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

Final Report

Jonathan Whiting
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September 2017

U.S. DEPARTMENT OF ENERGY

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Prepared for
The Nature Conservancy
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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.

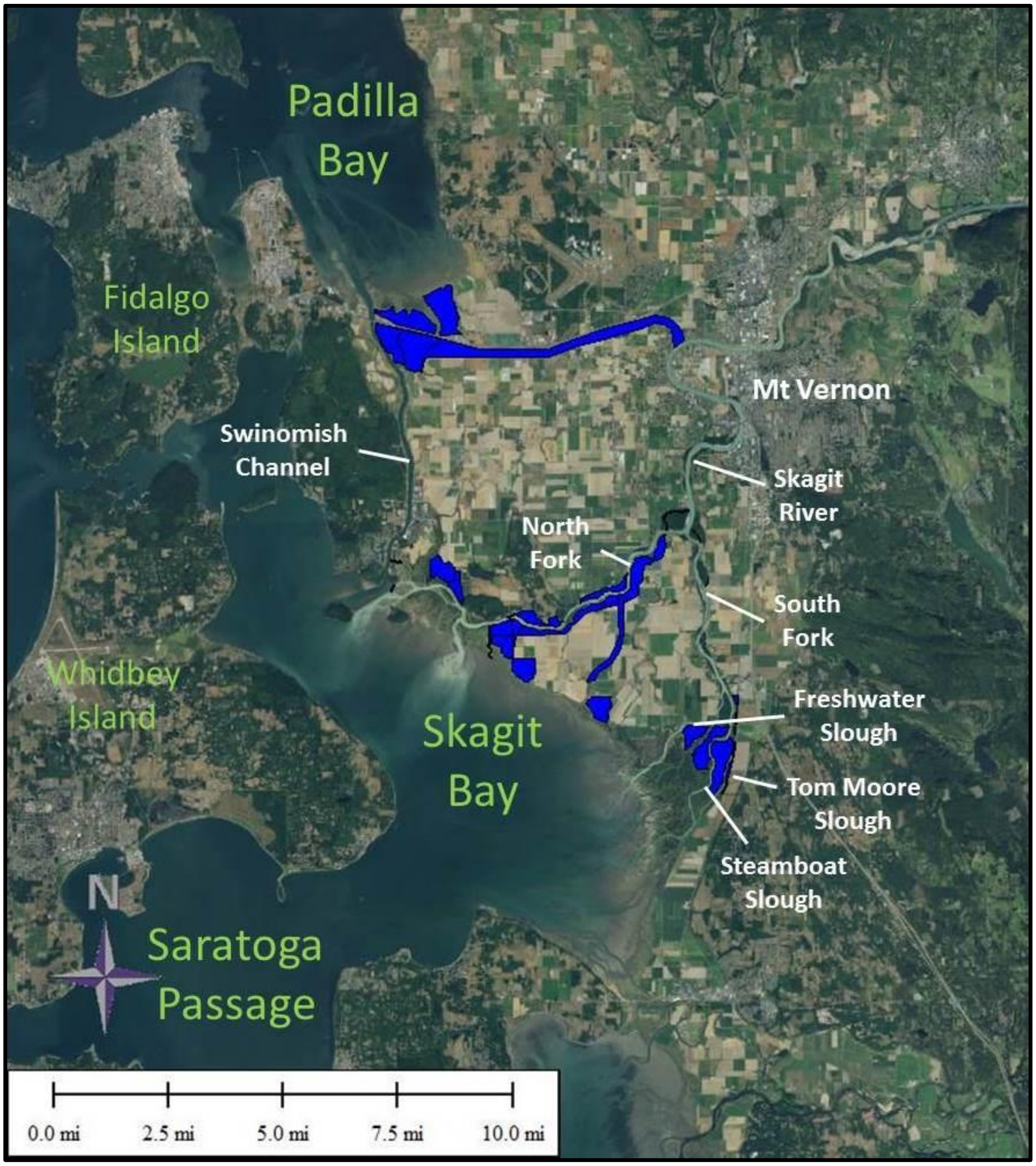

Figure 1.1. Map of the Skagit Bay region. Restoration areas are highlighted in blue.

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
Simulation 6	17	Milltown Island	Dike Breach	212
	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.

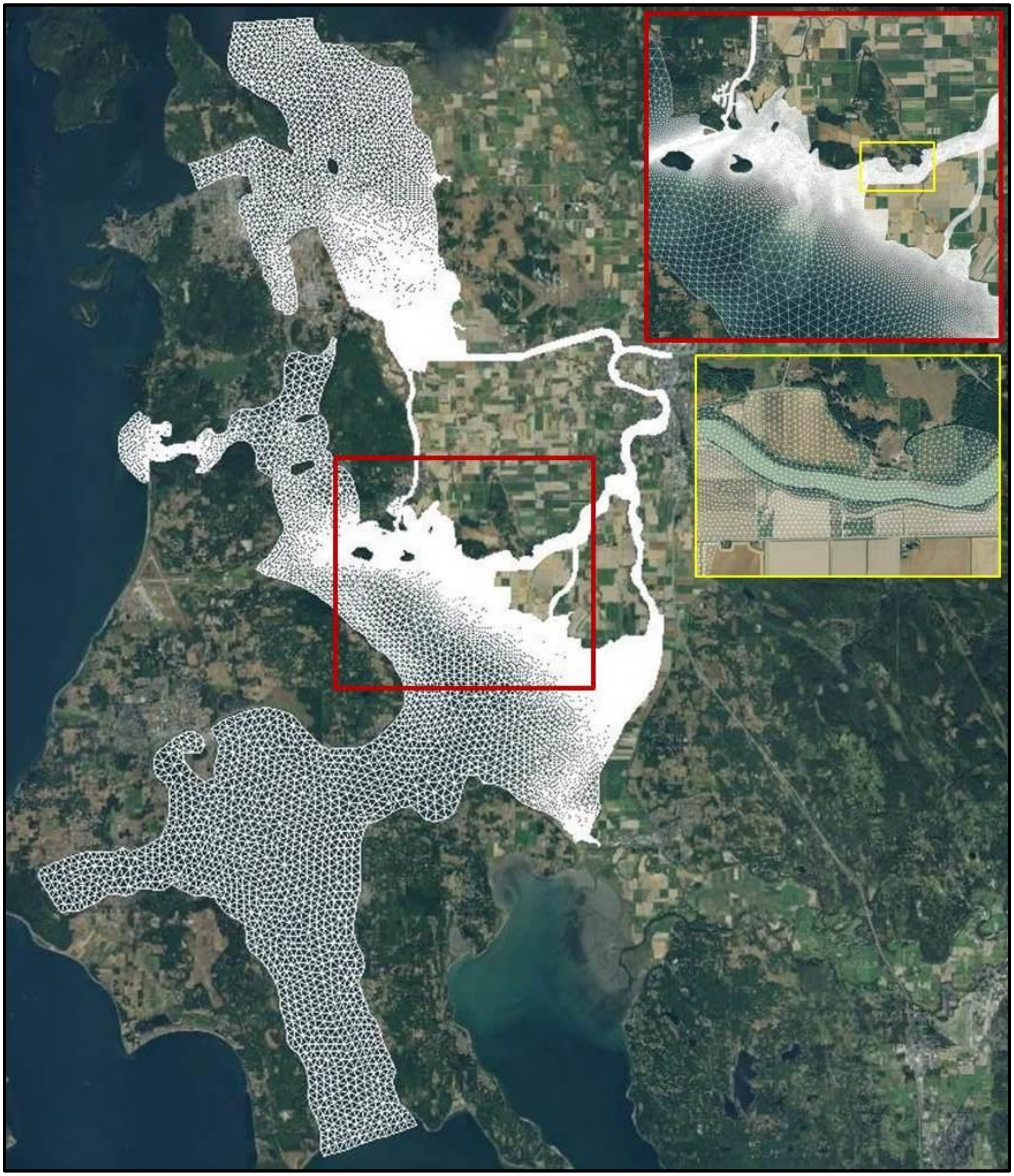

Figure 2.1. Model Grid for the Skagit River estuary.

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.

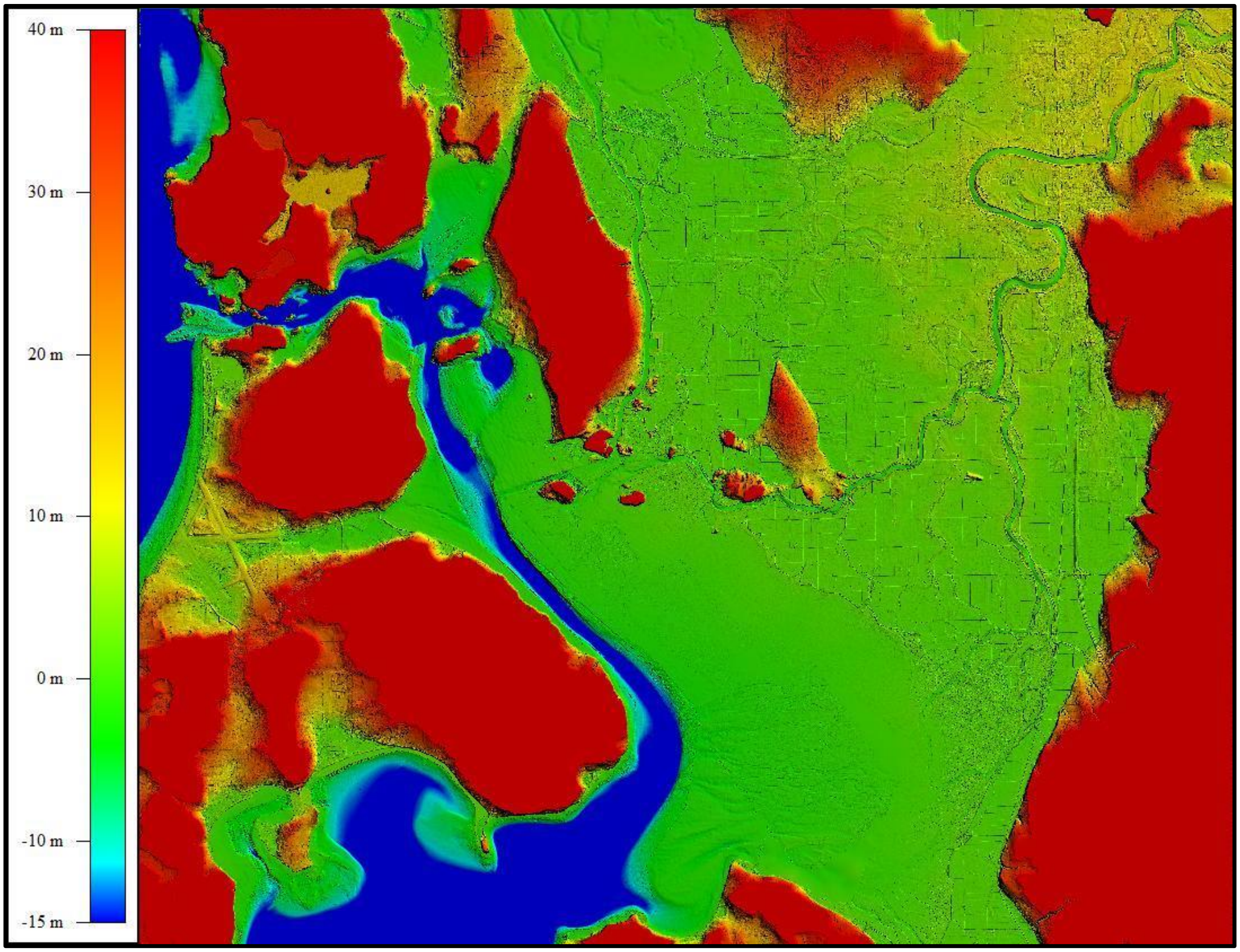

Figure 2.2. Lidar topography and bathymetry in the continuous elevation raster provided by the USGS based on a 2014 data set.

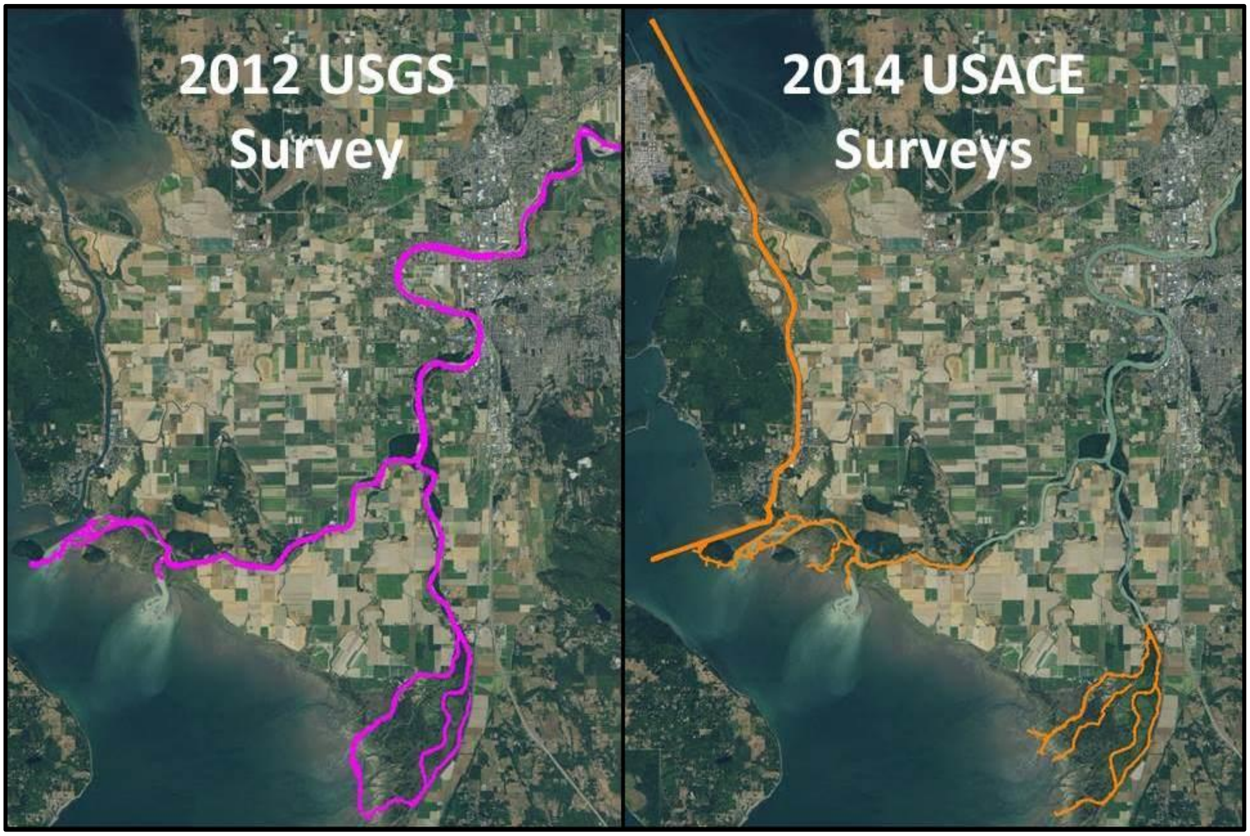

Figure 2.3. Supplemental bathymetry data available from various USGS and USACE boat surveys from years 2012 and 2014.

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.

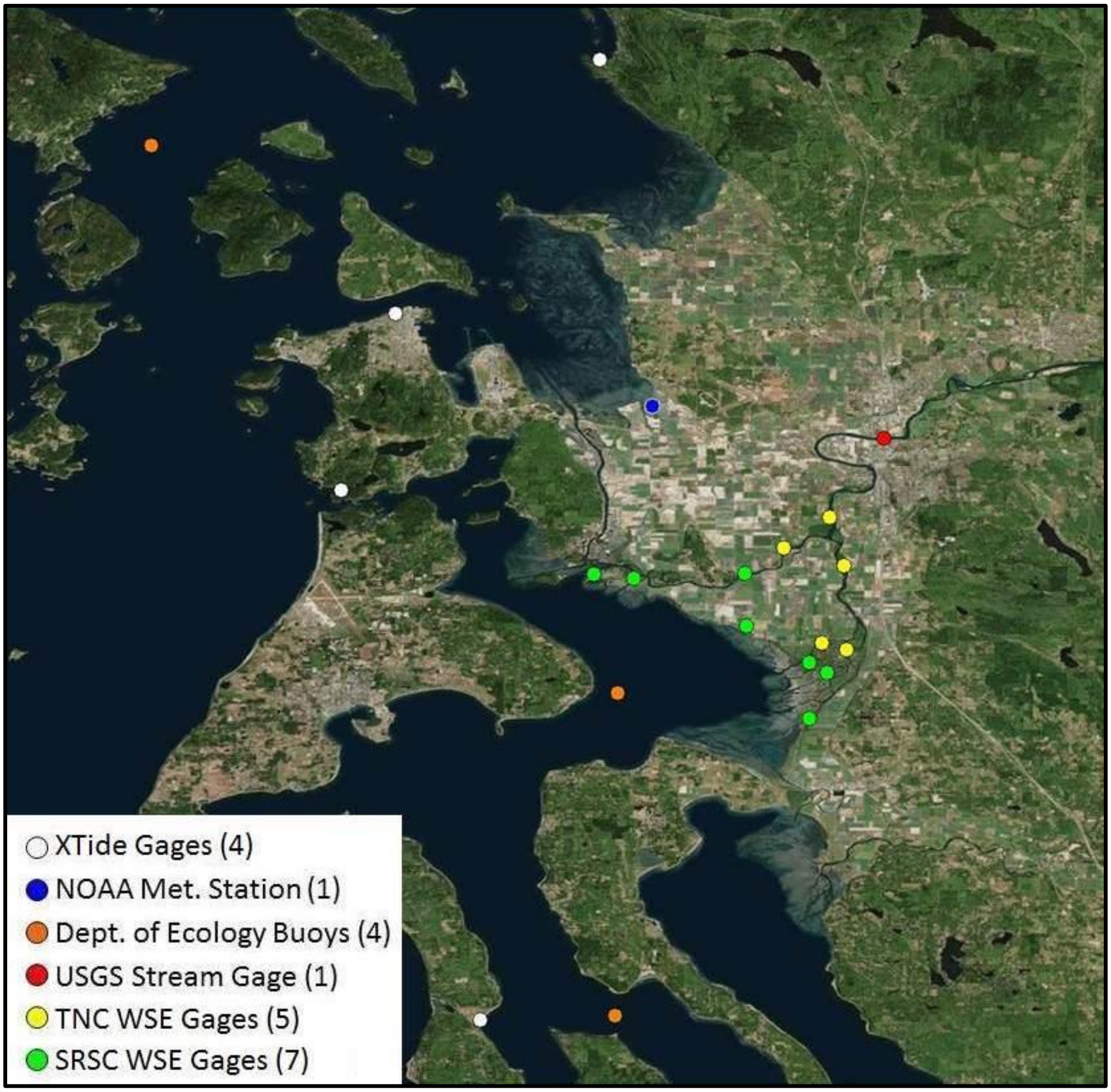

Figure 2.4. Overview of all gauges, buoys, and stations across the Skagit region where data were used for calibration or validation.

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.

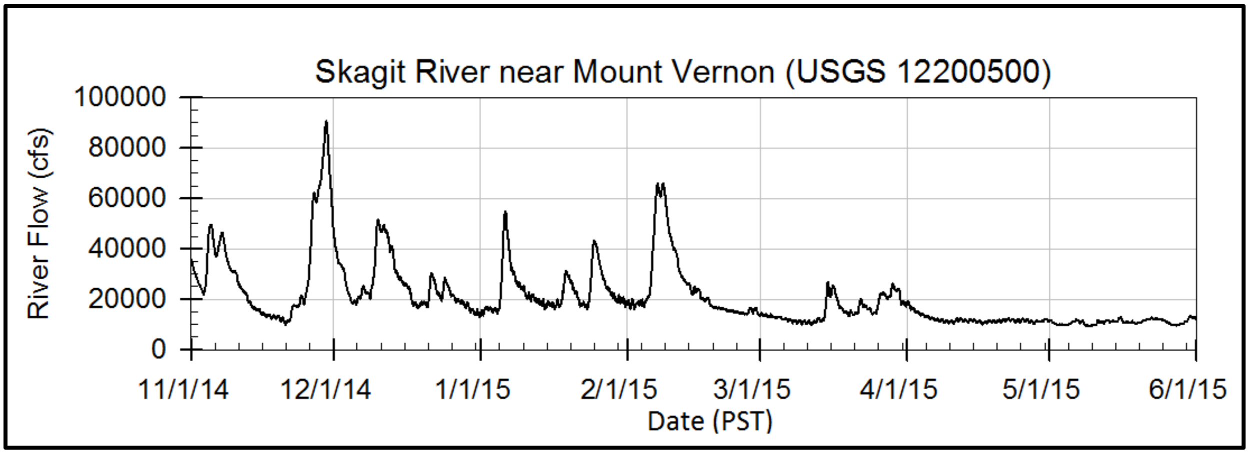

Figure 2.5. Time series of stream flow provided by USGS gauge 12200500 near Mount Vernon.

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.

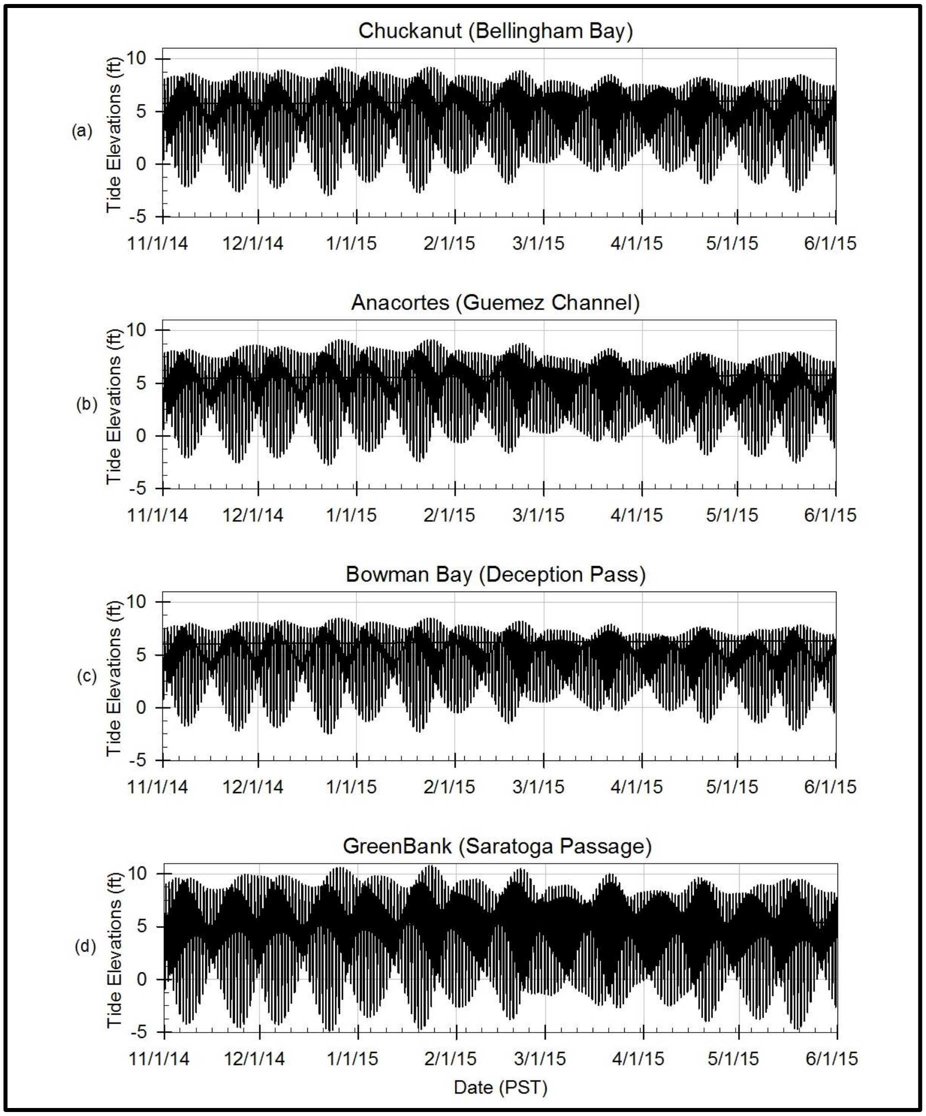

Figure 2.6. Predicted tidal elevations at the Chuckanut, Anacortes, Bowman Bay, and Greenbank stations. Elevations are with reference to North American Vertical Datum of 1988 (NAVD88) datum.

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.

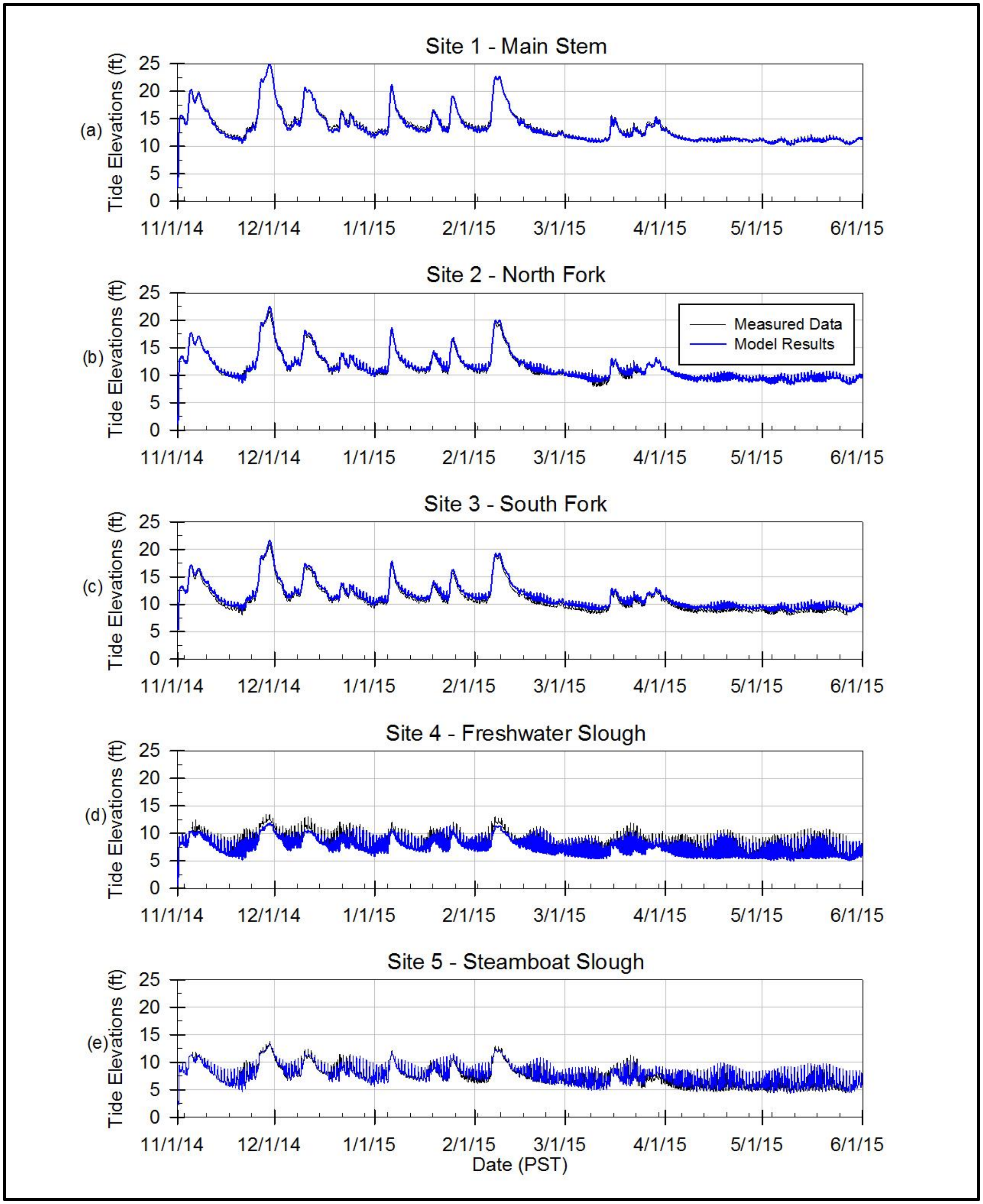

Figure 2.8. Calibration time series graphs at each of the five WDFW gauges. Elevations are with reference to NAVD88 datum.

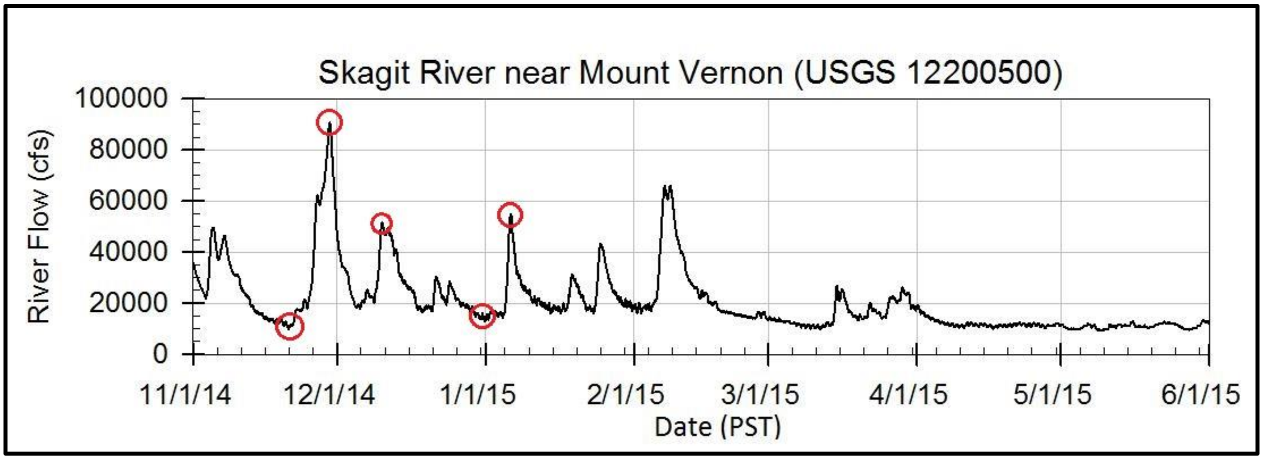

Figure 2.9. Extreme flow values where validation occurred on a time series of stream flow provided by USGS gauge 12200500 near Mount Vernon.

