation per elevation bin during a flood event

Data used: PNNL world files for reduced water surface elevation and channel centerlines adjusted by TNC from WDNR data

Steps:

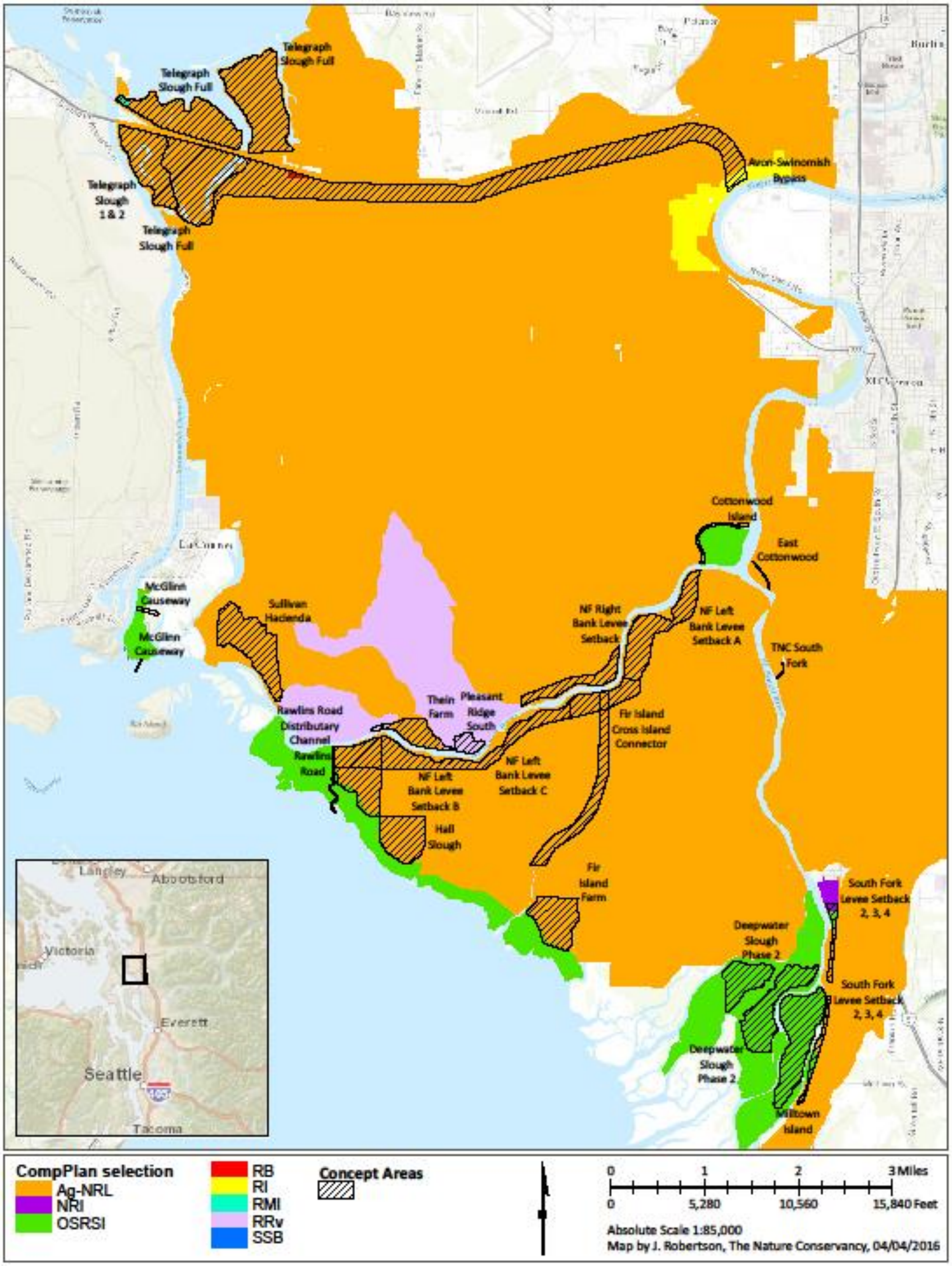
1. Data for shear stress and water surface elevation are delivered by PNNL in a *.png file type spatial referenced with *.pgw World Files. PNNL is generally responsible for georeferencing these files.
2. The following steps were taken to display the PNNL data appropriately in ArcMap:
   iii) Open an ArcMap document.
   iv) Open ArcMap Options from the Customize menu dropdown.
   v) Click on Raster tab and Raster Layer subtab.
   vi) Check the box for "Use wavelength information when available" and ensure Red is band 1, Green is band 2, and Blue is band 3.
   vii) Check the box for Enable Custom Rendering Defaults and ensure Display Resampling is set to Nearest Neighbor and Stretch type is Mininum-Maximum. Stand Dev = 2, Persent Clip Min = 2, and Percent Clip Max = 2. Do not turn on Apply Gamma Stretch.
   viii) Check the box for Display Background Value, enter 255 for all three values, and show the color as No Color. Also Display NoData as No Color.
   ix) Click Apply and OK.
   x) Add the HDM data to ArcMap and check that they are in the correct location. If they are not, check the *.pgw file is in the same folder with the *.png file. If the data still do not line up properly, check that the ArcMap Data Frame is projected as UTM Zone 10 NAD83. If the data still not line up properly, there is likely a problem with the World File.
   xi) If the data line up correctly but colors look off, open the data's layer properties and click the Symbology tab. Check that the bands are displayed in this order: Red (Band 1), Green (Band 2), Blue (Band 3). Turn on Display Background Value and set values to 255 and No Color. Change the Stretch Type to Minimum-Maximum. Turn off Apply Gamma Stretch and Pan Sharpening.
3. The following steps were taken to calculate length of reduced WSE:
   xii) Use Raster Function on relevant *.png input files
      (1) Open toolbar called Image Analysis from the menu dropdown
      (2) Highlight the input raster
      (3) Under "Processing" window of Image Analysis, click on the "Add Function" button (which looks like a pencil on top of *fx*)
      (4) In the Function Template Editor, expand the Function Chain and right-click on the input raster name, mouse over "Insert Function" and click "Band Arithmetic Function"
         (a) In "Band Arithmetic" tab, keep the default Input Raster name, select "User Defined" from Method dropdown list, and type in Expression: **(B1*1000000)+(B2*1000)+B3**
         (b) In "General" tab, be sure the Output Pixel Type is **32 Bit Float**
         (c) Click OK
         (d) A new raster will be added called Func_[input raster name]
      (5) Convert the new Func_... raster to Integer using the Int tool in Spatial Analyst Toolbox|Math. For output file, change "Func" to "int" and change the file type from PNG to TIF, which is *.tif)

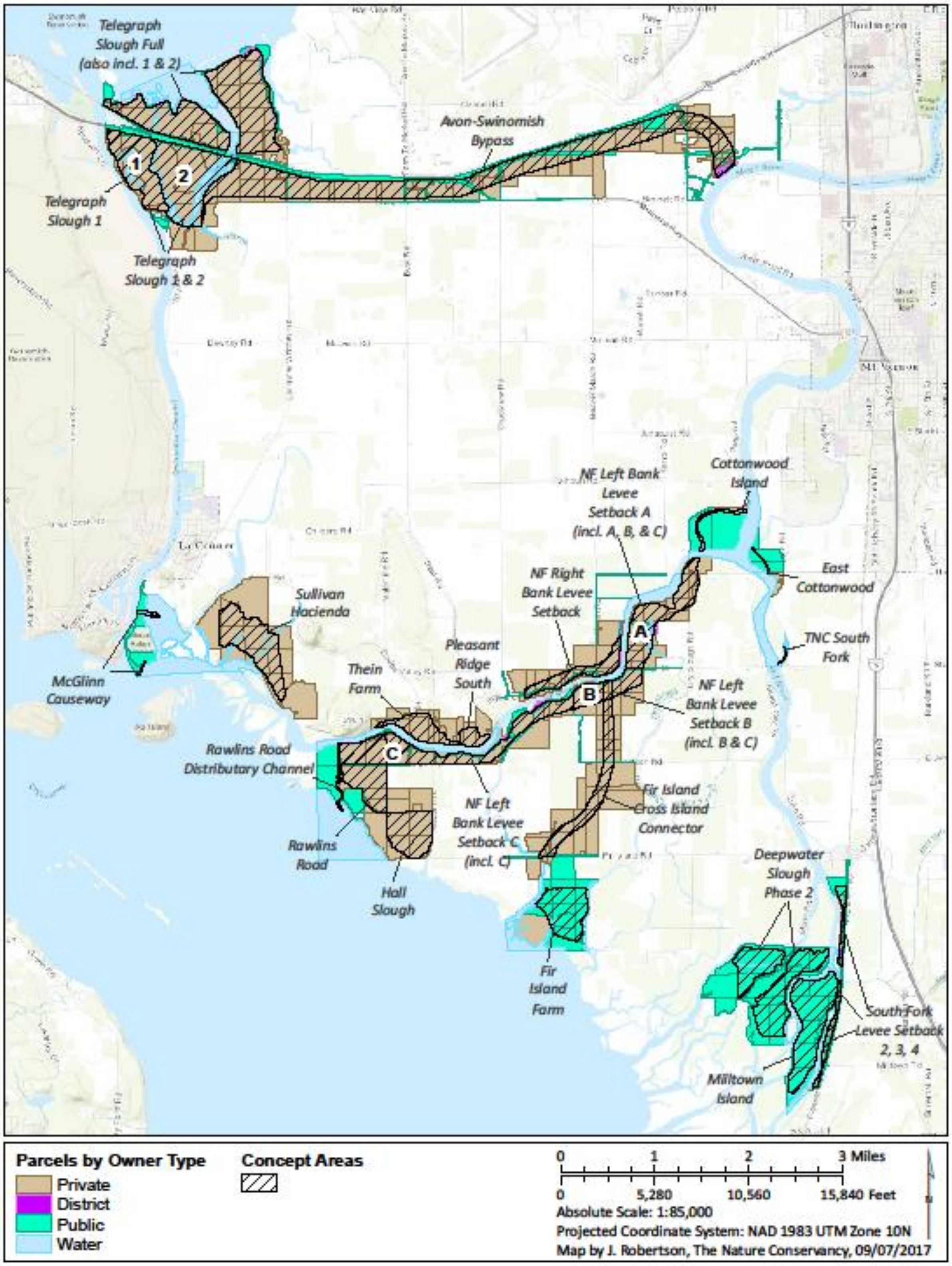
(6) THIS IS JUST A WAY TO TEST THE COLORS AND CREATE A COLOR MAP. Open the attribute table of the newly created integer tif file. Add three new fields of type Integer, and name them respectively: Red, Green, Blue.
   (a) For Red, use Raster Calculator expression:
      (i) int(!Value!/1000000)
   (b) For Green, use Raster Calculator expression:
      (i) ((int(!Value! /1000) * 1000) - (int(!Value!/1000000) * 1000000)) /1000
   (c) For Blue, use Raster Calculator expression:
      (i) !Value! - (int(!Value! / 1000) * 1000)
(7) Add new float or double field called “DecreWSE” and add new text field called “txt_decre” to the “int” raster tables. Edit the field values of the fields with the WSE decrease values. Do this by zooming to the legend. Start Editing, open the “int” table, click on a row to select it, see which legend value highlighted with the selection, and then enter the WSE decrease value. Only do the ones with decreasing values. Make all positive and other DecreWSE values equal to 0 (zero). Save and stop editing. Calculate the values of “txt_decre” based on the newly added “DecreWSE” values.
   (a) NOTE: The R3 scenario may have slightly varied colors from the others. This won’t be visible except by viewing the RGB values. To keep things standard, consider editing the values in the R3’s “int” table to match the other scenarios.
   (b) NOTE: Too speed up the process, as long as the tables’ RGB values are equivalent, the tables can be joined and DecreWSE fields calculated from the first one done manually. If unsure about the RGB equivalency, just manually edit the values for each table as described above.
(8) Convert the “int” rasters to polygons with the “txt_decre” field.
(9) Create a river channel layer from DNR hydro lines. Select the mainstems and appropriate branches. Digitize additional lines as needed, and adjust existing lines to better align the river channels and HDM data.
(10) Select and export the appropriate channel lines for each scenario run, calling them “channel_[scenario name]”.
(11) If necessary, define projection or re-project the polygons and channel data to UTM Zone10 NAD83.
(12) Tabulate Intersection: length of channel per WSE decrease value.

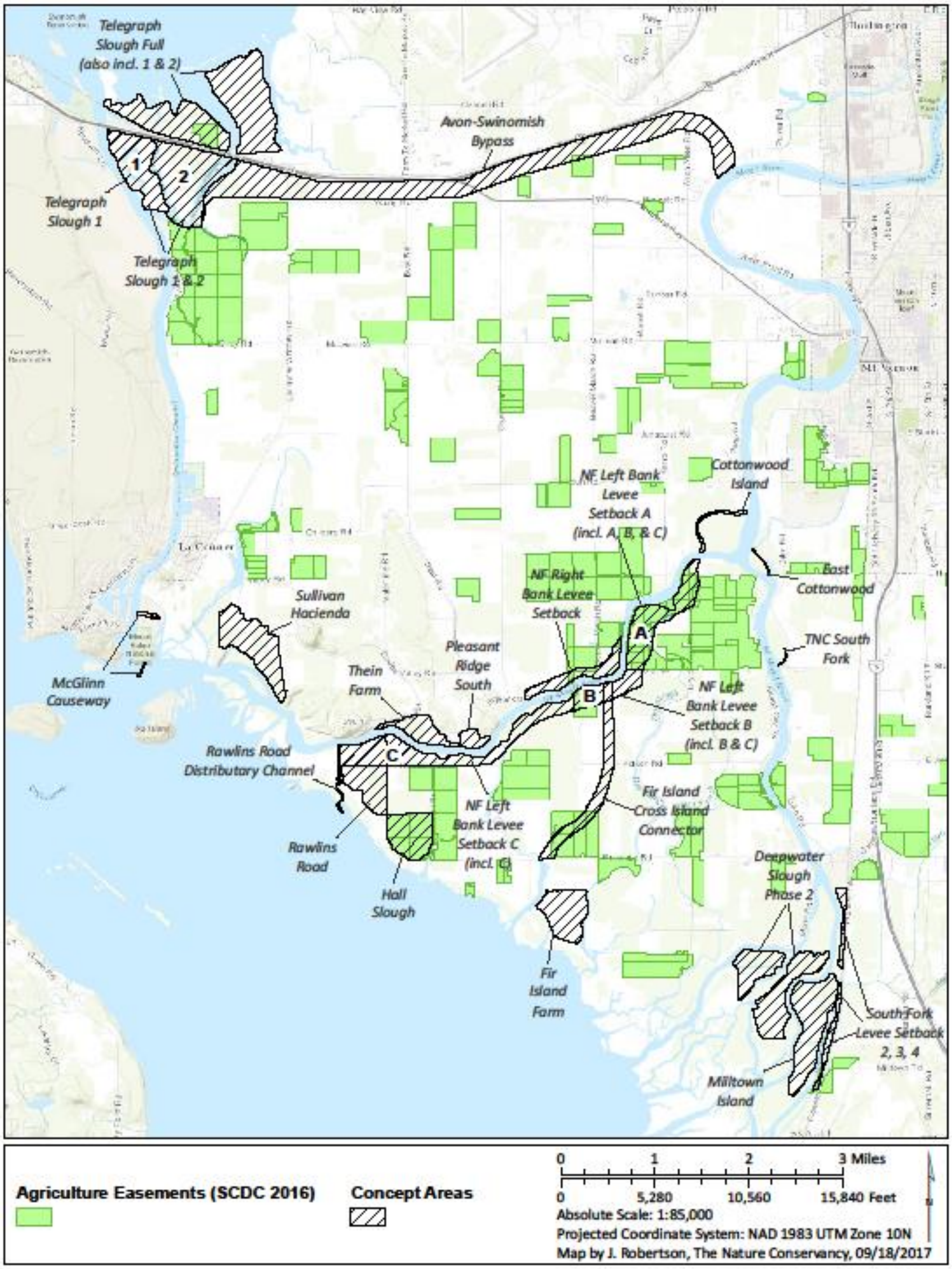
Python Script:

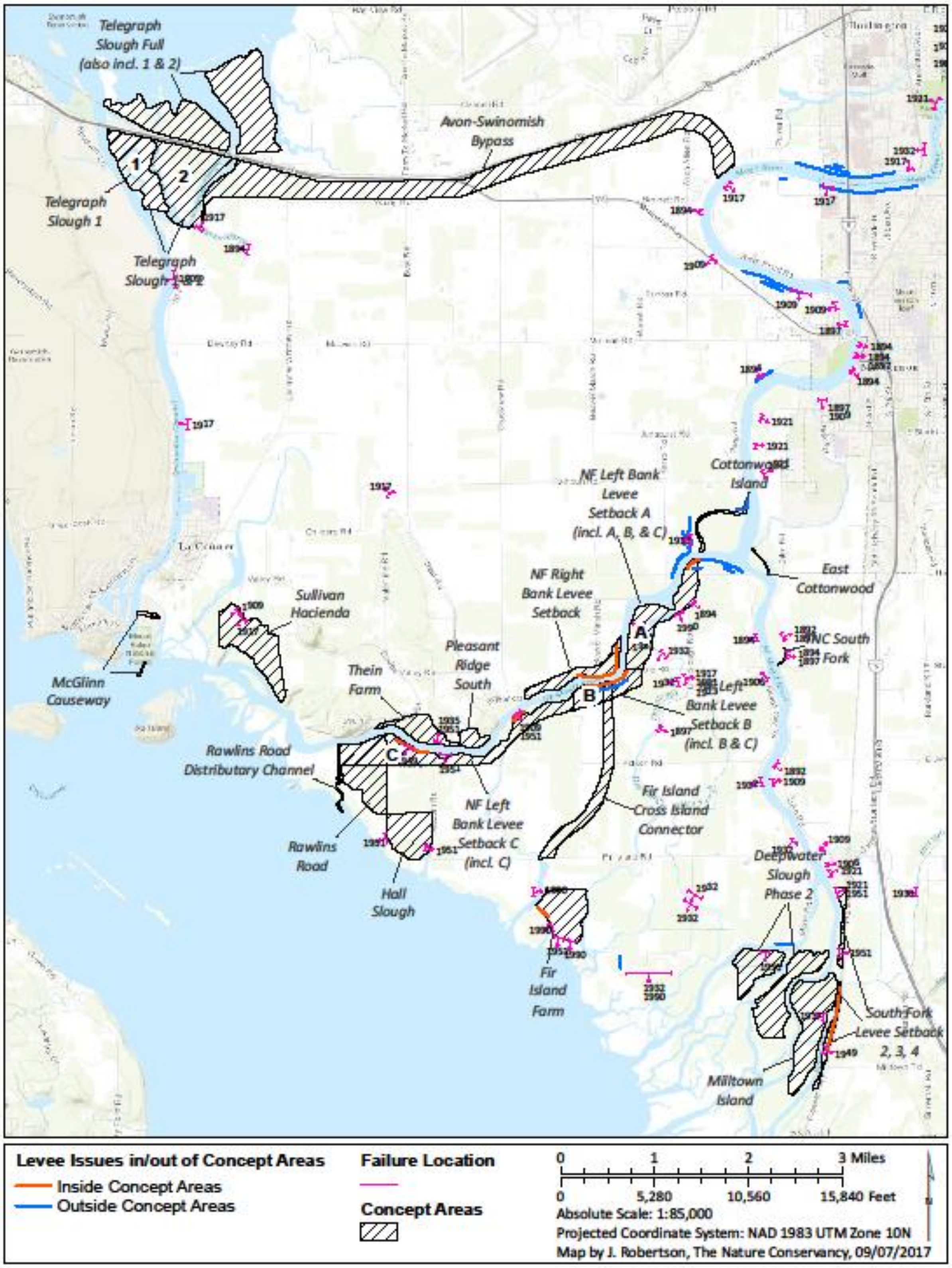
```
import arcpy, os
from arcpy import env
from arcpy.sa import *

# Set output location variables
out_gdb_loc = "C:/Users/jrobertson/Box Sync/WAFO_GIS"
out_gdb_name = "TabulateArea_FGDB.gdb"

# Create output workspace
if arcpy.Exists(out_gdb_loc + "/" + out_gdb_name):
   print("Verified output file geodatabase exists.")
else:
   arcpy.CreateFileGDB_management(out_gdb_loc, out_gdb_name)
   print("Created new output file geodatabase.")

# Set environment settings
env.workspace = out_gdb_loc + "/" + out_gdb_name    # Workspace is output geodatabase created above
print(env.workspace)
# env.snapraster = "Box
Sync/WAFO_GIS_Projects/Freshwater/Projects/3FI/dem/dem1m_zfeet_pnnlHDM_rounded_clpConcAreas.tif"
env.overwriteOutput = "TRUE"                    # Not necessary to keep True.  Can use False.

# Set local variables
inZoneData = "C:/Users/jrobertson/Box
Sync/WAFO_GIS_Projects/Freshwater/Projects/3FI/Data_3FI_FGDB_2.gdb/hdm_project_areas_20160204"
zoneField = "Projects_JoinTable_20160128_Proj_Name"
inClassData = "C:/Users/jrobertson/Box
Sync/WAFO_GIS/WAFO_Base_Data.gdb/wa_mgmt_Parcels_SkagitCDC2016"
classField = "ResTargNam"                       # Class field to run Tabulate Area
inClassRas = env.workspace + "/inClassRasAgr"      # Raster created from class data for input to Tabulate Area
tool
finTableLoc = out_gdb_loc                       # Output location of final table
finTable = "tabareaCursor_concept_CDCD16"         # Name of final table
processingCellSize = 1                          # Processing cell size in units of the input zones data
i = 0                                           # Base counting variable for output file names

# Check out the ArcGIS Spatial Analyst extension license
arcpy.CheckOutExtension("Spatial")

# Create subset layer from Class data based on SQL query
if arcpy.Exists(inClassRas):
   print("Verified {} exists.".format(inClassRas))
   arcpy.MakeFeatureLayer_management(inClassData, "inClassLayer", "ResTargNam = 'Agriculture'")
else:
   print ("Creating raster dataset from: {}.".format(inClassData))
   arcpy.MakeFeatureLayer_management(inClassData, "inClassLayer", "ResTargNam = 'Agriculture'")
```

```
    env.extent = inZoneData
    env.outputCoordinateSystem = inZoneData
    arcpy.FeatureToRaster_conversion("inClassLayer", classField, inClassRas, 1)

# Select zones which intersect classes to only process those zones (speeds up processing)
arcpy.MakeFeatureLayer_management(inZoneData, "inZoneSel")                      # Make feature layer from zones
arcpy.SelectLayerByLocation_management("inZoneSel", "INTERSECT", "inClassLayer")    # Select only zones
which intersect classes

# Loop through each Zone feature to run area tabulation within Class layer
with arcpy.da.SearchCursor("inZoneSel", zoneField) as cursor:
    for row in cursor:
        if arcpy.Exists("inZoneLayer"):
            arcpy.Delete_management("inZoneLayer")
        arcpy.MakeFeatureLayer_management("inZoneSel", "inZoneLayer", zoneField + " = '" + str(row[0]) + "'")
        classRasField = classField.upper()[:10] # Formate field name for Tabulate Area input
        i = i + 1                              # Unique counting variable for output field names
        tabRowArea = "in_memory\out" + str(i)
        arcpy.sa.TabulateArea("inZoneLayer", zoneField, inClassRas.lower(), classRasField, tabRowArea, 1)
        flist = [f.name for f in arcpy.ListFields(tabRowArea)]                      # Lists output fields for next line
        arcpy.CalculateField_management(tabRowArea, flist[1], '"' + str(row[0]) + '"')  # Ensures the correct input
zone name is in the output zone name field
        if arcpy.Exists(finTableLoc + "/" + finTable):
            arcpy.Append_management(tabRowArea, finTableLoc + "/" + finTable, "NO_TEST")
        else:
            arcpy.TableToTable_conversion(tabRowArea, finTableLoc, finTable)
        print ("Completed zone feature: " + str(row[0]))

del cursor, row

# Add the zones which do not intersect classes to the final table with area values equaling zero
arcpy.SelectLayerByAttribute_management("inZoneSel", "SWITCH_SELECTION") # Select only zones which DO
NOT intersect classes
otherZones = [row[0] for row in arcpy.da.SearchCursor("inZoneSel", zoneField)]


arcpy.Delete_management("inZoneLayer")
arcpy.Delete_management("in_memory")
del cursor, row

print ("Script complete.  See results in table: " + finTable)
```


Telegraph Slough Full
Telegraph Slough Full
Telegraph Slough 1 & 2
Telegraph Slough Full
Avon-Swinomish Bypass
La Conner
McGlinn Causeway
McGlinn Causeway
Sullivan Hacienda
Cottonwood Island
East Cottonwood
NF Right Bank Levee Setback
NF Left Bank Levee Setback A
TNC South Fork
Thein Farm
Pleasant Ridge South
Rawlins Road Distributary Channel
Rawlins Road
Fir Island Cross Island Connector
NF Left Bank Levee Setback B
NF Left Bank Levee Setback C
Hall Slough
Fir Island Farm
South Fork Levee Setback 2, 3, 4
Deepwater Slough Phase 2
South Fork Levee Setback 2, 3, 4
Deepwater Slough Phase 2
Milltown Island
Langley
Abbotsford
Victoria
Everett
Seattle
Tacoma
CompPlan selection
Ag-NRL
NRI
OSRSI
RB
RI
RMI
RRv
SSB
Concept Areas
0 1 2 3 Miles
0 5,280 10,560 15,840 Feet
Absolute Scale 1:85,000
Map by J. Robertson, The Nature Conservancy, 04/04/2016