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	

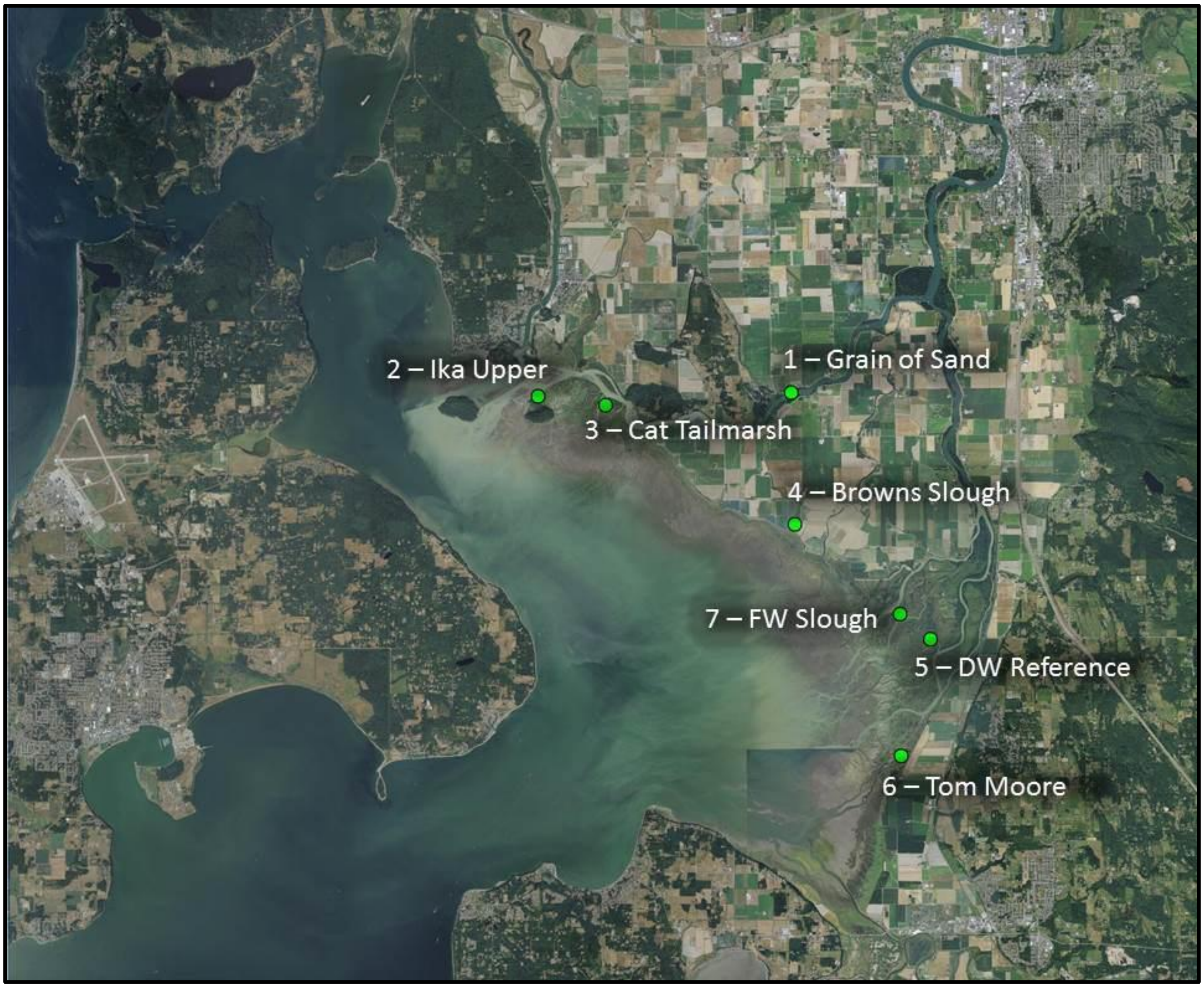

Figure 2.10. Map showing the locations of level logger gauges maintained by SRSC and used for model validation.

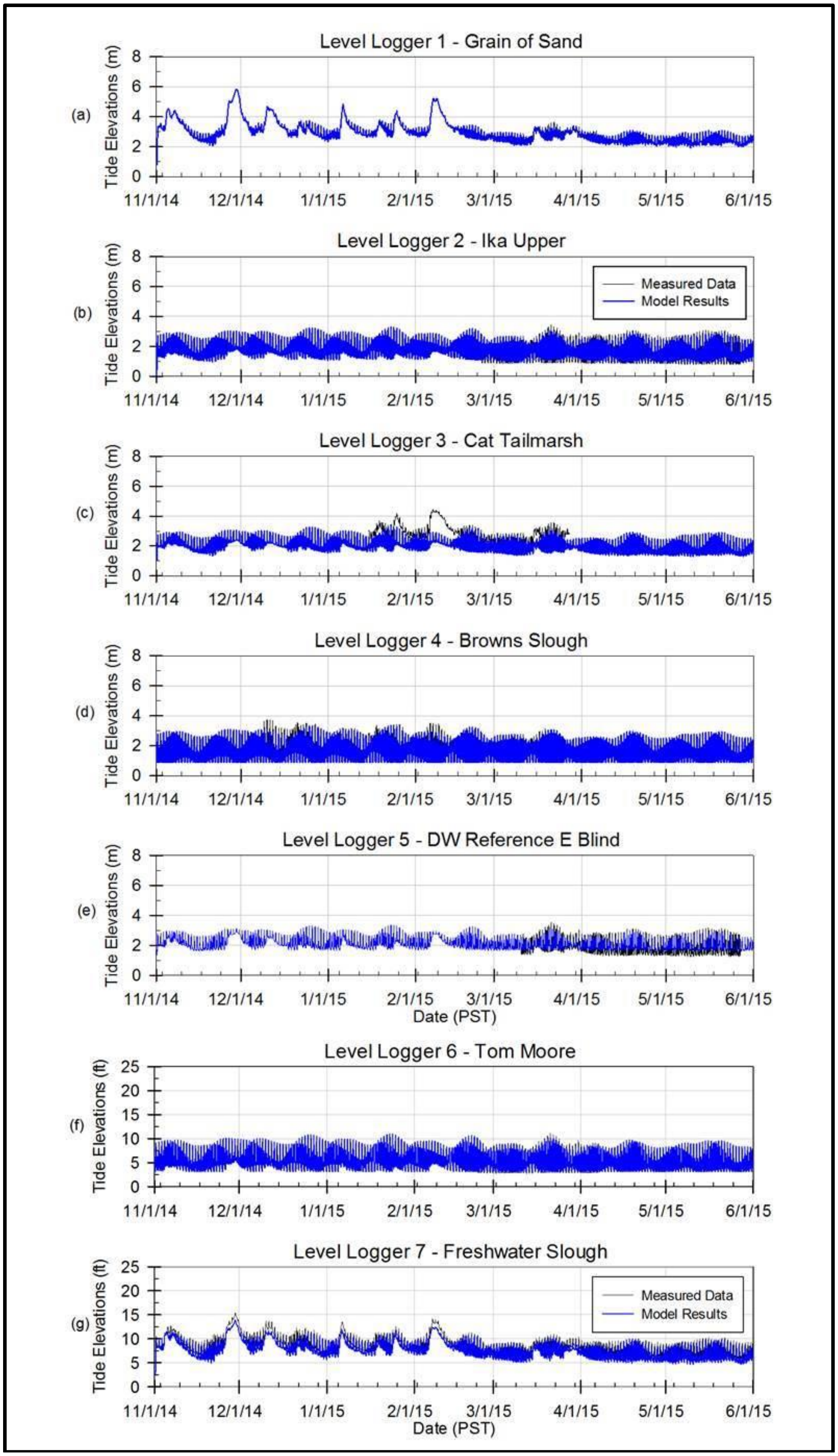

Figure 2.11. Validation time series graphs at each of the seven intertidal SRSC gauges. Elevations are with reference to NAVD88 datum.

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.

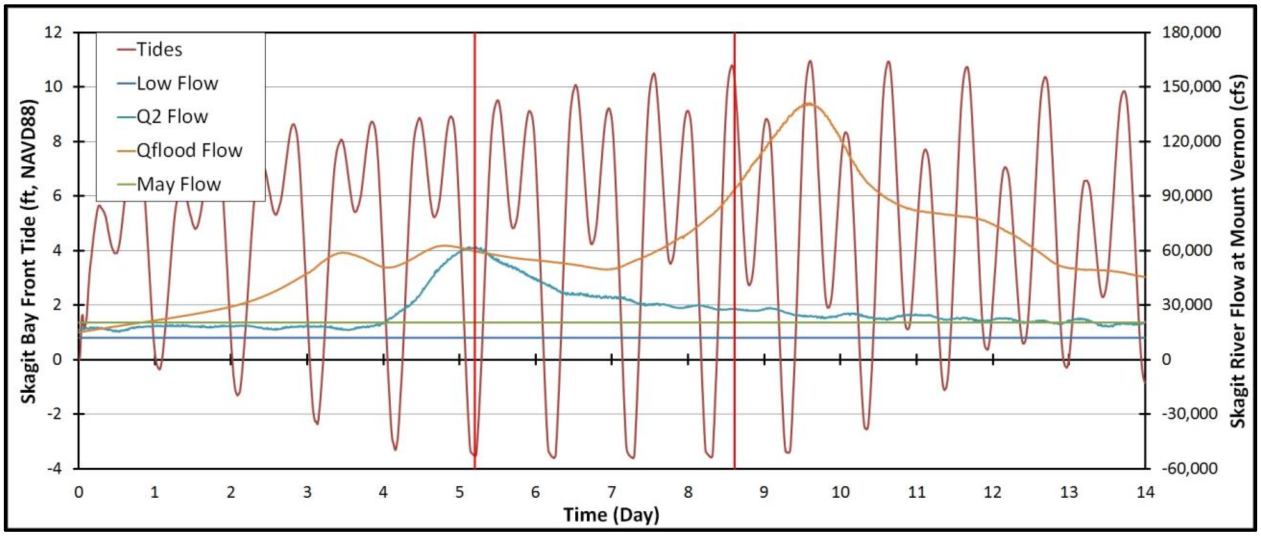

Figure 3.1. Current river hydrograph and tide conditions corresponding to the 2-week design runs. The first vertical red line corresponds to the low spring tide conditions, while the second red vertical line corresponds to the flood condition.

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.

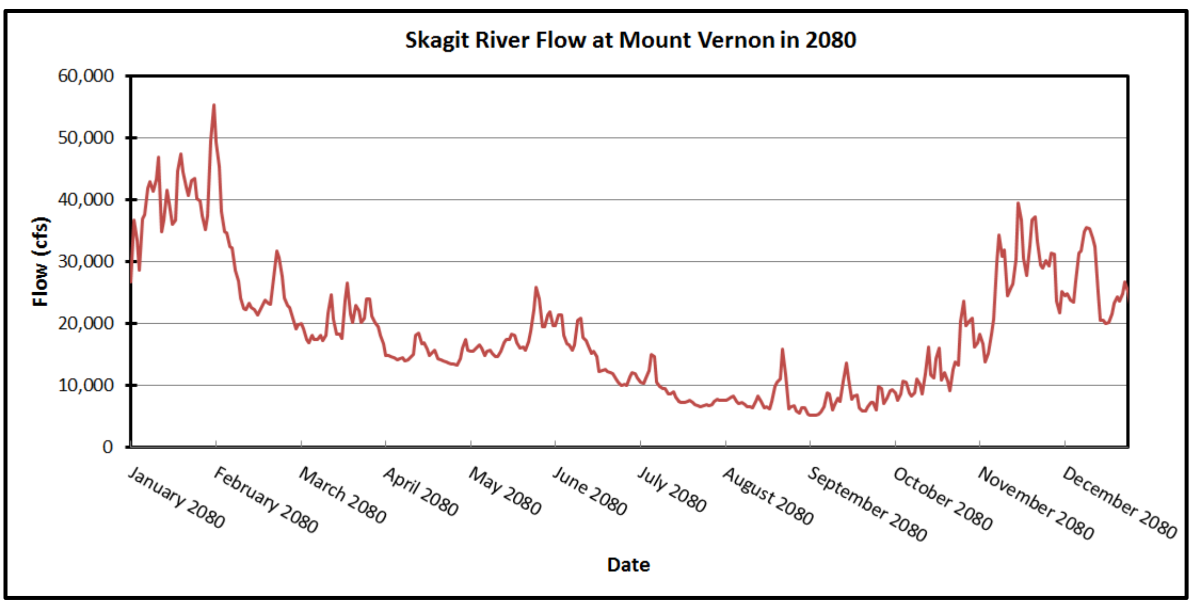

Figure 3.2. Future daily hydrograph used for the March to June 2080 simulation.

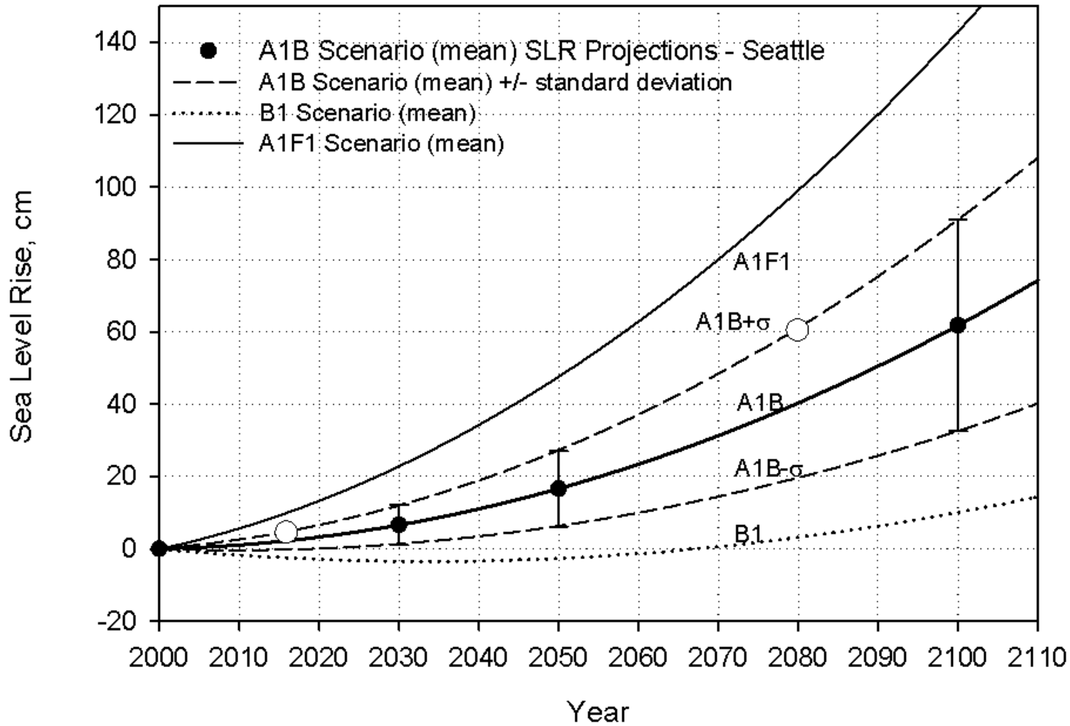

Figure 3.3. Projected SLR for Salish Sea (Seattle, WA) region of the Pacific Northwest for A1B, B1 and A1F1 scenarios (Source: NRC 2012). The upper and lower bounds of the model emissions scenario A1B are shown with a dashed line (modified from Khangaonkar et al. 2016).

The last two simulations used these conditions. The future conditions design runs can be seen in **Figure 3.4**.

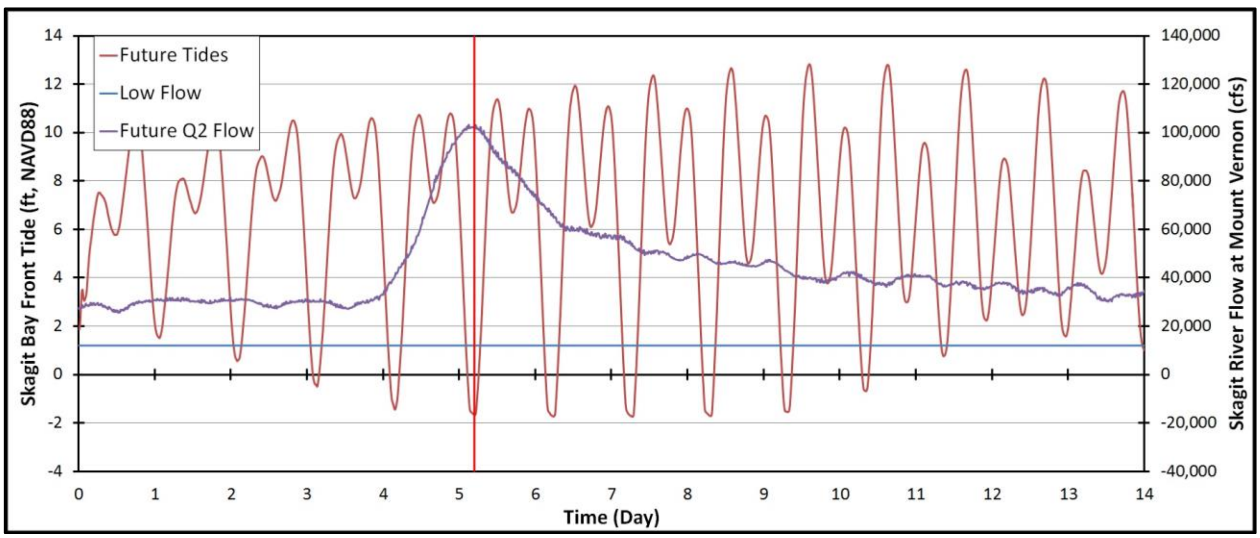

Figure 3.4. Future river hydrograph and tide conditions corresponding to the 2-week design runs. The vertical red line corresponds to the low spring tide condition.

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).

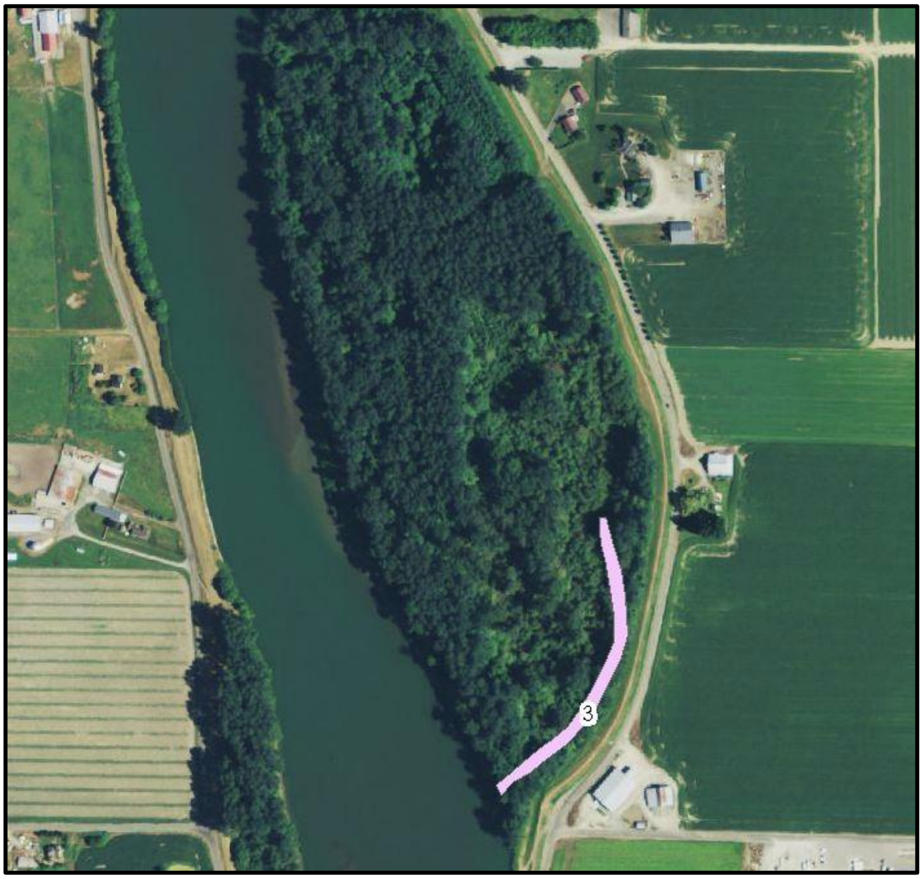

Figure 3.8. Outline of the TNC South Fork backwater channel project.

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).

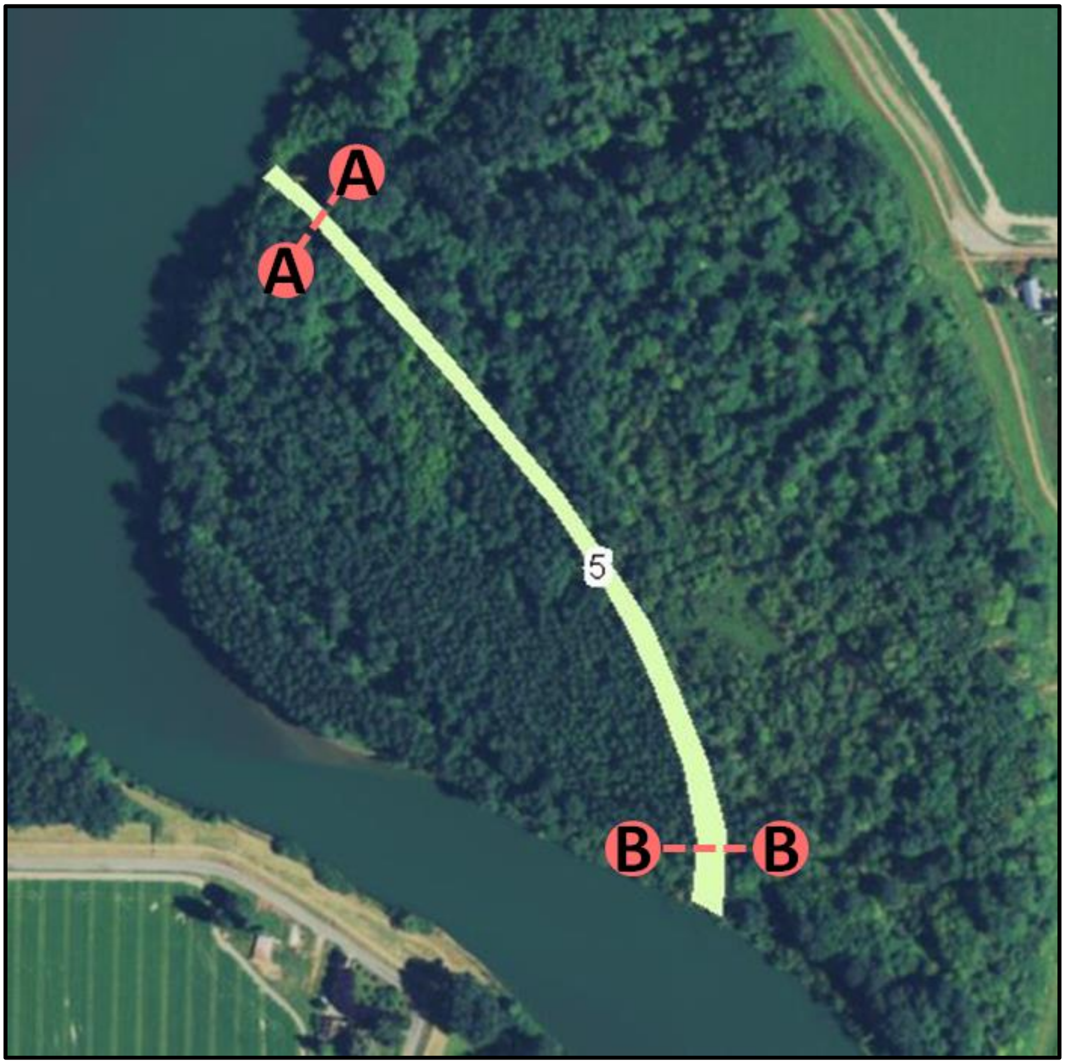

Figure 3.10. Outline of the East Cottonwood backwater channel project.

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).

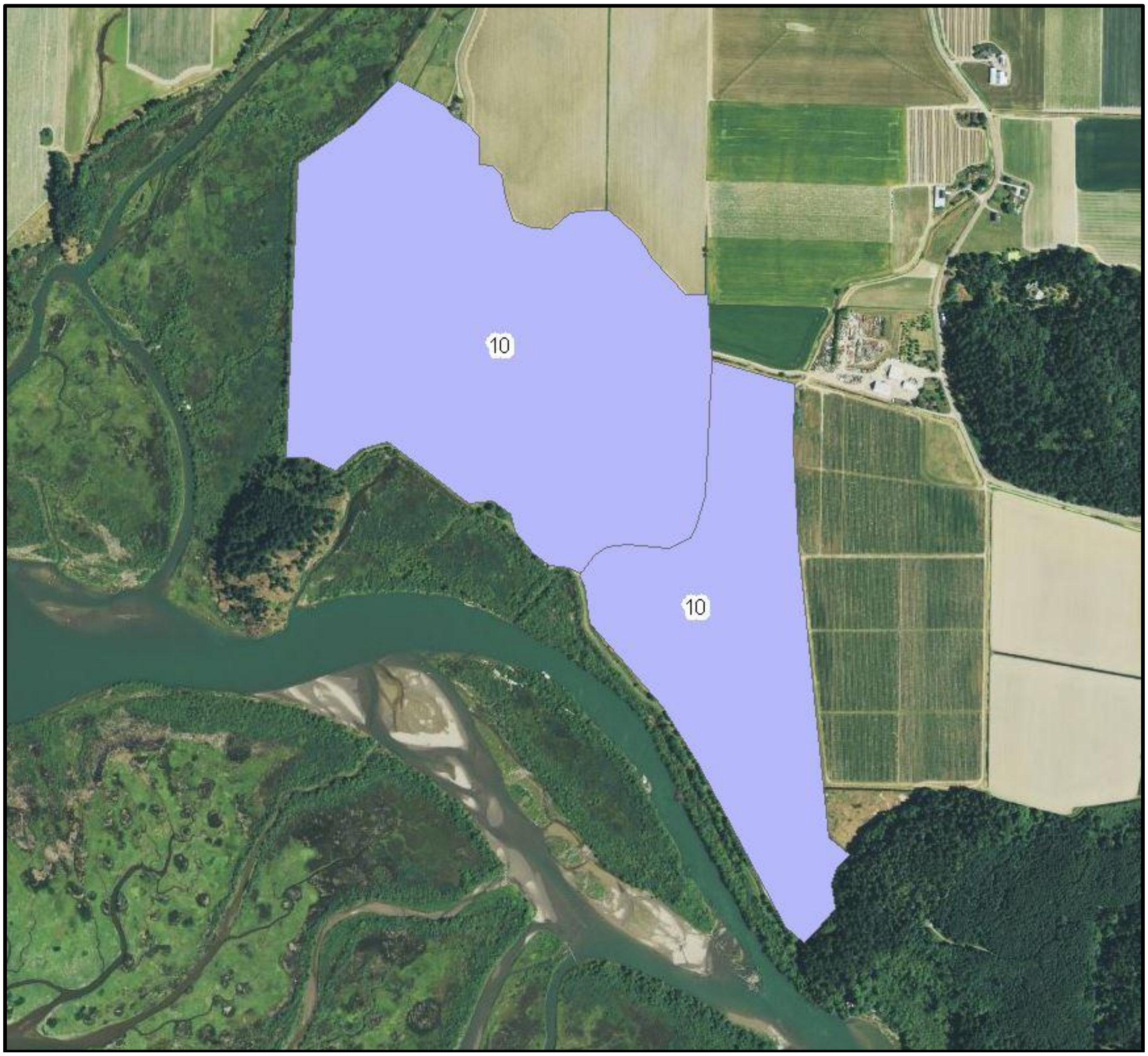

Figure 3.15. Outline of the Sullivan Hacienda dike setback project.

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.

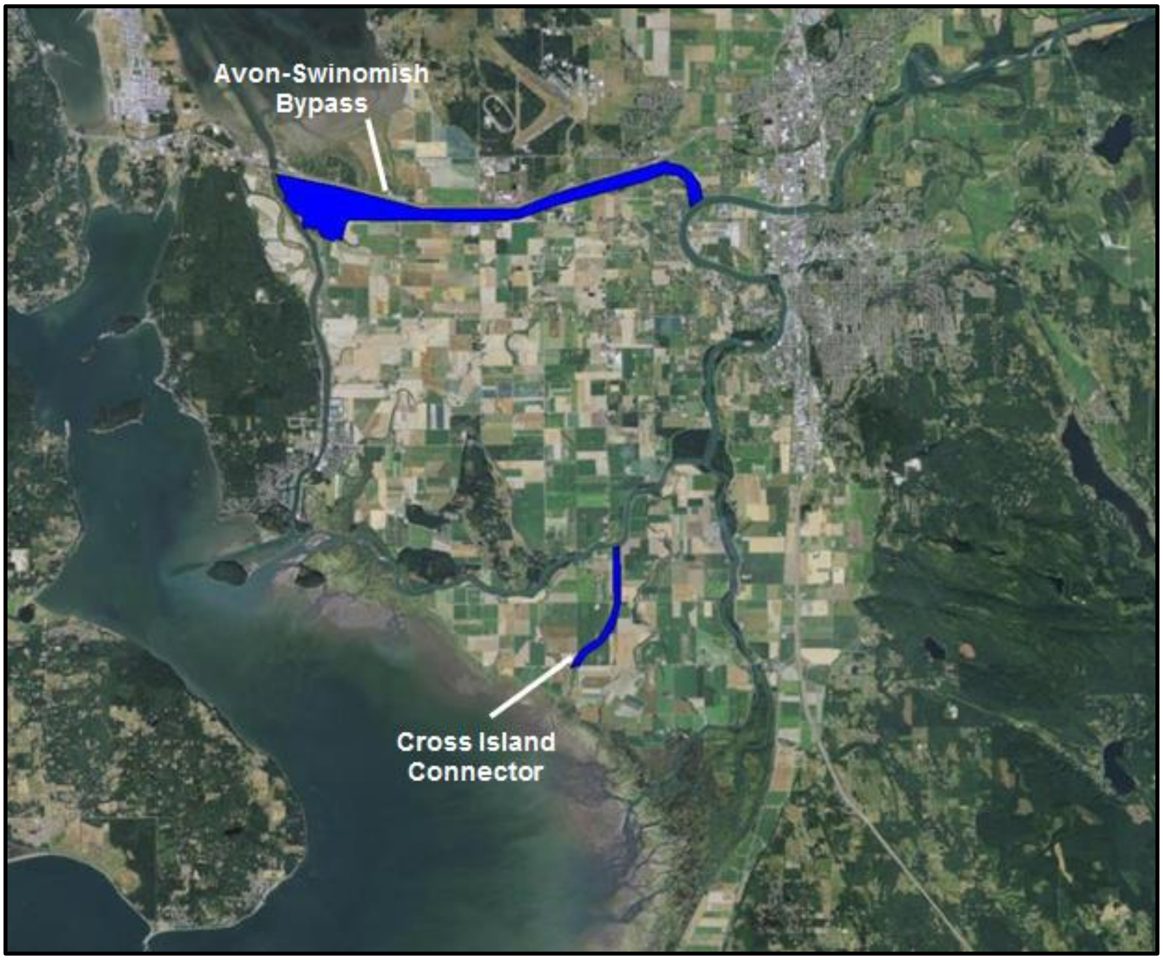

Figure 3.17. A map of both project areas in the Major Hydraulic Project simulations.

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.

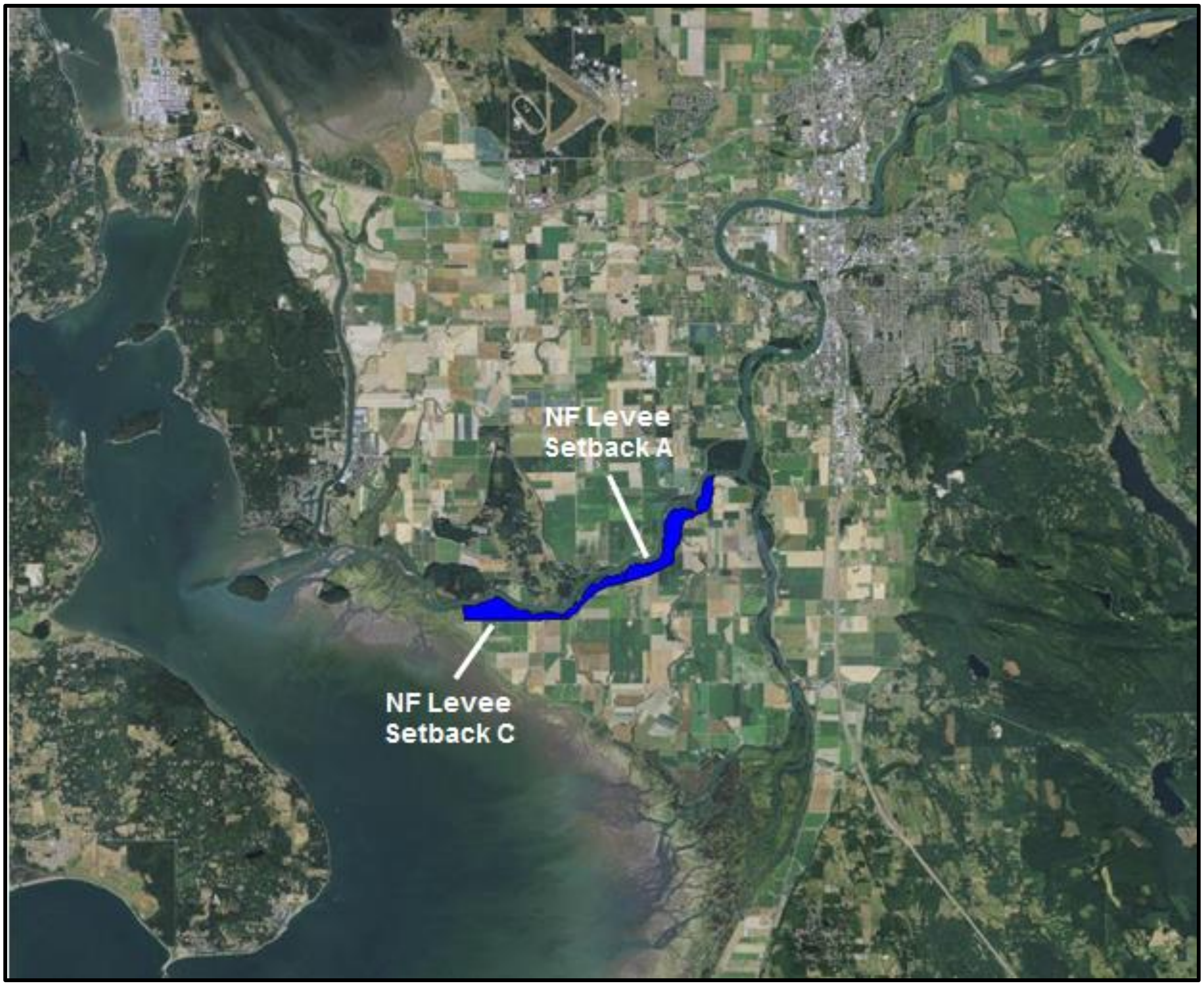

Figure 3.20. A map of both project areas in the Major Setback Project simulations (Setback A encompasses the area of Setback C).

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).

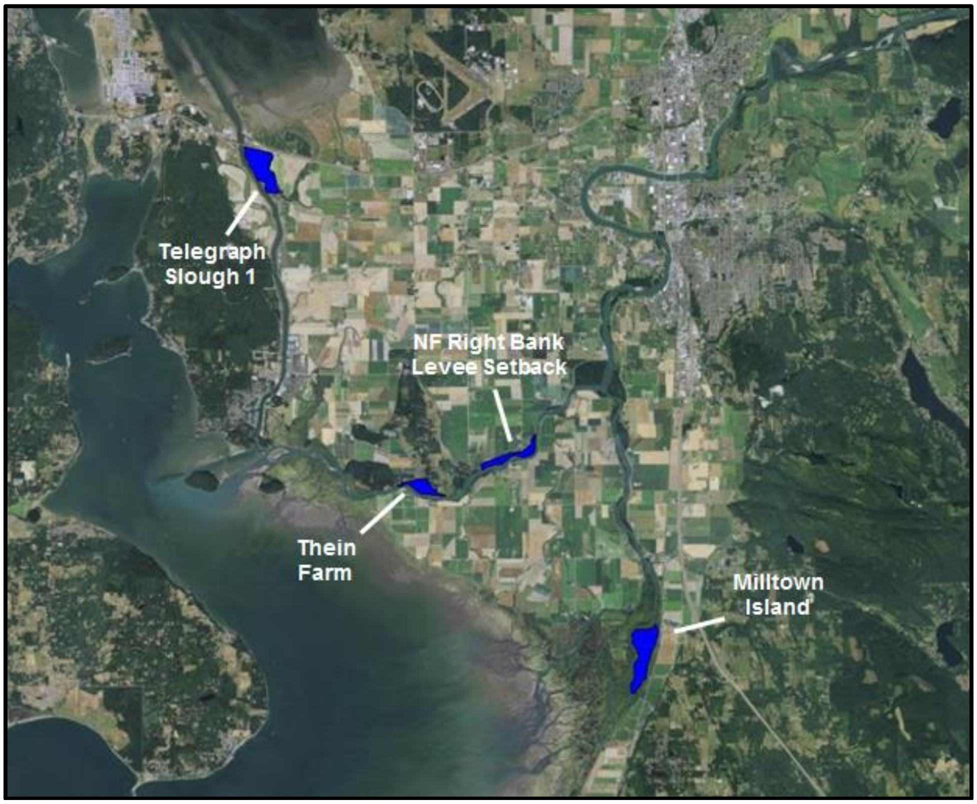

Figure 3.22. A map of project areas in Simulation 6 for Moderate Influence Projects.

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).

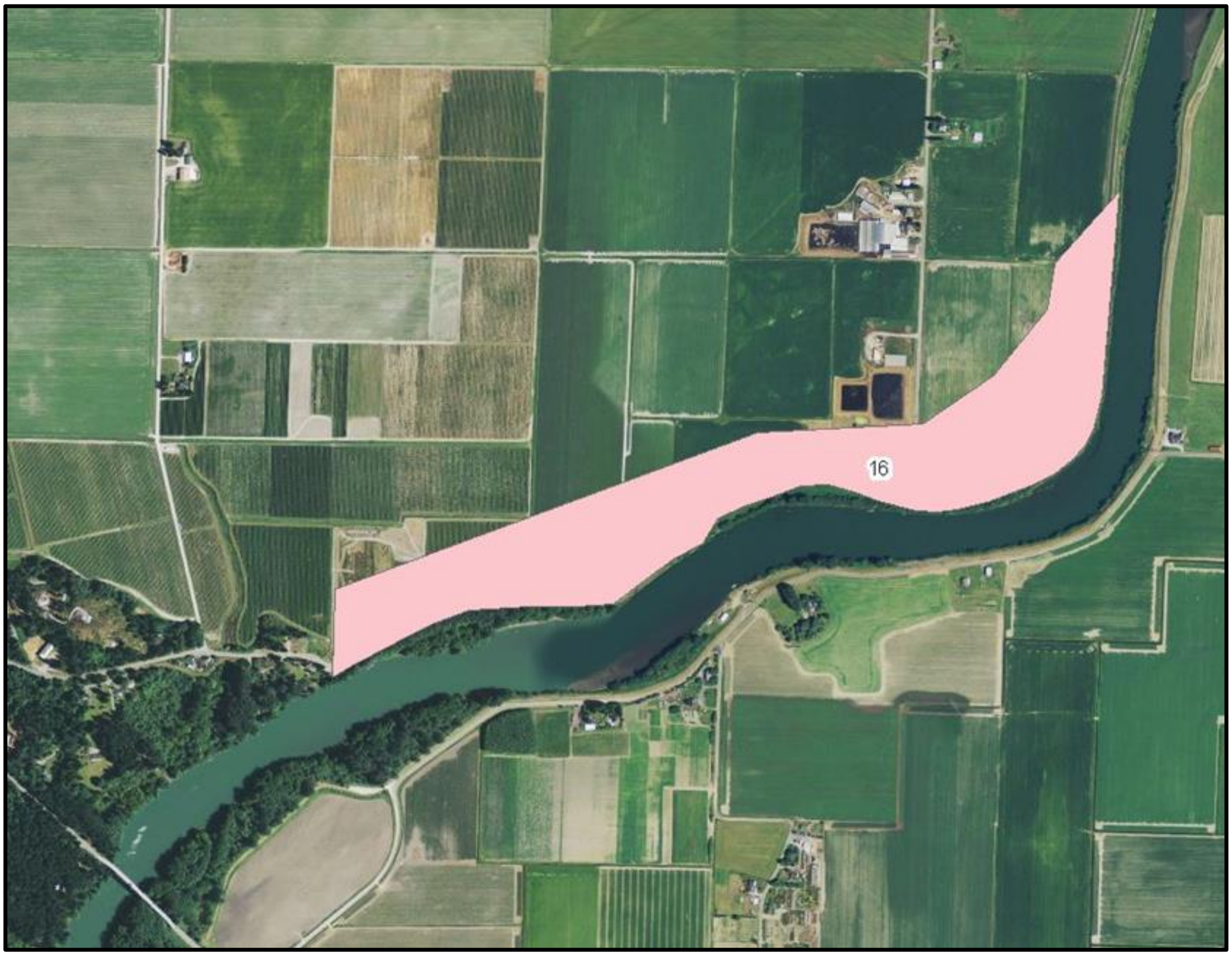

Figure 3.24. Outline of the North Fork Right Bank Levee Setback project.

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).

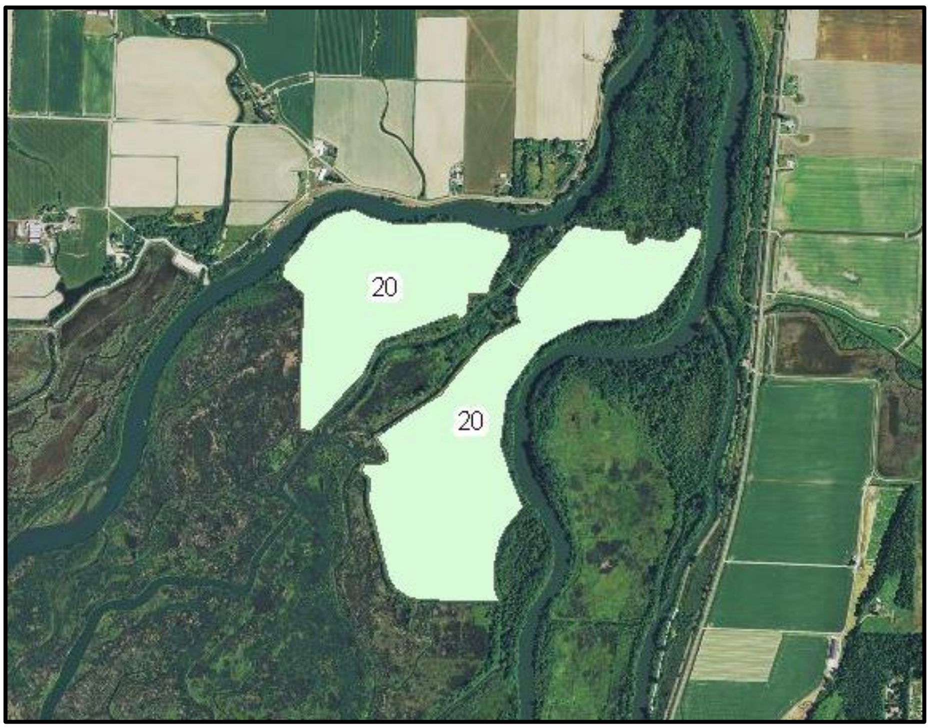

Figure 3.28. Outline of the Deepwater Slough Phase 2 dike breach project.

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).

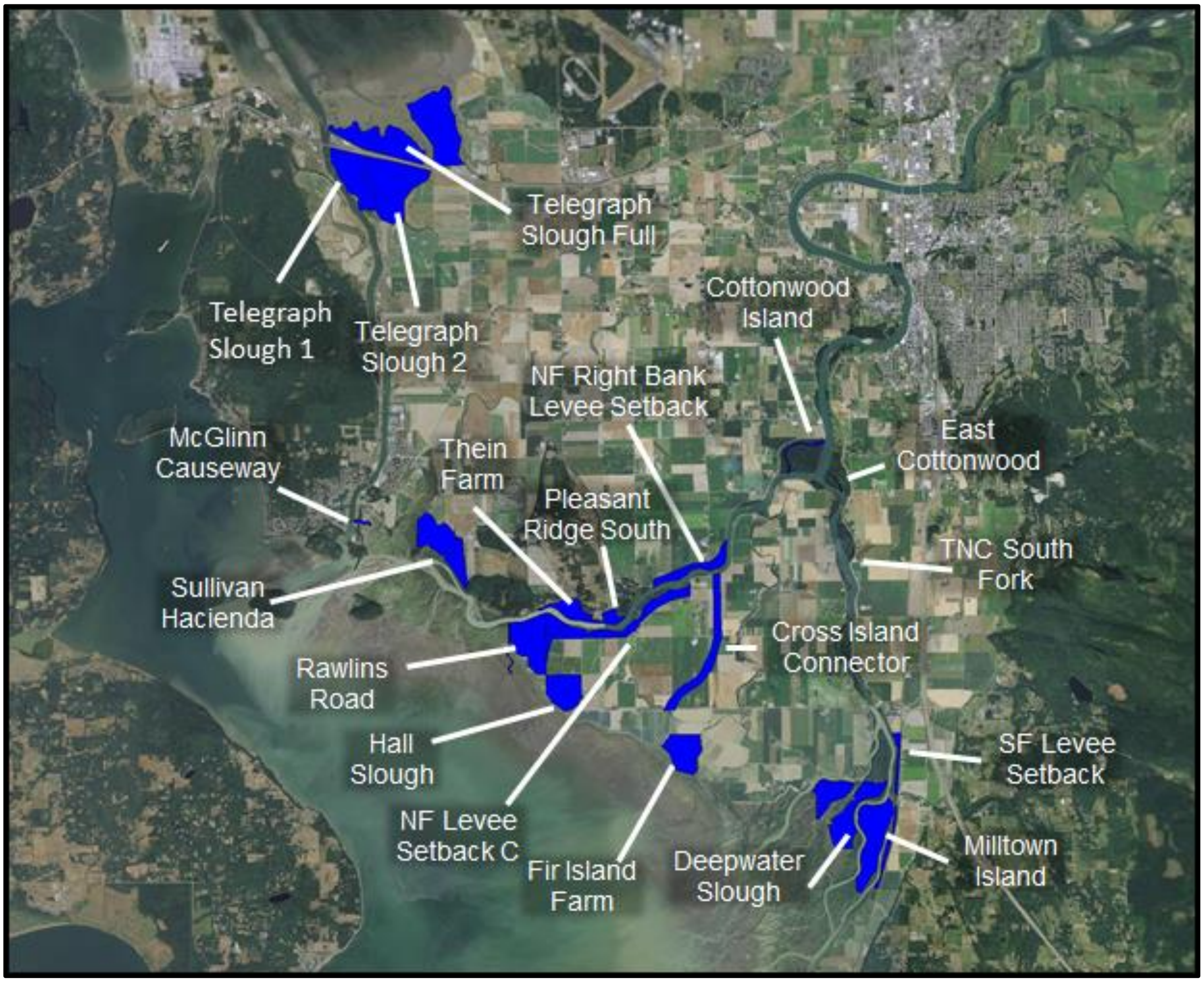

Figure 3.31. A map of project areas in Selected Projects simulation.

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.

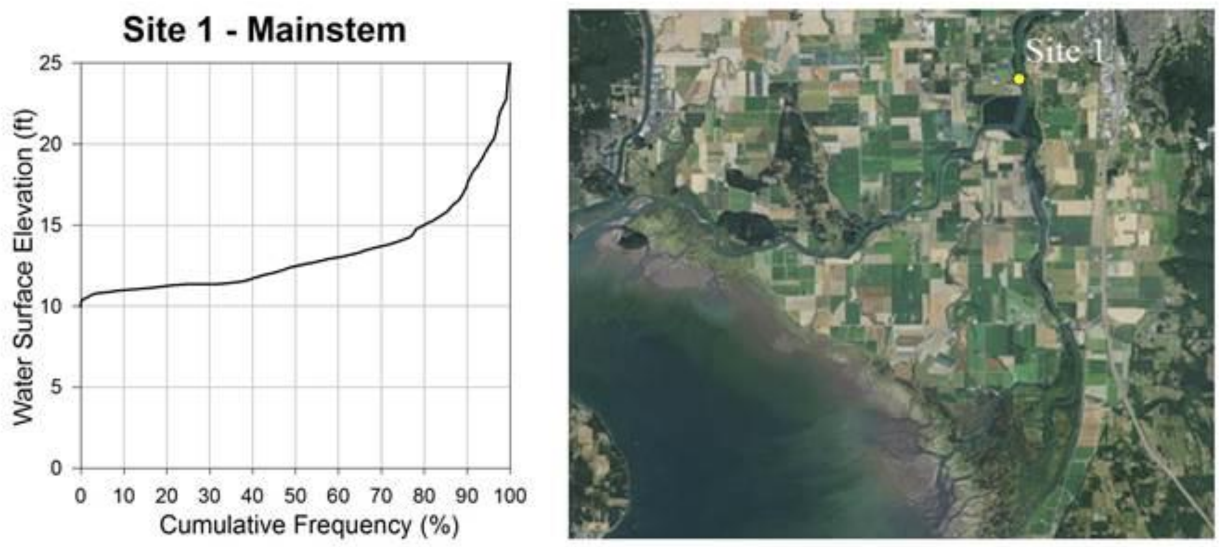


Figure A.1. Cumulative frequency plot and corresponding map for Site 1 (Mainstem) during the Baseline Simulation. The gauge location is designated by the yellow dot on the map.

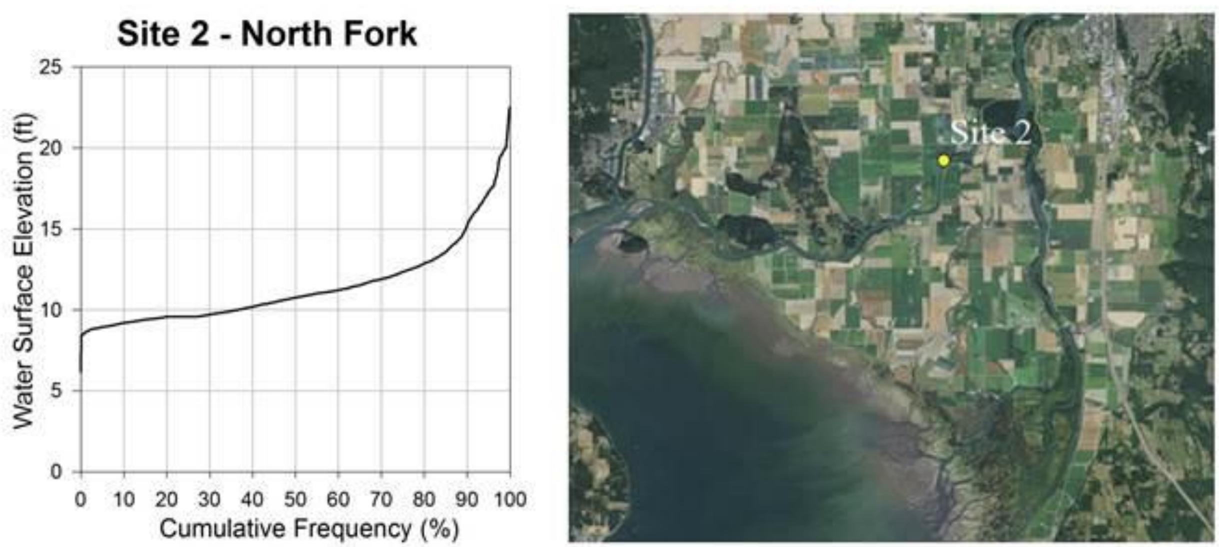


Figure A.2. Cumulative frequency plot and corresponding map for Site 2 (North Fork) during the Baseline Simulation. The gauge location is designated by the yellow dot on the map.

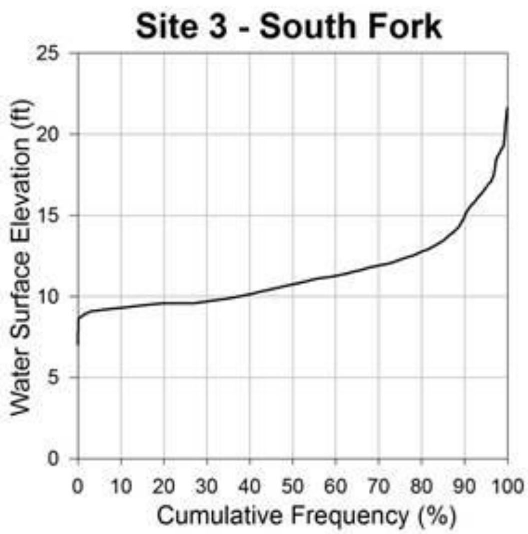


Figure A.3. Cumulative frequency plot and corresponding map for Site 3 (South Fork) during the Baseline Simulation. The gauge location is designated by the yellow dot on the map.

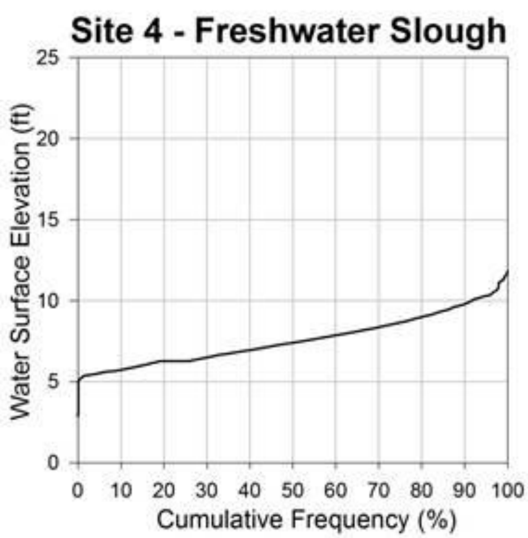


Figure A.4. Cumulative frequency plot and corresponding map for Site 4 (Freshwater Slough) during the Baseline Simulation. The gauge location is designated by the yellow dot on the map.

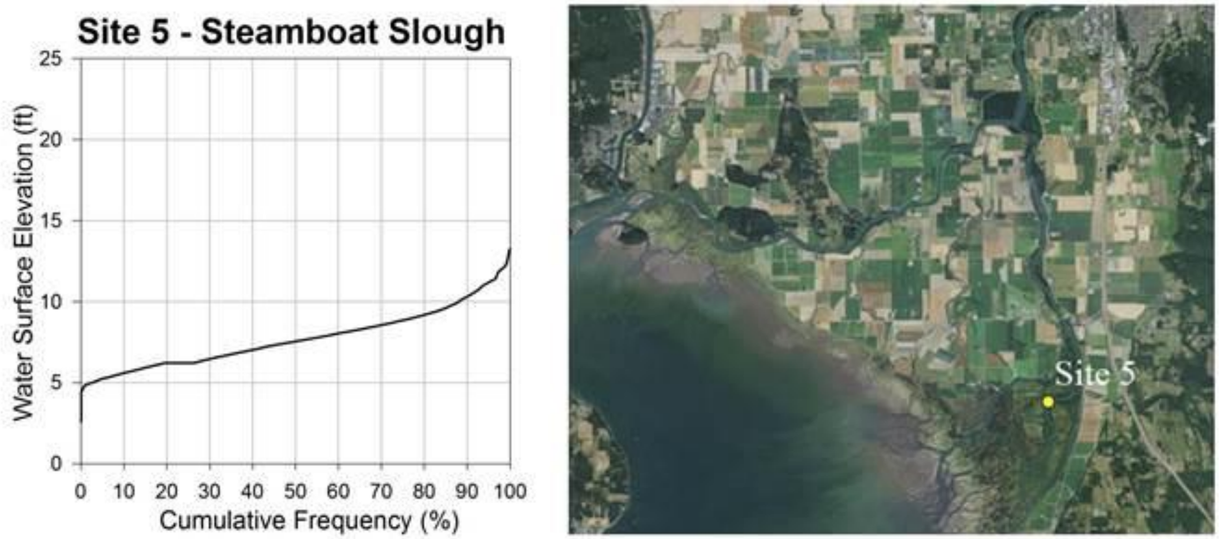


Figure A.5. Cumulative frequency plot and corresponding map for Site 5 (Steamboat Slough) during the Baseline Simulation. The gauge location is designated by the yellow dot on the map.

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.

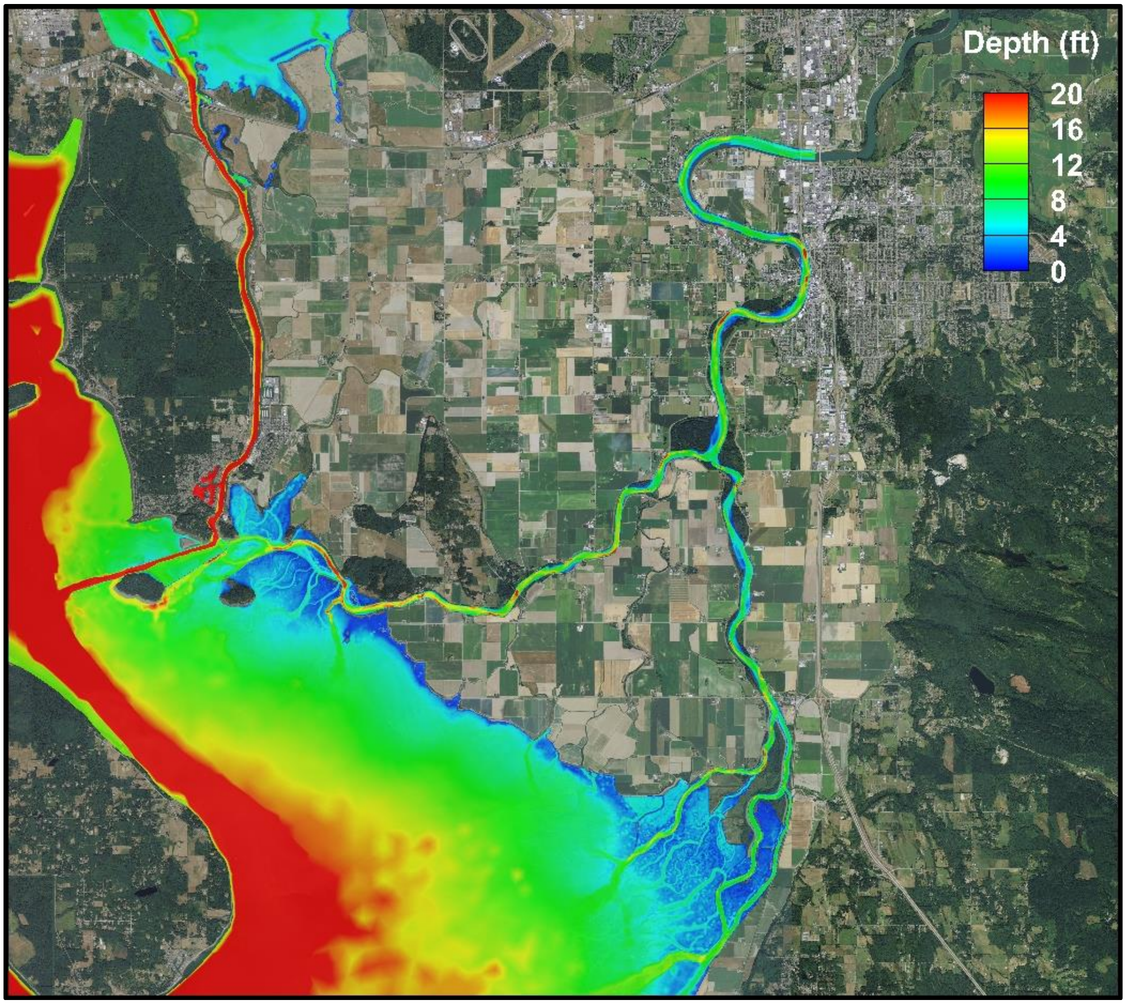


Figure A.6. Contour map of the depth for the full domain during the Baseline Simulation with low flow and high spring tide.