Telegraph Slough Full (also incl. 1 & 2)
Avon-Swinomish Bypass
1
2
Telegraph Slough 1
Telegraph Slough 1 & 2
Cottonwood Island
NF Left Bank Levee Setback A (incl. A, B, & C)
East Cottonwood
NF Right Bank Levee Setback
TNC South Fork
A
Sullivan Hacienda
Pleasant Ridge South
Thein Farm
McGlinn Causeway
B
NF Left Bank Levee Setback B (incl. B & C)
Rawlins Road Distributary Channel
C
Fir Island Cross Island Connector
NF Left Bank Levee Setback C (incl. C)
Rawlins Road
Hall Slough
Deepwater Slough Phase 2
Fir Island Farm
South Fork Levee Setback 2, 3, 4
Milltown Island
La Conner
Mt Vernon
Parcels by Owner Type
Private
District
Public
Water
Concept Areas
0 1 2 3 Miles
0 5,280 10,560 15,840 Feet
Absolute Scale: 1:85,000
Projected Coordinate System: NAD 1983 UTM Zone 10N
Map by J. Robertson, The Nature Conservancy, 09/07/2017


Telegraph Slough Full (also incl. 1 & 2)
Telegraph Slough 1
Telegraph Slough 1 & 2
1
2
Avon-Swinomish Bypass
NF Left Bank Levee Setback A (incl. A, B, & C)
Cottonwood Island
East Cottonwood
NF Right Bank Levee Setback
A
TNC South Fork
Sullivan Hacienda
Pleasant Ridge South
Thein Farm
B
NF Left Bank Levee Setback B (incl. B & C)
McGlinn Causeway
Rawlins Road Distributary Channel
C
Fir Island Cross Island Connector
NF Left Bank Levee Setback C (incl. C)
Rawlins Road
Hall Slough
Deepwater Slough Phase 2
Fir Island Farm
South Fork Levee Setback 2, 3, 4
Milltown Island
La Conner
Burlington
Mt Vernon
Agriculture Easements (SCDC 2016)
Concept Areas
0 1 2 3 Miles
0 5,280 10,560 15,840 Feet
Absolute Scale: 1:85,000
Projected Coordinate System: NAD 1983 UTM Zone 10N
Map by J. Robertson, The Nature Conservancy, 09/18/2017



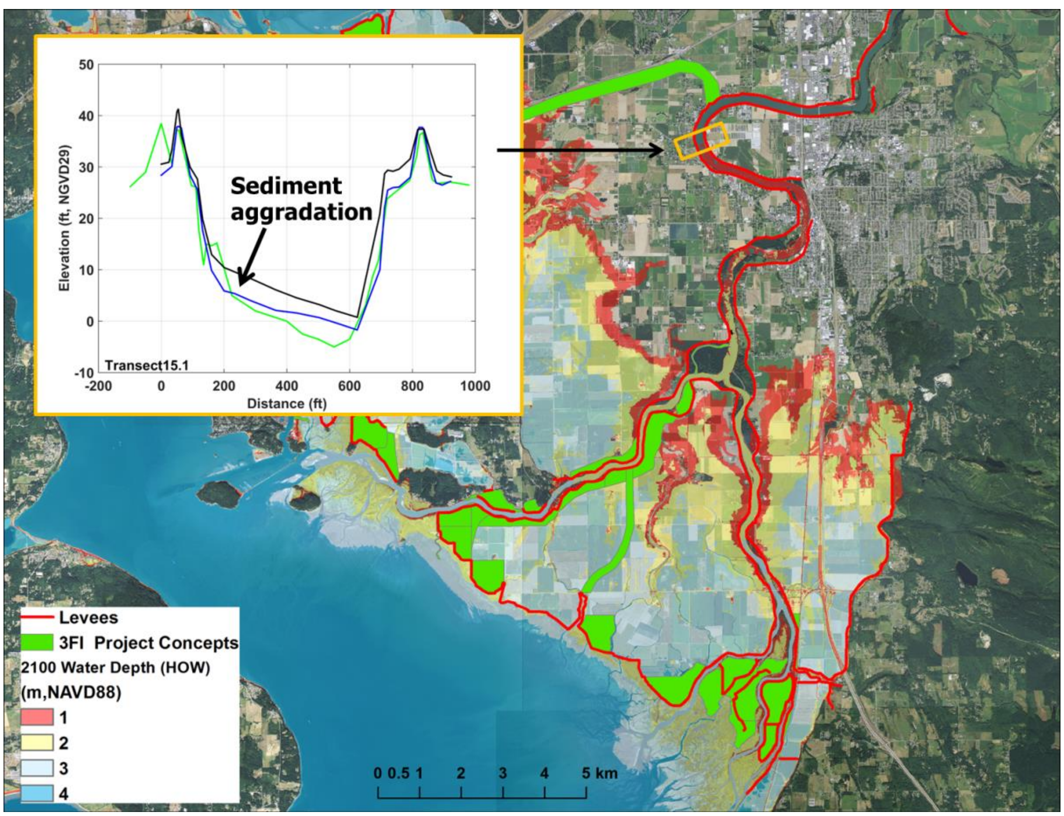
Telegraph Slough Full (also incl. 1 & 2)
Avon-Swinomish Bypass
1
2
Telegraph Slough 1
Telegraph Slough 2
NF Left Bank Levee Setback A (incl. A, B, & C)
Cottonwood Island
East Cottonwood
NF Right Bank Levee Setback
A
B
C
NC South Fork
Left Bank Levee Setback B (incl. B & C)
Sullivan Hacienda
McGlinn Causeway
Pleasant Ridge South
Thein Farm
Rawlins Road Distributary Channel
NF Left Bank Levee Setback C (incl. C)
Fir Island Cross Island Connector
Rawlins Road
Hall Slough
Fir Island Farm
Deepwater Slough Phase 2
South Fork Levee Setback 2, 3, 4
Milltown Island
Levee Issues in/out of Concept Areas
Inside Concept Areas
Outside Concept Areas
Failure Location
Concept Areas
0 1 2 3 Miles
0 5,280 10,560 15,840 Feet
Absolute Scale: 1:85,000
Projected Coordinate System: NAD 1983 UTM Zone 10N
Map by J. Robertson, The Nature Conservancy, 09/07/2017

Appendix F: USGS Report

In cooperation with The Nature Conservancy, NOAA Restoration Center, and Washington Department of Fish and Wildlife

DRAFT- Bathymetric Change to Inform Sediment Impact Pathways to Communities and Ecosystems in the lower Skagit River and Estuary, Washington

By Eric E. Grossman



Report Series 20XX–XXXX

U.S. Department of the Interior
U.S. Geological Survey

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Bathymetric Change to Inform Sediment Impact Pathways to Communities and Ecosystems in the lower Skagit River and Estuary, Washington

By Eric E. Grossman

Abstract

A comprehensive analysis of recently acquired high-resolution bathymetric and land-surface elevation data were integrated to generate the first continuous seamless onshore-offshore digital elevation model for the lower Skagit River. Comparisons of the new bathymetric data with channel cross-sections collected in 1975 and 1999 reveal that the lower Skagit River has been characterized by increasing the channel bed elevations interpreted to reflect sediment aggradation which increases flood risk as flow conveyance is reduced. Extensive sediment aggradation was observed at four sites in the vicinity of Mount Vernon where the bed elevations have increased 7-10 ft since 1999. Select areas near the mainstem confluence with the North and South Fork Skagit Distributary channels and across the lower North Fork distributary and North fork tidal flats show moderate to high sediment aggradation that likely affect flood stage a considerable distance upstream given that tidal influence reaches Mount Vernon. A sediment aggradation characterization regime was generated through this study to help resource managers evaluate opportunities for flood risk management, additional research and communications.

Introduction

Recent research and stakeholder engagements of the Farms, Fish and Floods Initiative (3FI), Floodplains by Design, Sustainable Lands Strategy, and Skagit Climate Science Consortium (*skagitclimatescience.org*) indicate the need for integrating research on hydrodynamics, sediment transport and floodplain/estuary habitat restoration (Beamer et al., 2006, Simenstad et al. 2011) in order to implement strategies that mutually benefit salmon recovery, flood hazard reduction, and valuable agricultural productivity in the Pacific Northwest (*Skagit Delta Hydrodynamic Modeling Team Report*, *2014*). The USGS Coastal Habitats in Puget Sound Large Rive Deltas Project coordinates interdisciplinary research to examine sediment transport and its influence on habitat structure, ecosystem function and natural hazards that pose risk to communities and infrastructure. Recent results of this research indicate that ongoing and legacy land-use effects continue to modify sediment transport patterns that adversely impact salmon habitat (wetlands, tidal channels, eelgrass) and recovery efforts (insufficient sediment connectivity) and challenge flood protection strategies (Grossman et al, 2011). Recent findings predict that reductions in snowpack and glaciers as climate across the Pacific Northwest warms will lead to 3-6 times more fluvial sediment delivery to the Puget Sound lowlands from North Cascade watersheds like the Skagit (Lee et al. In Press). The fate of this sediment is of concern, in particular the extent that it will accumulate in stream channels, reduce flood conveyance and raise flood risk. In addition, sea level rise is expected to exacerbate sediment aggradation in estuaries and the lower rivers. In the Skagit tidal influence reaches Mount Vernon, so a focus of the CHIPS research is to improve understanding of sediment dynamics and establish important baseline data with which to track changes in channel sedimentation and its effects on ecosystems and risk to communities. This report synthesizes and compares new bathymetry data collected across the lower Skagit River to historic data sets collected in 1975 and 1999. The goal is to refine our understanding of changes and trends in channel bed sediment and elevation with which to assess likely future changes and outcomes of restoration alternatives aiming to reduce flood risk, which themselves are susceptible to sediment flux associated with high flows.

Background

Site Description

The Skagit River is the third largest river along the US West Coast that drains a very steep watershed extending across 6900 km^2 of the Pleistocene-glaciated Northern Cascades Range. Measurements since the 1970s show that the Skagit River contributes 30-35% of all freshwater and perhaps up to 40% of all fluvial sediment delivered to Puget Sound (Beamer et al. 2005; Czuba et al., 2011; Curran et al., In Review). Maximum daily discharge of the Skagit River at Mt. Vernon ranges from 1,400 to 3,680 m^3/s and is characterized by variable autumn and winter rain-fed runoff and generally predictable late spring to early summer snow-melt runoff. Although dams emplaced on the Baker River and Skagit River above Newhalem beginning in the 1920s control flow from ~40-50% of the Skagit watershed, mass-wasting, historic logging, and retreating snowpack and glaciers in the Sauk and Cascade River watersheds contribute significant sediment to the Skagit system (Paulson, 1997). The Skagit River is the largest salmon producing river-delta complex in Puget Sound, but like many deltas in Washington it has experienced 80-90% loss of estuarine habitat since the 1850s as a result of large-scale river-delta channelization and wetland reclamation to support agriculture (Bortelson, 1980; Collins, 2000). Today, the

Skagit lowlands are one of the most important agricultural centers along the U.S. West Coast, producing 50-95% of the nation's vegetable seed market for important vegetable crops.

The study area is focused on the lower Skagit River and Delta between Sedro-Woolley and Skagit Bay where several floodplain and estuary restoration alternatives identified in the Skagit Chinook Recovery Plan (Beamer et al. 2005) are being assessed for potential benefits to reducing stream flood risk and impacts (**Figure 1**). This is an area of high stream flood impact, with damaging floods occurring every 2-6 years. The lower Skagit River is low-lying with an extensive network of flood protection levees in place to safeguard the lowland communities and diverse land uses. Current projections for sea-level rise out to the year 2100 indicate that the area is likely to experience considerable increase in inundation by tides and storm surge, which will overtop the present configuration of levees of the Skagit lowlands and require significant planning to adapt (**Figure 1**). More importantly to the focus of this study, sea level rise is expected to increase the amount of sediment that is trapped in the lower river and estuary as the base level of Puget Sound retards flow downstream and salinity intrusion promotes increased sediment flocculation.

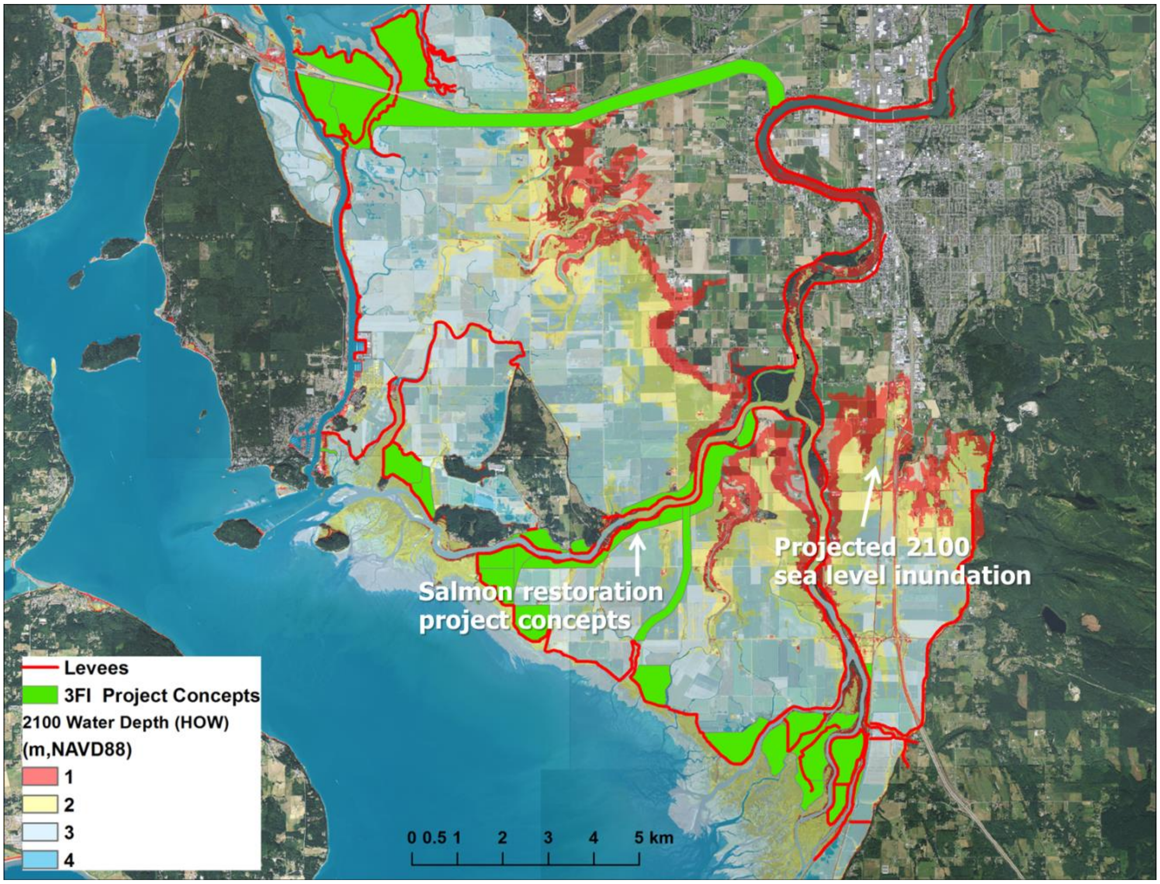

Figure 1. Map showing the lower Skagit River and Delta study area.

Study Objectives

The goals of this study were to (1) analyze recently collected and historic elevation and bathymetry data to characterize the morphology and change of the lower Skagit River, and (2) evaluate the sedimentation regime of the lower Skagit River and its effects on valued habitats and flood risk management through analyses of change in bathymetry and morphology relative to knowledge of the sediment budget and hydrologic processes that influence sediment.

Previous Studies

The Skagit River has a long history of flooding, human modifications to reduce flooding, and research to examine change (Collins, 2000). In the mid-1800s, western settlers began modifying the Skagit River and its floodplains in a significant way, removing large woody debris and dredging sediment to facilitate deep-draft vessel navigation where the river channel was historically shallow and clogged with woody debris (Collins 1998; Nesbit 1885). These activities artificially deepened the channel and were very effective in moving an enormous amount of material downstream where it accumulated across the lower delta. The amount of material was significant enough to fill portions of Skagit Bay with sediment 15 to 30 m thick and the accumulation led to delta progradation seaward of ~ 0.5 km along its entire length of ~15 km from Hope Island in the north to Camano Island in the south (Grossman et al. In Review). With the recognition of impacts to salmon, wide-scale dredging and snagging ended in the 1960s and as a result the entire lower Skagit River and delta have been adjusting, and it is presumed that a natural response would include some aggradation as the system finds a new level of equilibrium between flow conveyance, flow magnitudes and sediment delivery and the composition of sediments in transport.

Studies to address morphologic change in the Skaigit River mainstem and distributary channels have been conducted for some time and the first report with data for use toward bathymetric change analysis was furnished by West Consultants (2001) and reported in Pentec Environmental (2002). This study conducted for the US Corps of Engineers collected new bathymetry data in 1999 along channel cross-sections that had been measured in 1976. West Consultants reported measureable aggradation of the channel bed between 1975 and 1999, especially in the North fork around river mile 6.2 where the river bed increased by 10 ft in the South Fork around river mile 7 and in the mainstem between river miles 8 to 19.0 where the longitudinal gradient decreased by ~18% consistent with sediment aggradation (**Figure 2**),. Upstream of Burlington, the channel was complex and difficult to discern patterns of net aggradation or erosion.

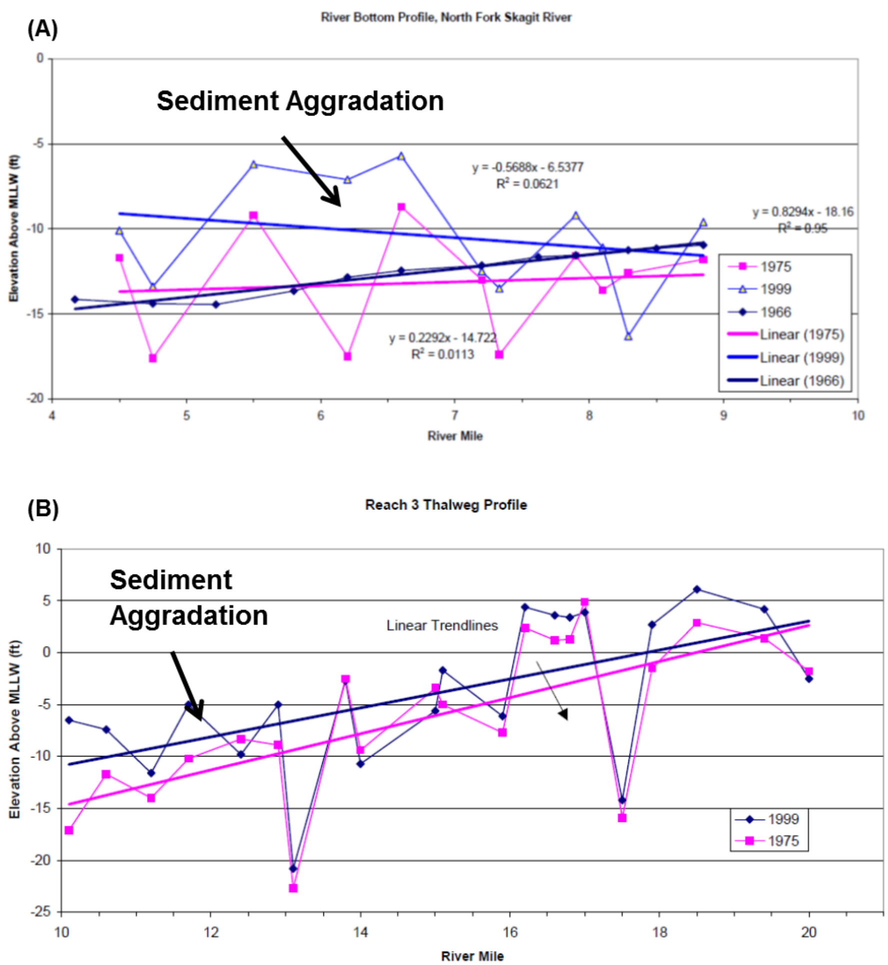

Figure 2. Plots showing results of 2002 analyses of change including measureable aggradation between 1999 and 1975 in the North Fork (A, Fig. 8 of Pentec Environmental 2002) and lower mainstem (B, Fig. 14 of Pentec Environmental 2002).

Methods

Data Collection and Processing

Three approaches were used to examine recent changes in Skagit River channel morphology and their relationships to sediment behavior and included comparison of bathymetry or cross-section data, comparison of gridded surface elevation/bathymetry, and examination of the stage-discharge relationship at the USGS Mount Vernon gage #12200500 (Skagit River near Mount Vernon, WA). Bathymetry and elevation data for these analyses were directly collected through sonar and LiDAR surveys or synthesized from partners who led similar efforts (**Figure 3**). Specific channel cross-section (distance-elevation) profile data available for this study spanned the region from Sedro-Woolley to the confluence between the Skagit River mainstem and the North and South Fork distributaries (**Figure 4**). A brief description of these efforts and sources of data are provided.

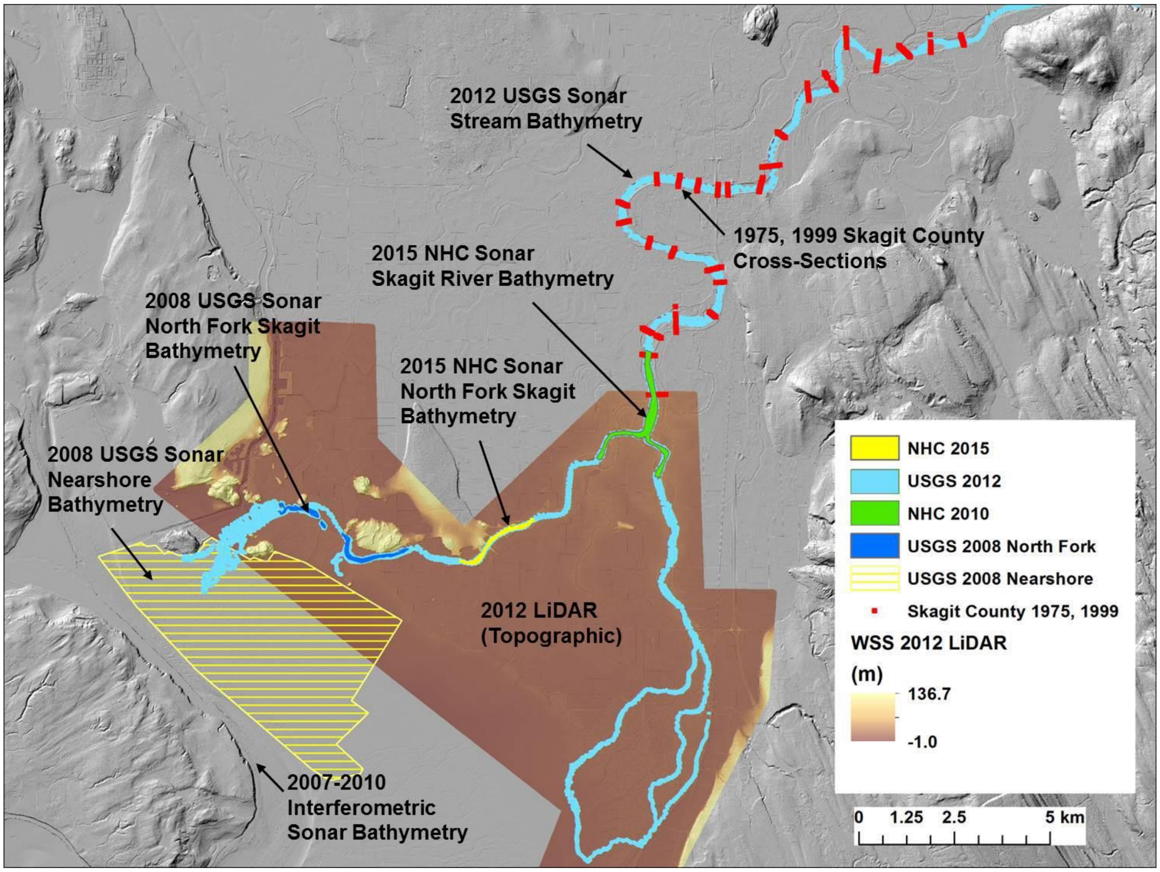

Figure 3. Map showing data collected and utilized in this study across the lower Skagit River and Delta.

Figure 4. Map showing channel cross-section data available for comparison in this study.

Skagit River Bathymetry

Single-Beam Sonar Surveys

The principal data establishing the current bathymetry of the Skagit River channel is single-beam sonar data from USGS activity W-06-12-PS. Between September 11 and September 16, 2012, elevation and bathymetric data were collected between Sedro-Woolley and Skagit Bay (**Figure 3**) along the channel thalweg, zig-zags across the channels separated at ~100-m, across emergent bars and islands, and along cross-channel transects where surveys had been made in the past by Skagit County and USACE. Bathymetric soundings were collected using 200 kHz single beam sonars mounted to two personal watercraft and one 16-ft skiff (**Figure 5**) while topographic surveys utilized RTK-GPS in a walking survey mode. On the water craft, Odom and Garmin sounders collected depth data at 1 Hz and merged with position data derived from RTK-GPS recorded at 1 Hz using Hypack survey software. Sound velocity profiles gathered with a Sontek Castaway sound velocity profiler were integrated into data collection. Hypack merged the sonar data with RTK-GPS positioning using the Washington State Reference network. RTK-GPS instrumentation consisted of a Trimble R7 receiver and a Zephyr Model 2 Antennae. WA State Reference Corrections were made real-time via an internet connection and Trimble TCS3 controller running Trimble Access Software.