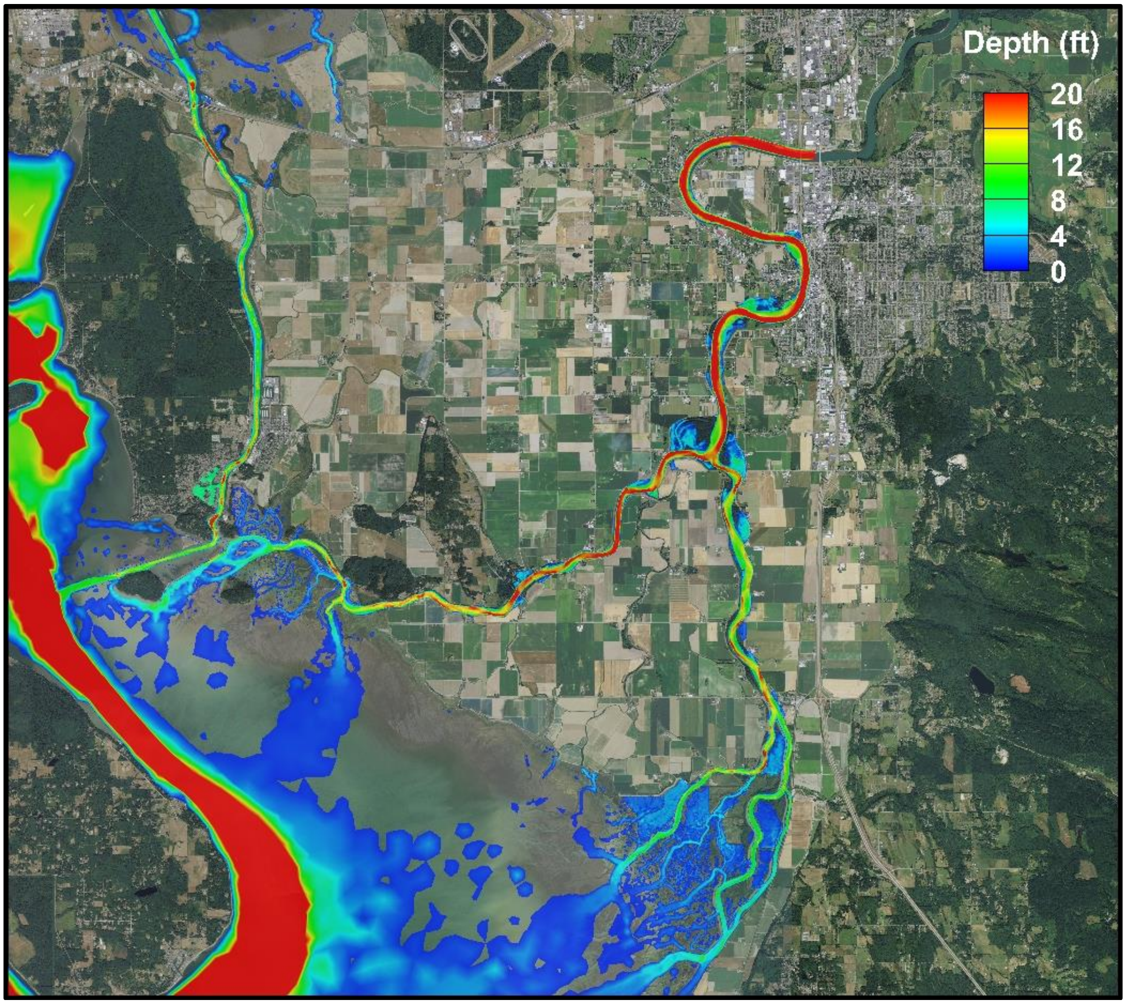


Figure A.7. Contour map of the depth for the full domain during the Baseline Simulation with Q2 flow and low spring tide.

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.

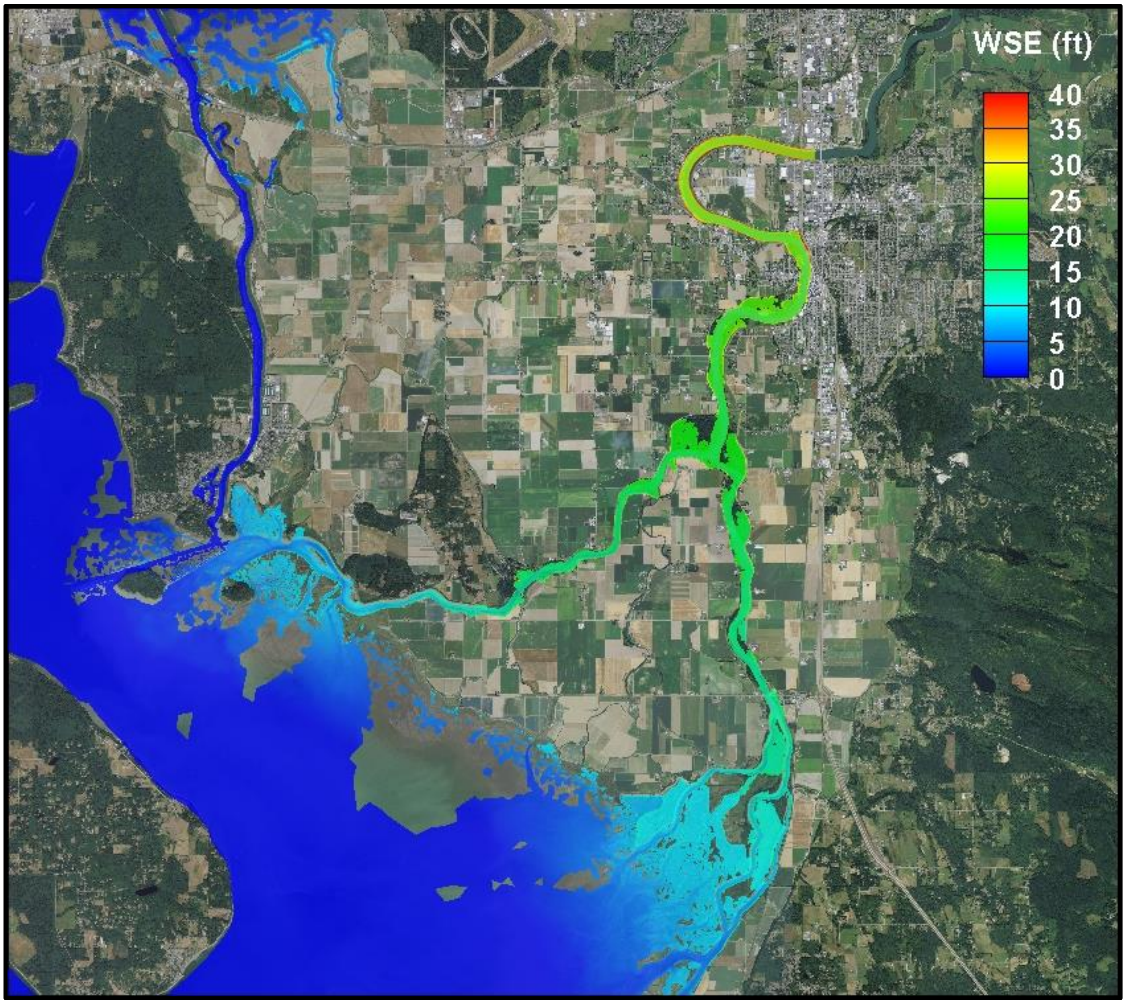


Figure A.8. Contour map of water surface elevation for the full domain during the Baseline Simulation with Q2 flow and low spring tide.

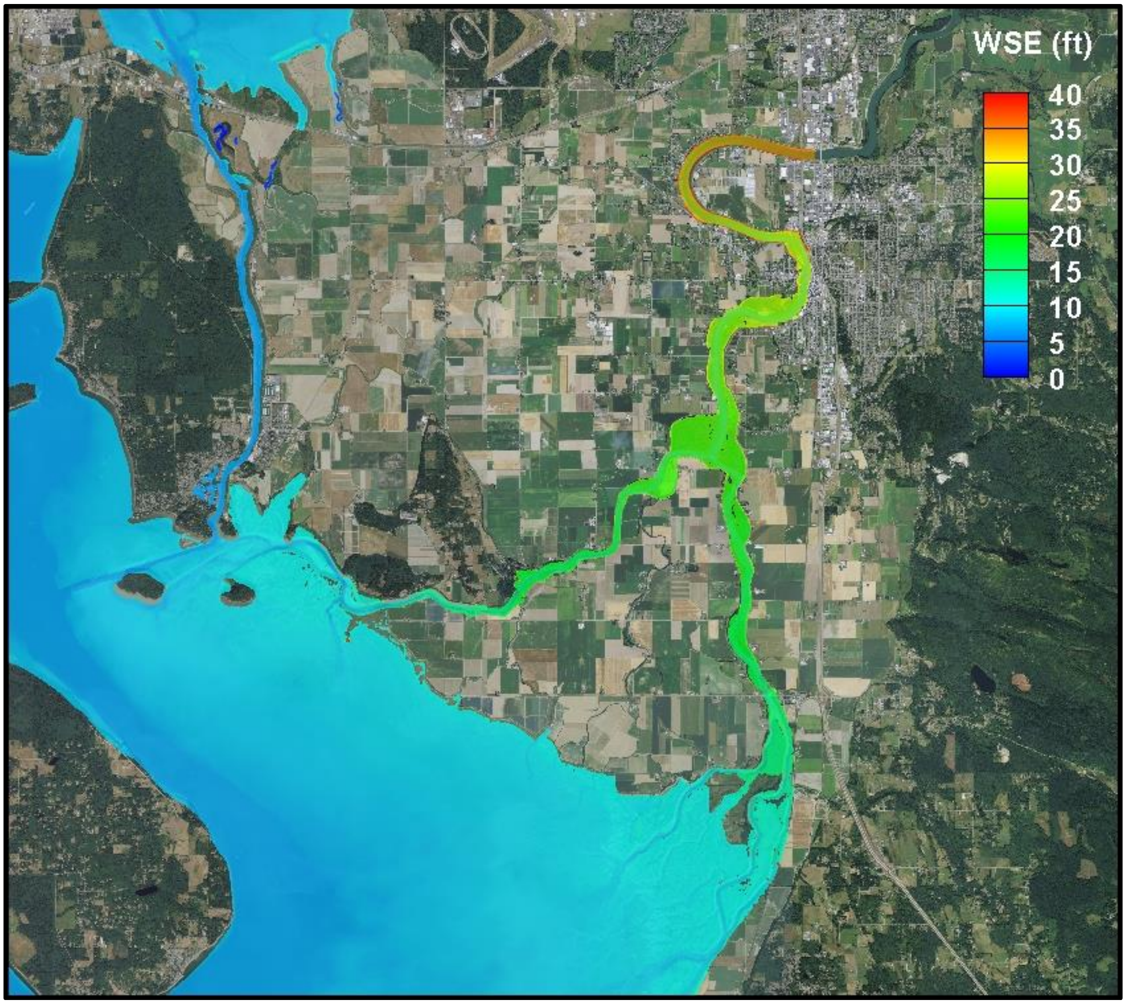


Figure A.9. Contour map of water surface elevation for the full domain during the Baseline Simulation with flood flow and high spring tide.

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.

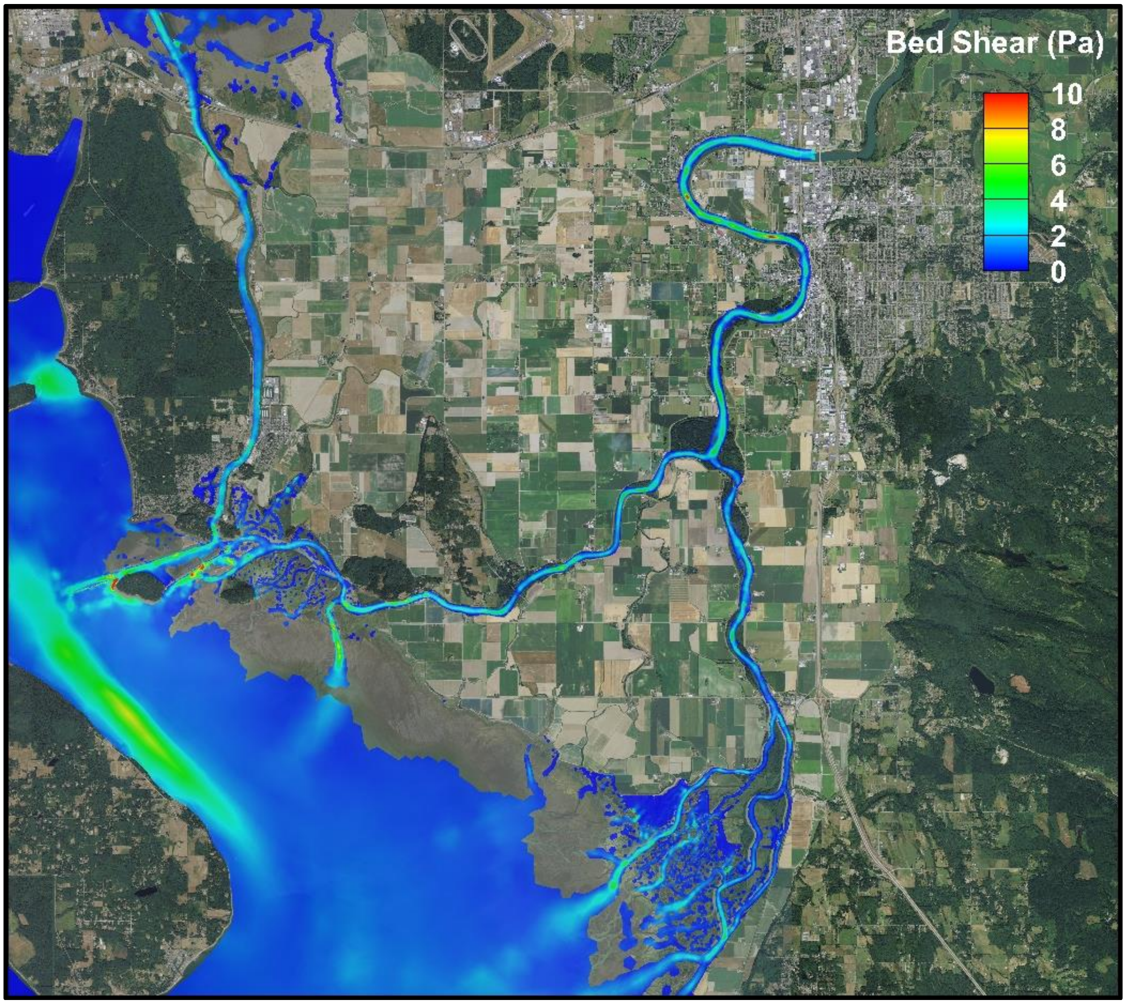


Figure A.10. Contour map of peak shear stress for the full domain during the Baseline Simulation with low flow across the full tidal cycle.

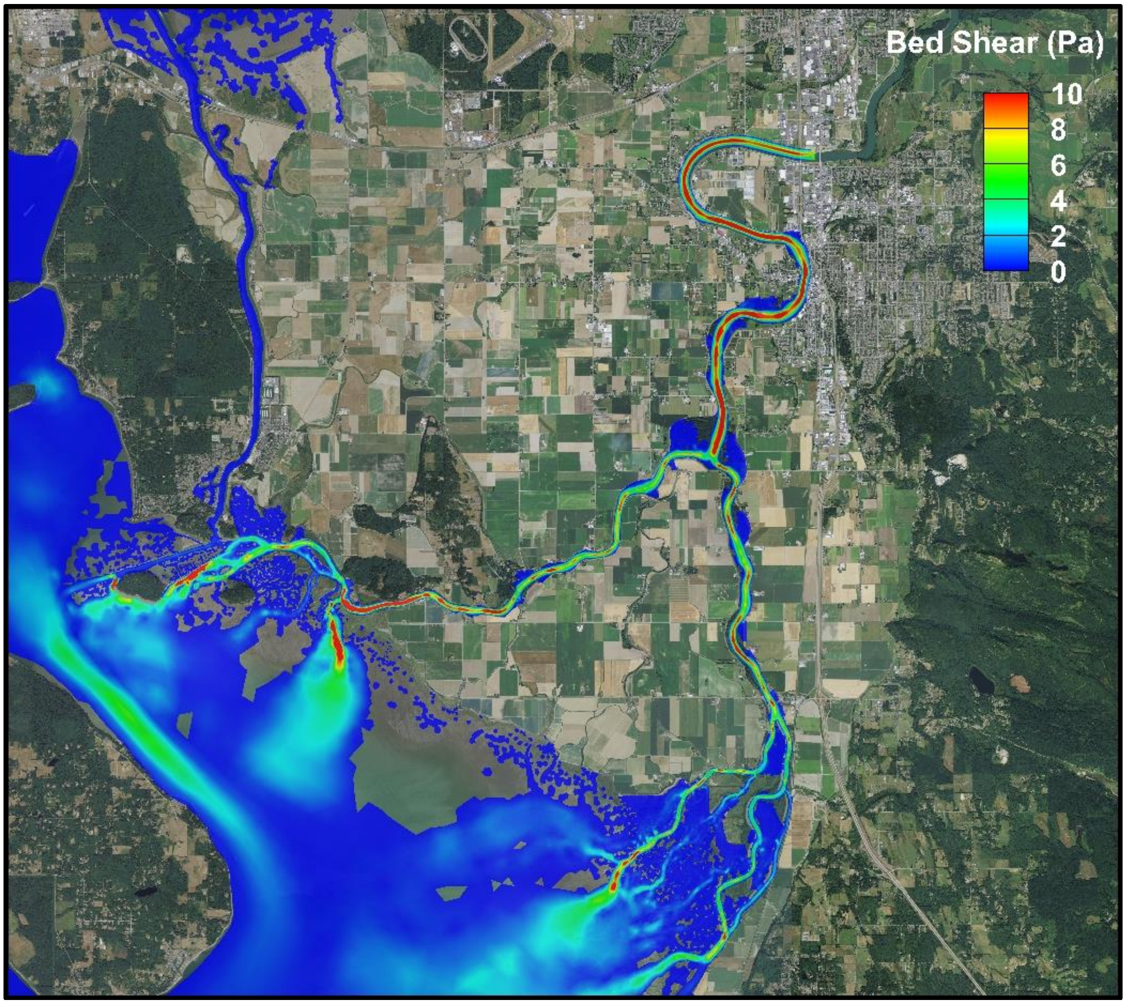


Figure A.11. Contour map of shear stress for the full domain during the Baseline Simulation with Q2 flow and low spring tide.

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.

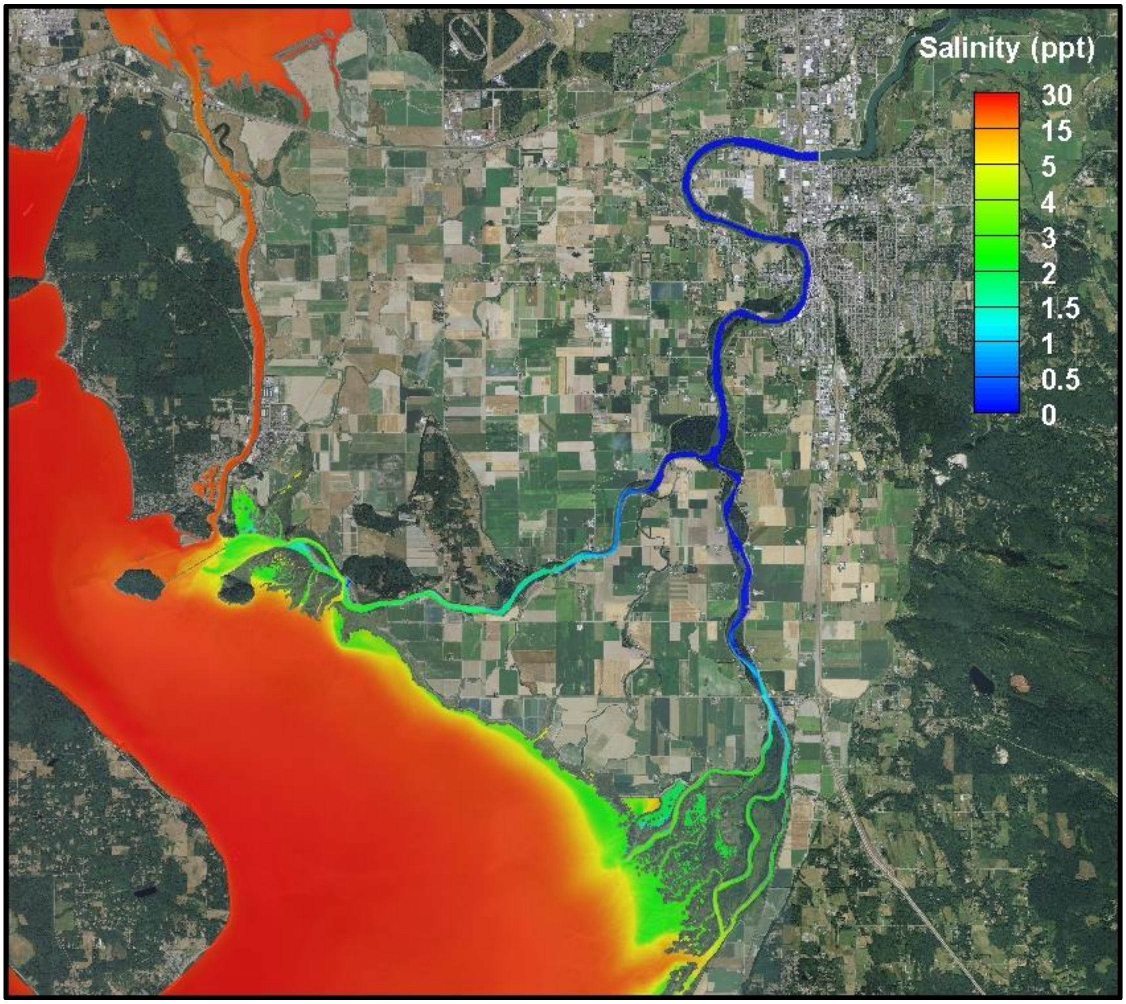


Figure A.12. Contour map of salinity for the full domain during the Baseline Simulation with low flow and high spring tide.

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.

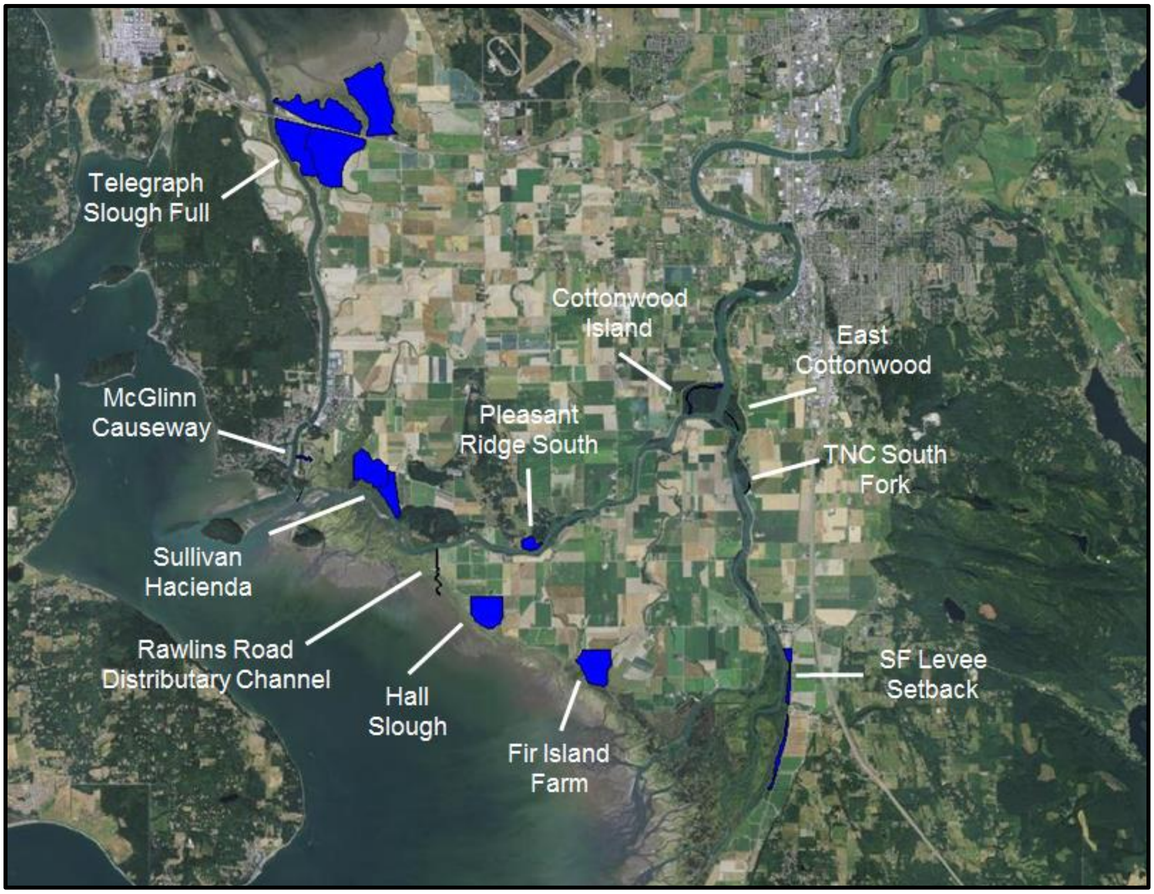


Figure B.1. A map of project areas in the Small Projects simulation.

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.

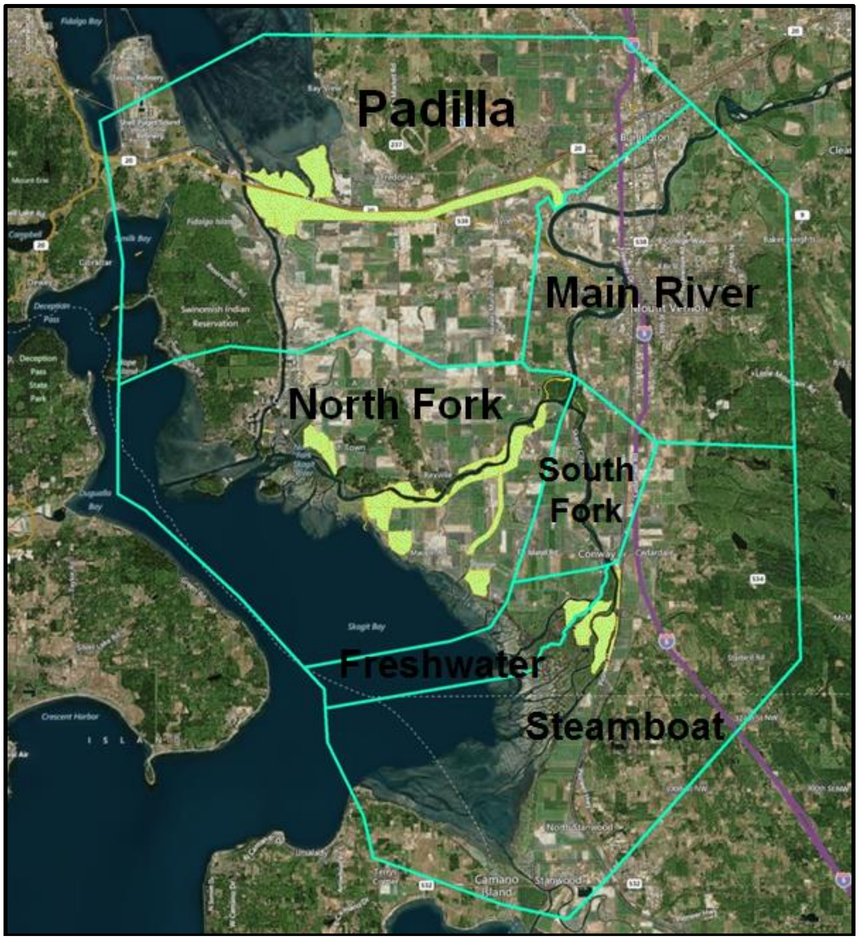


Figure B.2. Sub-basins within the Skagit region used for area calculations.

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.

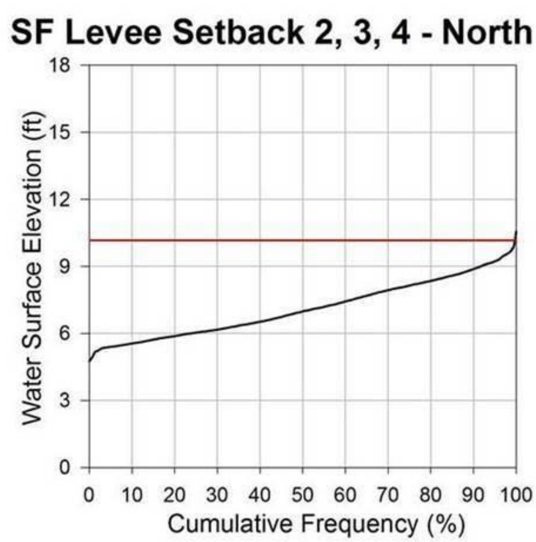
Table B.2. Table entry showing area increase for each project under tidal and riverine conditions during the Small Projects simulation. Measurements correspond to a measured area that differs from the true project footprint because of grid resolution.

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.



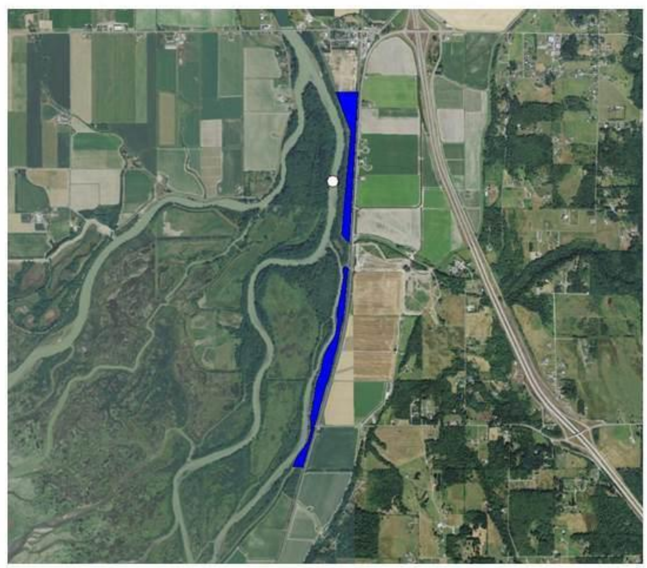


Figure B.3. Cumulative frequency plot and corresponding map for SF Levee Setbacks 2, 3, and 4 (north) during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

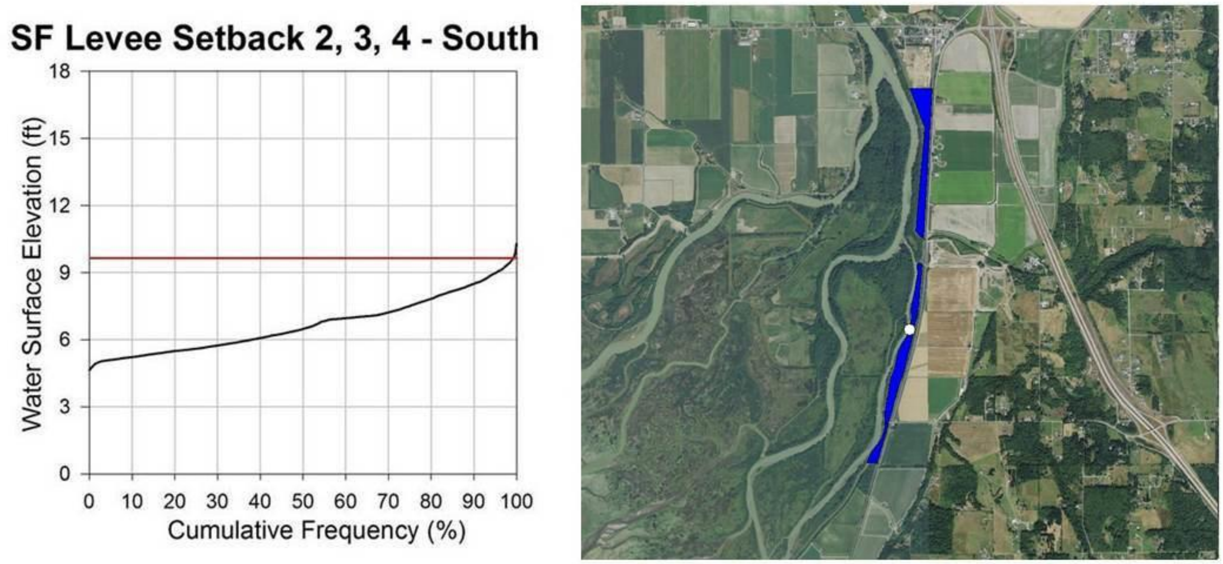


Figure B.4. Cumulative frequency plot and corresponding map for SF Levee Setbacks 2, 3, and 4 (south) during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

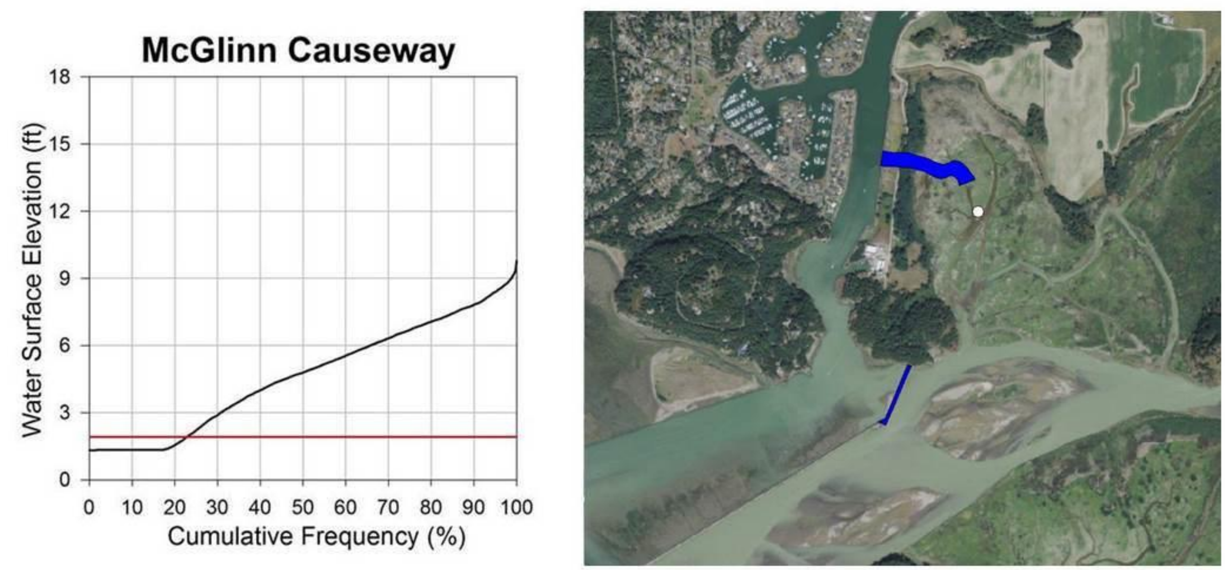


Figure B.5. Cumulative frequency plot and corresponding map for McGlinn Causeway during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

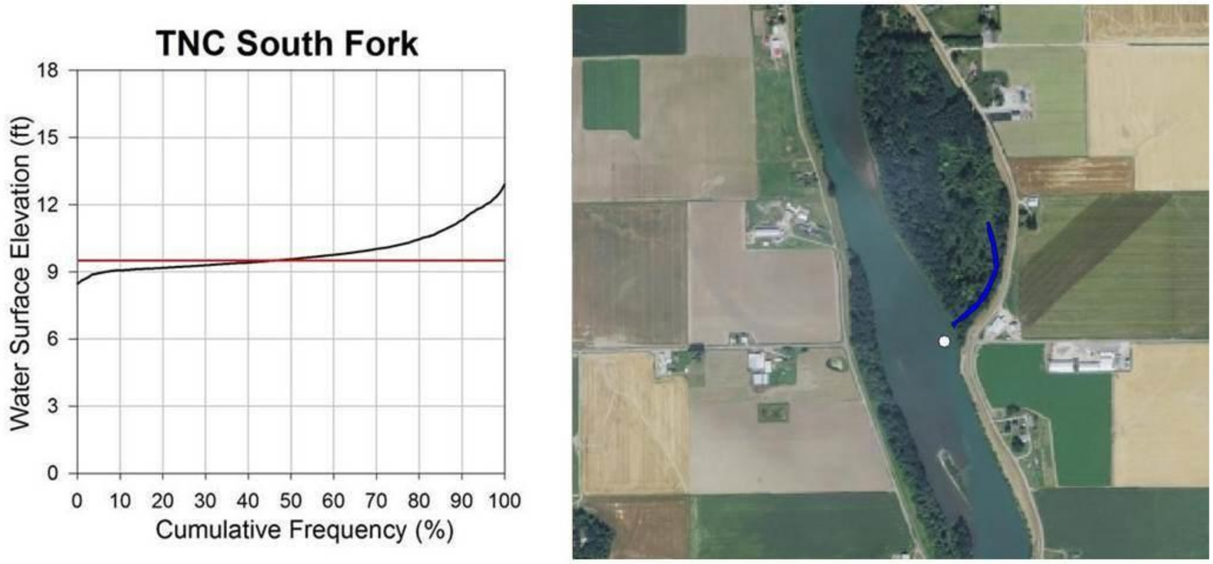


Figure B.6. Cumulative frequency plot and corresponding map for TNC South Fork during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

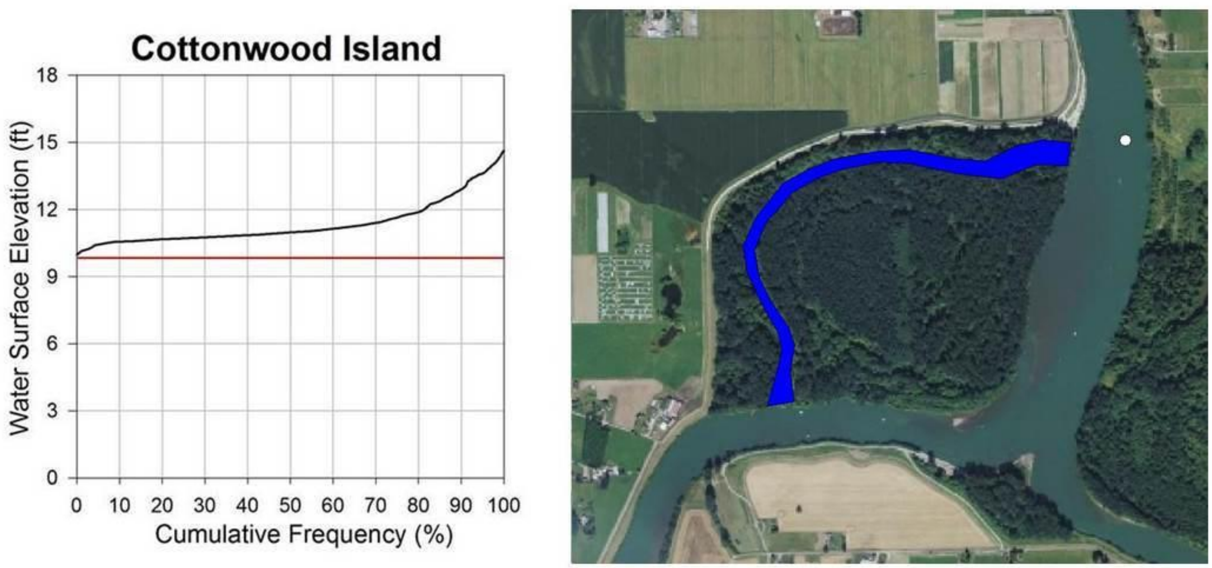


Figure B.7. Cumulative frequency plot and corresponding map for Cottonwood Island during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

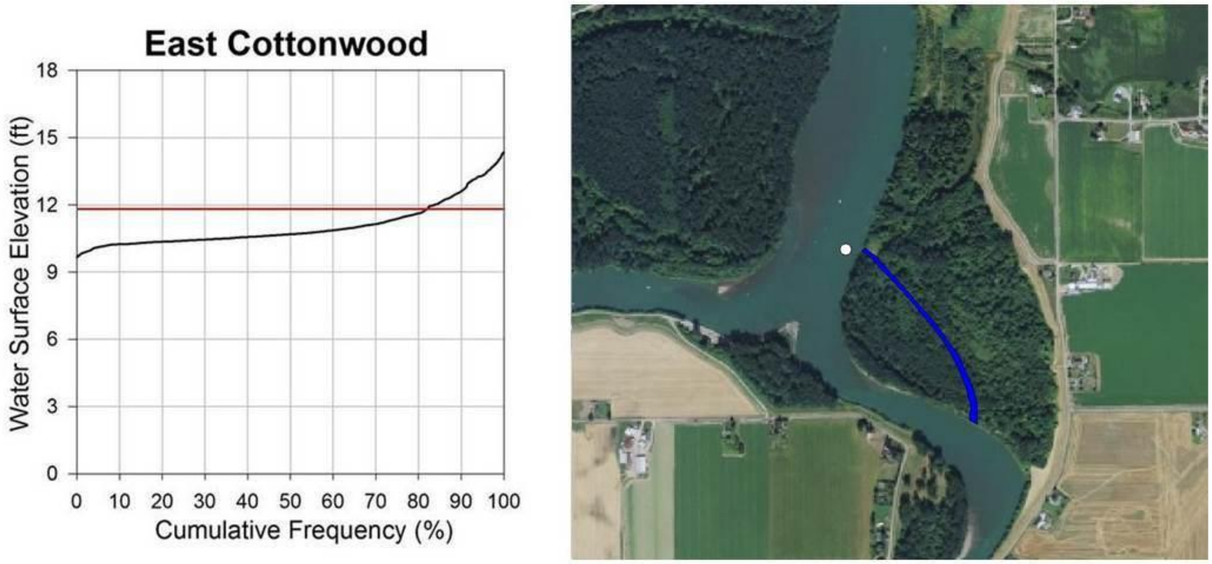


Figure B.8. Cumulative frequency plot and corresponding map for East Cottonwood during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

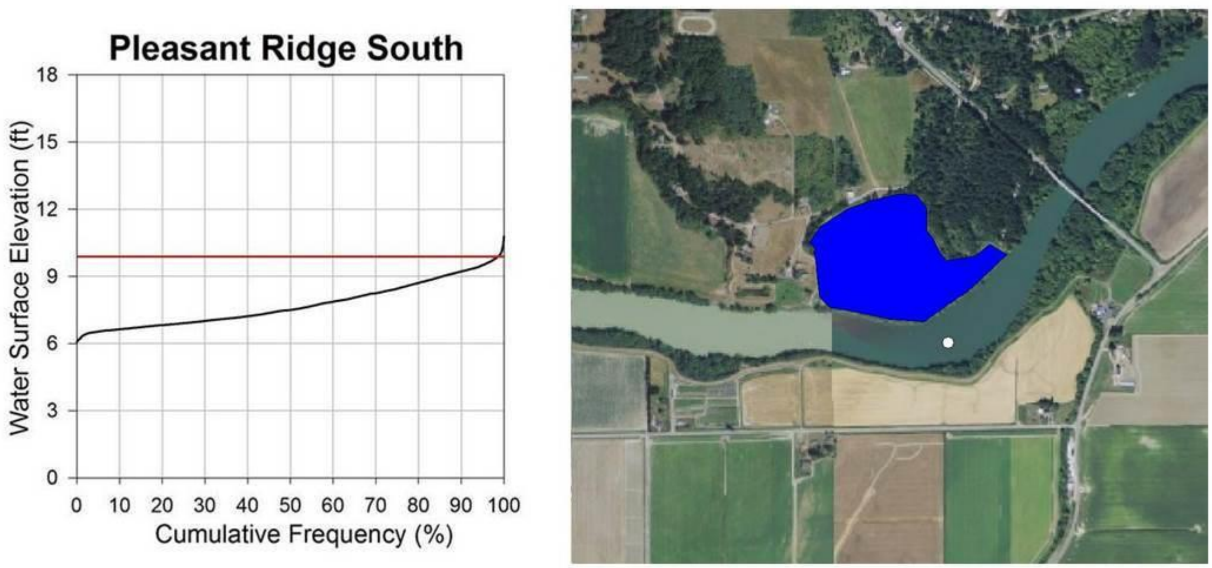


Figure B.9. Cumulative frequency plot and corresponding map for Pleasant Ridge South during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

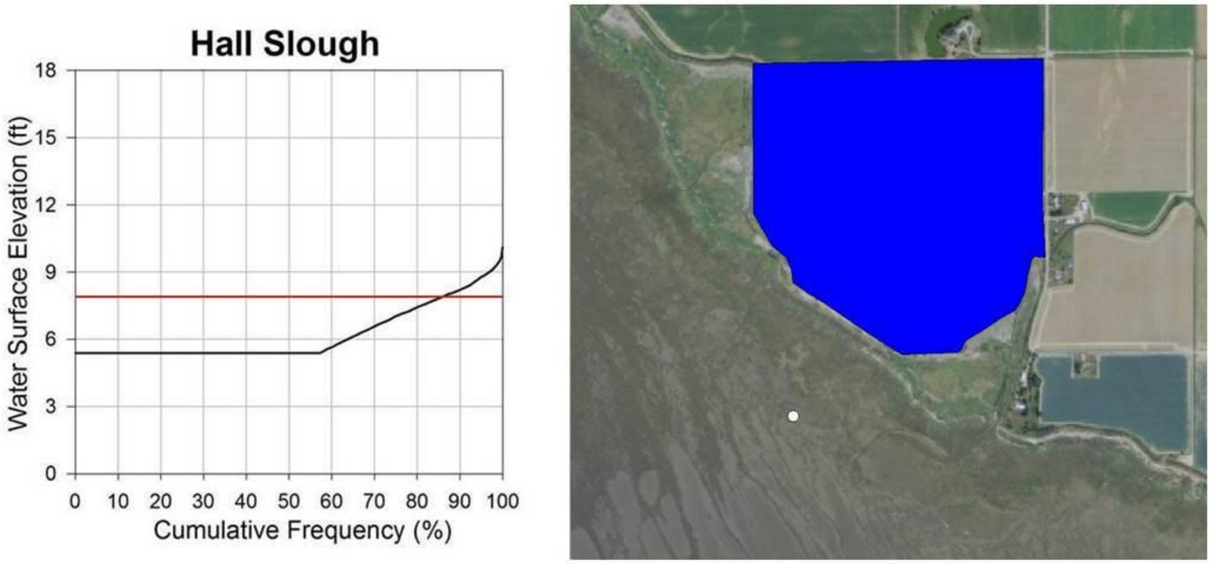


Figure B.10. Cumulative frequency plot and corresponding map for Hall Slough during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

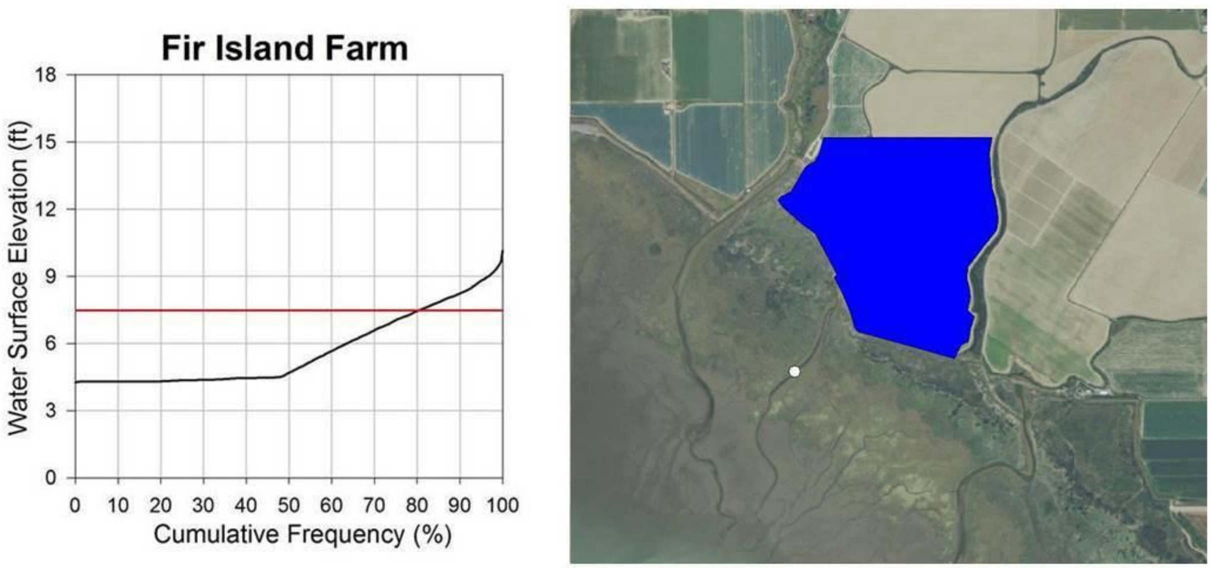


Figure B.11. Cumulative frequency plot and corresponding map for Fir Island Farm during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

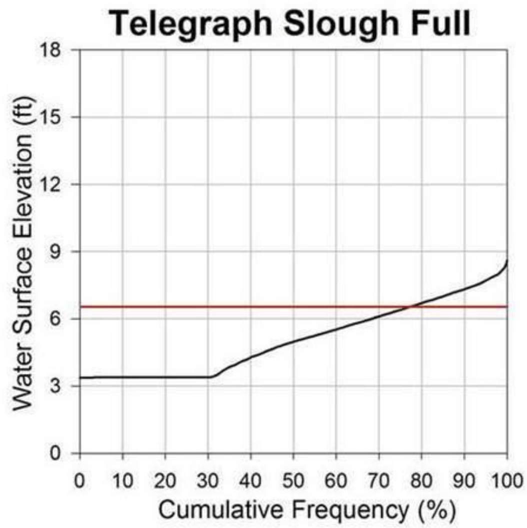
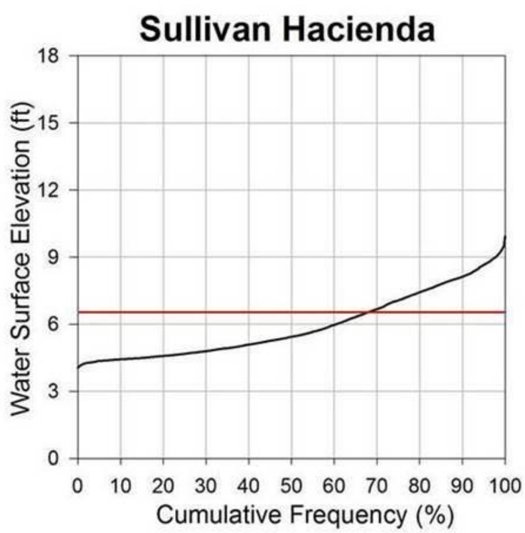


Figure B.12. Cumulative frequency plot and corresponding map for Telegraph Slough Full during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.



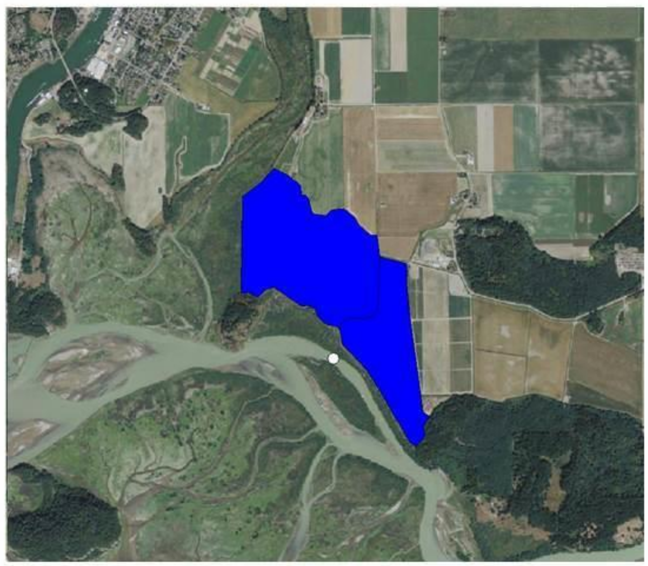


Figure B.13. Cumulative frequency plot and corresponding map for Sullivan Hacienda during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

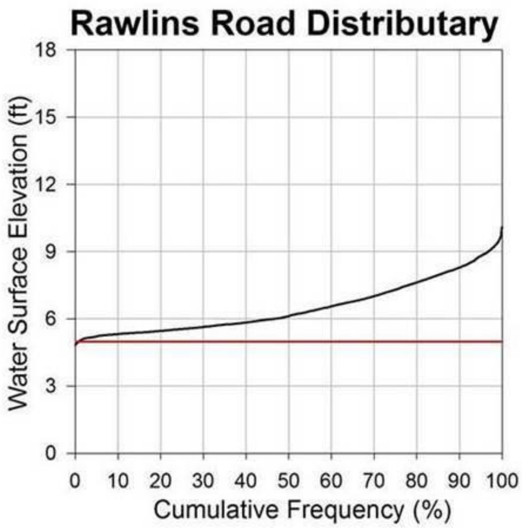


Figure B.14. Cumulative frequency plot and corresponding map for Rawlins Road Distributary during the Small Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

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.

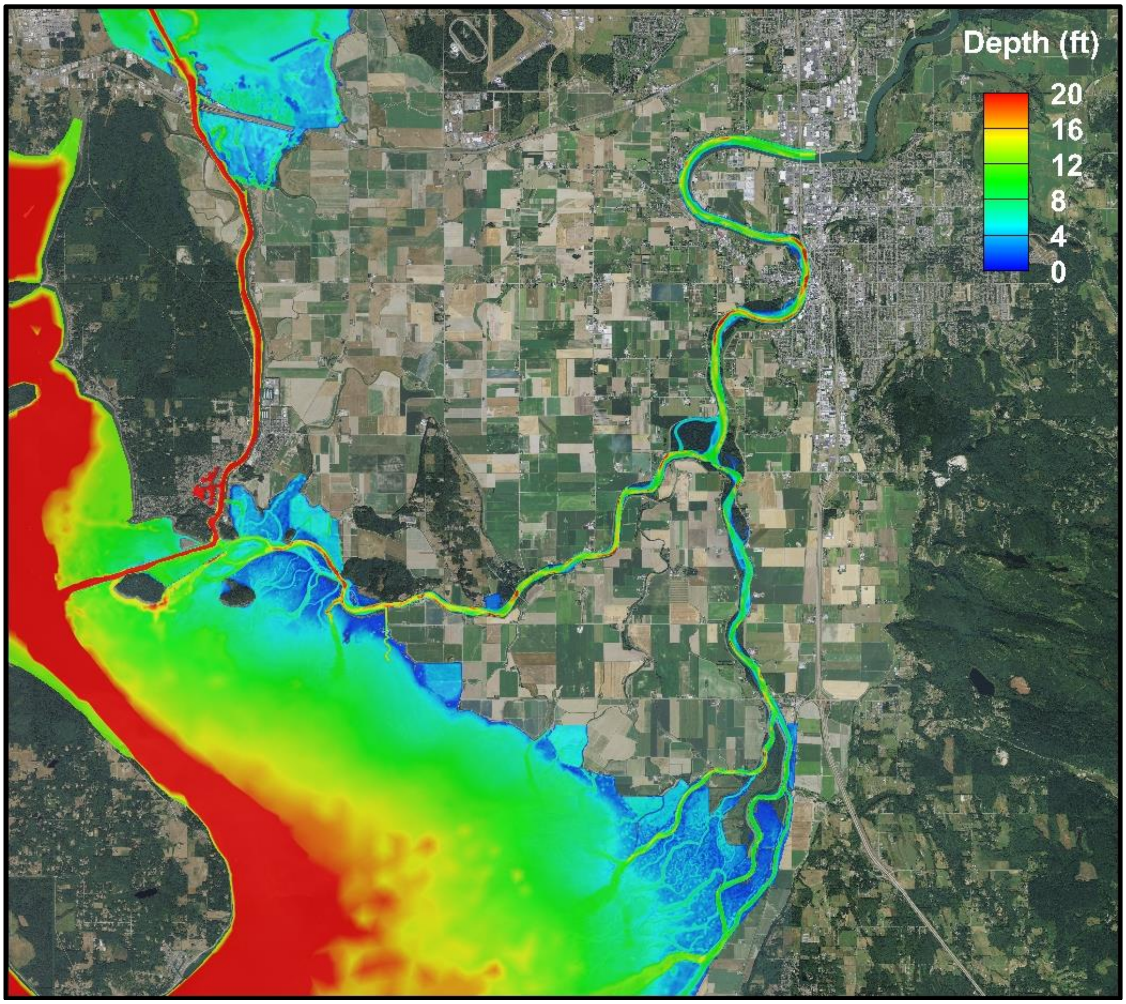


Figure B.15. Contour map of depths for the full domain during the Small Projects simulation with May flow and high spring tide.