Figure 5. Photographs of the sonar data collection platforms including personal watercraft (A), small skiffs (B, C) and topographic surveys (D).

Soundings were filtered for outliers and merged into a database by survey line along with the topographic survey results. The data were then input to ArcGIS as point feature files and gridded into surfaces with nearest-neighbor interpolation algorithms in Mathworks Matlab, Sufer, and ArcMap. Surfaces were hillshaded and contoured. Soundings on flat smooth surfaces within 0.5 to 1.0 m that were recorded at transect line crossings during the survey and recent similar efforts reveal that the precision ranges 0.1 to 0.2 m. Total vertical error was estimated to be <0.25m based on standard errors of the GPS, sonar, and environmental variability.

RTK-GPS Surveys

Elevation data was also collected across emergent bars and island and channels during extreme low tides using RTK-GPS survey instruments while walking/wading. RTK-GPS instrumentation consisted of Trimble R7 receivers and Zephyr Model 2 Antennaes or Trimble R8 (integrated) receiver/antennaes. WA State Reference Corrections were made real-time via an internet connection and Trimble TCS3 controller running Trimble Access Software. Elevations were typically measured while walking at 1-sec intervals (~1 m spacing) or at specific sites (habitat structural features, inflection points) with a 2-m stadia rod. Elevation data were collected in Projected units (UTM Zone 10 NAD 83) and with respect to the vertical datum of NAVD88. Accuracy was established by comparison to vertical control monuments installed and/or surveyed by TNC, Ducks Unlimited, WA Depts. of Natural Resources and Transportation and agreed within 0.005 to 0.050 m and a mean of 0.03m.

Skagit Nearshore

Single Beam Sonar

A single beam sonar mounted to Personal Water Craft (**Figure 5**) was used to map the shallow areas of the North Skagit tide flats and the lower North Fork Skagit River in April 2008 (USGS Activity B-1-08-PS). Transects were mapped every 50-m across the broad tidal flats, unlike the continuous overlapping data obtained from the interferometer. Positions for these measurements were obtained using Real-Time Kinetic GPS sent from a base station at shore to a GPS receiver on the PWC. Positions were recorded in the UTM WGS 84 coordinate system with vertical measurements made relative to the Ellipsoid (WGS 84) to eliminate the need for tidal corrections. The vertical positions were subsequently converted to NAVD88, and repeat measurements indicated that total vertical uncertainty ranged <10 cm.

Dual Frequency Sonar

A dual frequency 430 and 200 kHz Biosonics sonar mounted to a small vessel was used to map bathymetry and submerged aquatic vegetation along the north and central delta front and outer tidal flats in April 2008 (USGS Activity B-1-08-PS) following protocols set forth in Stevens et al. (2008). The Biosonics has proven effective to map seafloor depth and vegetation height where aquatic vegetation is moderately dense and difficult for other bathymetric technologies to discern bottom sounding from plant interference. The high sampling rate of the Biosonics enables sufficient data to be collected with which to differentiate seafloor depth from vegetation. Positional information for this survey was also collected using Real-Time Kinetic GPS sent from a base station at shore to a GPS receiver on the small vessel. Positions were recorded in the UTM WGS 84 coordinate system with vertical measurements made relative to the Ellipsoid (WGS 84) to eliminate the need for tidal corrections. The vertical positions were subsequently converted to NAVD88, and repeat measurements and overlapping results indicated that total vertical uncertainty was ~10 cm. The final filtered data were gridded using a nearest-neighbor averaging algorithm in Surfer and imported into ArcGIS.

LiDAR Surveys

We make use of several light detection and ranging (LiDAR) data sets including the 2006 Skagit County LiDAR, 2012 USGS Topographic LiDAR (collected by Watershed Sciences, now Quantum Spatial), and a 2014 USGS Bathymetric LiDAR (collected by USACE JALBTCX).

Information for the 2006 data can be found at the Puget Sound Lidar Consortium (*http://pugetsoundlidar.ess.washington.edu/lidardata/restricted/usgs2006nps/*). Briefly these data gathered elevation data at 4-8 pulses per square meter and contain a vertical error ranging 0.05 to 0.2 m. A topographic LiDAR survey collected in April 2012 by airplane at an altitude of 900 m during low tide achieved between 4 and 6 pulses per square meter. In Sept of 2014, a bathymetric (water penetrating) LiDAR survey gathered between 3 and 6 pulses per square meter from an altitude of ~800 m. For both of these surveys, motion of the airplane controlled for using on board differential GPS and inertial measurement units. Ground surface elevations were independently determined by standard RTK-GPS elevation surveys at a subset of points. The final absolute vertical accuracy of the 2012 LIDAR was determined to be 3.0 cm and final absolute vertical accuracy of the 2014 LiDAR was determined to be 5.0 – 10.0 cm.

Historical Cross-Channel Surveys

Another source of historic geomorphic change data include cross channel survey data that Skagit County contracted along the Skagit River mainstem in 1975 and again in 1999. Not much is known of the technology used for the 1975 data collect, but the data from field notes have been digitized and mapped and location information was used for subsequent repeat surveys in 1999 and again in this study. The positional accuracy of the 1975 data are not well known but likely within 0.5 m based on typical survey technology of the time. The vertical accuracy of the 1975 data are also not well known, but assumed to be ~0.25 to 0.5 m also based on technology of the era. The 1999 data were collected along the same cross-channel transects in order to quantify change between 1975 and 1999. Similar accuracy is assumed for these data. Both the 1975 and 1999 data are georeferenced to Washington State Plane North (feet) and NGDV29.

Stage–Discharge Relationships at USGS Stream Gage #12200500, Skagit River near Mount Vernon, WA

Historical measurements along cableways at USGS stream gages along with observations and corrections made at USGS stream gages for changes in the stage-discharge rating relationships provide insight into geomorphic changes. Here we use the history of measured stage and discharge at the USGS Stream Gage #12200500 (Skagit River near Mount Vernon, WA) and the documented shifts made to the ratings since 1987 to evaluate variations in the channel flow conveyance commonly cause by fill and scour in the channel. Peak annual floods were tabulated and ranked in order of magnitude and the 90, 50 and 10% exceedance flood values were determined and used for this analysis. Then the gage shifts applied by the streamgager for each rating change over time were used to reconstruct a plot of the stage for the three discharges analysed. Any changes in the relationship of the resulting stage for a given discharge therefore reflect changes in the flow conveyance capacity of the reach and areas downstream that influence the site. For example, if stage for a given discharge increases, the channel conveyance must have decreased. Possible explanations are channel sedimentation (fill) or human modification to reduce channel volume.

Results

New Continuous Stream Channel Bathymetry

The results of the 2012 single beam sonar mapping generated the first continuous bathymetric data set to characterize the morphology of the lower Skagit River and develop a continuous seamless digital elevation model surface of the mainstem, North and South Fork channels (**Figure 6**). Coverage was achieved between Sedro-Woolley and Skagit Bay in the mainstem and most of the estuary channels of the North and South Forks. Detailed images of individual reaches show the complex morphology of riffles, bars, bar scarps, islands, scour depressions, sills and constrictions that previously were poorly characterized (**Figures 7-14**).

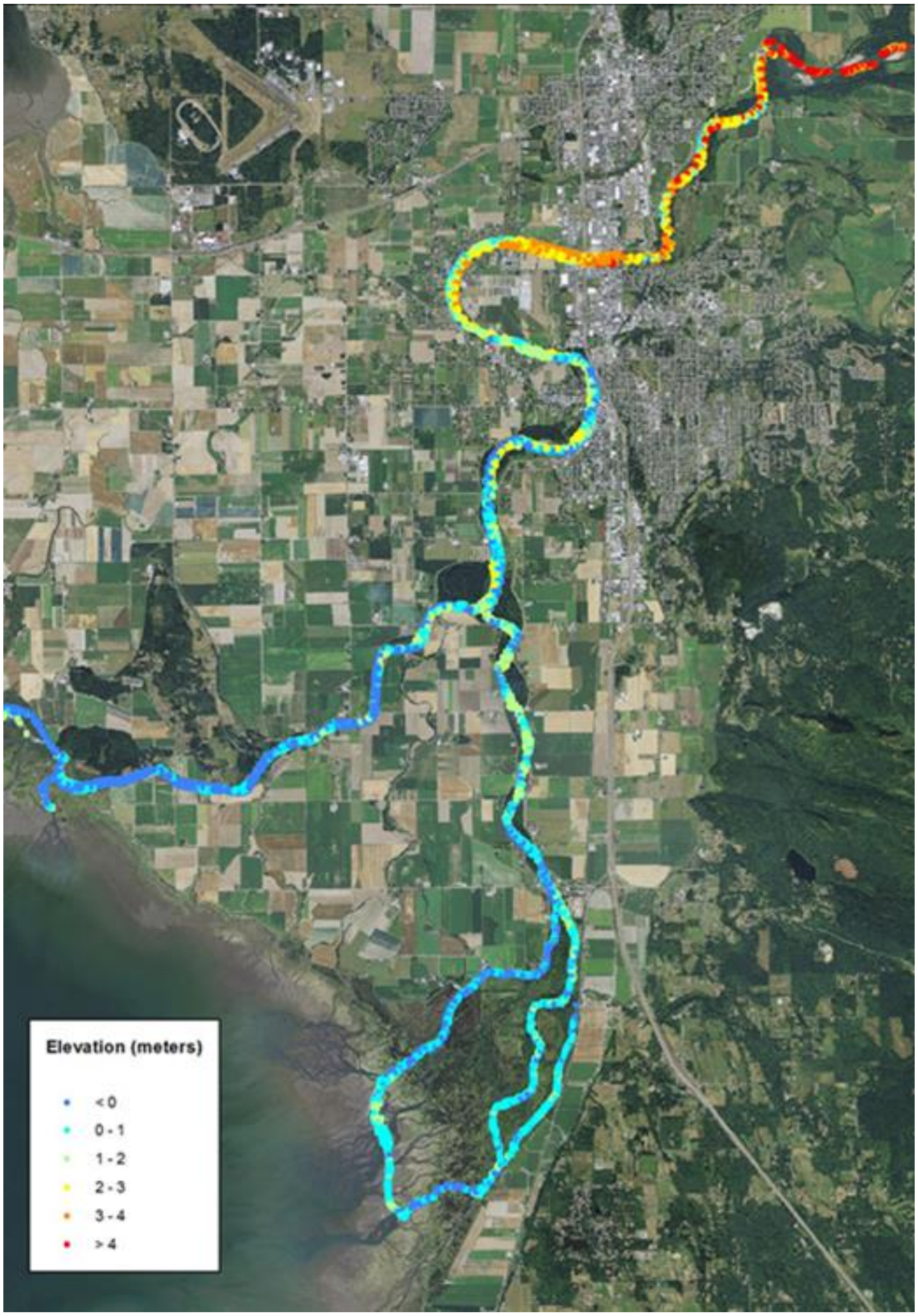

Figure 6. Map showing coverage of the 2012 Skagit River channel survey.

In the vicinity of Burlington the channel thalweg shallows out of two or three deeper sections across relatively shallow sills (**Figure 7**). These sills are just below the channel cross-sections that have been monitored since 1975 and it remains uncertain how these have changed over time.

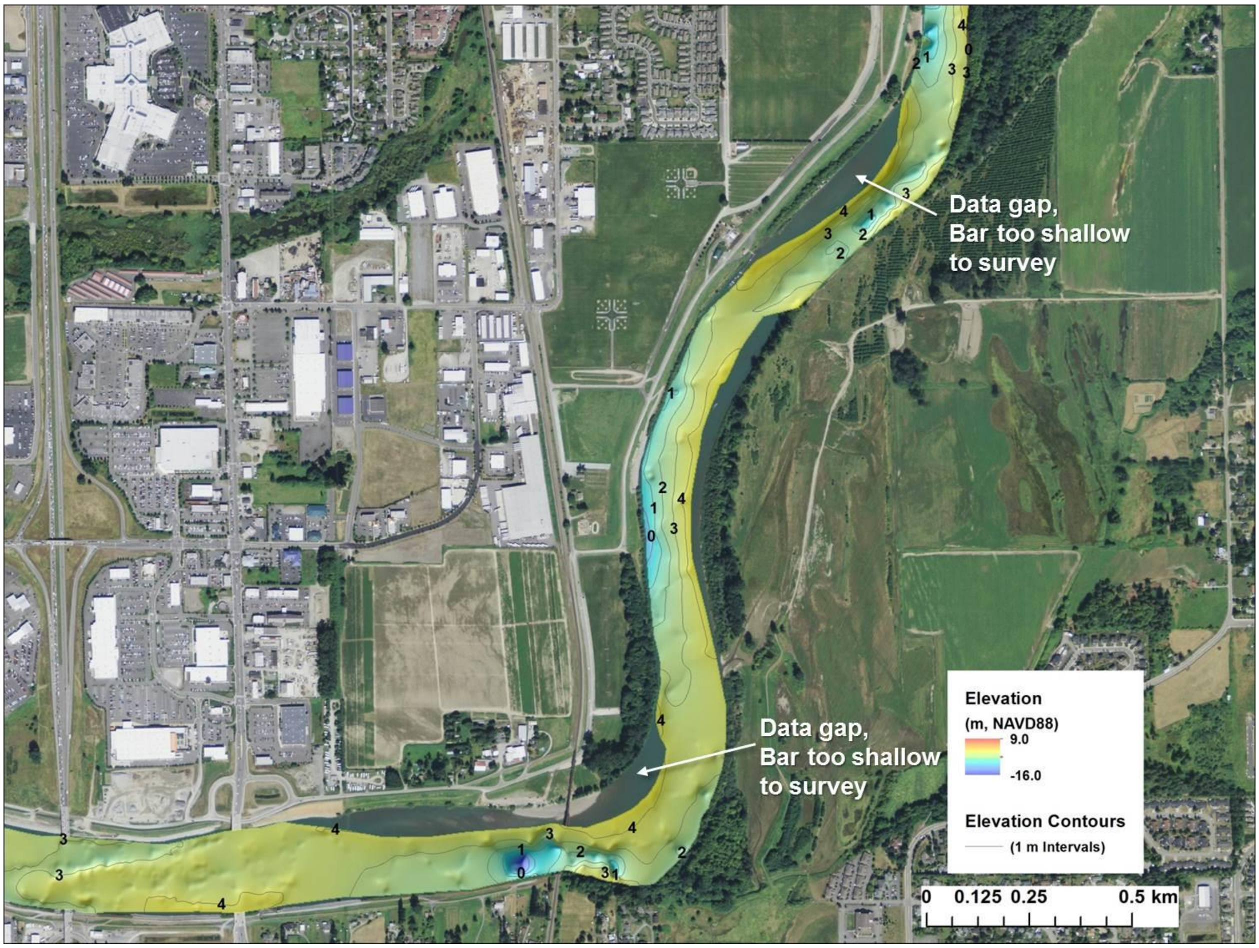

Figure 7. Map showing detailed bathymetric model surface of the 2012 Skagit River channel survey near Burlington.

In the vicinity of Mount Vernon the channel thalweg winds around shallow bars with very steep scarps that appear strongly modified by high flows **(Figure 8)**. The thalweg is more uniformly deep through this section relative to near Burlington.

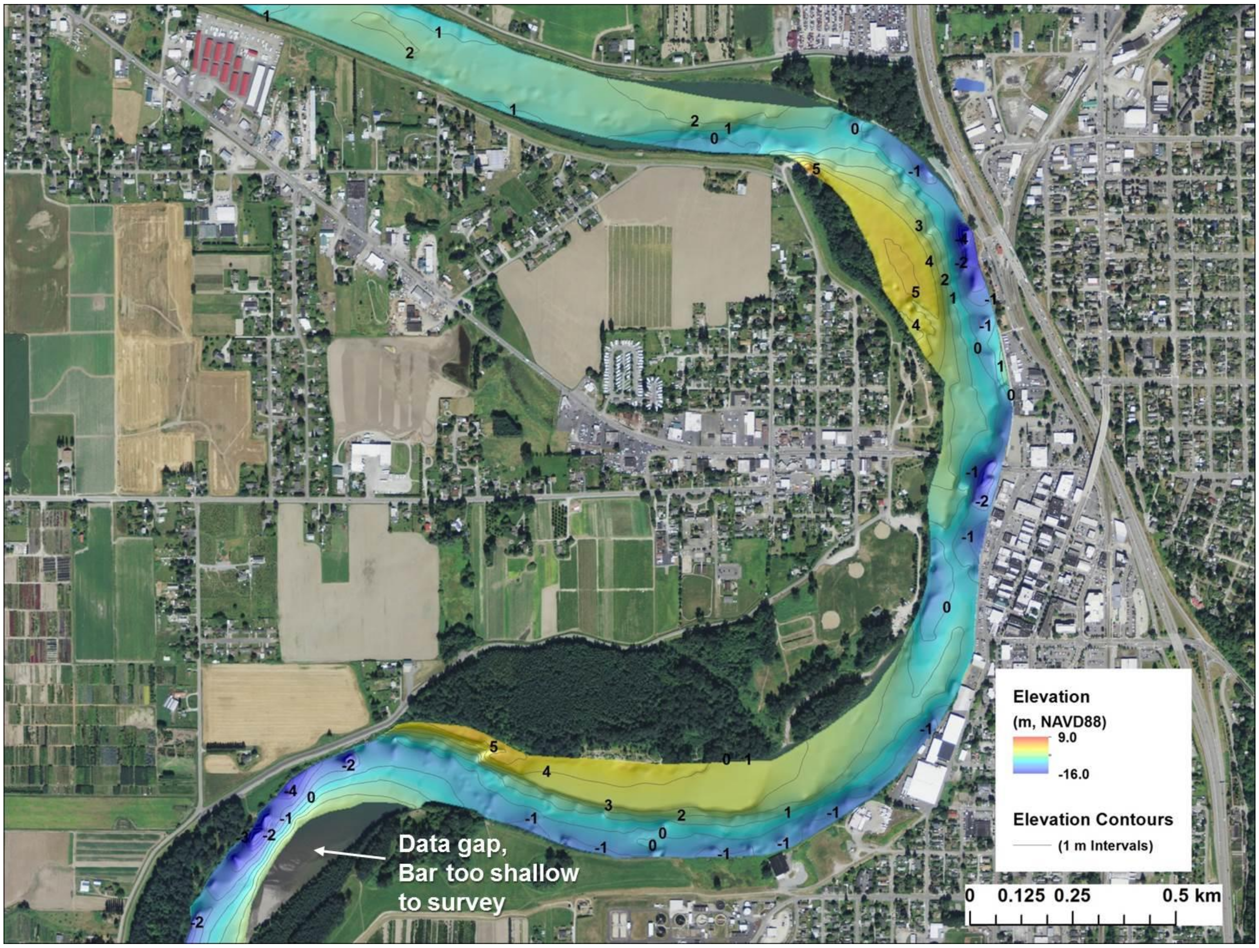

Figure 8. Map showing detailed bathymetric model surface of the 2012 Skagit River channel survey near Mount Vernon.

Near the confluence between the mainstem and the North and South Fork Skagit distributary channels, and extensive bars along the right bank of the mainstem and a pronounced sill at the junction with the South Fork are shallow and likely affect flow. Steep scarps along these bars attest to active incision **(**Figure 9).

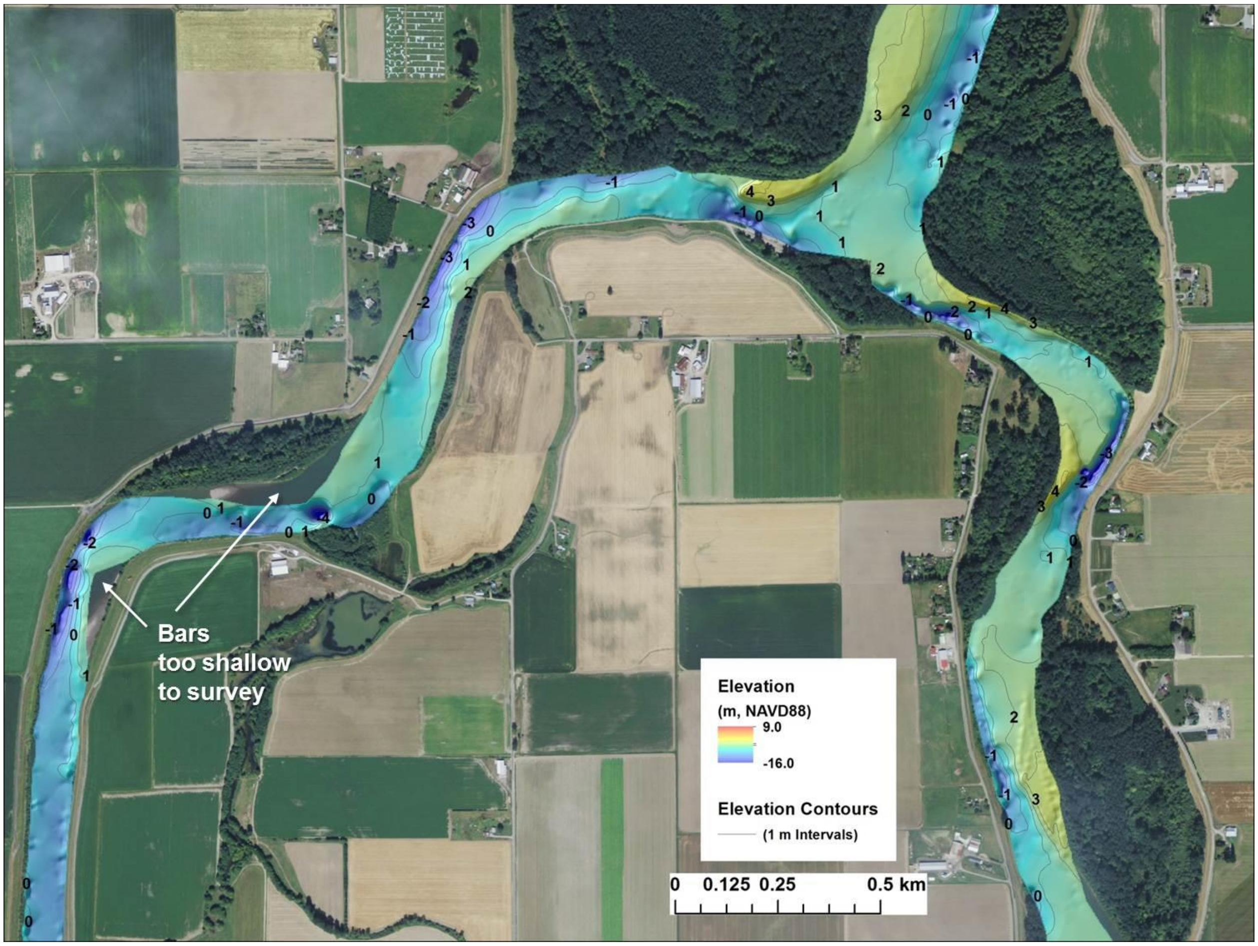

Figure 9. Map showing detailed bathymetric model surface of the 2012 Skagit River channel survey at the confluence of the North and South Forks Skagit River.