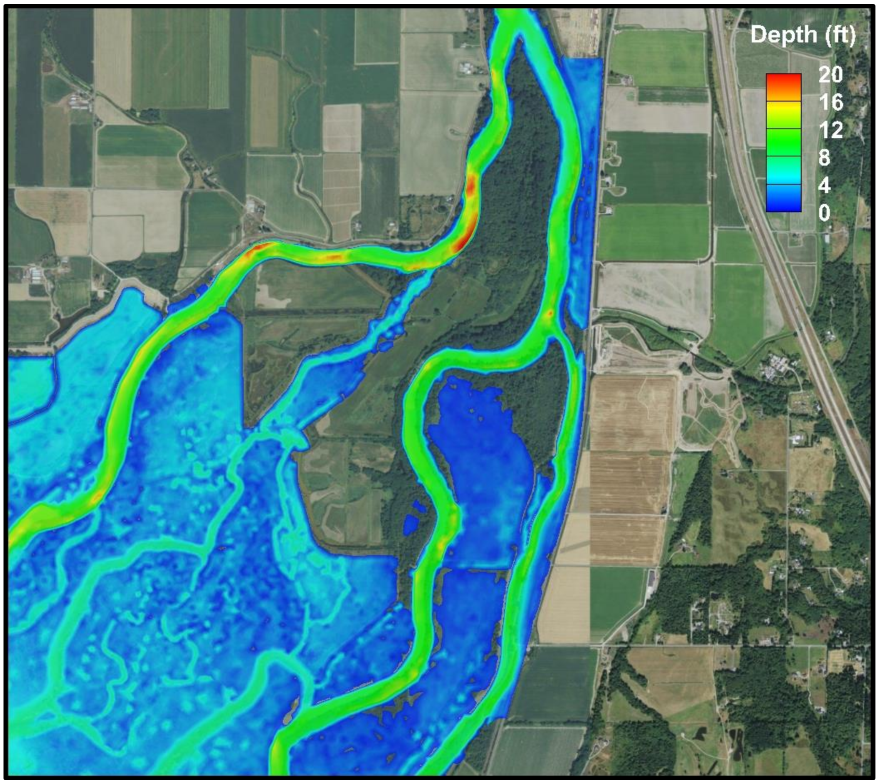


Figure B.16. Contour map of depths for SF Levee Setbacks 2, 3, and 4 during the Small Projects simulation.

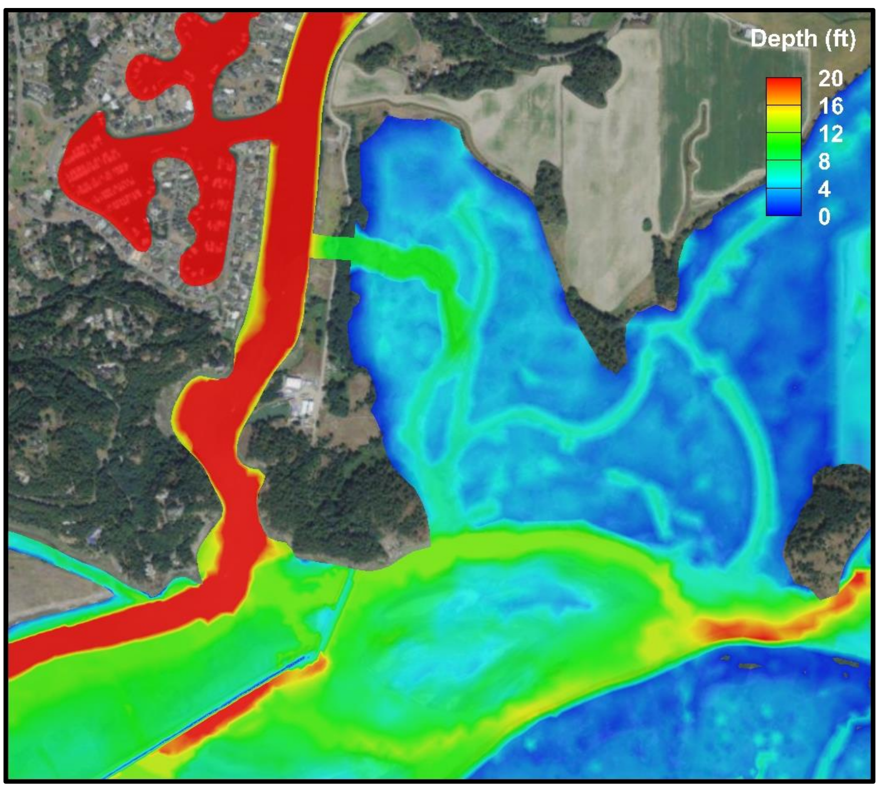


Figure B.17. Contour map of depths for McGlinn Causeway during the Small Projects simulation.

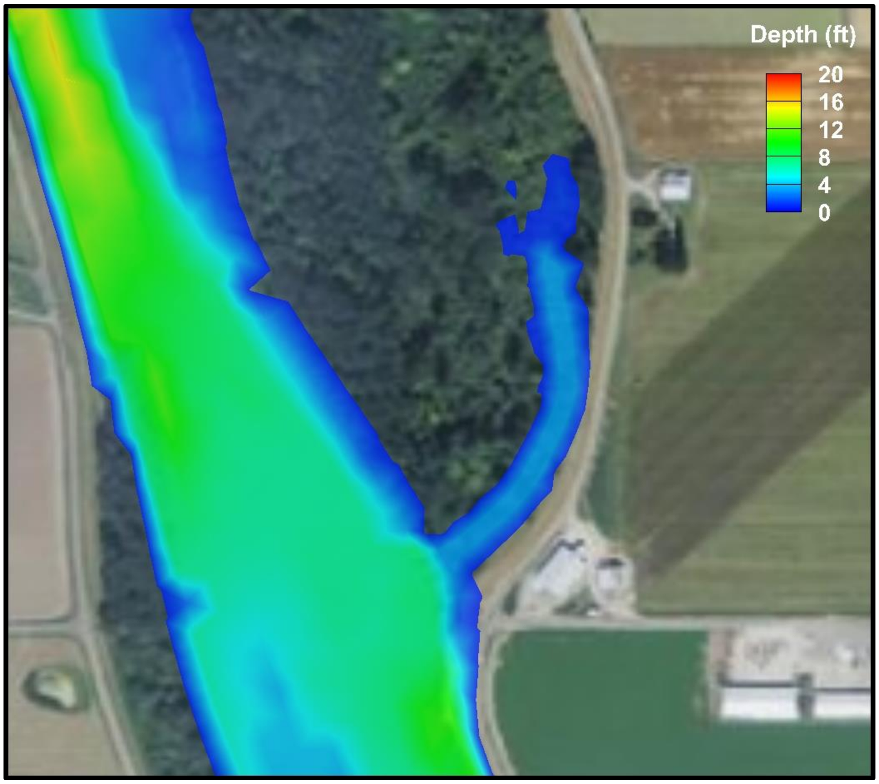


Figure B.18. Contour map of depths for TNC South Fork during the Small Projects simulation.

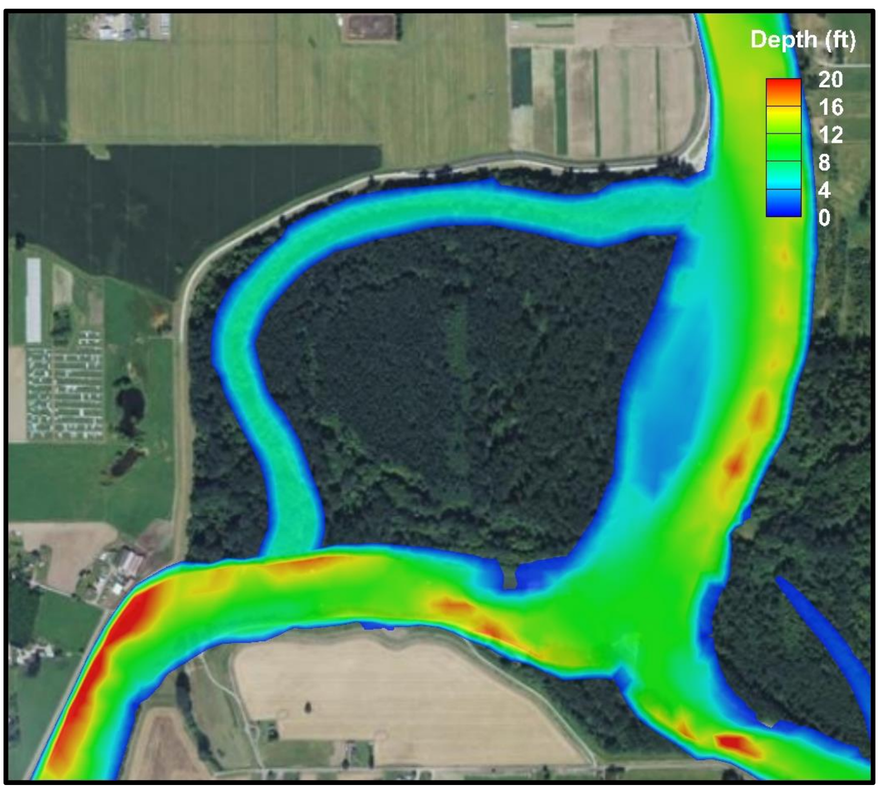


Figure B.19. Contour map of depths for Cottonwood Island during the Small Projects simulation.

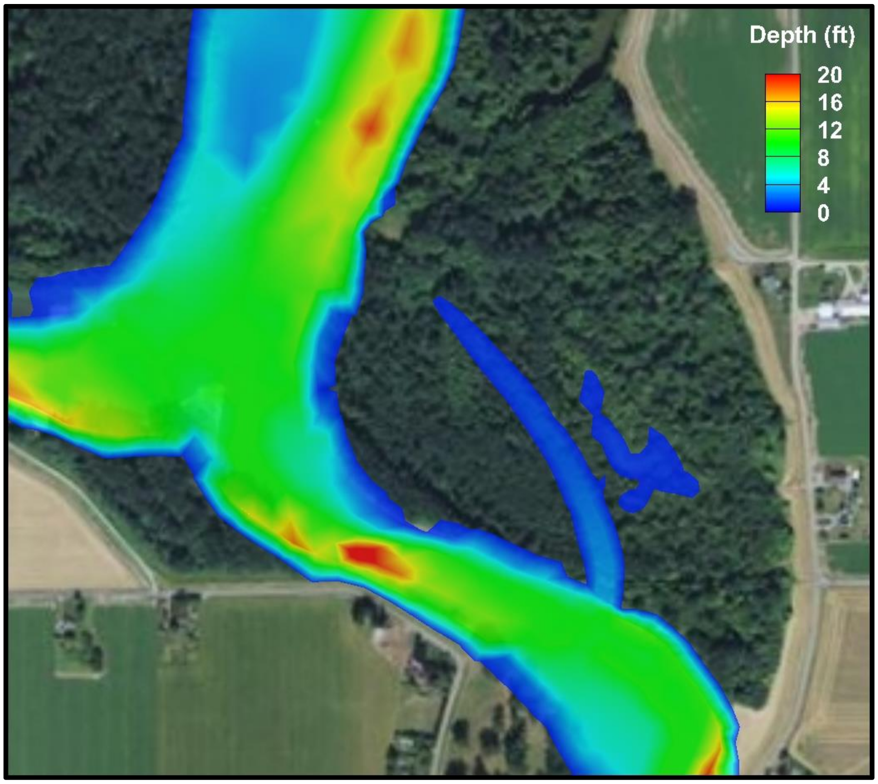


Figure B.20. Contour map of depths for East Cottonwood Island during the Small Projects simulation.

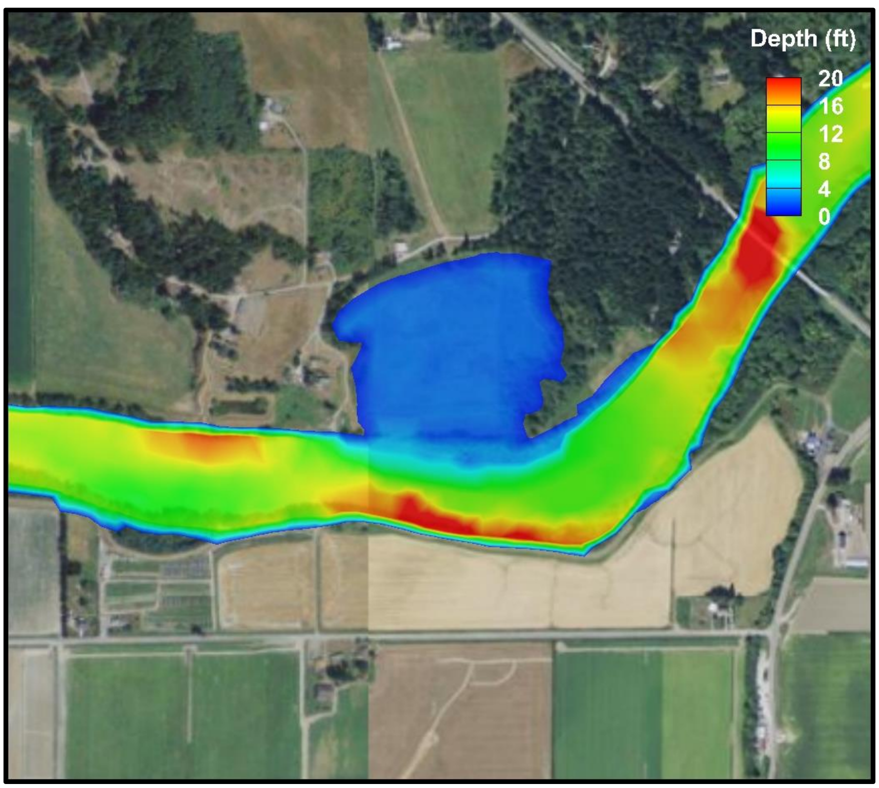


Figure B.21. Contour map of depths for Pleasant Ridge South during the Small Projects simulation.

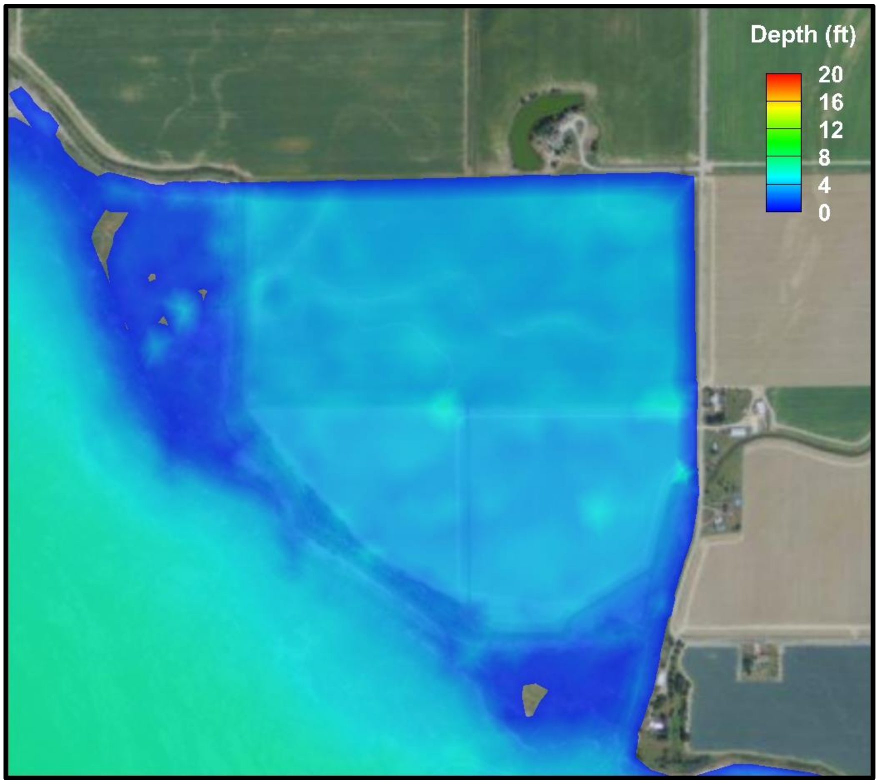


Figure B.22. Contour map of depths for Hall Slough during the Small Projects simulation.

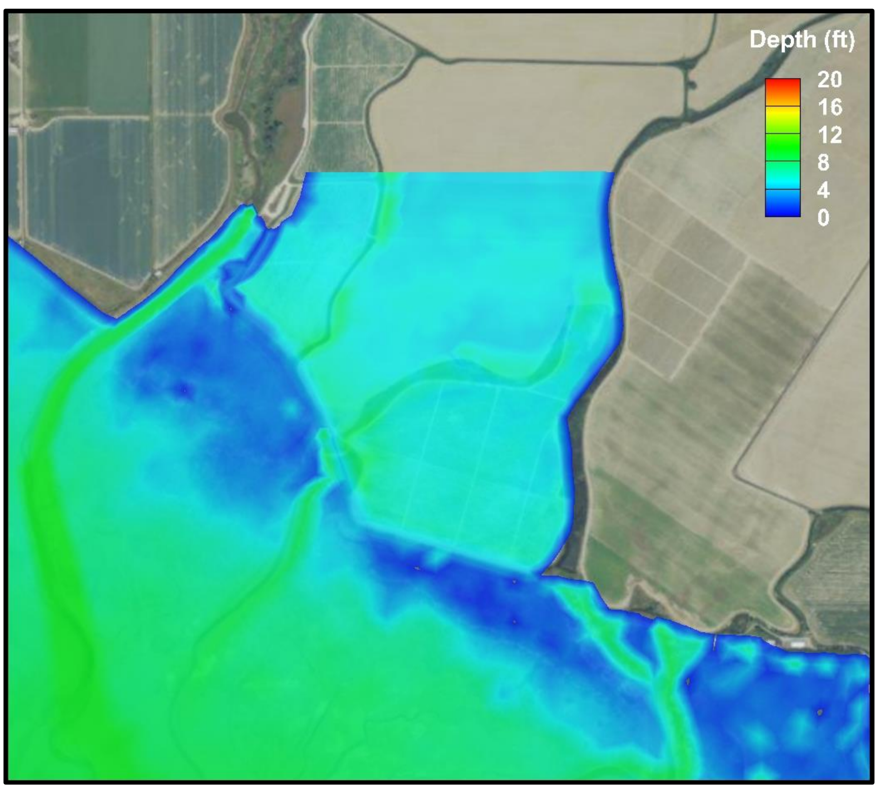


Figure B.23. Contour map of depths for Fir Island Farm during the Small Projects simulation.

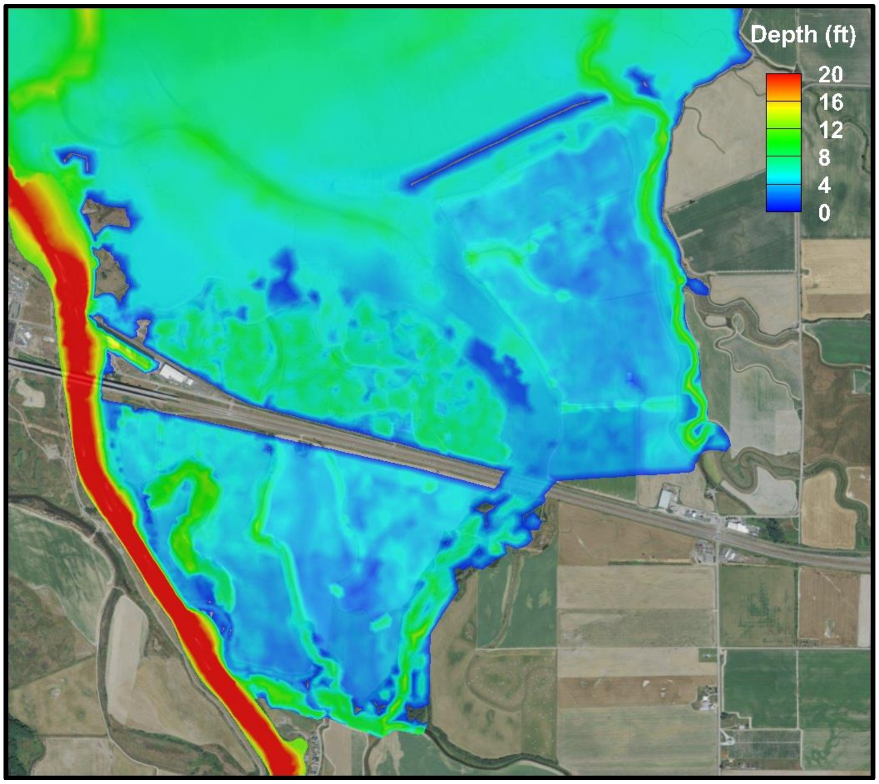


Figure B.24. Contour map of depths for Telegraph Slough Full during the Small Projects simulation.

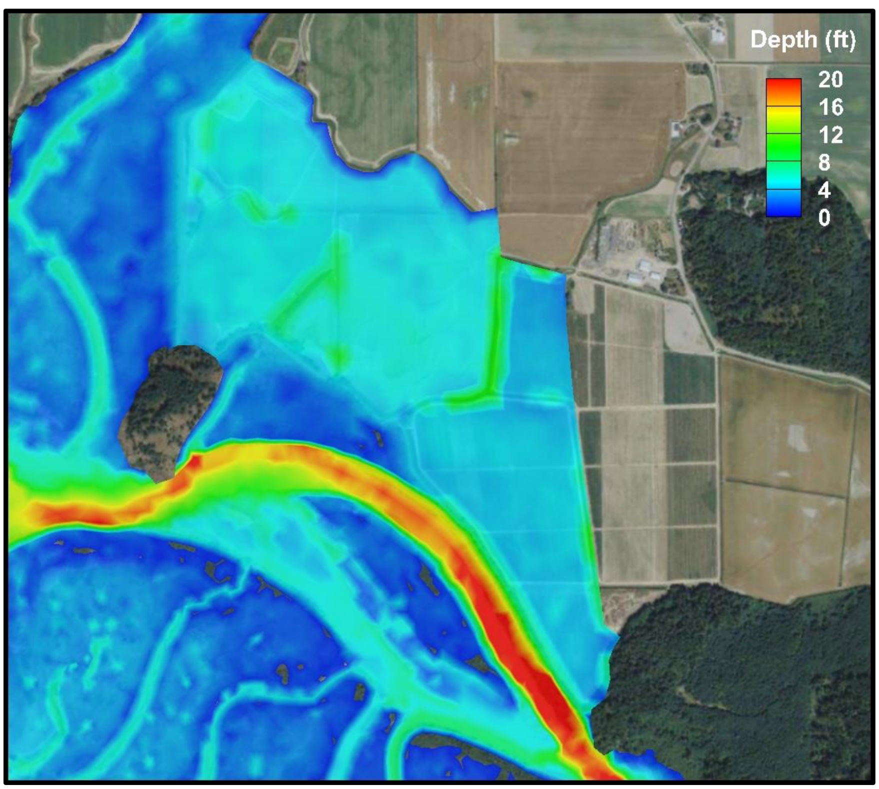


Figure B.25. Contour map of depths for Sullivan Hacienda during the Small Projects simulation.

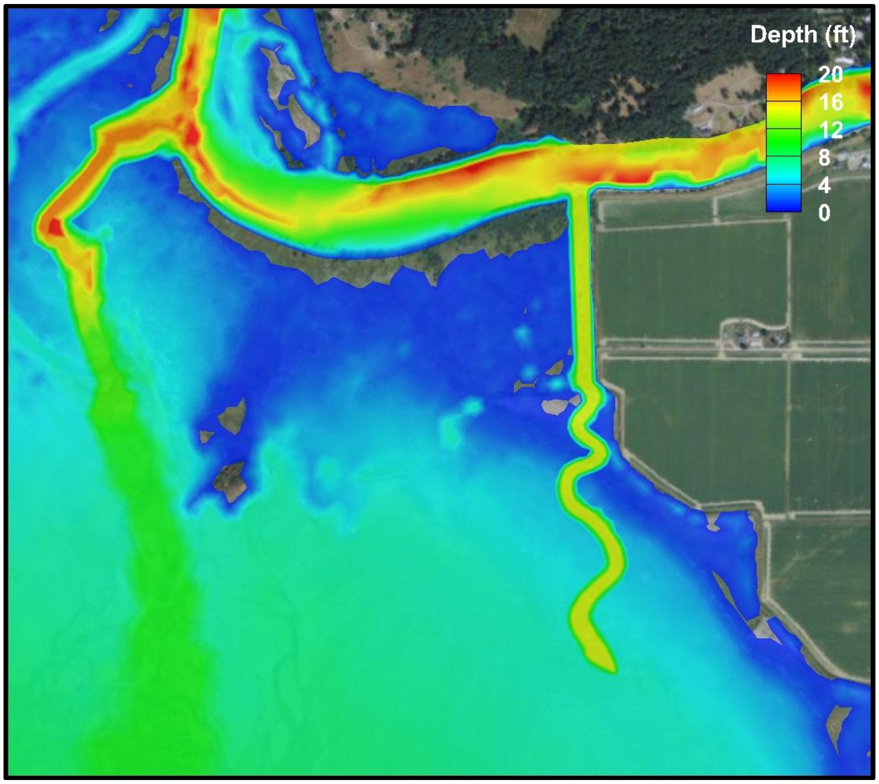


Figure B.26. Contour map of depths for Rawlins Road Distributary during the Small Projects simulation.

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.

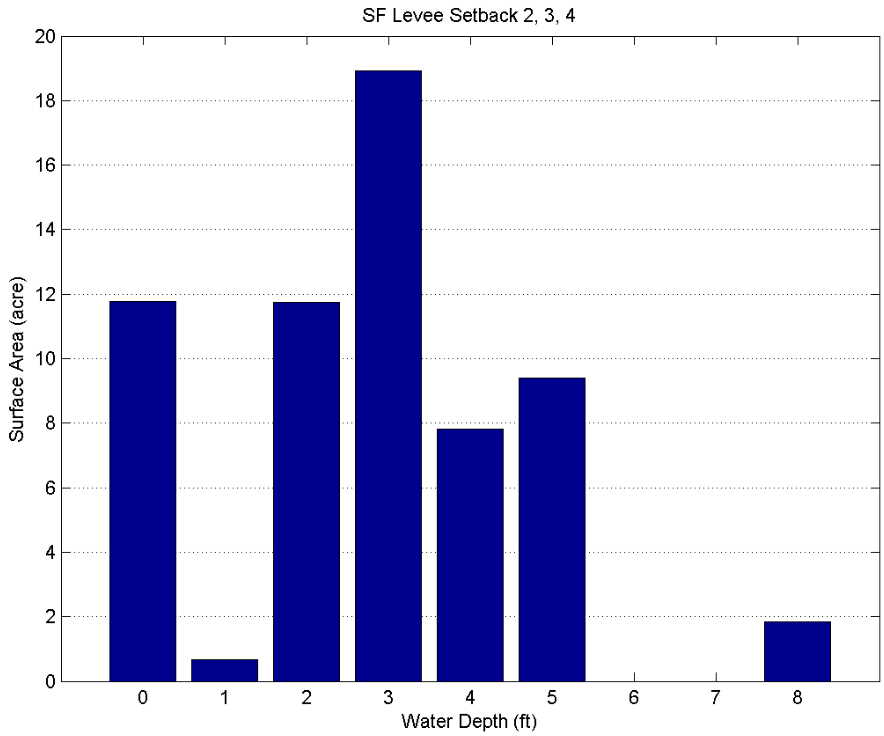


Figure B.27. Histogram of depths for SF Levee Setbacks 2, 3, and 4.

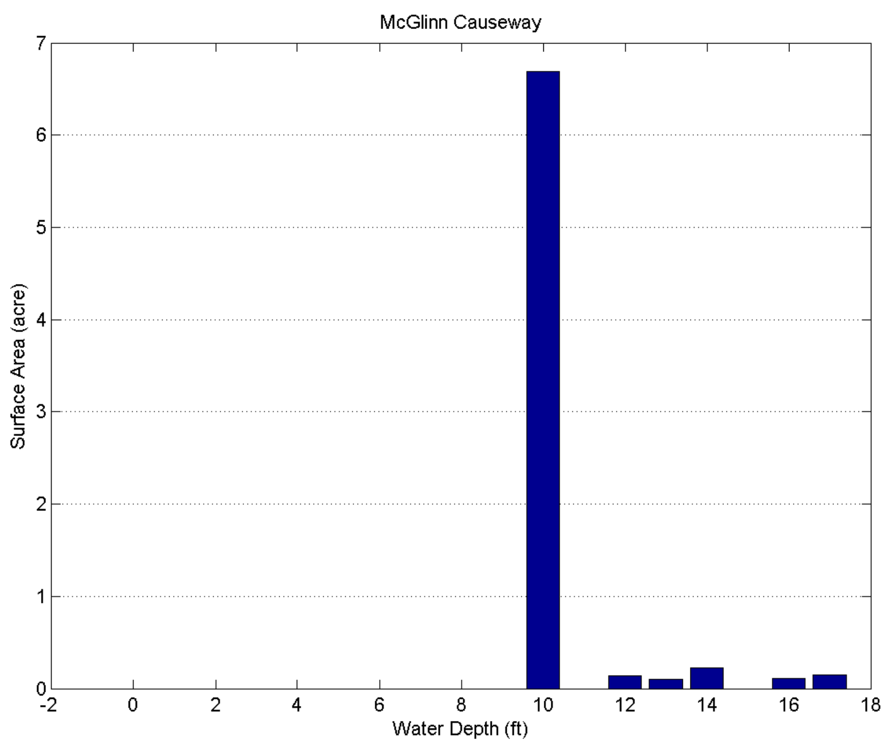


Figure B.28. Histogram of depths for McGlinn Causeway.

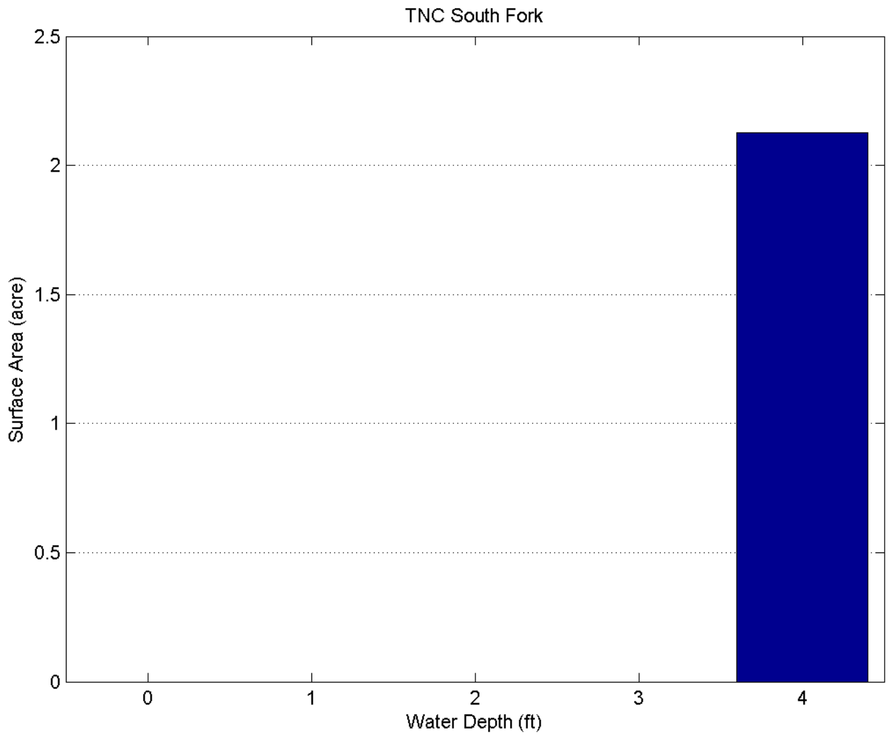


Figure B.29. Histogram of depths for TNC South Fork.

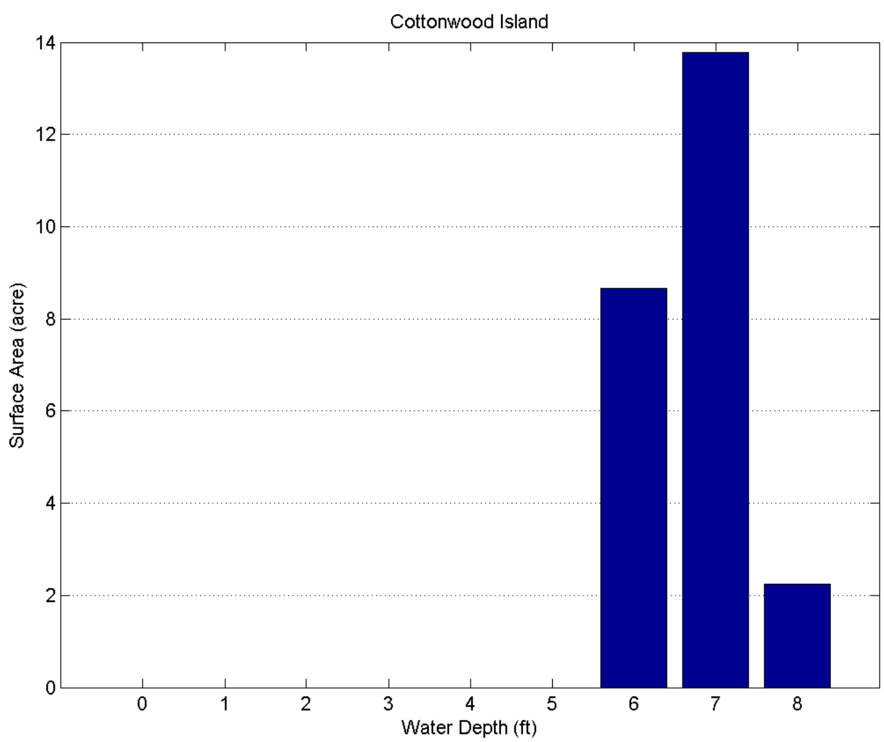


Figure B.30. Histogram of depths for Cottonwood Island.

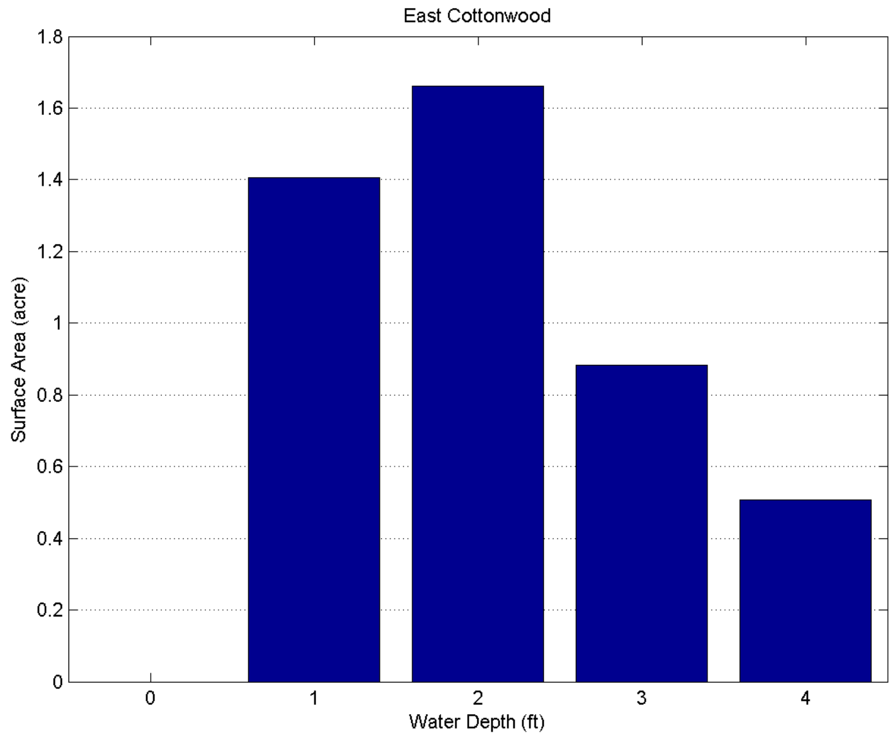


Figure B.31. Histogram of depths for East Cottonwood.

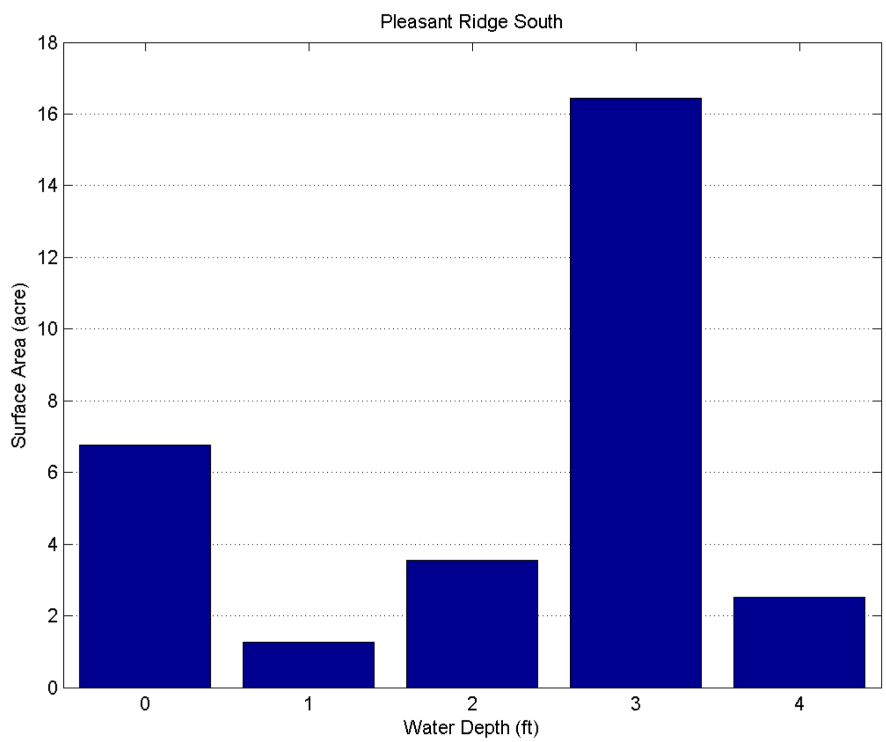


Figure B.32. Histogram of depths for Pleasant Ridge South.

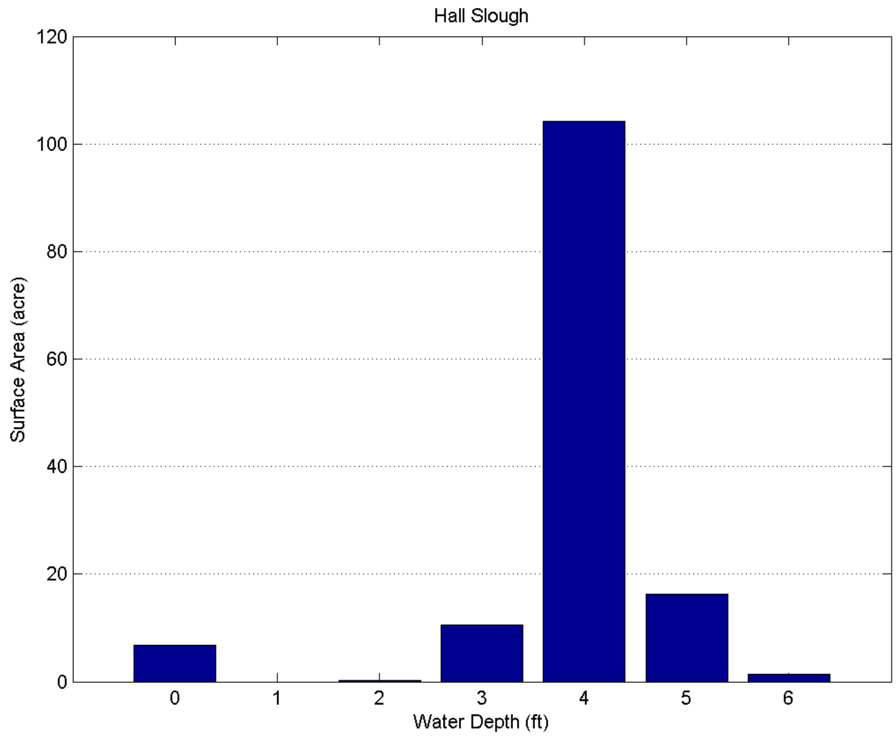


Figure B.33. Histogram of depths for Hall Slough.

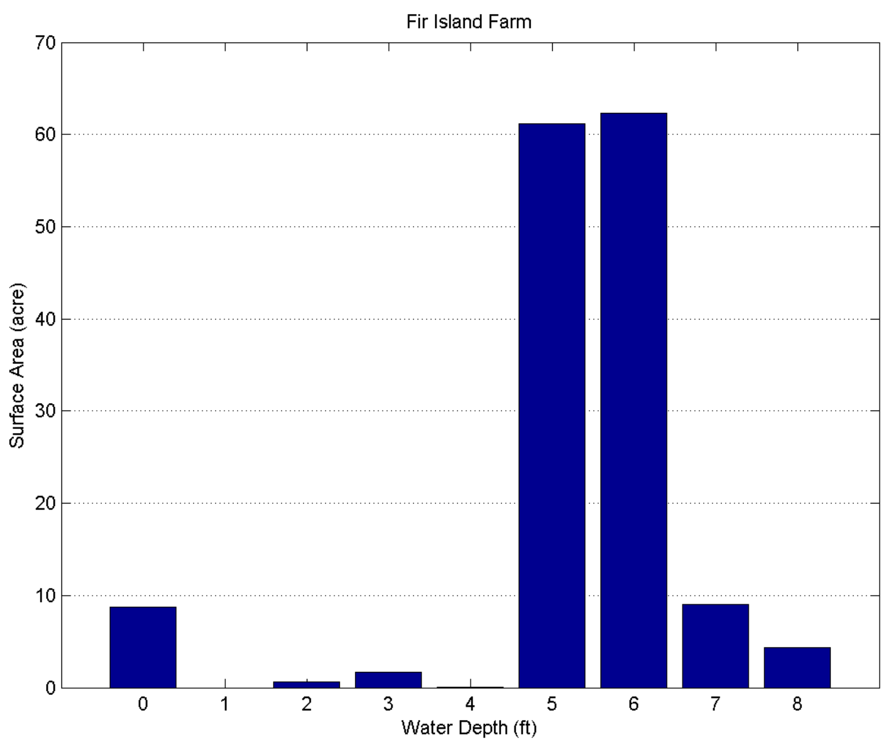


Figure B.34. Histogram of depths for Fir Island Farm.

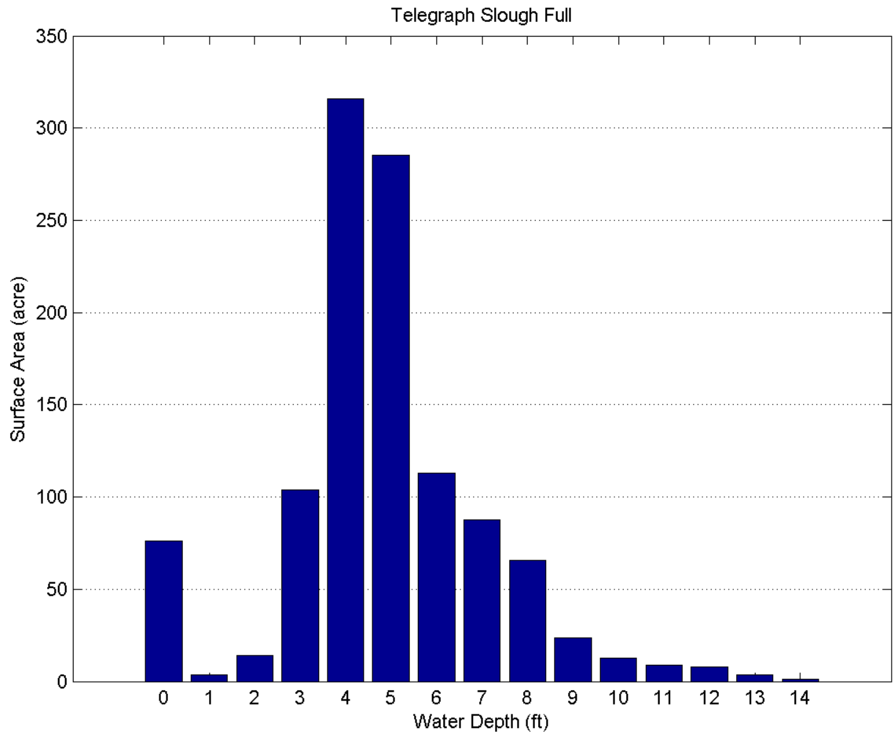


Figure B.35. Histogram of depths for Telegraph Slough Full.

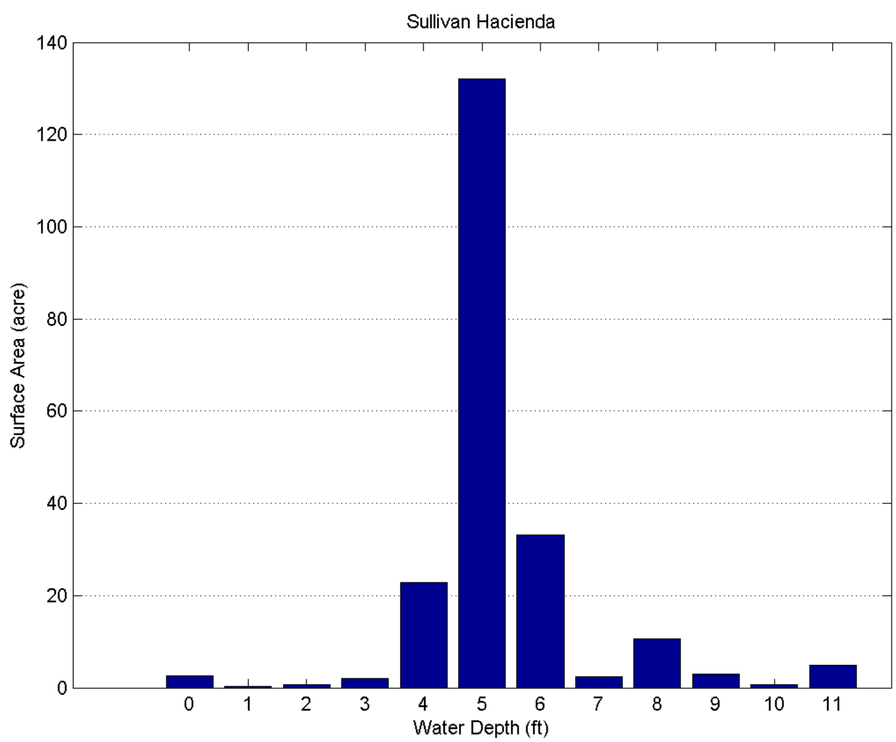


Figure B.36. Histogram of depths for Sullivan Hacienda.

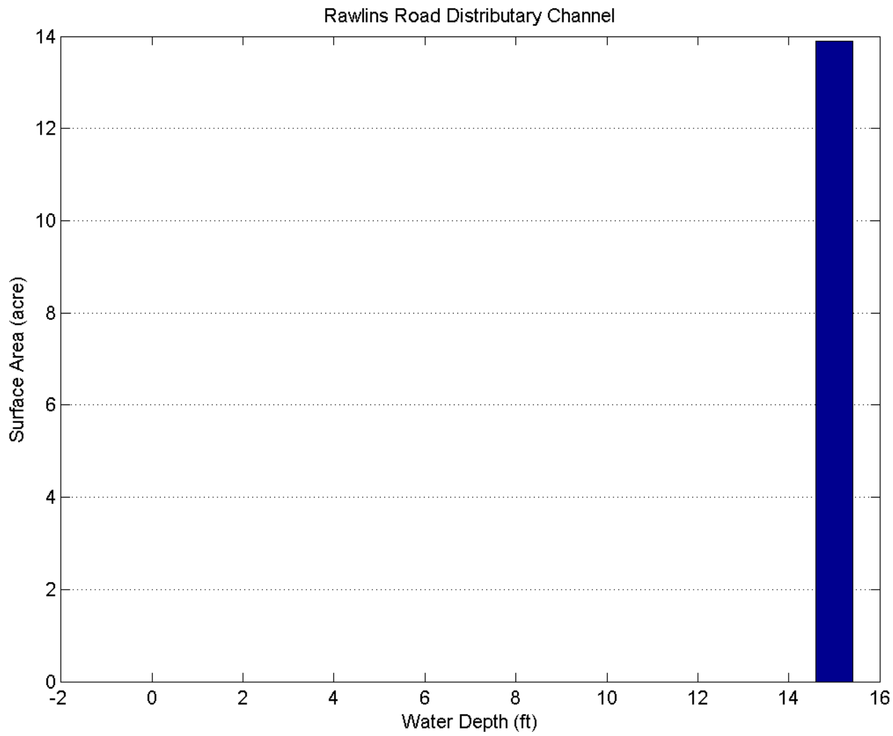


Figure B.37. Histogram of depths for Rawlins Road Distributary Channel.

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.

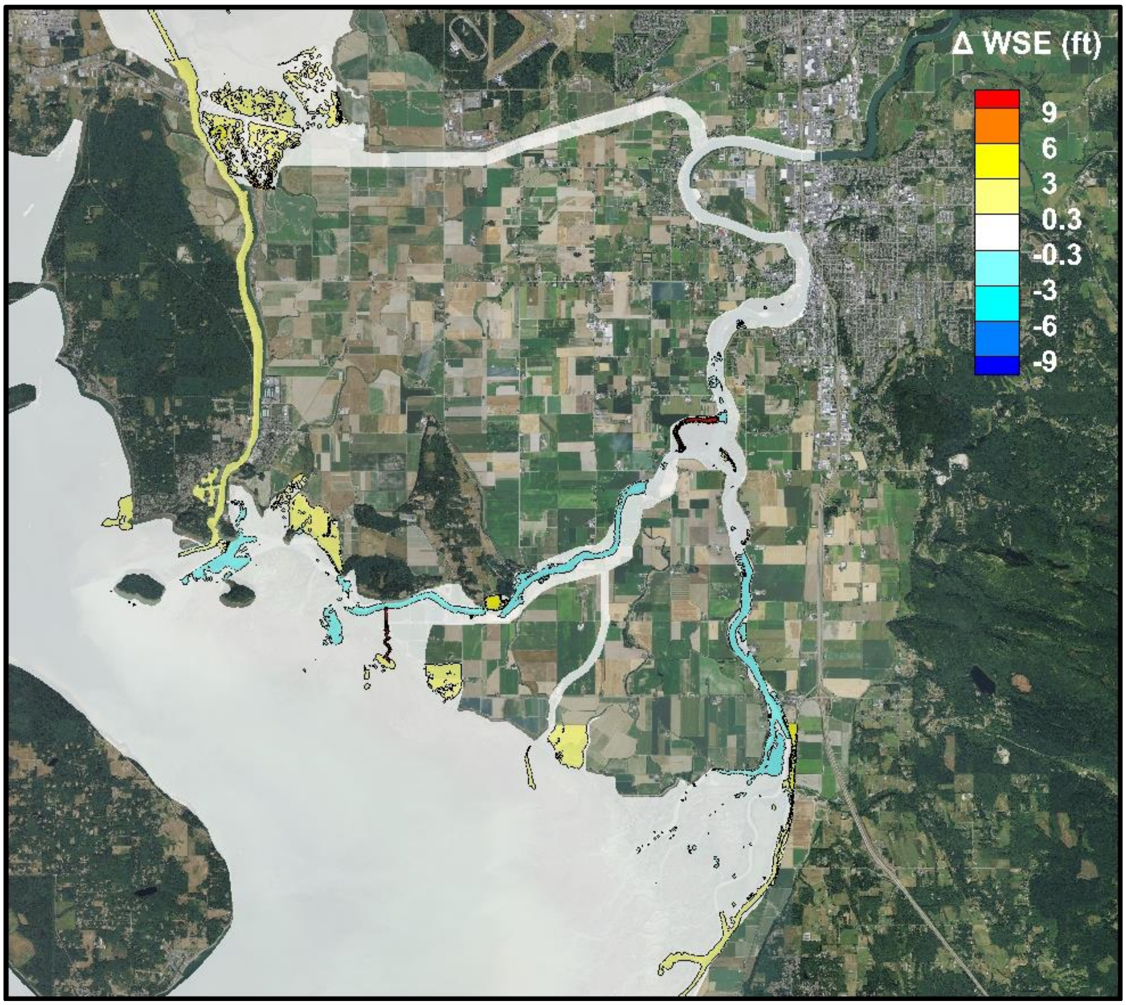


Figure B.38. Contour map of change in WSE from the Baseline to Small Projects simulation with Q2 flow and low tide.

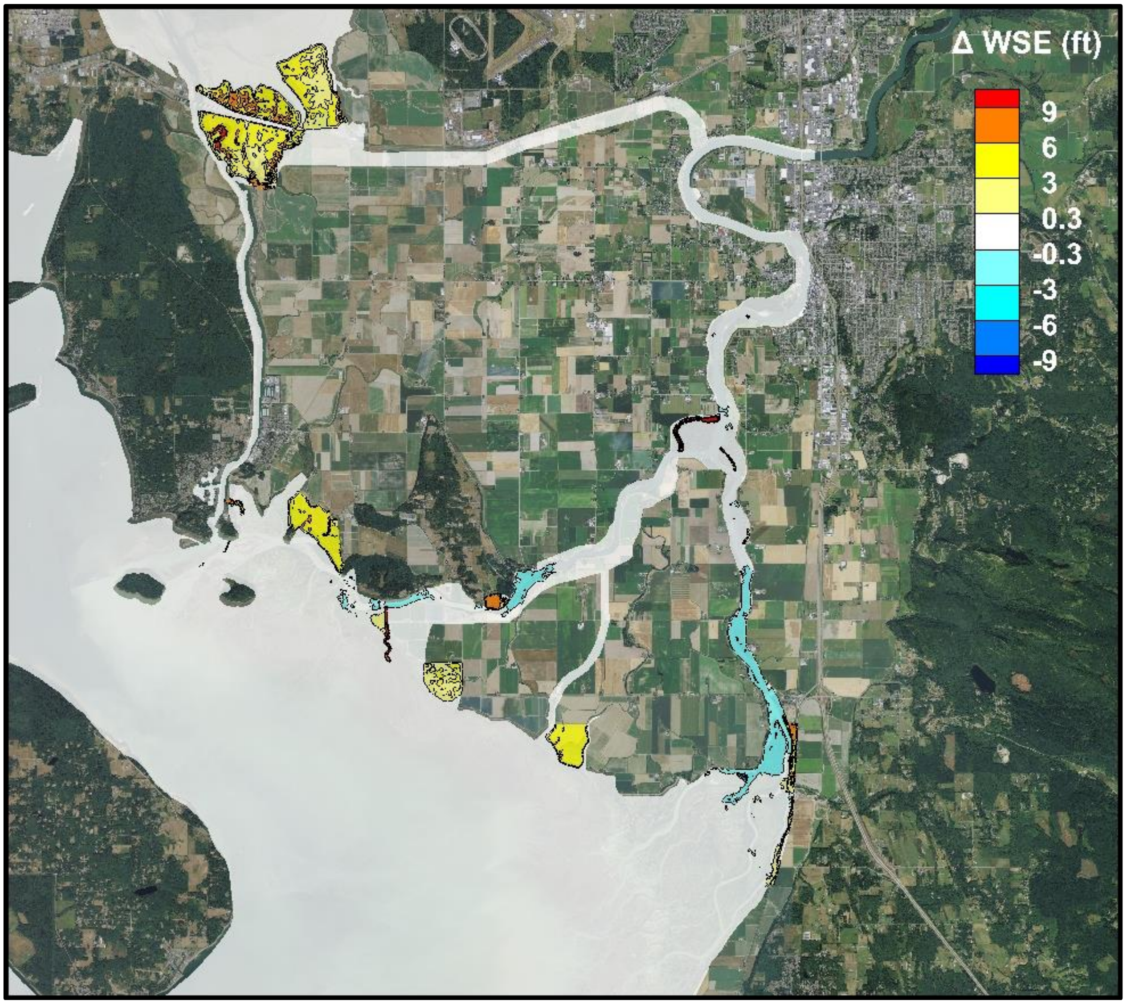


Figure B.39. Contour map of change in WSE from the Baseline to Small Projects simulation with flood flow and high tide.

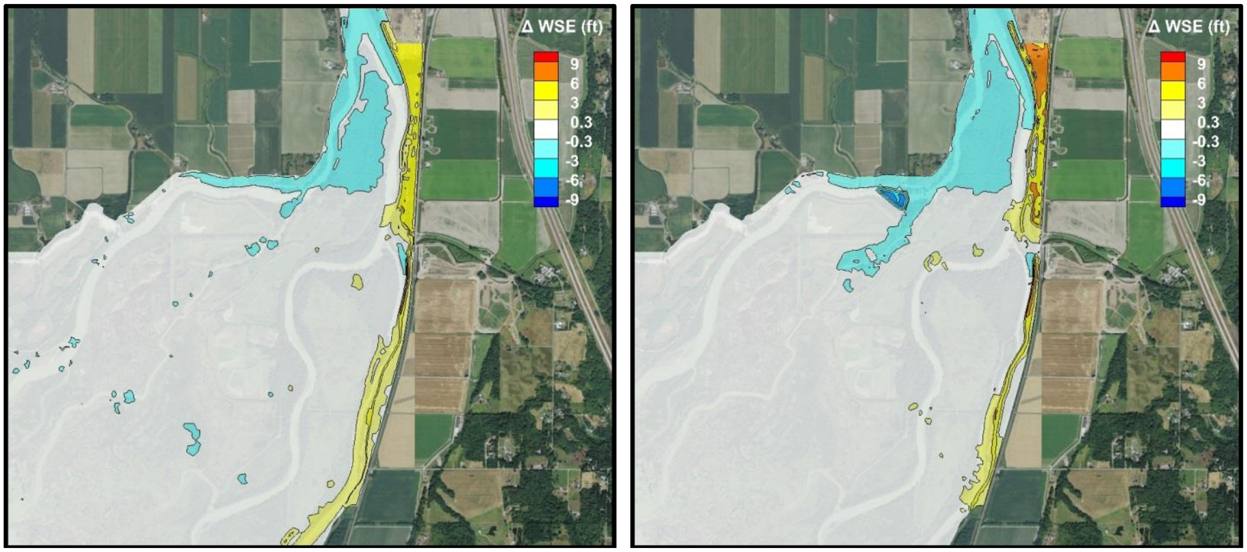


Figure B.40. Contour map of change in WSE from the Baseline to Small Projects simulation for SF Levee Setbacks 2, 3, and 4 with Q2 flow and low tide (left) and flood flow and high tide (right).