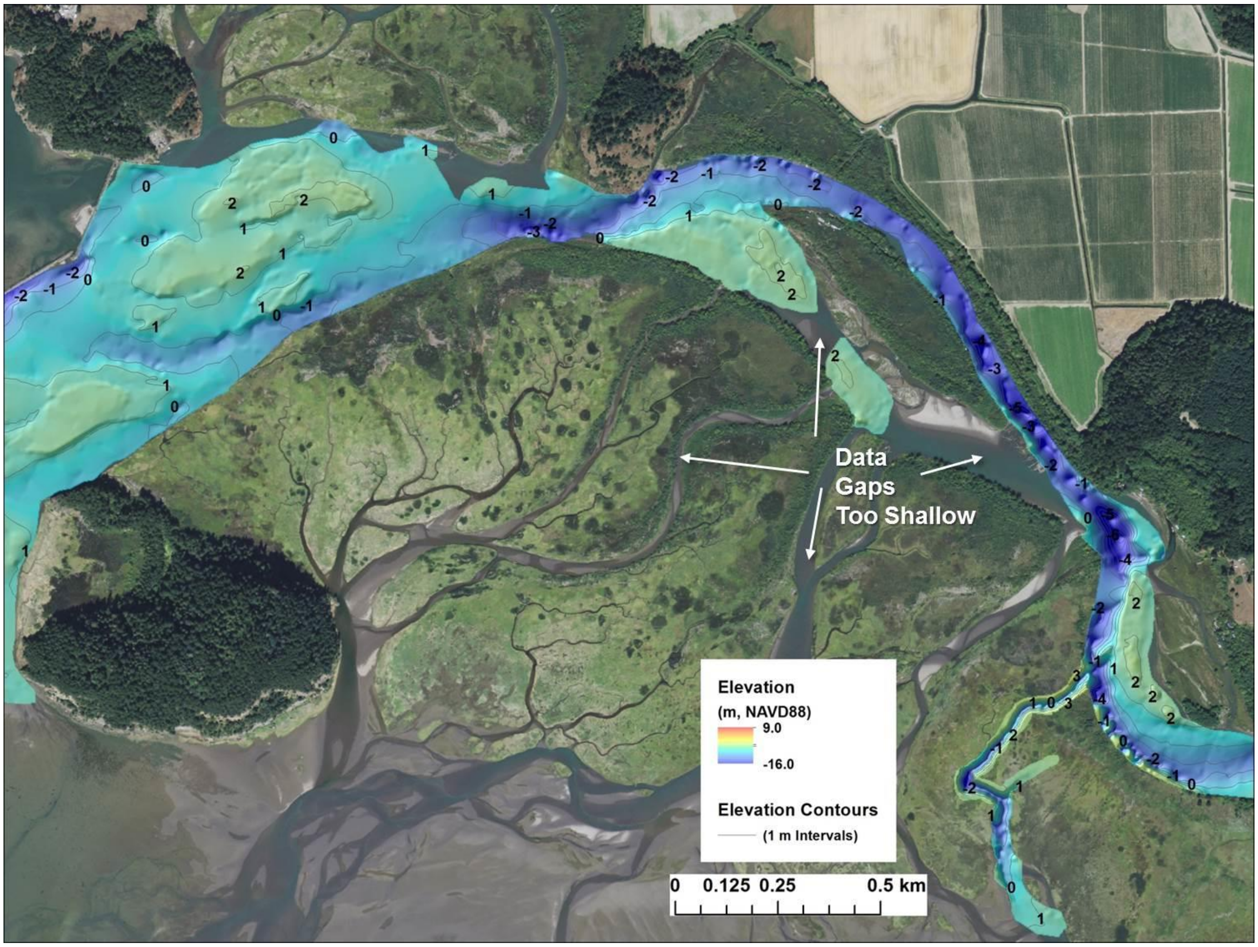

Figure 10. Map showing detailed bathymetric model surface of the 2012 Skagit River channel survey along the North Fork Skagit River.

Along many reaches of the North and South Forks, controls on flow in the form of levees and revetments can be observed in these data to promote incision of the channel bed and point bars where normally they would show depositional characteristics associated with natural meanders that are now modified **(Figures 11 - 14)**.

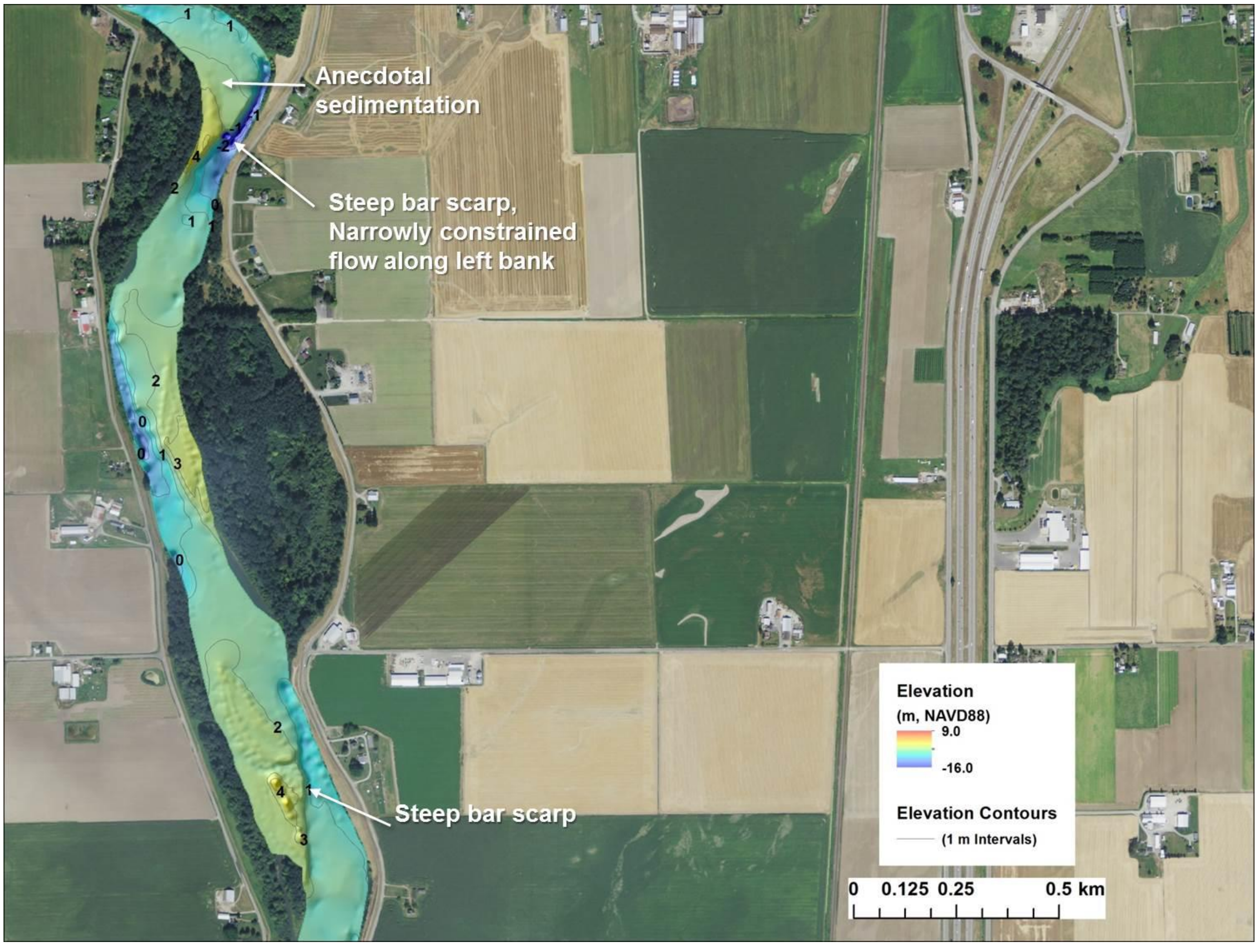

Figure 11. Map showing detailed bathymetric model surface of the 2012 Skagit River channel survey along the upper South Fork Skagit River.

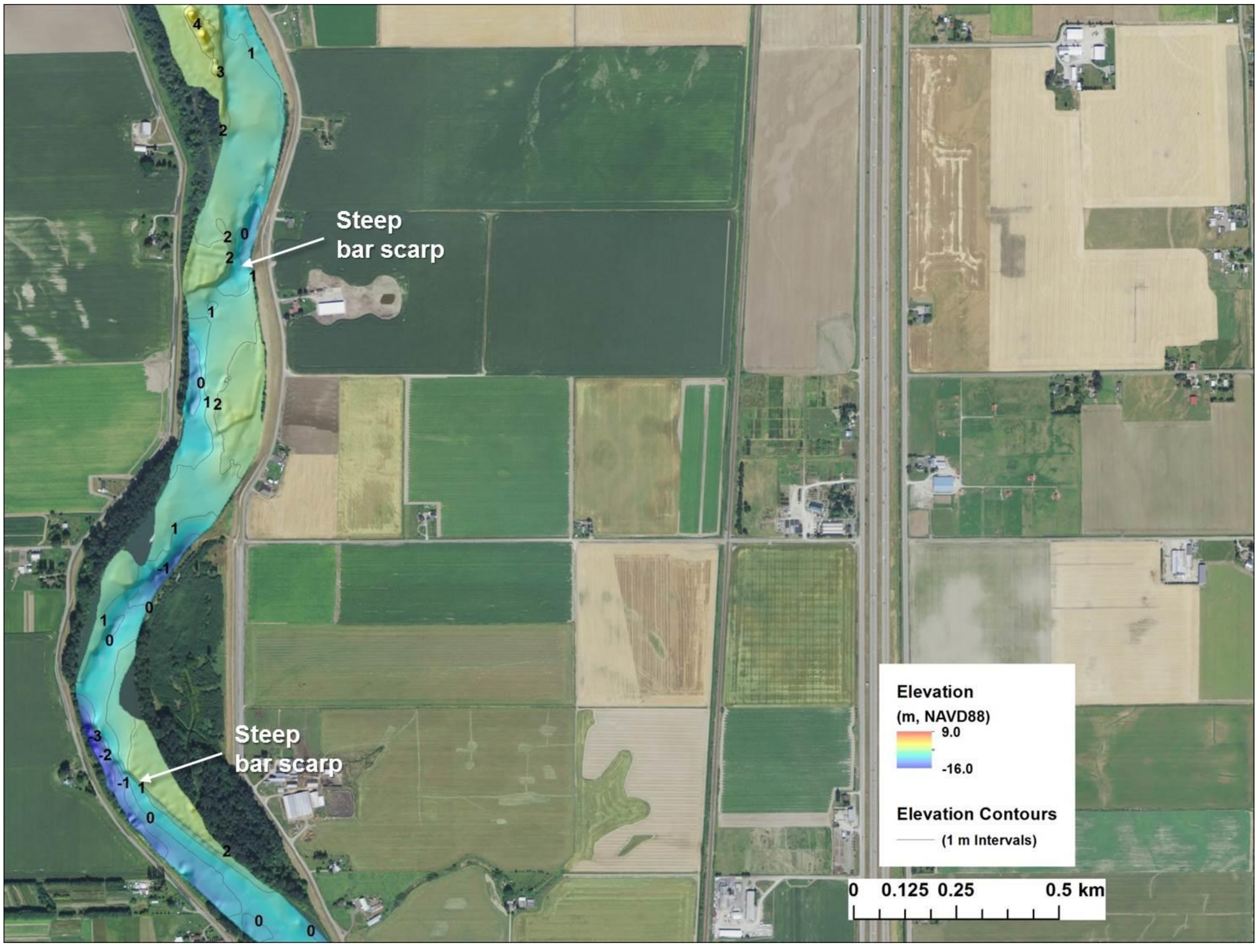

Figure 12. Map showing detailed bathymetric model surface of the 2012 Skagit River channel survey along the upper middle South Fork Skagit River.

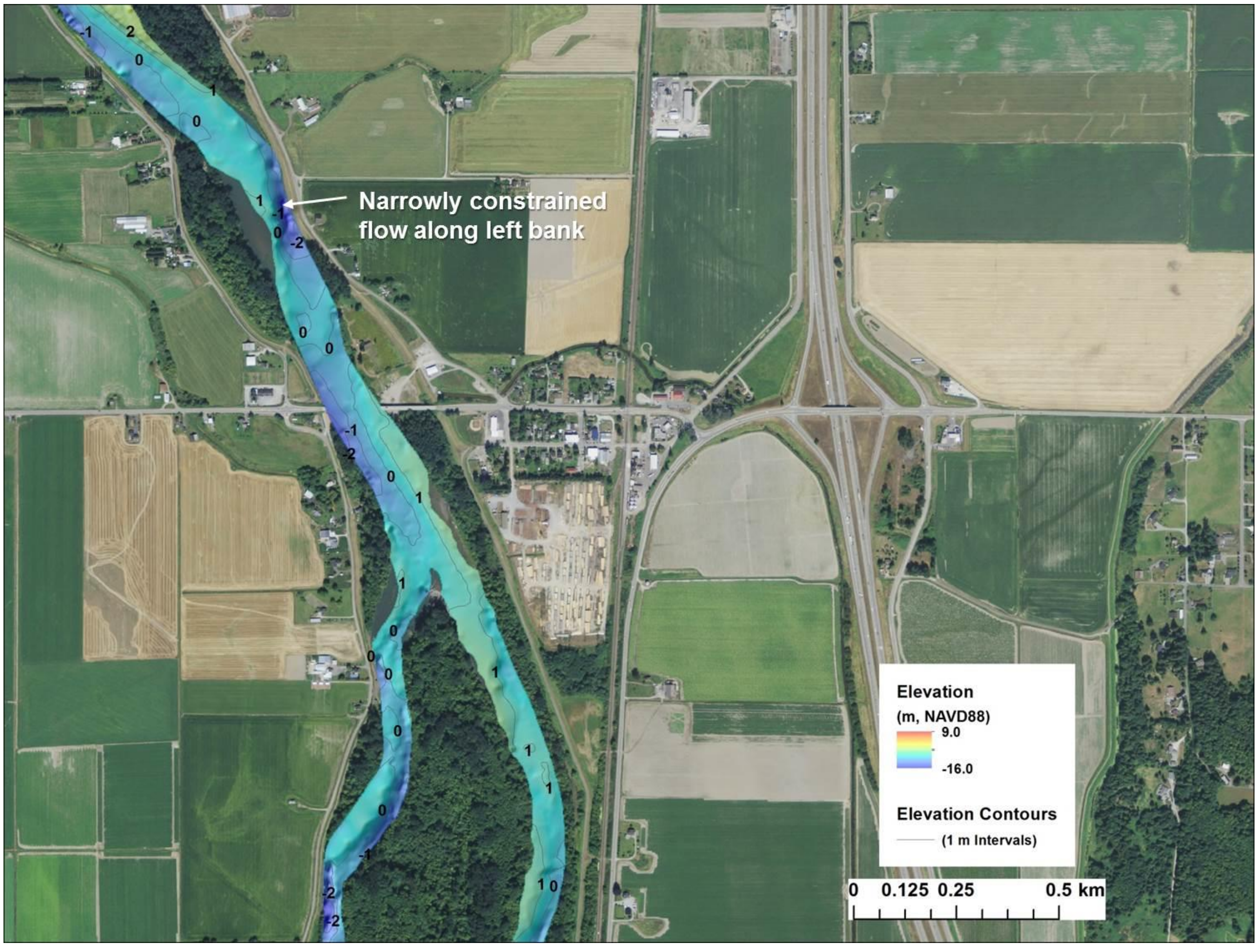

Figure 13. Map showing detailed bathymetric model surface of the 2012 Skagit River channel survey along the lower middle South Fork Skagit River.

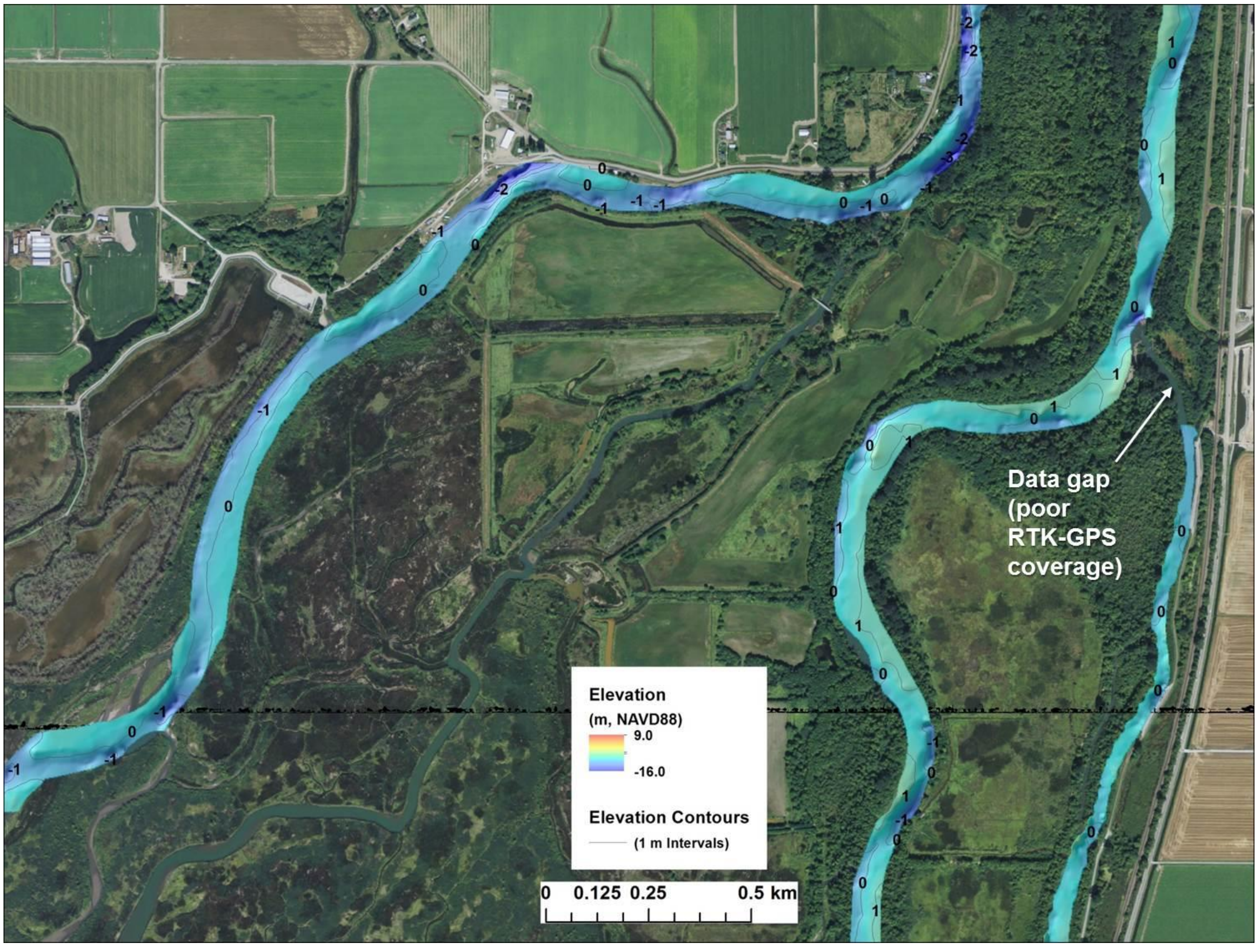

Figure 14. Map showing detailed bathymetric model surface of the 2012 Skagit River channel survey along the lower South Fork Skagit River.

Seamless Onshore-Offshore Digital Elevation Model

Integrating the detailed Skagit River bathymetry with existing elevation data including the 2006 Skagit County LiDAR, 2012 Watershed Sciences LiDAR, 2014 JALBTCX LiDAR, and sonar bathymetry offshore gathered over 2005 – 2010 into a single, seamless onshore-offshore digital elevation model provides an important data set to examine geomorphic and habitat linkages across the landscape and in relation to river and tidal flow (**Figure 15**). This new DEM is also a critical data set to use as boundary conditions for modeling and to detect and track changes associated with climate and land use including restoration actions.

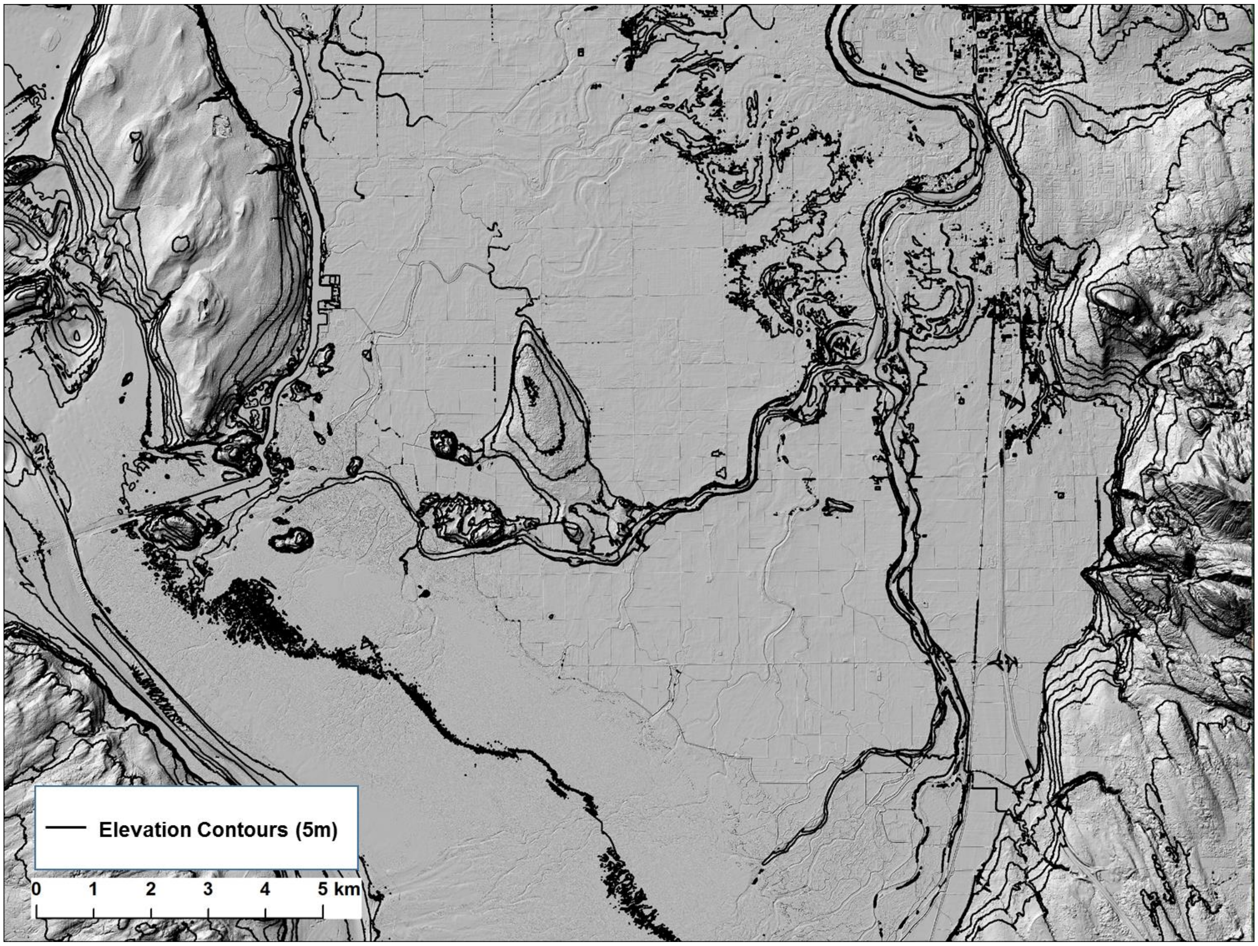

Figure 15. Map showing hillshade of the final merged seamless onshore-offshore digital elevation model for the lower Skagit River watershed.

Historic Changes in Stream Channel Cross-Sections

Analyses of changes in stream channel cross-sections offer insight to reaches that have undergone sedimentation or erosion and to assess changes in flood conveyance capacity that affect future flood risk. To assess changes in cross-sections over time, we compared results of the 2012 stream survey to data furnished by Skagit County from 1975 and 1999. Results of comparing soundings directly between years agreed with results of comparing 1975 and 1999 soundings to the interpolated values of the 2012 gridded stream channel elevation surface. Comparison of the interpolated 2012 values of the gridded stream channel elevation surface and individual 2012 soundings across a random set of 63,652 sounding locations showed a mean difference of 0.009 m indicating the capacity of the interpolated surface to accurately represent the 2012 channel elevations (**Figure 16**).

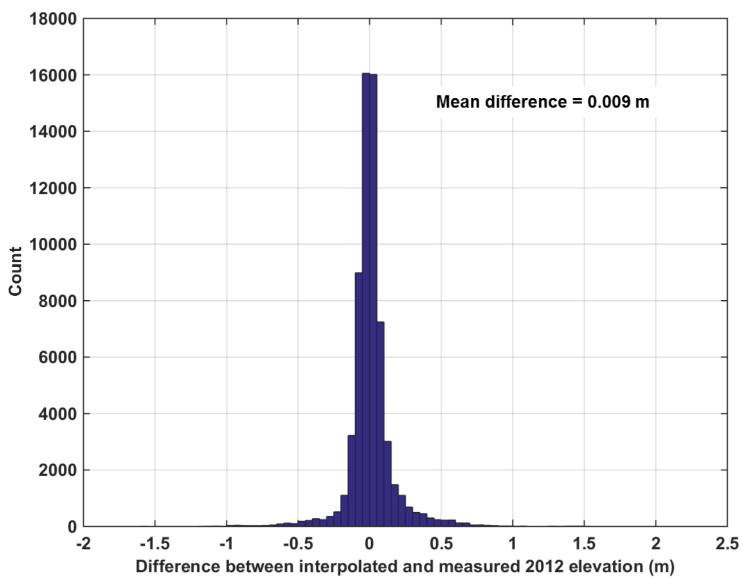

Figure 16. Plot showing the distribution of error upon differencing the interpolated 2012 elevation surface values from the measured 2012 elevations. A mean difference of 0.009 m indicates that the interpolated surface represents the 2012 data with high certainty.

We therefore extracted the value of the 2012 gridded data set at the 1975 and 1999 Skagit County survey locations in order to more efficiently georeference the positions of all data for the intercomparison as surveyed locations were not reported for the 1975 data (1**7-22**). Data for each of the three survey periods exist at all sites, except transects at river miles 13.0, 13.1, and 14.6. Essentially all of the channel cross-sections between Sedro-Woolley and Skagit Bay showed net sediment aggradation between 1975 and 2012 and greater than the accepted error of 1-2 ft (~0.5 m) of the 1975 data. At all sites, the majority of the channel bed was higher in 2012 than in 1999, although exceptions exist on just a few transects and usually across only a small fraction of the channel cross section. Also of interest, only a few transects showed higher elevations in 1975 than 1999. Channel cross-section elevations in 2012 were generally 2-5 ft higher than in 1999 and 1975 although at transects 18.5, 16.8, 16.6, 14.0, and 13.0 the channel in 2012 ranged 5–10 ft higher than in 1999 or 1975. The changes observed are consistent with sedimentation and the magnitude of the changes ranging 2 – 10 ft appear equally distributed across the study area.

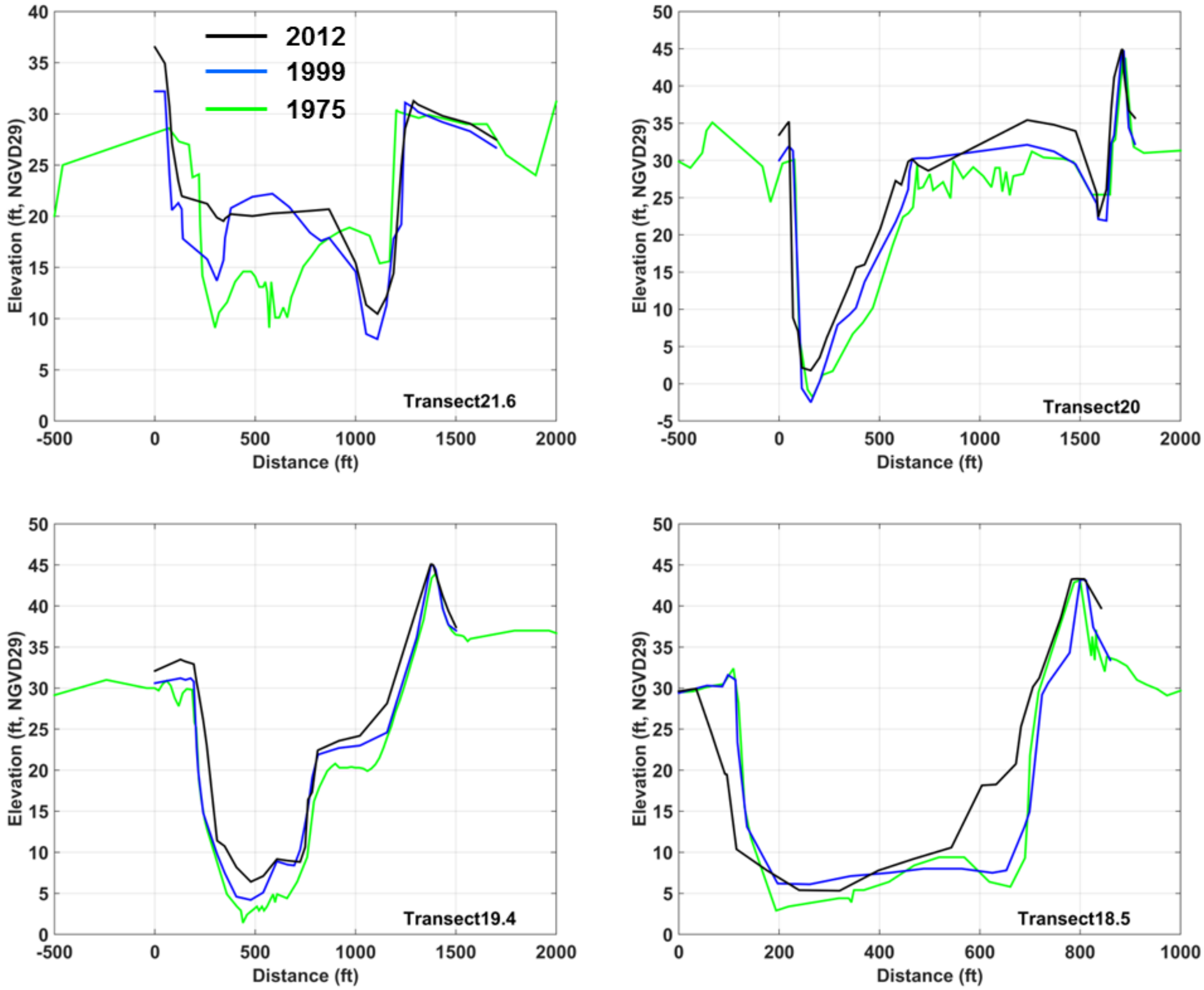

Figure 17. Plots showing comparison of channel cross-section distance-elevation profiles for transects at river miles 21.6, 20.0, 19.4, and 18.5.

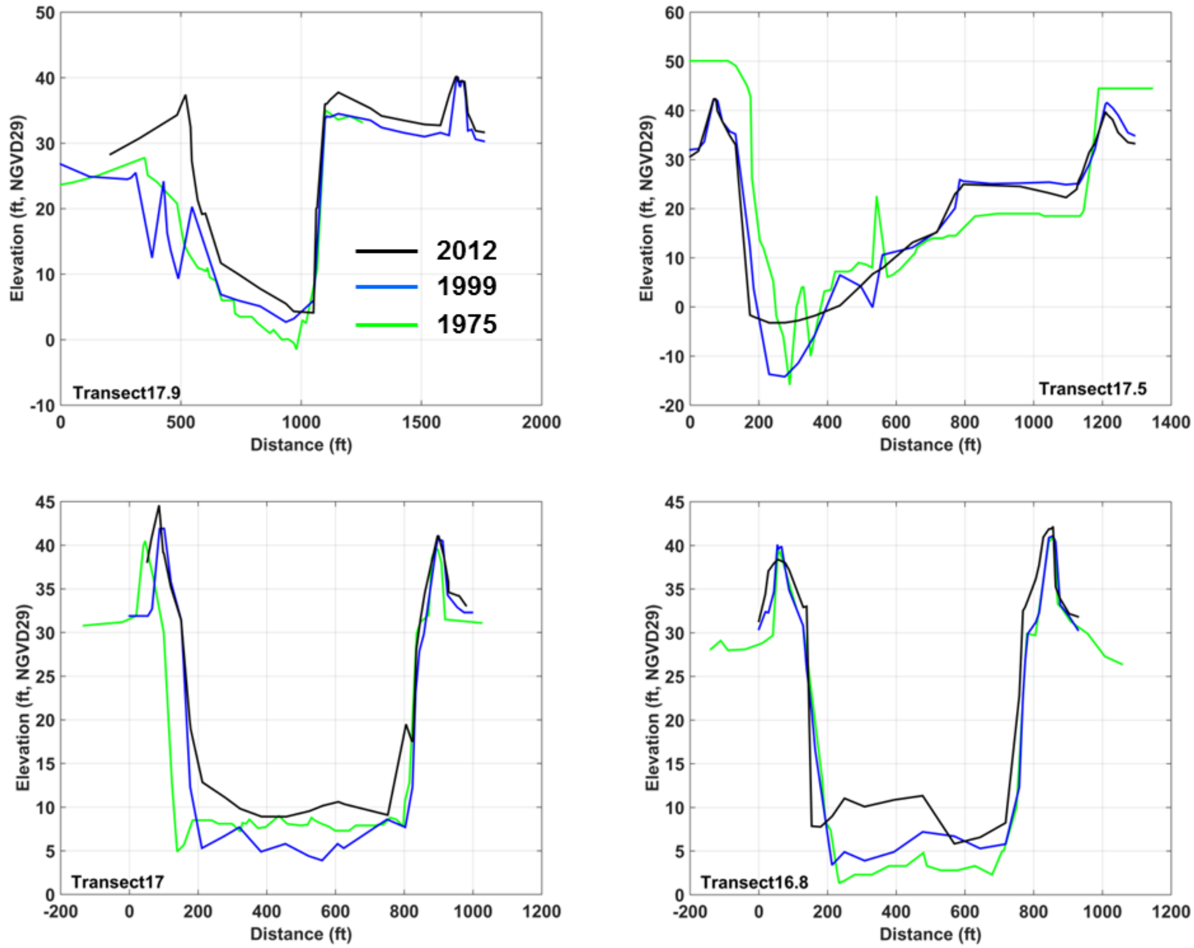

Figure 18. Plots showing comparison of channel cross-section distance-elevation profiles for transects at river miles17.9, 17.5, 17.0 and 16.8.

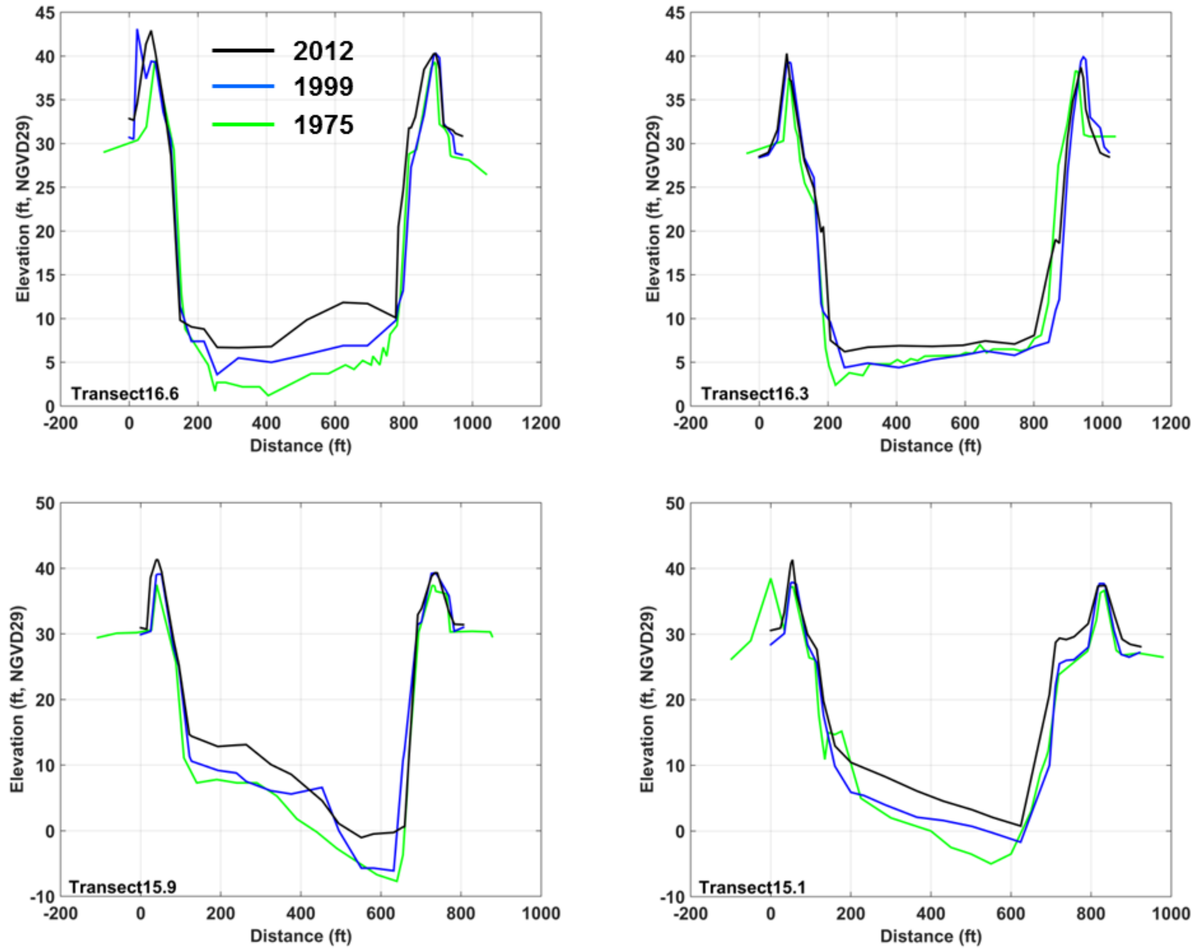

Figure 19. Plots showing comparison of channel cross-section distance-elevation profiles for transects at river miles16.6, 16.3, 15.9, and 15.1.

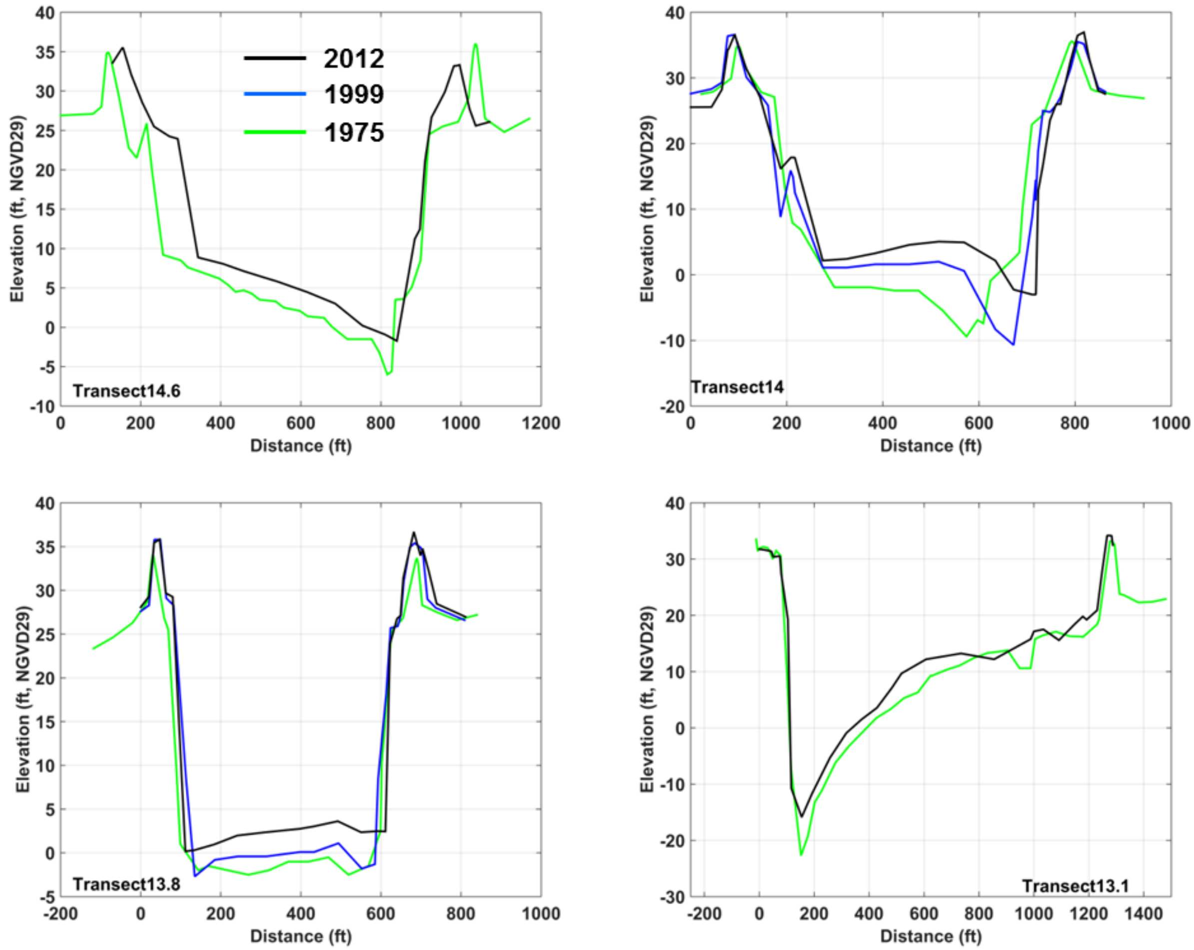

Figure 20. Plots showing comparison of channel cross-section distance-elevation profiles for transects at river miles 14.6, 14.0, 13.8, and 13.1.

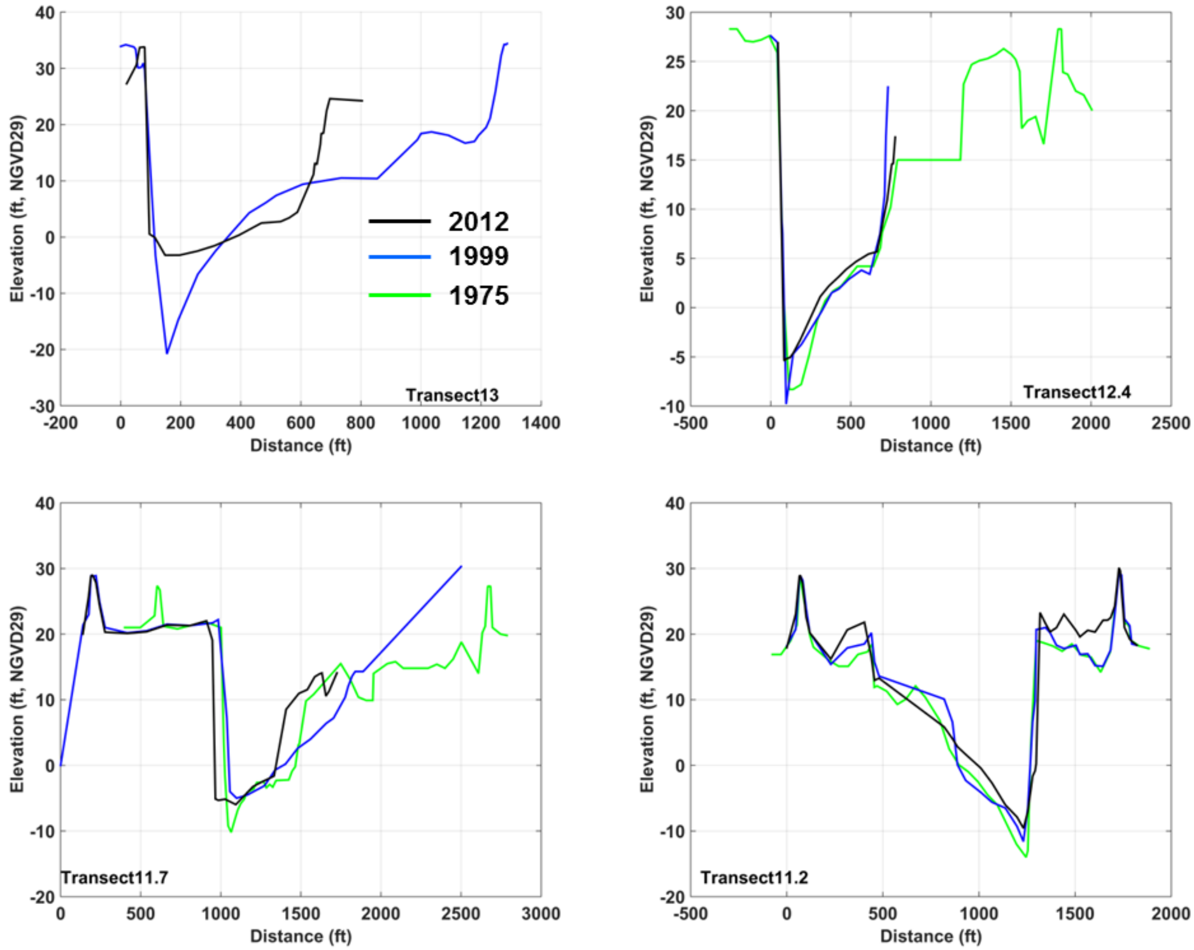

Figure 21. Plots showing comparison of channel cross-section distance-elevation profiles for transects at river miles 13.0, 12.4, 11.7, and 11.2.

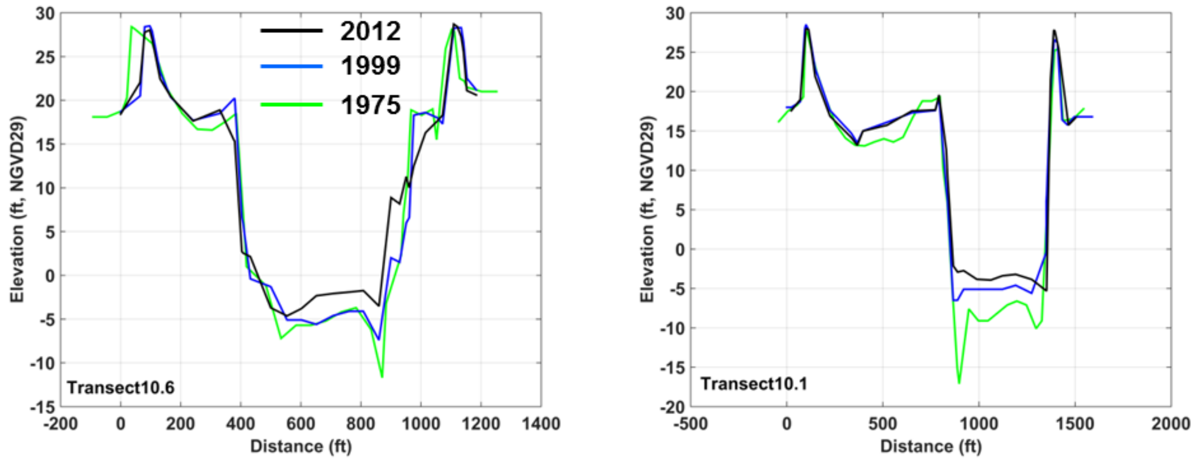

Figure 22. Plots showing comparison of channel cross-section distance-elevation profiles for transects at river miles 10.6 and 10.1.

Recent Changes in Stream Channel Bed Elevations

Additional comparisons were made between digital elevation surfaces generated from dense sounding data like the 2012 survey data reported above and recent dense sonar mapping near the mainstem confluence with the North and South Forks and in the middle North Fork by Northwest Hydraulic Consultants, and in the lower North Fork Skagit River by USGS. Each of these data sets, the NHC 2010 (confluence), NHC 2015 (N Fork), and USGS 2008 lower North Fork data are comparable with the 2012 data in terms of data density with multiple along and cross-channel survey tracks compared to the single channel cross-section data above.

Comparison of the 2015 and 2012 survey data in the North Fork distributary show a mean vertical change of 0.25 m over an area spanning 2.4 km around the North Fork Bridge (**Figure 23**). Isolated areas of greater change indicate sedimentation of up to 3 m. Areas of change of up to ~10 m are suggested along the right bank but are suspected to be erroneous and should be investigated further. Away from the banks in the middle of the channel of the North Fork, areas of erosion are commonly range 1- 2 m. A mean increase in bed elevation of 0.25 m over this area would represent ~700,000 m^3 of sedimentation between 2012 and 2015.

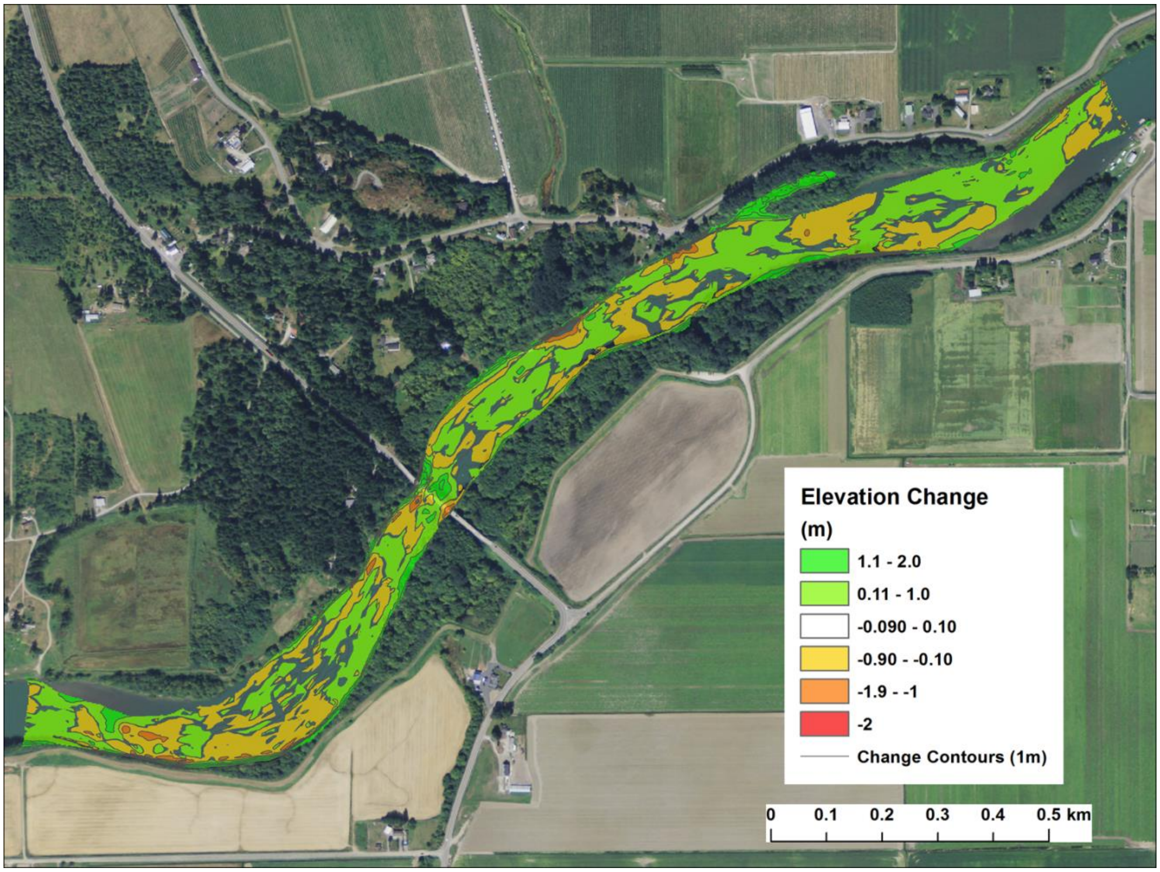

Figure 23. Map showing the bathymetric change between 2015 and 2012 in the vicinity of the North Fork Skagit River Bridge derived from differencing the two interpolated surface elevation models.

Comparison of the 2012 and 2010 survey data in the confluence area shows a mean vertical change of 0.006 m over the reach that extends ~2.5 km on the mainstem above the bifurcation, 2 km downstream in the North Fork and about 1.5 km down the South Fork (**Figure**

24). The net change in bed elevation over this time is within the error of the surveys, however, isolated areas of sedimentation and erosion are likely real and significant. Bed elevation increase, particularly along the right bank just downstream of the bifurcation in the form of a bar appears to have also influenced scour along the far left bank. The elevation change suggests more than 2 m of sedimentation along the bar and 1.0 to 1.5 m of erosion in the channel.

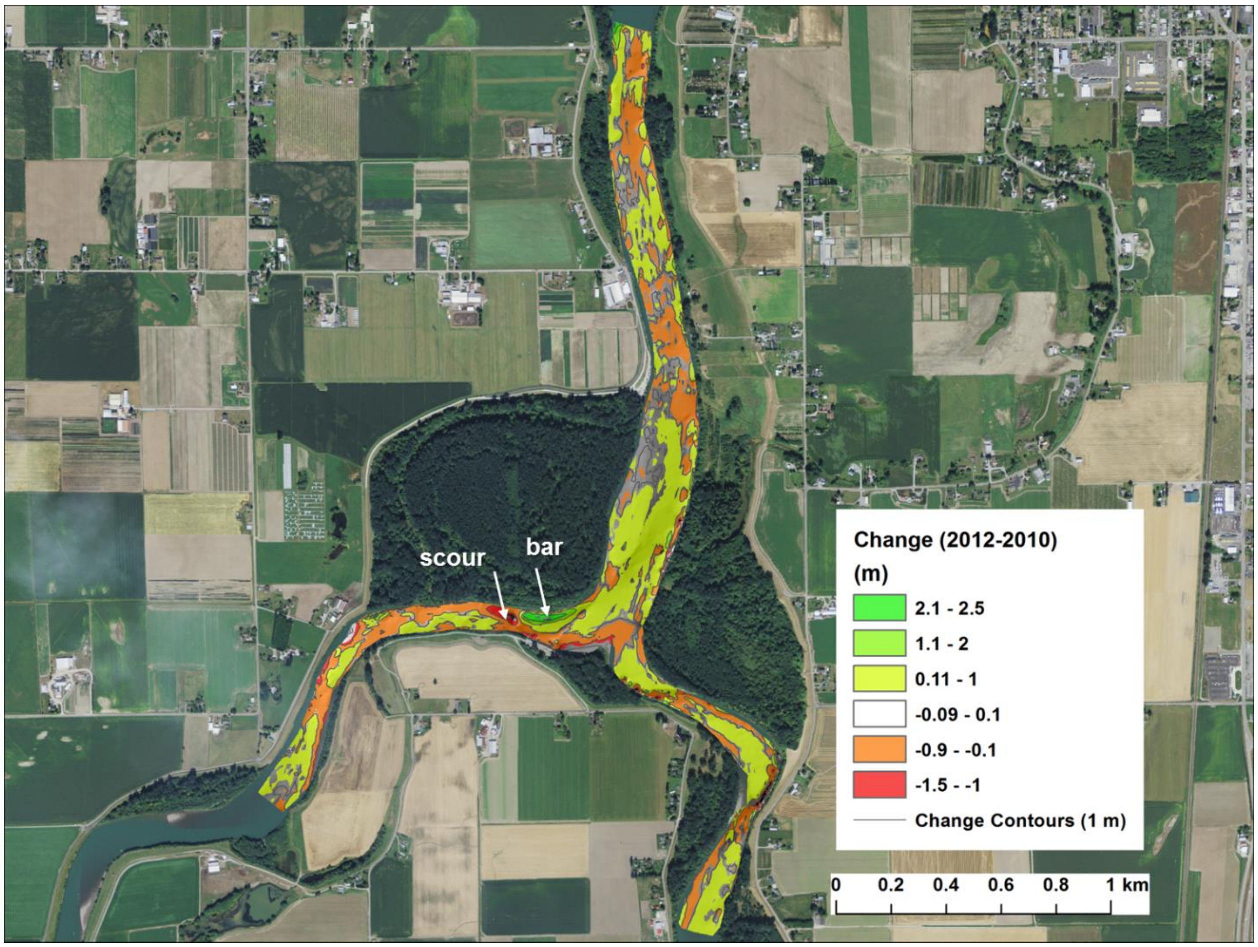

Figure 24. Map showing the bathymetric change between 2012 and 2010 in the vicinity of the mainstem – N/S Fork confluence.

Comparison of 2012 and 2008 survey data across the lower North Fork show a more uniform signal of bed elevation increase (**Figure 25**). A mean change over this time of 0.7m over approximately 65% of the area surveyed is consistent with sedimentation and is likely an underestimate of the net change as ~30-35% of the area was not accessible in 2012 due to filling. Significant change continues in this reach as an avulsion noted in late November 2014 has rapidly evolved to redirect a majority of the North Fork flow down the channel now known as "The Gauntlet".

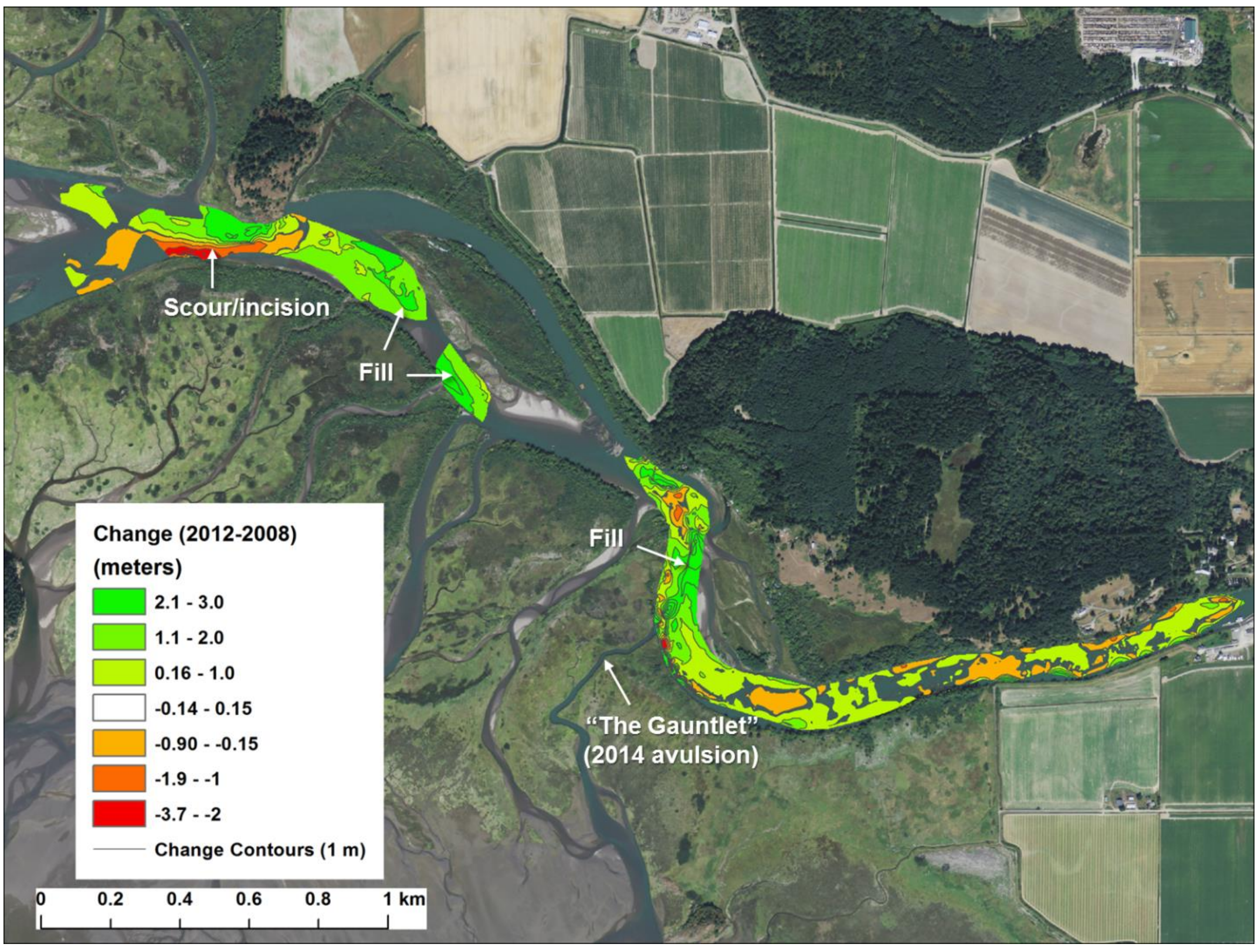

Figure 25. Map showing the bathymetric change between 2012 and 2008 in the lower North Fork River.

Recent Changes in Nearshore Coastal Elevations

Additional comparisons were made between 2014 bathymetric LiDAR data and 2008 nearshore sonar data across the North Fork Skagit Delta nearshore (**Figure 26**). These comparisons provide key insight to coastal elevation changes at and downstream of the river and distributary channel mouths that influence stream flow conveyance and sedimentation an uncertain distance upstream. Large areas offshore of the principal channel show elevation increases of up to 2 m during this time, though it is uncertain whether this aggradation will be permanent or reworked by coastal processes. A mean increase in elevation of 0.22 over the entire area is indicative of accumulation of 4,070,500 m^3 of sediment between 2008 and 2014.

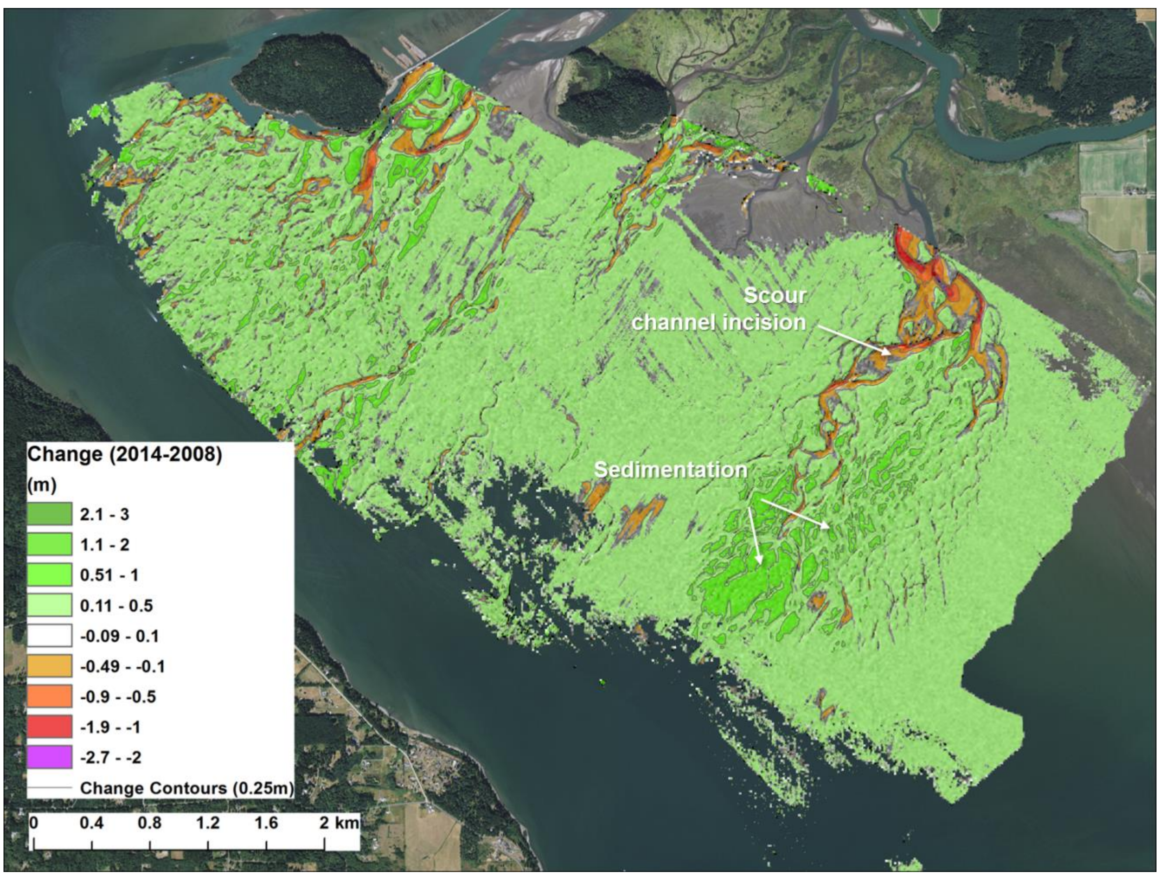

Figure 26. Map showing the bathymetric change between 2015 and 2008 across the North Fork Skagit tidal flats. Significant sedimentation has been followed by channel incision.

Changes in Stage-Discharge at USGS gage #12200500 (Skagit R. near Mount Vernon, WA)

Analyses of changes in flood stage relative to specific discharge volumes during high flows at the USGS gage #12200500 (Skagit River near Mount Vernon, WA), indicate changes in reach-scale flow conveyance between 1987 and 2014 (**Figure 27**). The extent that downstream channel morphology influences the gage remains uncertain. A plot of the relationship between discharge and stage for the 90-, 50- and 10% peak flood exceedances shows increases in stage between 1994 and 2001, and again between 2004 and 2006 indicative of reductions in flow conveyance or fill. An abrupt decrease in stage for the given discharges in 2001, and a significant drop in late 2005/early 2006 of more than 2 ft suggest increases in flow conveyance or scour. Following the significant decrease in stage in early 2006 until 2012, stage for each of the discharges analyzed experienced a period of general increase suggestive of fill or reduced conveyance, before an abrupt increase suspected to be associated with levee renovation just below the gage.

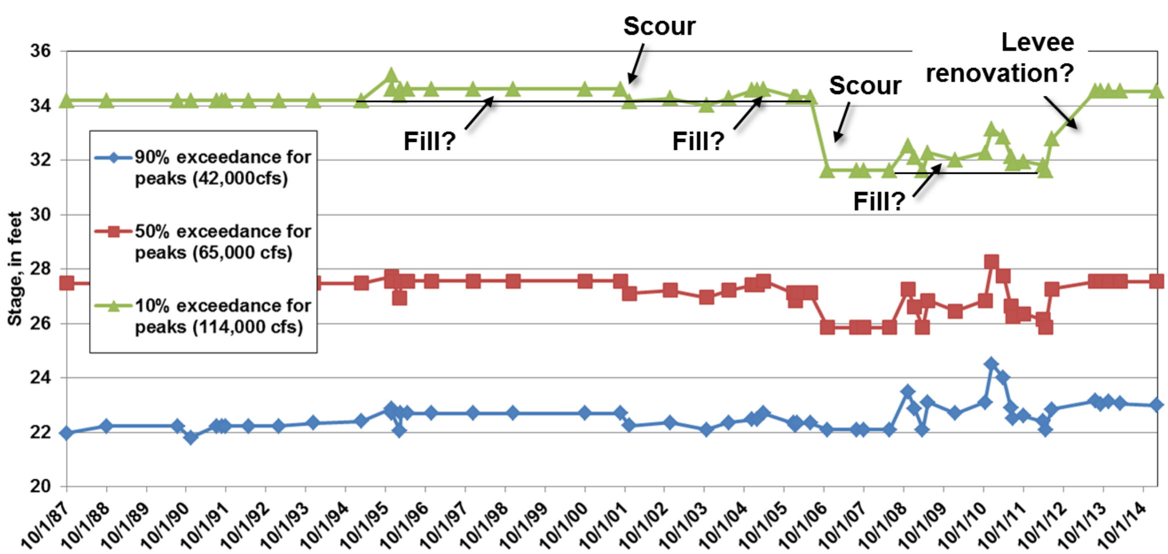

Figure 27. Plot showing the relationship between discharge and stage for the 90-, 50-, and 10-% exceedances for peak floods at the USGS gage #12200500 (Skagit River near Mount Vernon, WA).

Spatial and Temporal Trends in Channel Change across the Lower Skagit River and Delta

While additional higher resolution and denser data would greatly help to refine our understanding of trends in channel geomorphic change, the analyses conducted here provide a snap shot of trends at select channel cross-sections and across several “reach” scale areas of the lower Skagit River and delta. A summary of the net changes between 1999 and 2014 where georeferencing of the data is documented indicates that a relative uniform pattern of sediment aggradation characterizes the entire study area between Sedro-Woolley and Skagit Bay and is consistent with the trends observed between 1975 and 1999 (**Figure 28**).

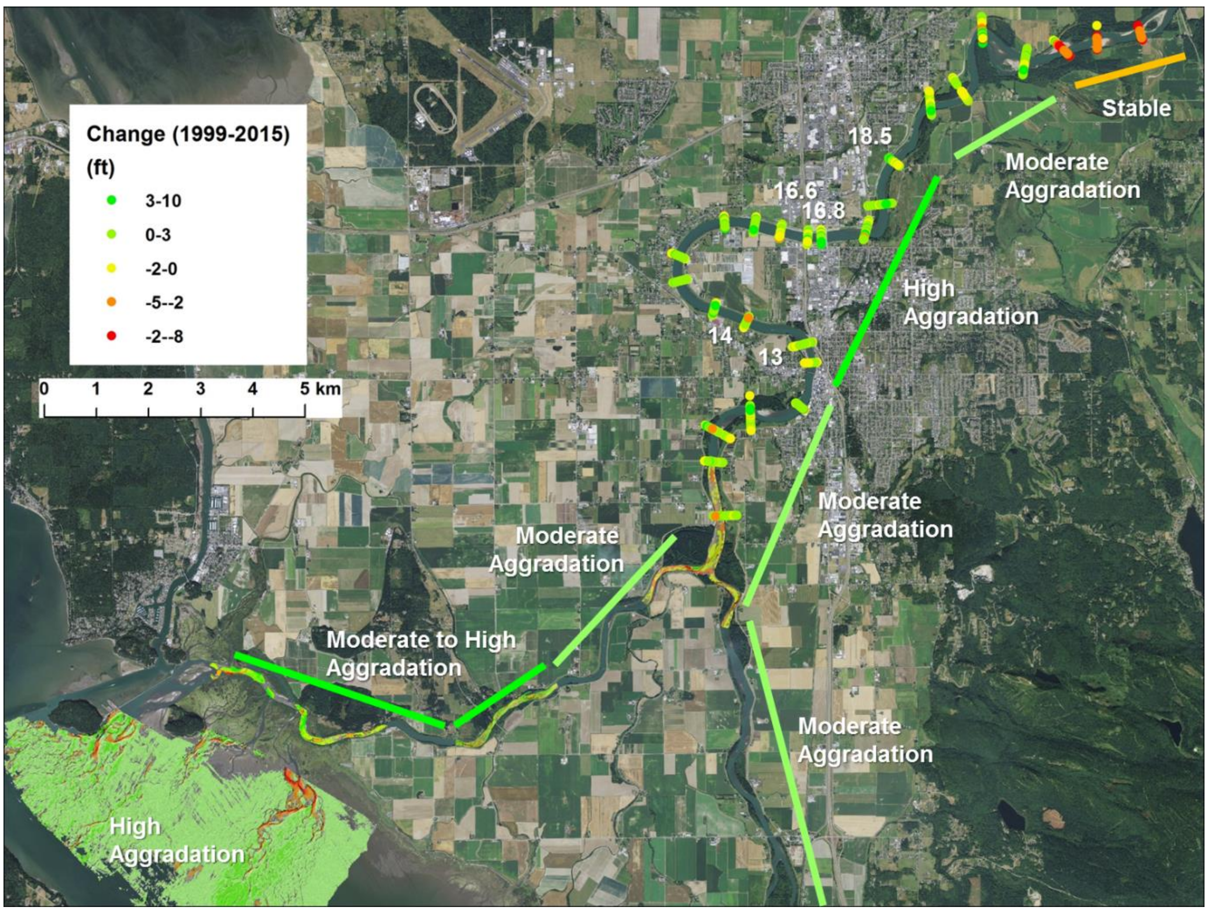

Figure 28. Map showing the sediment aggradation regime of the lower Skagit River and Delta and the sites of greatest bed elevation increase at river miles 13, 14, 16.6, 16.8, and 18.5.

Between river miles 20 and 22.4 near Sedro-Woolley the channel has been relatively stable since 1999 and is characterized as stable as elevation change between 1999 and 2012 has been similar to or lower than between 1975 and 1999. We note that at river mile 21.6 however isolated sections of the channel have experienced appreciable aggradation. Between river mile 18.5 and 20, the reach is characterized as moderate aggradation reflecting an increase in the elevation of the bed of 2-5 ft between 1999 and 2012 in addition to appreciable aggradation between 1975 and 1999. At river mile 18.5 in particular, aggradation in the recent period reached ~10 ft. Between river miles 13.0 and 18.5 around Mount Vernon, the reach is characterized by high aggradation as all channel cross-sections showed generally continuous aggradation between 1975, 1999 and on into 2012, with generally 3-7 ft at all sites, and upwards of 10-ft at sites 13, and 14 since 1999 alone. The lower Skagit River through to the Skagit Bay is characterized as moderate aggradation where bed elevation increase has ranged 2-5 ft, except in the middle to lower North Fork where it is characterized by moderate to high aggradation where recent bed elevation increase of 2-5 ft and entire filling of distributaries has been observed. While the South Fork lacks comparable data, it is characterized by moderate aggradation based on our knowledge that roughly 40% of the Skagit River sediment load fluxes through the South fork (Curran et al. In Review), is characterized by a lower stream gradient, and is subject to equal if not more frequent tidal influences that would promote sediment trapping.

Local knowledge of morphologic change and sedimentation

Interestingly, dozens of citizens interested in the surveys conducted for this study and attracted to our mapping vessels and personal watercraft shared their local knowledge of recent changes and sedimentation. All of the stories shared which were based on decades of local experience fishing and boating on the river described a general pattern of steady sedimentation and infilling of the Skagit River channels. These perspectives are consistent with stories from local tribal fishermen and recreational kayakers that also described steadily shallowing conditions across the North Fork Skagit River during the last 10 years. Important questions that remain are whether and to what extent the recent sedimentation is associated with changes in sediment delivery, transient phasing of sediment flux through the lower river, and/or trapping of sediment by sea-level rise.

Conclusions

Analyses that compare historical Skagit River channel cross-sections to newly acquired mapping data provides updated quantitative information to assess channel changes and establish a baseline of geomorphic condition for resource managers and planners to be able to detect and track changes in the future. A new data set consisting of the first-ever continuous elevation surface for the lower Skagit River and its estuary distributaries help resolve important geomorphic features and likely changes that affect channel flow conveyance and flood risk. The results derived in this study along with information for sediment budgets, flow and sediment routing and inundation frequency across the floodplains, estuary and nearshore need to be integrated in order to test models of sediment transport and refine understanding of the physical processes that lead to channel responses including channel bed sediment aggradation and scour documented here. These are important for planning for flood risk mitigation and ecosystem restoration outcomes that are susceptible to abrupt changes and longer-term trends in sediment impacts that are projected with forecasted climate change and sea-level rise.

This study highlighted a few specific areas that would be good to monitor to test whether trends in aggradation continue and to determine the extent across each reach that changes observed influence flow conveyance at sites of concern to flood risk managers and restoration actions. In particular reaches in the vicinity of river miles 13, 14, 16.6, 16.8, and 18.5 have experienced long-term net aggradation of between 3 and 10 ft which can have significant influence on reducing flood conveyance during future floods, depending on the extent of channel fill, composition of sediment (coarser material armor the bed), and capacity of impending floods to scour material. A generalized aggradation regime characterizing the lower Skagit River derived from this study based on the persistence and magnitude of aggradation observed since 1975 intends to help resource managers evaluate potential sediment impacts and sediment influences on land use planning, including floodplain and estuary habitat restoration alternatives. While the results here provide an assessment of recent patterns, trends and rates of channel bed elevation change interpreted to be associated with sedimentation or scour, integration of these results with analyses of sediment budgets, sediment routing, physical processes like flow that transports sediment, and inundation frequency are needed to assess likely influences on target actions across the landscape.

Acknowledgments

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Appendix G: Changes to Objectives and Indicators During Phase 2

changes to indicators during phase 2

FISH	number	objective	indicator	change (if any)
Restore Sufficient Estuary Habitat to Produce 1.35 Million Smolts		Increase Area Subject to Natural Tidal and Riverine Processes.	Total project area with restored processes	removed and replaced (2 lines below)
	Fish 1	Increase Area Subject to Natural Tidal and Riverine Processes.	within restoration project footprint increases in wetted area (tidal or Q2)	added
	Fish 2	Minimize Impacts to Existing Habitats Subject to Tidal and Riverine Processes	Outside restoration project footprint decreases in wetted area (Q2)	added
	Fish 3a	Increase Area of Tidal and Riverine Channels Suitable To Chinook Rearing Fry.	Total number of acre-hours suitable habitat predicted	no change
	Fish 3b	Increase Area of Tidal and Riverine Channels Suitable To Chinook Rearing Fry.	Steady state predictions of channel area	no change
	Fish 4	Increase Chinook Smolt Production	Estimated new smolts produced annually	no change
	Fish 5	Increase the Landscape Connectivity	Increased connectivity to existing habitat - index of connectivity across study area	no change
		Enhance Valued Nearshore Rearing Habitats By Reducing Sediment Impacts.	H,M,L potential for increased sediment storage	removed
	Fish 6	Maintain and/or Improve Diversity of Tidal Marsh Habitats.	Diveristy metric of habitat types across elevation gradient	no change

FLOOD	number	objective	indicator	change (if any)
Reduce Flood Damages and Risks to Safety	Flood 1	Reduce Water Surface Elevation Within the Study Area.	Reduced WSE during a flood stage relative to existing conditions	no change
		Reduce Risk of Levee Failure By Constructing New Engineered Levees.	Linear feet of replaced or relocated levee in known risk locations	removed and replaced (3 lines below)
	Flood 2a	Reduce Risk of Levee Failure By Constructing New Engineered Levees.	Linear feet of replaced or relocated river levee	added
	Flood 2b	Reduce Risk of Levee Failure By Constructing New Engineered Levees.	Linear feet of replaced or relocated marine dike	added
	Flood 2c	Reduce Risk of Levee Failure By Constructing New Engineered Levees.	Includes an area with known weakness	added
		Reduce Risk of Unplanned Levee Overtopping.	Linear feet of replaced or relocated levee/sea dike in potential overtopping locations	removed
		Reduce Risk Of Levee Failure Associated with Scour Locations.	A scour site or site predicted by model is reduced or removed with project condition	removed
	Flood 3	Avoid increases to operations, maintenance and risk	length of new levee/dike where none previously existed	added
	Flood 4	Improve Agriculture Flood Drainage	includes a flood flow return site identified by CDD#22 & Skagit County	no change

FARM	number	objective	indicator	change (if any)
Protect Short and Long Term Viability of Agriculture	Farm 1	Minimize Conversion of Farmland.	Acres of converted farmland	no change
	Farm 2	Maximize Smolts Per Acre of converted agricultural land	Predicted smolts/acre of converted farmland - Fish 4/Farm 1	no change
	Farm 3	Support Tidegate Maintenance Through the TFI Implementation Agreement.	Restoration acres that support TFI credits (roughly equivalent to Fish 1)	no change
	Farm 4	Restore Public Land First.	Landownership	no change
		Avoid Conversion of Protected Farmland Parcels.	Yes or No whether restoration footprint overlaps existing farmland easement	removed and replaced (line below)
	Farm 5	Minimize Conversion of Protected Farmland Parcels	acres of protected farmland that overlaps a restoration project concept footprint	added

Appendix H: Farm Objectives Calculations

SHDM PROJECT - Farm Objective Scores
Final November 7, 2017
Farm Objective #1: Minimize conversion of agricultural land

Project Concept	Agricultural NRL	Rural Business	Rural Intermediate	Small Scale Business	Public Open Space (OSRI)	Natural Resource Industry	Rural marine Industry	Rural Reserve	Acres (AG-NRL + OSRSI)	Normalized Score
Avon-Swinomish Bypass	1,170.9	9.3	15.5	1.5					1,170.9	1.00
Cottonwood Island	5.1[N1]				0.5[N1]				0.0	0.00
Deepwater Slough Phase 2					268.4				268.4	0.23
East Cottonwood	1.9[N1]								0.0	0.00
Fir Island Cross Island Connector	149.9								149.9	0.13
Fir Island Farm	136.6				2.6				139.2	0.12
Hall Slough	133.0				0.8				133.8	0.11
McGlinn Causeway					1.8[N1]				0.0	0.00
Milltown Island					218.8				0.0	0.00
NF Left Bank Levee Setback A	553.2				0.2				553.4	0.47
NF Left Bank Levee Setback B	371.2				0.2				371.4	0.32
NF Left Bank Levee Setback C	275.4				0.2				275.7	0.24
NF Right Bank Levee Setback	85.9							0.2	85.9	0.07
Pleasant Ridge South								29.4	29.4	0.03
Rawlins Road	184.1							7.8	191.8	0.16
Rawlins Road Distributary Channel								7.1[N1]	0.0	0.00
South Fork Levee Setback 2, 3, 4	36.5[N1]				12.6[N1]	5.5[N1]			0.0	0.00
Sullivan Hacienda	204.6							0.6	205.2	0.18
Telegraph Slough 1	161.4								161.4	0.14
Telegraph Slough 1 & 2	398.9								398.9	0.34
Telegraph Slough Full	940.0						6.5[N1]		940.0	0.80
Thein Farm	64.9							11.4[N1]	64.9	0.06
TNC South Fork	1.1[N1]								0.0	0.00
McGlinn & TS 1	161.4	0.0	0.0	0.0	1.8[N1]	0.0	0.0	0.0	161.4	0.14
McGlinn & TS 1&2	398.9	0.0	0.0	0.0	1.8[N1]	0.0	0.0	0.0	398.9	0.34
McGlinn & TS Full	940.0	0.0	0.0	0.0	1.8[N1]	0.0	6.5[N1]	0.0	940.0	0.80

N1. No history of agriculture

SHDM PROJECT - Farm Objective Scores
Final November 7, 2017
Farm Objective #2: Maximize the number of smolts per acre of converted agricultural land

Project Concept	Project Area (ac)*	Estimated # of smolts per project	Acres Farmland Converted (AG-NRL + OSRSI)	smolts/acre	Normalized score
Avon-Swinomish Bypass	1,292.6	182,844	1,170.9	141.5	0.08
Cottonwood Island	15.4	13,695	0.0	0.0	1.00
Deepwater Slough Phase 2	268.3	160,334	268.4	597.7	0.34
East Cottonwood	1.9	41,509	0.0	0.0	1.00
Fir Island CIC	150.0	264,486	149.9	1,763.7	1.00
Fir Island Farm	139.7	65,000	139.2	465.3	0.26
Hall Slough	133.7	22,889	133.8	171.2	0.10
McGlinn Causeway	6.9	40,898	0.0	0.0	1.00
Milltown Island	221.9	27,179	0.0	0.0	1.00
NF Left Bank Levee Setback A	552.1	85,239	553.4	154.4	0.09
NF Left Bank Levee Setback B	370.2	65,468	371.4	176.8	0.10
NF Left Bank Levee Setback C	274.5	53,476	275.7	194.8	0.11
NF Right Bank Levee Setback	86.1	8,119	86.1	94.3	0.05
Pleasant Ridge South	30.1	2,488	29.4	82.8	0.05
Rawlins Road	191.7	49,936	191.8	260.5	0.15
Rawlins Road Distributary Channel	8.4	9,268	0.0	0.0	1.00
SF Levee Setback 2, 3, 4	56.5	3,027	0.0	0.0	1.00
Sullivan Hacienda	205.0	219,936	205.2	1,072.9	0.61
Telegraph Slough 1	185.0	13,956	161.4	75.4	0.04
Telegraph Slough 1&2	494.8	61,365	398.9	124.0	0.07
Telegraph Slough Full	1,048.5	102,855	940.0	98.1	0.06
Thein Farm	78.3	30,000	64.9	383.1	0.22
TNC South Fork	1.1	5,326	0.0	0.0	1.00
McGlinn & TS 1	191.9	66,716	161.4	347.6	0.20
McGlinn & TS 1&2	501.7	154,426	398.9	307.8	0.17
McGlinn & TS Full	1,055.4	231,183	940.0	219.0	0.12

SHDM PROJECT - Farm Objective Scores
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Farm Objective 3. Support tidegate maintenance through TFI Implementation Agreement

Project Concept	Area inundated during Q2 or 10.8ft tide	TFI Credit Factor	TFI credits	Normalized Score
Avon-Swinomish Bypass	1,204.4	50%	602.2	0.58
Cottonwood Island	7.4	0%	0	0.00
Deepwater Slough Phase 2	268.3	100%	268.3	0.26
East Cottonwood	0.5	0%	0	0.00
Fir Island CIC	138.0	100%	138	0.13
Fir Island Farm	139.2	100%	139.2	0.13
Hall Slough	132.7	100%	132.7	0.13
McGlinn Causeway	1.7	0%	0	0.00
Milltown Island	6.0	0%	0	0.00
NF Left Bank Levee Setback A	546.2	100%	546.2	0.52
NF Left Bank Levee Setback B	370.2	100%	370.2	0.35
NF Left Bank Levee Setback C	275.5	100%	275.5	0.26
NF Right Bank Levee Setback	82.2	100%	82.2	0.08
Pleasant Ridge South	27.4	100%	27.4	0.03
Rawlins Road	191.7	100%	191.7	0.18
Rawlins Road Distributary Channel	0.8	0%	0	0.00
SF Levee Setback 2, 3, 4	50.1	0%	0	0.00
Sullivan Hacienda	205.0	100%	205	0.20
Telegraph Slough 1	164.2	50%	82.1	0.08
Telegraph Slough 1&2	446.2	50%	223.1	0.21
Telegraph Slough Full	1,047.0	50%	523.5	0.50
Thein Farm	64.3	100%	64.3	0.06
TNC South Fork	0.0	0%	0	0.00
McGlinn & TS 1	164.2	100%	164.2	0.16
McGlinn & TS 1&2	446.2	100%	446.2	0.43
McGlinn & TS Full	1,047.0	100%	1047	1.00

SHDM PROJECT - Farm Objective Scores

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Farm Objective 4. Prioritize Public Land

			1			1		
Project Concept	Private (acres)	Normalized Score	Wtd	Public + District (acres)	Normalized Score	Wtd	Final Score	Total Normalized Score
Avon-Swinomish Bypass	1,110.44	0.00	0.00	95.60	0.36	0.36	0.36	0.18
Cottonwood Island	4.91	1.00	1.00	4.46	0.02	0.02	1.01	0.51
Deepwater Slough Phase 2	0.00	1.00	1.00	262.44	1.00	1.00	2.00	1.00
East Cottonwood	0.13	1.00	1.00	1.77	0.01	0.01	1.01	0.50
Fir Island Cross Island Connector	147.83	0.87	0.87	1.82	0.01	0.01	0.87	0.44
Fir Island Farm	2.34	1.00	1.00	135.75	0.52	0.52	1.52	0.76
Hall Slough	133.79	0.88	0.88	0.00	0.00	0.00	0.88	0.44
McGlinn Causeway	0.00	1.00	1.00	2.87	0.01	0.01	1.01	0.51
Milltown Island	0.00	1.00	1.00	216.24	0.82	0.82	1.82	0.91
NF Left Bank Levee Setback A	525.22	0.53	0.53	22.96	0.09	0.09	0.61	0.31
NF Left Bank Levee Setback B	351.75	0.68	0.68	19.34	0.07	0.07	0.76	0.38
NF Left Bank Levee Setback C	260.05	0.77	0.77	15.27	0.06	0.06	0.82	0.41
NF Right Bank Levee Setback	78.01	0.93	0.93	8.04	0.03	0.03	0.96	0.48
Pleasant Ridge South	29.81	0.97	0.97	0.00	0.00	0.00	0.97	0.49
Rawlins Road	187.56	0.83	0.83	4.25	0.02	0.02	0.85	0.42
Rawlins Road Distributary Channel	0.15	1.00	1.00	7.14	0.03	0.03	1.03	0.51
South Fork Levee Setback 2, 3, 4	28.64	0.97	0.97	25.97	0.10	0.10	1.07	0.54
Sullivan Hacienda	203.49	0.82	0.82	0.04	0.00	0.00	0.82	0.41
Telegraph Slough 1	158.61	0.86	0.86	1.81	0.01	0.01	0.86	0.43
Telegraph Slough 1 & 2	398.08	0.64	0.64	9.69	0.04	0.04	0.68	0.34
Telegraph Slough Full	920.27	0.17	0.17	34.90	0.13	0.13	0.30	0.15
Thein Farm	77.67	0.93	0.93	0.06	0.00	0.00	0.93	0.47
TNC South Fork	0.00	1.00	1.00	0.10	0.00	0.00	1.00	0.50
McGlinn & TS 1	158.61	0.86	0.86	4.67	0.02	0.02	0.87	0.44
McGlinn & TS 1&2	398.08	0.64	0.64	12.56	0.05	0.05	0.69	0.34
McGlinn & TS Full	920.27	0.17	0.17	37.77	0.14	0.14	0.32	0.16

SHDM PROJECT - Farm Objective Scores

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Farm Objective 5. Minimize conversion of farmland preservation easements

Project Concept	Acres of farmland easements	Normalized Score
Avon-Swinomish Bypass	7.4	0.04
Cottonwood Island	0.0	0.00
Deepwater Slough Phase 2	0.0	0.00
East Cottonwood	0.0	0.00
Fir Island Cross Island Connector	43.9	0.23
Fir Island Farm	0.0	0.00
Hall Slough	132.8	0.71
McGlinn Causeway	0.0	0.00
Milltown Island	0.0	0.00
NF Left Bank Levee Setback A	187.0	1.00
NF Left Bank Levee Setback B	29.6	0.16
NF Left Bank Levee Setback C	0.0	0.00
NF Right Bank Levee Setback	10.0	0.05
Pleasant Ridge South	0.0	0.00
Rawlins Road	0.0	0.00
Rawlins Road Distributary Channel	0.0	0.00
South Fork Levee Setback 2, 3, 4	2.4	0.01
Sullivan Hacienda	0.0	0.00
Telegraph Slough 1	0.0	0.00
Telegraph Slough 1 & 2	1.8	0.01
Telegraph Slough Full	35.8	0.19
Thein Farm	0.0	0.00
TNC South Fork	0.0	0.00
McGlinn & TS 1	0.0	0.00
McGlinn & TS 1&2	1.8	0.01
McGlinn & TS Full	35.8	0.19

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SHDM PROJECT - Farm Objective Scores

Project Concept	20.0 Farm #2: maximize smolts/acre		20.0 Farm #3: TFI Credits		20.0 Farm #4: Prioritze Public Land		Total Benefit Score	20.0 Farm #1: Conversion of Ag land		20.0 Farm #5: Conversion of FLP		Total Impact Score
	Norm. Score	Wtd Score	Norm. Score	Wtd Score	Norm. Score	Wtd Score		Norm. Score	Wtd Score	Norm. Score	Wtd Score	
Avon-Swinomish Bypass	0.08	1.6	0.58	11.5	0.18	3.6	16.8	1.00	20	0.04	0.8	20.8
Cottonwood Island	1.00	20.0	0.00	0.0	0.51	10.1	30.1	0.00	0.0	0.00	0.0	0.0
Deepwater Slough Phase 2	0.34	6.8	0.26	5.1	1.00	20.0	31.9	0.23	4.6	0.00	0.0	4.6
East Cottonwood	1.00	20.0	0.00	0.0	0.50	10.1	30.1	0.00	0.0	0.00	0.0	0.0
Fir Island Cross Island Connector	1.00	20.0	0.13	2.6	0.44	8.7	31.4	0.13	2.6	0.23	4.7	7.3
Fir Island Farm	0.26	5.3	0.13	2.7	0.76	15.2	23.1	0.12	2.4	0.00	0.0	2.4
Hall Slough	0.10	1.9	0.13	2.5	0.44	8.8	13.3	0.11	2.3	0.71	14.2	16.5
McGlinn Causeway	1.00	20.0	0.00	0.0	0.51	10.1	30.1	0.00	0.0	0.00	0.0	0.0
Milltown Island	1.00	20.0	0.00	0.0	0.91	18.2	38.2	0.00	0.0	0.00	0.0	0.0
NF Left Bank Levee Setback A	0.09	1.8	0.52	10.4	0.31	6.1	18.3	0.47	9.5	1.00	20.0	29.5
NF Left Bank Levee Setback B	0.10	2.0	0.35	7.1	0.38	7.6	16.6	0.32	6.3	0.16	3.2	9.5
NF Left Bank Levee Setback C	0.11	2.2	0.26	5.3	0.41	8.2	15.7	0.24	4.7	0.00	0.0	4.7
NF Right Bank Levee Setback	0.05	1.1	0.08	1.6	0.48	9.6	12.2	0.07	1.5	0.05	1.1	2.5
Pleasant Ridge South	0.05	0.9	0.03	0.5	0.49	9.7	11.2	0.03	0.5	0.00	0.0	0.5
Rawlins Road	0.15	3.0	0.18	3.7	0.42	8.5	15.1	0.16	3.3	0.00	0.0	3.3
Rawlins Road Distributary Channel	1.00	20.0	0.00	0.0	0.51	10.3	30.3	0.00	0.0	0.00	0.0	0.0
South Fork Levee Setback 2, 3, 4	1.00	20.0	0.00	0.0	0.54	10.7	30.7	0.00	0.0	0.01	0.3	0.3
Sullivan Hacienda	0.61	12.2	0.20	3.9	0.41	8.2	24.3	0.18	3.5	0.00	0.0	3.5
Telegraph Slough 1	0.04	0.9	0.08	1.6	0.43	8.6	11.1	0.14	2.8	0.00	0.0	2.8
Telegraph Slough 1 & 2	0.07	1.4	0.21	4.3	0.34	6.8	12.5	0.34	6.8	0.01	0.2	7.0
Telegraph Slough Full	0.06	1.1	0.50	10.0	0.15	3.0	14.2	0.80	16.1	0.19	3.8	19.9
Thein Farm	0.22	4.3	0.06	1.2	0.47	9.3	14.9	0.06	1.1	0.00	0.0	1.1
TNC South Fork	1.00	20.0	0.00	0.0	0.50	10.0	30.0	0.00	0.0	0.00	0.0	0.0
McGlinn & TS 1	0.20	3.9	0.16	3.1	0.44	8.7	15.8	0.14	2.8	0.00	0.0	2.8
McGlinn & TS 1&2	0.17	3.5	0.43	8.5	0.34	6.9	18.9	0.34	6.8	0.01	0.2	7.0
McGlinn & TS Full	0.12	2.5	1.00	20.0	0.16	3.2	25.6	0.80	16.1	0.19	3.8	19.9

Appendix I: Fish Objectives Calculations

SHDM PROJECT - Fish Objective Scores

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Fish Objective #1: Increase in the area subject to natural tidal and riverine processes in the study area

Project Concept	Project Area (ac)[N1]	Tidal/Riverine Process Dominate			Within Project Habitat Gain			Normalized Score
		Tidal	River	Both	Tidal	Q2	Total Gain	
Avon-Swinomish Bypass	1,292.6		X			1,204.4	1,204.4	1.00
Cottonwood Island[N1]	15.4		X			7.4	7.4	0.01
Deepwater Slough Phase 2	268.3	x			270.8	268.1	268.3	0.22
East Cottonwood[N1]	1.9		X			0.5	0.5	0.00
Fir Island CIC	150.0		X			116.9	138.0	0.11
Fir Island Farm	139.7	X			139.2	137.1	139.2	0.12
Hall Slough	133.7	X			132.7	118.9	132.7	0.11
McGlinn Causeway	6.9			X	1.7	-1.8	1.7	0.00
Milltown Island	221.9			X	6.0	4.0	6.0	0.00
NF Left Bank Levee Setback A	553.1			X	271.9	546.2	546.2	0.45
NF Left Bank Levee Setback B	370.5			X			356.7	0.30
NF Left Bank Levee Setback C	275.5			X	266.5	280.4	275.5	0.23
NF Right Bank Levee Setback	86.0			X	24.7	82.2	82.2	0.07
Pleasant Ridge South	30.1			X	22.3	27.4	27.4	0.02
Rawlins Road	191.7	X			193.9	193.9	191.7	0.16
Rawlins Road Distributary	8.4	X			0.8	13.3	0.8	0.00
SF Levee Setback 2, 3, 4	56.5	X			50.1	50.5	50.1	0.04
Sullivan Hacienda	205.0	X			212.1	207.7	205.0	0.17
Telegraph Slough 1	185.0	X			164.2	96.0	164.2	0.14
Telegraph Slough 1&2	494.8	X			446.2	300.4	446.2	0.37
Telegraph Slough Full	1,048.5	X			1,047.0	672.7	1,047.0	0.87
Thein Farm	78.3			X	64.1	64.3	64.3	0.05
TNC South Fork[N1]	1.1		X			0.0	0.0	0.00
McGlinn & TS 1				X			164.2	0.14
McGlinn & TS 1&2				X			446.2	0.37
McGlinn & TS Full				X			1,047.0	0.87

N1. Narrow side channel concept projects were too small to be measured accurately using the PNNL node system.
Inundated area was measured in GIS.

SHDM PROJECT - Fish Objective Scores

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Fish Objective #2: Minimize impacts to existing habitats subject to tidal and riverine processes

Project Concept	offsite habitat lost (acres)	Normalized Score
Avon-Swinomish Bypass	336.4	1.00
Cottonwood Island[N1]	0.0	0.00
Deepwater Slough Phase 2	0.0	0.00
East Cottonwood[N1]	0.0	0.00
Fir Island CIC	97.6	0.29
Fir Island Farm	0.0	0.00
Hall Slough	0.0	0.00
McGlinn Causeway	0.0	0.00
Milltown Island	0.0	0.00
NF Left Bank Levee Setback A	132.5	0.39
NF Left Bank Levee Setback B	68.3	0.20
NF Left Bank Levee Setback C	40.8	0.12
NF Right Bank Levee Setback	23.3	0.07
Pleasant Ridge South	0.0	0.00
Rawlins Road	0.0	0.00
Rawlins Road Distributary	0.0	0.00
SF Levee Setback 2, 3, 4	0.0	0.00
Sullivan Hacienda	0.0	0.00
Telegraph Slough 1	0.0	0.00
Telegraph Slough 1&2	0.0	0.00
Telegraph Slough Full	0.0	0.00
Thein Farm	23.3	0.07
TNC South Fork[N1]	0.0	0.00
McGlinn & TS 1	0.0	0.00
McGlinn & TS 1&2	0.0	0.00
McGlinn & TS Full	0.0	0.00

Notes:

1. Area for projects calculated in GIS from inundation maps provided by PNNL.

SHDM PROJECT - Fish Objective Scores

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Fish Object #3: Increase the area of tidal and riverine channels suitable for Chinook rearing fry in the study area

Project Concept	fish 3a: midpoint channel estimates		wt 1	Fish 3b: Acre*hours suitable	wt 1	Total Score	Normalized Score
	(ha)	(acres)	wt score		wt score		
Avon-Swinomish Bypass	16.70	41.27	0.51	449,027	0.40	0.91	0.46
Cottonwood Island[N1]	3.81	9.40	0.12	29,222	0.03	0.14	0.07
Deepwater Slough Phase 2	9.10	22.49	0.28	280,722	0.25	0.53	0.27
East Cottonwood[N2]	3.16	7.80	0.10	1,847	0.00	0.10	0.05
Fir Island CIC[N3]	0.00	0.00	0.00	0	0.00	0.00	0.00
Fir Island Farm	7.06	17.45	0.22		0.00	0.22	0.11
Hall Slough	2.73	6.75	0.08	70,194	0.06	0.15	0.07
McGlinn Causeway[N3]	0.00	0.00	0.00	0	0.00	0.00	0.00
Milltown Island[N4]	1.05	2.60	0.03	43,609	0.04	0.07	0.04
NF Left Bank Levee Setback A	2.44	6.02	0.08	424,059	0.38	0.45	0.23
NF Left Bank Levee Setback B	2.08	5.14	0.06	370,732	0.33	0.39	0.20
NF Left Bank Levee Setback C	1.82	4.50	0.06	302,832	0.27	0.33	0.16
NF Right Bank Levee Setback	0.19	0.48	0.01	36,692	0.03	0.04	0.02
Pleasant Ridge South	0.08	0.20	0.00	7,547	0.01	0.01	0.00
Rawlins Road	3.81	9.41	0.12	142,035	0.13	0.24	0.12
Rawlins Road Distributary	0.42	1.04	0.01	0	0.00	0.01	0.01
SF Levee Setback 2, 3, 4	0.17	0.42	0.01	11,577	0.01	0.02	0.01
Sullivan Hacienda	14.06	34.74	0.43	187,234	0.17	0.60	0.30
Telegraph Slough 1	3.74	9.24	0.12	170,188	0.15	0.27	0.13
Telegraph Slough 1&2	16.70	41.27	0.51	449,027	0.40	0.91	0.46
Telegraph Slough Full	32.46	80.21	1.00	1,122,487	1.00	2.00	1.00
Thein Farm	1.04	2.57	0.03	82,753	0.07	0.11	0.05
TNC South Fork	0.41	1.00	0.01	2,217	0.00	0.01	0.01
McGlinn & TS 1	3.74	9.24	0.12	170,188	0.15	0.27	0.13
McGlinn & TS 1&2	16.70	41.27	0.51	449,027	0.40	0.91	0.46
McGlinn & TS Full	32.46	80.21	1.00	1,122,487	1.00	2.00	1.00

Notes:

N1. Channel area is from the 2011 Design Report

N2. Channel estimate is from design analsyis by WDFW and includes wetland ponds. A specific breakdown of the ponded area elevation by 1-ft bins was not provided; therefore the inundation time only includes channel area and not the ponded area.

N3. Distrubutary projects with no habitat creation elements included are given a score of 0.

N4. From PSNERP May 2012 Strategic Restoration Conceptual Report

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Fish Object #4: Increase Chinook smolt production

Project Concept	average smolt estimates			Normalized Score		
	low	mid	high	low	mid	high
Avon-Swinomish Bypass	71,057	182,844	470,139	0.80	0.69	0.86
Cottonwood Island[N1]	8,370	13,695	19,020	0.09	0.05	0.03
Deepwater Slough Phase 2	63,967	160,334	403,226	0.72	0.61	0.74
East Cottonwood[N2]		41,509			0.16	
Fir Island CIC[N3]		264,486			1.00	
Fir Island Farm		65,000			0.25	
Hall Slough	7,714	22,889	68,416	0.09	0.09	0.13
McGlinn Causeway[N3]		40,898			0.15	
Milltown Island[N4]		27,179			0.10	
NF Left Bank Levee Setback A	28,079	85,239	259,946	0.32	0.32	0.48
NF Left Bank Levee Setback B	21,811	65,468	199,243	0.25	0.25	0.37
NF Left Bank Levee Setback C	17,937	53,476	161,883	0.20	0.20	0.30
NF Right Bank Levee Setback	2,650	8,119	25,245	0.03	0.03	0.05
Pleasant Ridge South	933	2,488	7,776	0.01	0.01	0.01
Rawlins Road	18,742	49,936	133,686	0.21	0.19	0.25
Rawlins Road Distributary		9,268			0.04	
SF Levee Setback 2, 3, 4	883	3,027	8,940	0.01	0.01	0.02
Sullivan Hacienda	88,694	219,936	545,304	1.00	0.83	1.00
Telegraph Slough 1	5,560	13,956	34,963	0.06	0.05	0.06
Telegraph Slough 1&2	23,848	61,365	157,787	0.27	0.23	0.29
Telegraph Slough Full	40,197	102,855	217,215	0.45	0.39	0.40
Thein Farm[N3]		30,000			0.11	
TNC South Fork[N2]		5,326			0.02	
McGlinn & TS 1[N5]		66,716			0.25	
McGlinn & TS 1&2[N5]		154,426			0.58	
McGlinn & TS Full[N5]		231,183			0.87	

N1. Cottonwood Island data is from the 2011 design report, which used a smolt/square meter calculation using a floodplain (0.22 smolts/square meter) and river tidal floodplain (0.55 /square meter) carrying capacity estimates. The average mid-point was calculated as the average of these two estimates.

N2. Because Cottonwood East and TNC South Fork are in locations where the landscape connectivity is greater than the data set used to create the Chinook carrying capacity model. As a result the Chinook model may significantly overestimate the number of smolts that a cite would support. It was recommended to use an estimate of 13,150 fish/per hectare/year for these sites.

N3. Data is from the 2005 Skagit Chinook Recovery Plan (SCRP)

N4. Milltown data is the SCRP estimate of 57,179 smolts minus the current carrying capacity estimate of 30,000 (Eric Beamer personal communication)

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Fish Object #5: Increase landscape connectivity of the study area

Project Concept	Change in Connectivity Value	Normalized Score
Avon-Swinomish Bypass	3.11	1.00
Cottonwood Island	0.00	0.00
Deepwater Slough Phase 2	0.00	0.00
East Cottonwood	0.00	0.00
Fir Island CIC	2.10	0.68
Fir Island Farm	0.00	0.00
Hall Slough	0.00	0.00
McGlinn Causeway	1.84	0.59
Milltown Island	0.00	0.00
NF Left Bank Levee Setback A	0.00	0.00
NF Left Bank Levee Setback B	0.00	0.00
NF Left Bank Levee Setback C	0.00	0.00
NF Right Bank Levee Setback	0.00	0.00
Pleasant Ridge South	0.00	0.00
Rawlins Road	0.00	0.00
Rawlins Road Distributary	1.13	0.36
SF Levee Setback 2, 3, 4	0.00	0.00
Sullivan Hacienda	0.00	0.00
Telegraph Slough 1	0.00	0.00
Telegraph Slough 1&2	0.00	0.00
Telegraph Slough Full	0.00	0.00
Thein Farm	0.00	0.00
TNC South Fork	0.00	0.00
McGlinn & TS 1	1.84	0.59
McGlinn & TS 1&2	1.84	0.59
McGlinn & TS Full	1.84	0.59

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Fish Objective #6: Maintain or improve diversity of tidal marsh habitat along historical elevation gradient

Project Concept	*Total Area*	mudflat/ channel	emergent	shrub	floodplain/ riparian	Diversity Score	Normalize Score
Avon-Swinomish Bypass	1,291.3	72.0	696.3	43.1	480.0	2.31	0.83
Cottonwood Island	15.2	0.1	0.1	0.1	14.9	1.00	0.36
Deepwater Slough Phase 2	267.8	0.0	149.1	66.6	52.1	2.44	0.88
East Cottonwood	1.9	0.0	0.0	0.0	1.9	1.00	0.36
Fir Island Cross Island Connector	149.5	0.0	119.1	24.3	6.1	1.00	0.36
Fir Island Farm	139.5	0.6	133.2	1.8	3.9	1.10	0.39
Hall Slough	133.6	0.0	122.8	3.4	7.4	1.18	0.42
McGlinn Causeway	6.8	0.3	4.3	0.7	1.5	1.00	0.36
Milltown Island	221.6	2.5	15.6	114.2	89.2	2.31	0.83
NF Left Bank Levee Setback A	552.1	0.0	174.3	125.2	252.6	2.77	1.00
NF Left Bank Levee Setback B	370.5	0.0	169.6	112.3	88.5	2.79	1.00
NF Left Bank Levee Setback C	274.9	0.0	166.3	70.2	38.4	2.22	0.80
NF Right Bank Levee Setback	85.7	0.1	9.3	14.0	62.3	1.76	0.63
Pleasant Ridge South	30.0	0.1	0.8	15.6	13.6	2.11	0.76
Rawlins Road	191.5	0.0	168.6	10.5	12.5	1.28	0.46
Rawlins Road Distributary Channel	8.3	0.0	3.6	3.7	1.0	1.00	0.36
South Fork Levee Setback 2, 3, 4	56.1	0.3	6.3	15.0	34.5	2.16	0.78
Sullivan Hacienda	204.8	6.2	175.2	8.3	15.1	1.35	0.49
Telegraph Slough 1	184.8	27.8	143.4	3.8	9.8	1.59	0.57
Telegraph Slough 1 & 2	494.5	68.0	396.0	14.5	16.0	1.51	0.54
Telegraph Slough Full	1,047.7	172.5	794.6	33.9	46.8	1.65	0.59
Thein Farm	78.2	1.1	51.2	6.0	19.9	2.00	0.72
TNC South Fork	1.0	0.0	0.0	0.0	1.0	1.00	0.36
McGlinn & TS 1	191.7	28.1	147.7	4.6	11.3	1.61	0.58
McGlinn & TS 1&2	501.4	68.3	400.3	15.3	17.5	1.52	0.54
McGlinn & TS Full	1,054.5	172.8	798.9	34.6	48.3	1.66	0.59

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Project Concept	15 Fish #1: Habitat Gain		15 Fish #3: Suitable Habitat		25 Fish #4: Smolt Production		15 Fish #5: Improved Connectivity		15 Fish #6: Habitat Diversity		Total Benefit Score	15 Fish #2: Habitat Impacted		Total Impact Score
	N. Score	Wtd Score	N. Score	Wtd Score	N. Score	Wtd Score	N. Score	Wtd Score	N. Score	Wtd Score		N. Score	Wtd Score	
Avon-Swinomish Bypass	1.00	15.0	0.46	6.9	0.69	17.3	1.00	15.0	0.83	12.4	66.6	1.00	15.0	15.0
Cottonwood Island	0.01	0.1	0.07	1.1	0.05	1.3	0.00	0.0	0.36	5.4	7.8	0.00	0.0	0.0
Deepwater Slough Phase 2	0.22	3.3	0.27	4.0	0.61	15.2	0.00	0.0	0.88	13.1	35.6	0.00	0.0	0.0
East Cottonwood	0.00	0.0	0.05	0.7	0.16	3.9	0.00	0.0	0.36	5.4	10.1	0.00	0.0	0.0
Fir Island Cross Island Connector	0.11	1.7	0.00	0.0	1.00	25.0	0.68	10.1	0.36	5.4	42.2	0.29	4.4	4.4
Fir Island Farm	0.12	1.7	0.11	1.6	0.25	6.1	0.00	0.0	0.39	5.9	15.4	0.00	0.0	0.0
Hall Slough	0.11	1.7	0.07	1.1	0.09	2.2	0.00	0.0	0.42	6.3	11.3	0.00	0.0	0.0
McGlinn Causeway	0.00	0.0	0.00	0.0	0.15	3.9	0.59	8.9	0.36	5.4	18.1	0.00	0.0	0.0
Milltown Island	0.00	0.1	0.04	0.5	0.10	2.6	0.00	0.0	0.83	12.4	15.6	0.00	0.0	0.0
NF Left Bank Levee Setback A	0.45	6.8	0.23	3.4	0.32	8.1	0.00	0.0	1.00	14.9	33.2	0.39	5.9	5.9
NF Left Bank Levee Setback B	0.31	4.7	0.20	3.0	0.25	6.2	0.00	0.0	1.00	15.0	28.8	0.20	3.0	3.0
NF Left Bank Levee Setback C	0.23	3.5	0.16	2.4	0.20	5.1	0.00	0.0	0.80	11.9	22.9	0.12	1.8	1.8
NF Right Bank Levee Setback	0.07	1.1	0.02	0.3	0.03	0.8	0.00	0.0	0.63	9.5	11.6	0.07	1.0	1.0
Pleasant Ridge South	0.02	0.3	0.00	0.1	0.01	0.2	0.00	0.0	0.76	11.3	11.9	0.00	0.0	0.0
Rawlins Road	0.16	2.4	0.12	1.8	0.19	4.7	0.00	0.0	0.46	6.9	15.8	0.00	0.0	0.0
Rawlins Road Distributary Channel	0.00	0.0	0.01	0.1	0.04	0.9	0.36	5.5	0.36	5.4	11.8	0.00	0.0	0.0
South Fork Levee Setback 2, 3, 4	0.04	0.6	0.01	0.1	0.01	0.3	0.00	0.0	0.78	11.6	12.6	0.00	0.0	0.0
Sullivan Hacienda	0.17	2.6	0.30	4.5	0.83	20.8	0.00	0.0	0.49	7.3	35.1	0.00	0.0	0.0
Telegraph Slough 1	0.14	2.1	0.13	2.0	0.05	1.3	0.00	0.0	0.57	8.6	14.0	0.00	0.0	0.0
Telegraph Slough 1 & 2	0.37	5.6	0.46	6.9	0.23	5.8	0.00	0.0	0.54	8.1	26.3	0.00	0.0	0.0
Telegraph Slough Full	0.87	13.1	1.00	15.0	0.39	9.7	0.00	0.0	0.59	8.9	46.7	0.00	0.0	0.0
Thein Farm	0.05	0.8	0.05	0.8	0.11	2.8	0.00	0.0	0.72	10.8	15.2	0.07	1.0	1.0
TNC South Fork	0.00	0.0	0.01	0.1	0.02	0.5	0.00	0.0	0.36	5.4	6.0	0.00	0.0	0.0
McGlinn & TS 1	0.14	2.1	0.13	2.0	0.25	6.3	0.59	8.9	0.58	8.7	28.0	0.00	0.0	0.0
McGliin & TS 1&2	0.37	5.6	0.46	6.9	0.58	14.6	0.59	8.9	0.54	8.2	44.0	0.00	0.0	0.0
McGlinn & TS Full	0.87	13.1	1.00	15.0	0.87	21.9	0.59	8.9	0.59	8.9	67.7	0.00	0.0	0.0

Appendix J: Flood Objectives Calculations

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Flood Objective #1: Reduce water surface elevation within the study area

Project Concept	DROP			1		1		1		1		1		1		1		1		1	Sum (wtd)	Normalized Score
	Length (ft) of Delta WSE -0.3 to -0.5	Length (ft) of Delta WSE -0.5 to -1.0	Change WSE -1.0 to 1.5		Change WSE -1.5 to 2.0		Change WSE -2.0 to 2.5		Change WSE -2.5 to 3.0		Change WSE -3.0 to 3.5		Change WSE -3.5 to 4.0		Change WSE -4.0 to 4.5		Change WSE -4.5 to 5.0		Change WSE -5.0 to 5.5			
			Length (ft)	wtd factor	Length (ft)	wtd factor	Length (ft)	wtd factor	Length (ft)	wtd factor	Length (ft)	wtd factor	Length (ft)	wtd factor	Length (ft)	wtd factor	Length (ft)	wtd factor	Length (ft)	wtd factor		
Avon-Swinomish Bypass	8,375	10,420	6,830	1	7,795	1	13,390	1	17,405	1	34,360	1	10,460	1	4,350	1	7,910	1	3,770	1	106,270	1.00
Cottonwood Island	300			1		1		1		1		1		1		1		1		1	0	0.00
Deepwater Slough Phase 2	10,810	12,570	5,290	1	3,045	1	7,500	1	1,850	1	870	1	1,930	1	1,100	1		1		1	21,585	0.20
East Cottonwood				1		1		1		1		1		1		1		1		1	0	0.00
Fir Island Cross Island Connector	14,090	26,660	7,130	1	10,180	1	6,220	1	480	1		1		1		1		1		1	24,010	0.23
Fir Island Farm				1		1		1		1		1		1		1		1		1	0	0.00
Hall Slough				1		1		1		1		1		1		1		1		1	0	0.00
McGlinn Causeway				1		1		1		1		1		1		1		1		1	0	0.00
Milltown Island	4,080	2,150		1		1		1		1		1		1		1		1		1	0	0.00
NF Left Bank Levee Setback A	10,410	23,855	21,860	1	19,460	1	4,460	1	4,880	1		1		1		1		1		1	50,660	0.48
NF Left Bank Levee Setback B			18,800	1	16,736	1	3,836	1	4,197	1		1		1		1		1		1	43,568	0.41
NF Left Bank Levee Setback C	24,375	6,540	7,650	1	5,240	1	2,380	1	570	1	1,470	1		1		1		1		1	17,310	0.16
NF Right Bank Levee Setback	24,470	10,640		1		1		1		1		1		1		1		1		1	0	0.00
Pleasant Ridge South	2,540	2,430		1		1		1		1		1		1		1		1		1	0	0.00
Rawlins Road	8,555	8,705	4,980	1	3,130	1	1,690	1	1,480	1	920	1		1		1		1		1	12,200	0.11
Rawlins Road Distributary Channel	1,050	2,500		1		1		1		1		1		1		1		1		1	0	0.00
SF Levee Setback 2, 3, 4	6,560	9,520	6,660	1		1		1		1		1		1		1		1		1	6,660	0.06
Sullivan Hacienda	1,470			1		1		1		1		1		1		1		1		1	0	0.00
Telegraph Slough 1				1		1		1		1		1		1		1		1		1	0	0.00
Telegraph Slough 1&2				1		1		1		1		1		1		1		1		1	0	0.00
Telegraph Slough Full				1		1		1		1		1		1		1		1		1	0	0.00
Thein Farm	3,600	2,300		1		1		1		1		1		1		1		1		1	0	0.00
TNC South Fork				1		1		1		1		1		1		1		1		1	0	0.00
McGlinn & TS 1				1		1		1		1		1		1		1		1		1	0	0.00
McGliin & TS 1&2				1		1		1		1		1		1		1		1		1	0	0.00
McGlinn & TS Full				1		1		1		1		1		1		1		1		1	0	0.00

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Flood Objective 2: Reduce risk of levee failure by constructing new engineered levees

	Length Replaced River Levee				Length Replaced Marine Dike				Problem Area				
			1				1			1			
Project Concept	(LF)	Normalized Score	wtd factor	wtd score	(LF)	Normalized Score	wtd factor	wtd score	Type	wtd factor	wtd score	Sum (wtd)	Normalized Score
Avon-Swinomish Bypass	0	0.0	1	0.0	0	0.0	1	0.0	--	1	0	0.00	0.00
Cottonwood Island	0	0.0	1	0.0	0	0.0	1	0.0	--	1	0	0.00	0.00
Deepwater Slough Phase 2	0	0.0	1	0.0	0	0.0	1	0.0	--	1	0	0.00	0.00
East Cottonwood	0	0.0	1	0.0	0	0.0	1	0.0	--	1	0	0.00	0.00
Fir Island CIC	0	0.0	1	0.0	0	0.0	1	0.0	Seepage; Boils	1	0.5	0.50	0.25
Fir Island Farm	0	0.0	1	0.0	5,800	0.5	1	0.5	Overtopping	1	0.5	0.99	0.49
Hall Slough	0	0.0	1	0.0	7,567	0.6	1	0.6	--	1	0	0.63	0.32
McGlinn Causeway	0	0.0	1	0.0	0	0.0	1	0.0	--	1	0	0.00	0.00
Milltown Island	0	0.0	1	0.0	0	0.0	1	0.0	--	1	0	0.00	0.00
NF Left Bank Levee Setback A	27,408	1.0	1	1.0	0	0.0	1	0.0	Seepage; Boils	1	1	2.00	1.00
NF Left Bank Levee Setback B	15,586	0.6	1	0.6	0	0.0	1	0.0	Seepage; Boils	1	1	1.57	0.78
NF Left Bank Levee Setback C	12,830	0.5	1	0.5	0	0.0	1	0.0	Seepage; Boils	1	0.5	0.97	0.48
NF Right Bank Levee Setback	6,435	0.2	1	0.2	0	0.0	1	0.0	Seepage	1	0.5	0.73	0.37
Pleasant Ridge South	2,535	0.1	1	0.1	0	0.0	1	0.0	--	1	0	0.09	0.05
Rawlins Road	0	0.0	1	0.0	10,745	0.9	1	0.9	--	1	0	0.90	0.45
Rawlins Road Distributary Channel	0	0.0	1	0.0	0	0.0	1	0.0	--	1	0	0.00	0.00
SF Levee Setback 2, 3, 4	9,346	0.3	1	0.3	0	0.0	1	0.0	Bank Damage	1	0.5	0.84	0.42
Sullivan Hacienda	0	0.0	1	0.0	11,942	1.0	1	1.0	--	1	0	1.00	0.50
Telegraph Slough 1	0	0.0	1	0.0	5,036	0.4	1	0.4	--	1	0	0.42	0.21
Telegraph Slough 1&2	0	0.0	1	0.0	5,036	0.4	1	0.4	--	1	0	0.42	0.21
Telegraph Slough Full*	0	0.0	1	0.0	5,036	0.4	1	0.4	--	1	0	0.42	0.21
Thein Farm	1,000	0.0	1	0.0	0	0.0	1	0.0	--	1	0	0.04	0.02
TNC South Fork	0	0.0	1	0.0	0	0.0	1	0.0	--	1	0	0.00	0.00
McGlinn & TS 1	0	0.0	1	0.0	5,036	0.4	1	0.4	--	1	0	0.42	0.21
McGliin & TS 1&2	0	0.0	1	0.0	5,036	0.4	1	0.4	--	1	0	0.42	0.21
McGlinn & TS Full	0	0.0	1	0.0	5,036	0.4	1	0.4	--	1	0	0.42	0.21

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Flood Objective 3: Avoid creation of new flood protection infrastructure where none existed previously

Project Concept	Length New Levee (LF)	Normalized Score
Avon-Swinomish Bypass	77,088	1.00
Cottonwood Island	0	0.00
Deepwater Slough Phase 2	0	0.00
East Cottonwood	0	0.00
Fir Island CIC	30,000	0.39
Fir Island Farm	0	0.00
Hall Slough	0	0.00
McGlinn Causeway	0	0.00
Milltown Island	0	0.00
NF Left Bank Levee Setback A	0	0.00
NF Left Bank Levee Setback B	0	0.00
NF Left Bank Levee Setback C	0	0.00
NF Right Bank Levee Setback	0	0.00
Pleasant Ridge South	0	0.00
Rawlins Road	0	0.00
Rawlins Road Distributary Channel	0	0.00
SF Levee Setback 2, 3, 4	0	0.00
Sullivan Hacienda	0	0.00
Telegraph Slough 1	0	0.00
Telegraph Slough 1&2	0	0.00
Telegraph Slough Full*	0	0.00
Thein Farm	0	0.00
TNC South Fork	0	0.00
McGlinn & TS 1	0	0.00
McGliin & TS 1&2	0	0.00
McGlinn & TS Full	0	0.00

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Flood Objective 4: Improve agricultural flood drainage

Project Concept	Flood Return Structure[N1]			
	yes/no	Score	wtd factor	wtd score
Avon-Swinomish Bypass	NO	0.0	1	0.0
Cottonwood Island	NO	0.0	1	0.0
Deepwater Slough Phase 2	NO	0.0	1	0.0
East Cottonwood	NO	0.0	1	0.0
Fir Island CIC	YES	1.0	1	1.0
Fir Island Farm	YES	1.0	1	1.0
Hall Slough	YES	1.0	1	1.0
McGlinn Causeway	NO	0.0	1	0.0
Milltown Island	NO	0.0	1	0.0
NF Left Bank Levee Setback A	YES	1.0	1	1.0
NF Left Bank Levee Setback B	YES	1.0	1	1.0
NF Left Bank Levee Setback C	YES	1.0	1	1.0
NF Right Bank Levee Setback	YES	1.0	1	1.0
Pleasant Ridge South	NO	0.0	1	0.0
Rawlins Road	YES	1.0	1	1.0
Rawlins Road Distributary Channel	NO	0.0	1	0.0
SF Levee Setback 2, 3, 4	NO	0.0	1	0.0
Sullivan Hacienda	NO	0.0	1	0.0
Telegraph Slough 1	YES	1.0	1	1.0
Telegraph Slough 1&2	YES	1.0	1	1.0
Telegraph Slough Full	YES	1.0	1	1.0
Thein Farm	NO	0.0	1	0.0
TNC South Fork	NO	0.0	1	0.0
McGlinn & TS 1	YES	1.0	1	1.0
McGliin & TS 1&2	YES	1.0	1	1.0
McGlinn & TS Full	YES	1.0	1	1.0

N1. Defined as any location with an existing outfall/pump station that could be improved for flood return

SHDM PROJECT - Flood Objective Scores
Final November 7, 2017

Project Concept	25.0 Flood #1: Reduce WSE		25.0 Flood #2: Replace levee/dike		25.0 Flood #4 : Flood Return		Total Benefit Score	25.0 Flood #3: New levee/dike		Total Impact Score
	Score	Wtd Score	Score	Wtd Score	Score	Wtd Score		Score	Wtd Score	
Avon-Swinomish Bypass	1.00	25.0	0.00	0.0	0.00	0.0	25.0	1.00	25.0	25.0
Cottonwood Island	0.00	0.0	0.00	0.0	0.00	0.0	0.0	0.00	0.0	0.0
Deepwater Slough Phase 2	0.20	5.1	0.00	0.0	0.00	0.0	5.1	0.00	0.0	0.0
East Cottonwood	0.00	0.0	0.00	0.0	0.00	0.0	0.0	0.00	0.0	0.0
Fir Island Cross Island Connector	0.23	5.6	0.25	6.3	1.00	25.0	36.9	0.39	9.7	9.7
Fir Island Farm	0.00	0.0	0.49	12.3	1.00	25.0	37.3	0.00	0.0	0.0
Hall Slough	0.00	0.0	0.32	7.9	1.00	25.0	32.9	0.00	0.0	0.0
McGlinn Causeway	0.00	0.0	0.00	0.0	0.00	0.0	0.0	0.00	0.0	0.0
Milltown Island	0.00	0.0	0.00	0.0	0.00	0.0	0.0	0.00	0.0	0.0
NF Left Bank Levee Setback A	0.48	11.9	1.00	25.0	1.00	25.0	61.9	0.00	0.0	0.0
NF Left Bank Levee Setback B	0.41	10.2	0.78	19.6	1.00	25.0	54.9	0.00	0.0	0.0
NF Left Bank Levee Setback C	0.16	4.1	0.48	12.1	1.00	25.0	41.2	0.00	0.0	0.0
NF Right Bank Levee Setback	0.00	0.0	0.37	9.2	1.00	25.0	34.2	0.00	0.0	0.0
Pleasant Ridge South	0.00	0.0	0.05	1.2	0.00	0.0	1.2	0.00	0.0	0.0
Rawlins Road	0.11	2.9	0.45	11.2	1.00	25.0	39.1	0.00	0.0	0.0
Rawlins Road Distributary Channel	0.00	0.0	0.00	0.0	0.00	0.0	0.0	0.00	0.0	0.0
SF Levee Setback 2, 3, 4	0.06	1.6	0.42	10.5	0.00	0.0	12.1	0.00	0.0	0.0
Sullivan Hacienda	0.00	0.0	0.50	12.5	0.00	0.0	12.5	0.00	0.0	0.0
Telegraph Slough 1	0.00	0.0	0.21	5.3	1.00	25.0	30.3	0.00	0.0	0.0
Telegraph Slough 1&2	0.00	0.0	0.21	5.3	1.00	25.0	30.3	0.00	0.0	0.0
Telegraph Slough Full	0.00	0.0	0.21	5.3	1.00	25.0	30.3	0.00	0.0	0.0
Thein Farm	0.00	0.0	0.02	0.5	0.00	0.0	0.5	0.00	0.0	0.0
TNC South Fork	0.00	0.0	0.00	0.0	0.00	0.0	0.0	0.00	0.0	0.0
McGlinn & TS 1	0.00	0.0	0.21	5.3	1.00	25.0	30.3	0.00	0.0	0.0
McGliin & TS 1&2	0.00	0.0	0.21	5.3	1.00	25.0	30.3	0.00	0.0	0.0
McGlinn & TS Full	0.00	0.0	0.21	5.3	1.00	25.0	30.3	0.00	0.0	0.0