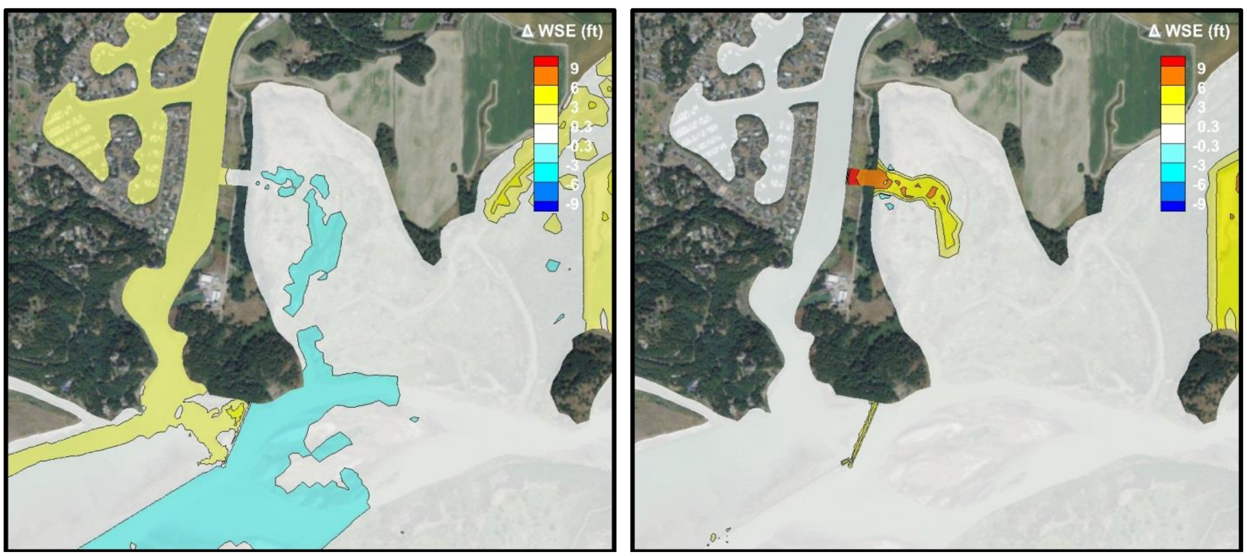


Figure B.41. Contour map of change in WSE from the Baseline to Small Projects simulation for McGlinn Causeway with Q2 flow and low tide (left) and flood flow and high tide (right).

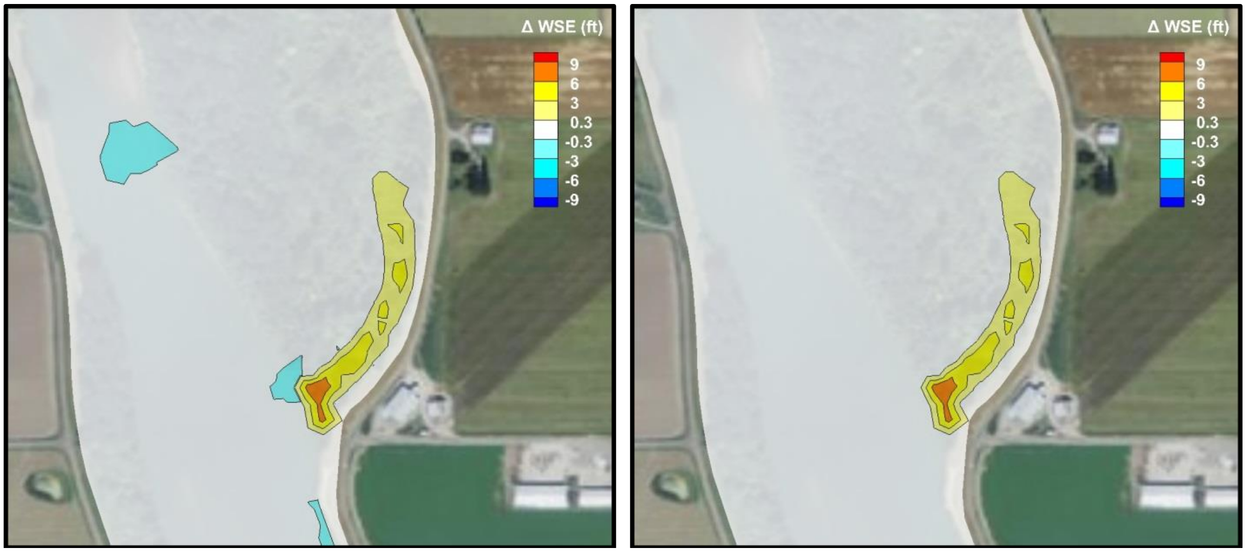


Figure B.42. Contour map of change in WSE from the Baseline to Small Projects simulation for TNC South Fork with Q2 flow and low tide (left) and flood flow and high tide (right).

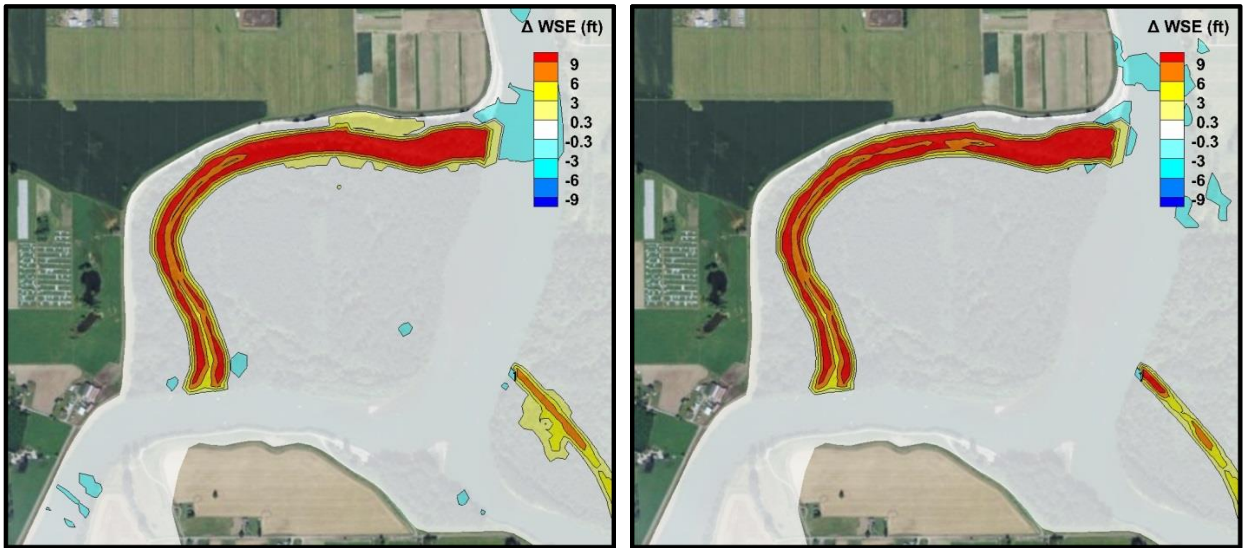


Figure B.43. Contour map of change in WSE from the Baseline to Small Projects simulation for Cottonwood Island with Q2 flow and low tide (left) and flood flow and high tide (right).

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).

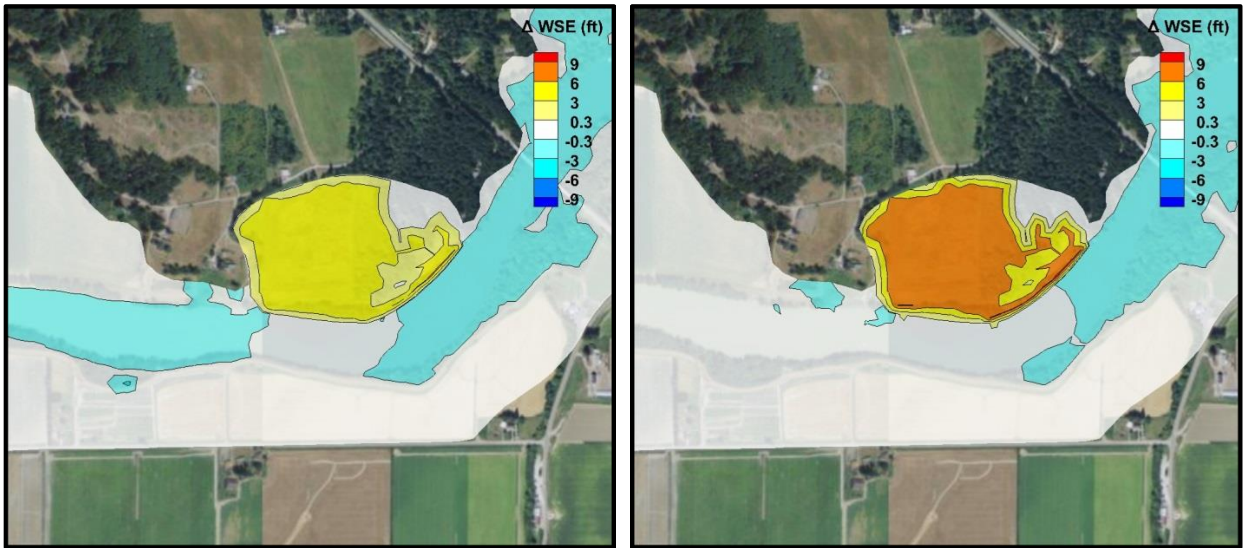


Figure B.45. Contour map of change in WSE from the Baseline to Small Projects simulation for Pleasant Ridge South with Q2 flow and low tide (left) and flood flow and high tide (right).

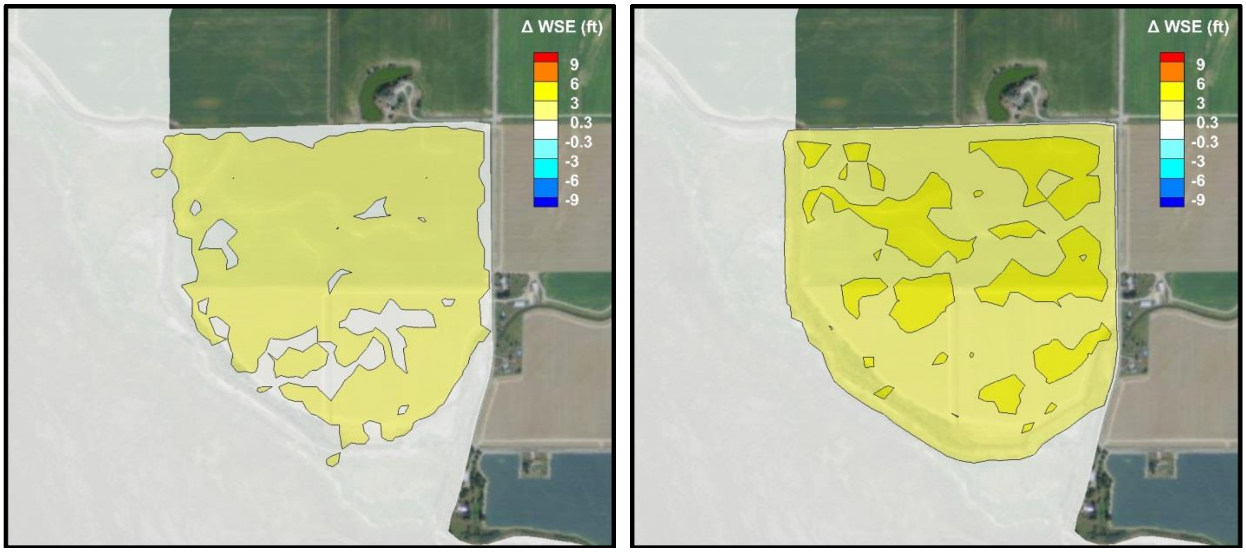


Figure B.46. Contour map of change in WSE from the Baseline to Small Projects simulation for Hall Slough with Q2 flow and low tide (left) and flood flow and high tide (right).

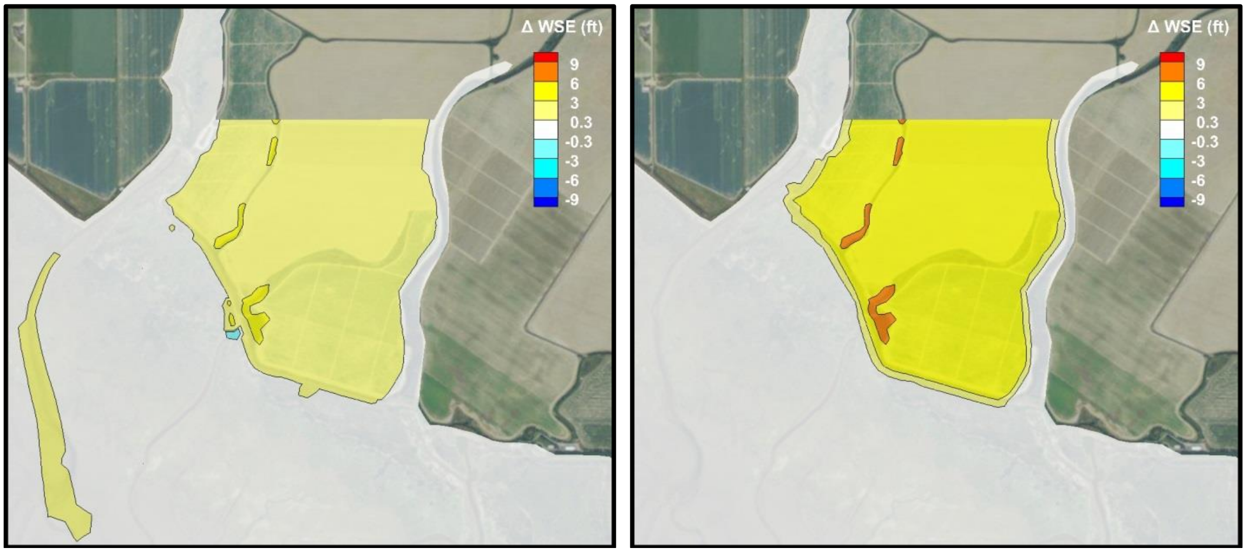


Figure B.47. Contour map of change in WSE from the Baseline to Small Projects simulation for Fir Island Farm with Q2 flow and low tide (left) and flood flow and high tide (right).

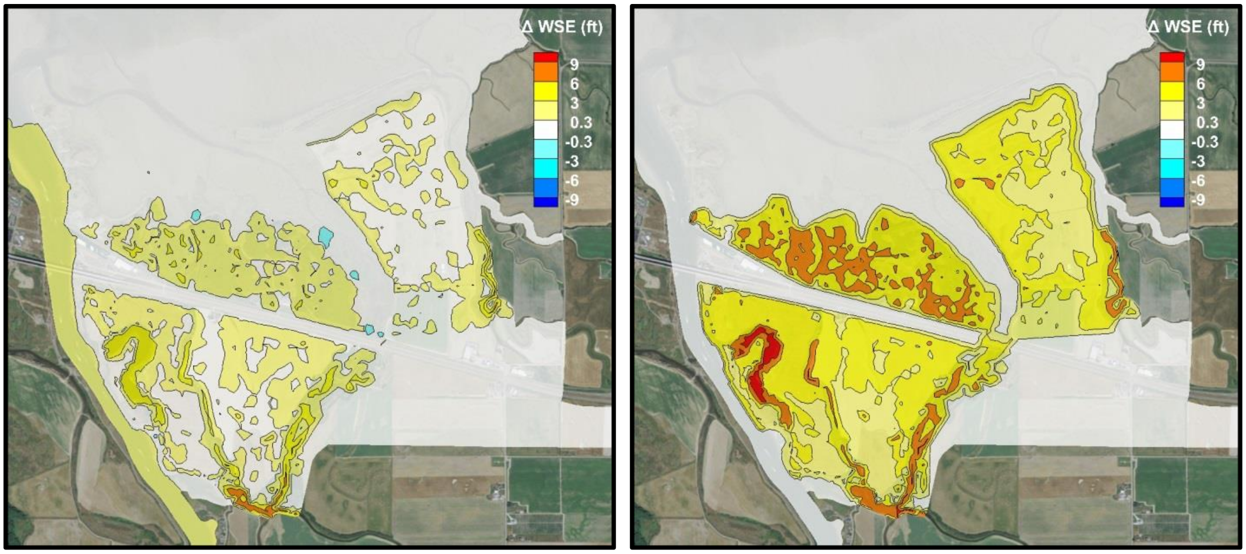


Figure B.48. Contour map of change in WSE from the Baseline to Small Projects simulation for Telegraph Slough Full with Q2 flow and low tide (left) and flood flow and high tide (right).

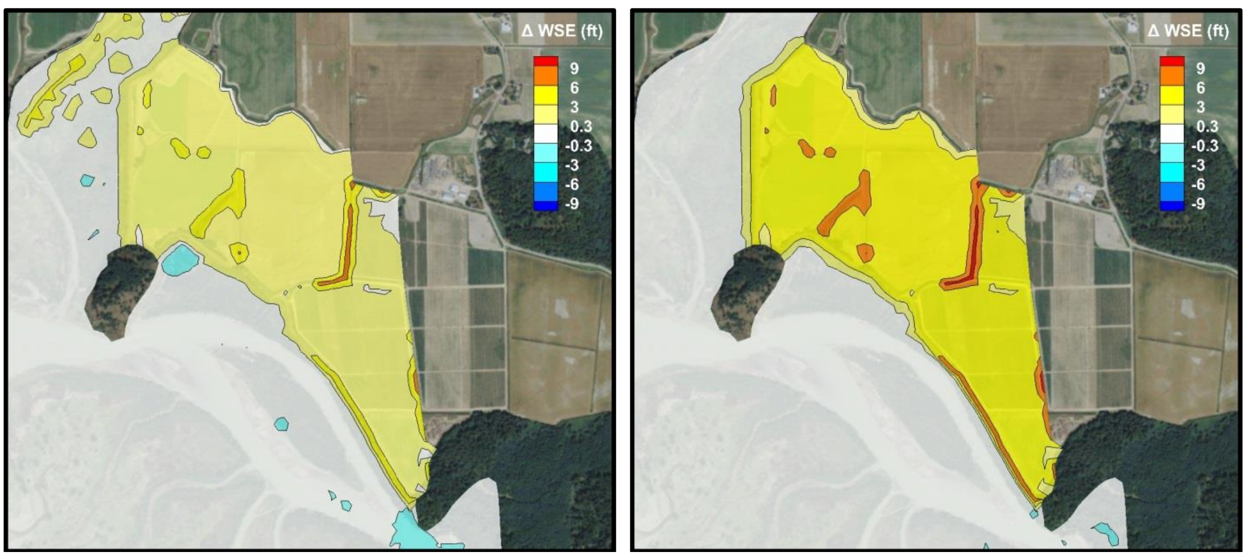


Figure B.49. Contour map of change in WSE from the Baseline to Small Projects simulation for Sullivan Hacienda with Q2 flow and low tide (left) and flood flow and high tide (right).

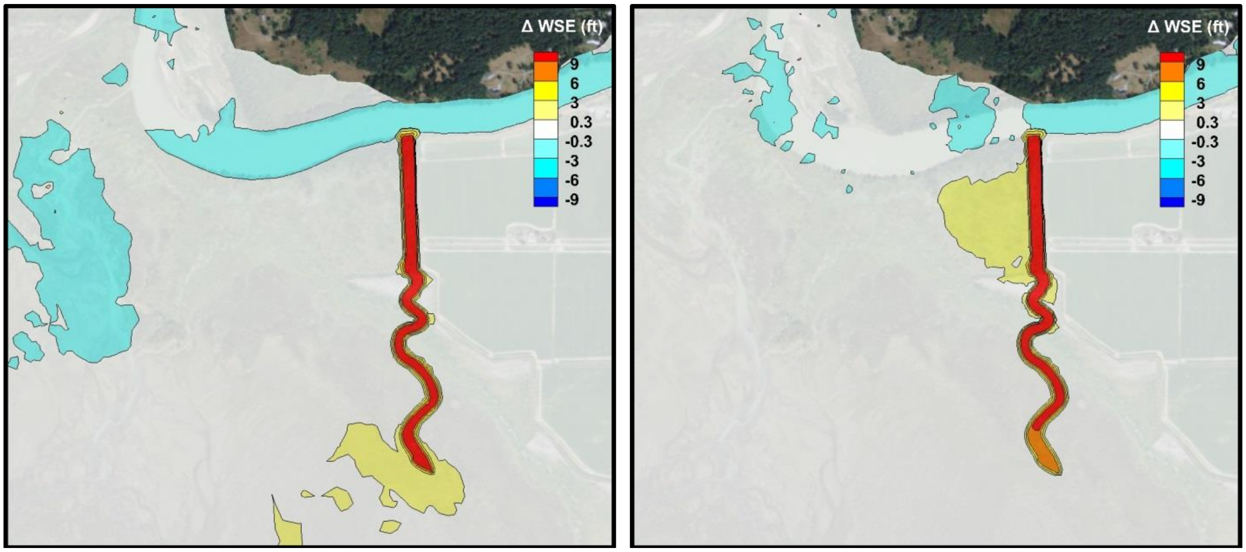


Figure B.50. Contour map of change in WSE from the Baseline to Small Projects simulation for Rawlins Road Distributary Channel with Q2 flow and low tide (left) and flood flow and high tide (right).

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.

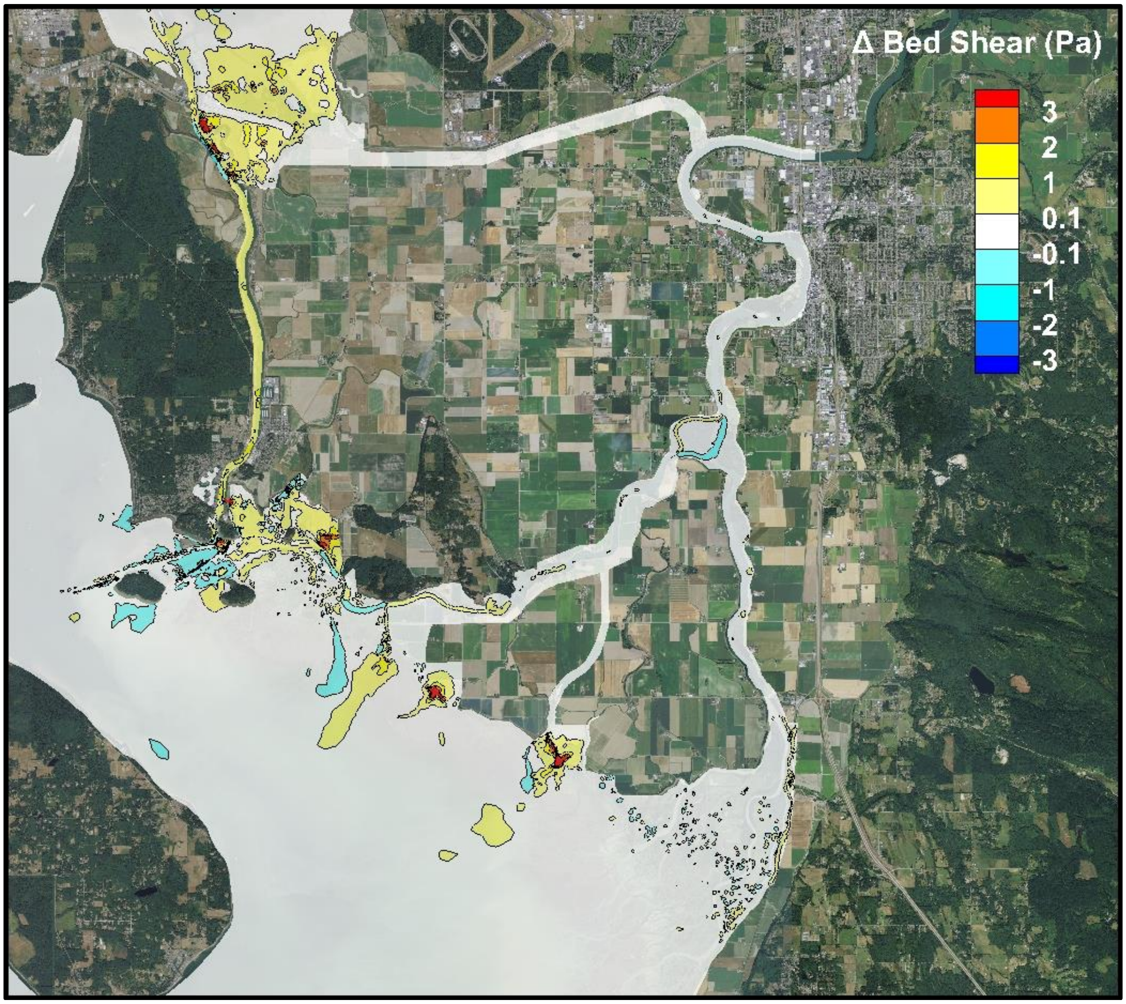


Figure B.51. Contour map of change in shear stress from the Baseline to Small Projects simulation with peak shear across a full tidal cycle at low flow.

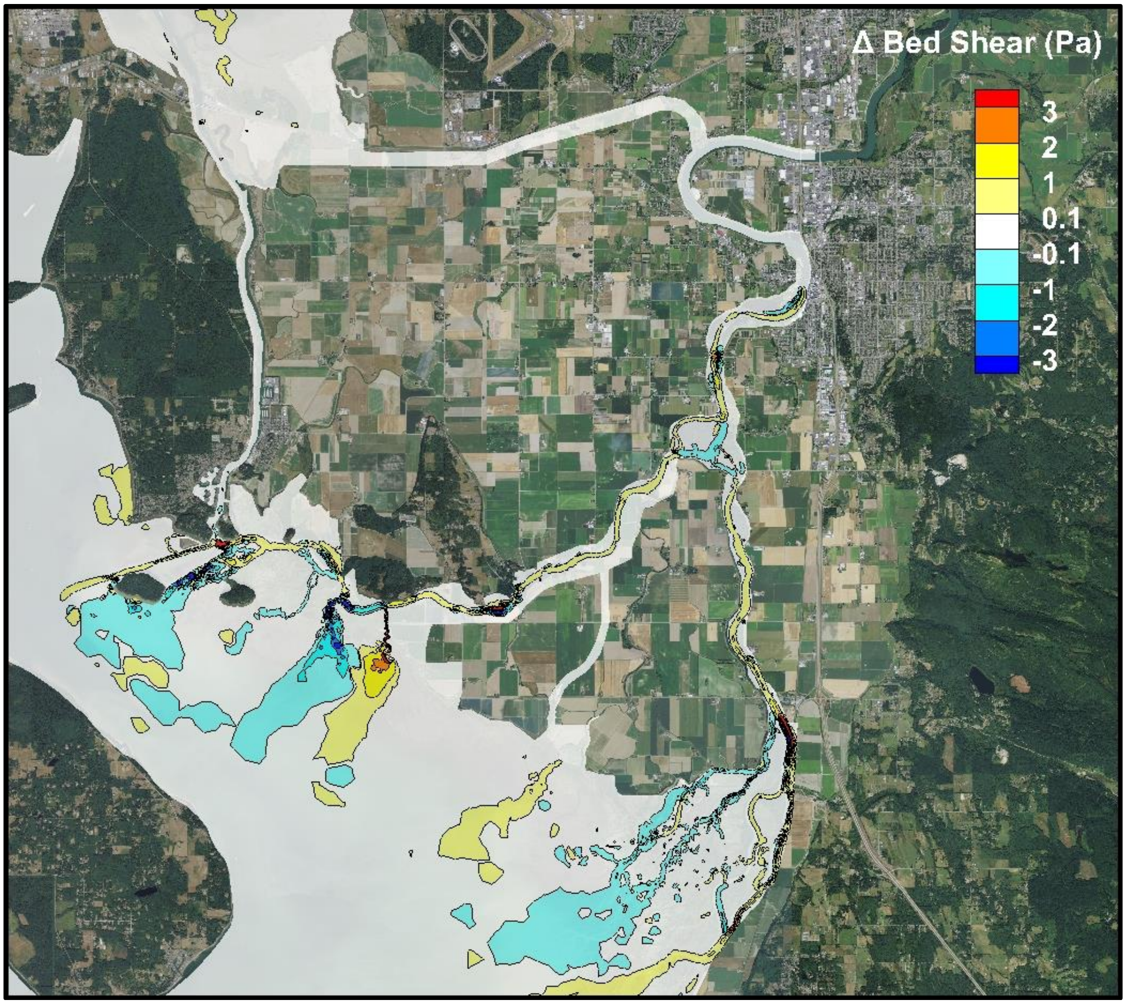


Figure B.52. Contour map of change in shear stress from the Baseline to Small Projects simulation with Q2 flow and low tide.

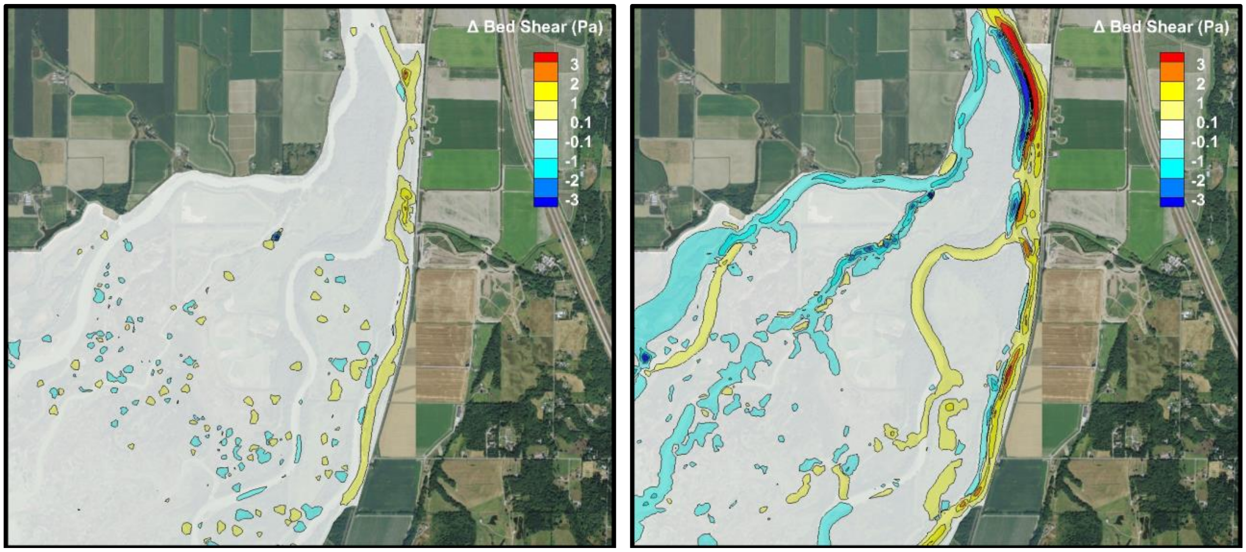


Figure B.53. Contour map of change in shear stress from the Baseline to Small Projects simulation for SF Levee Setbacks 2, 3, and 4 with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

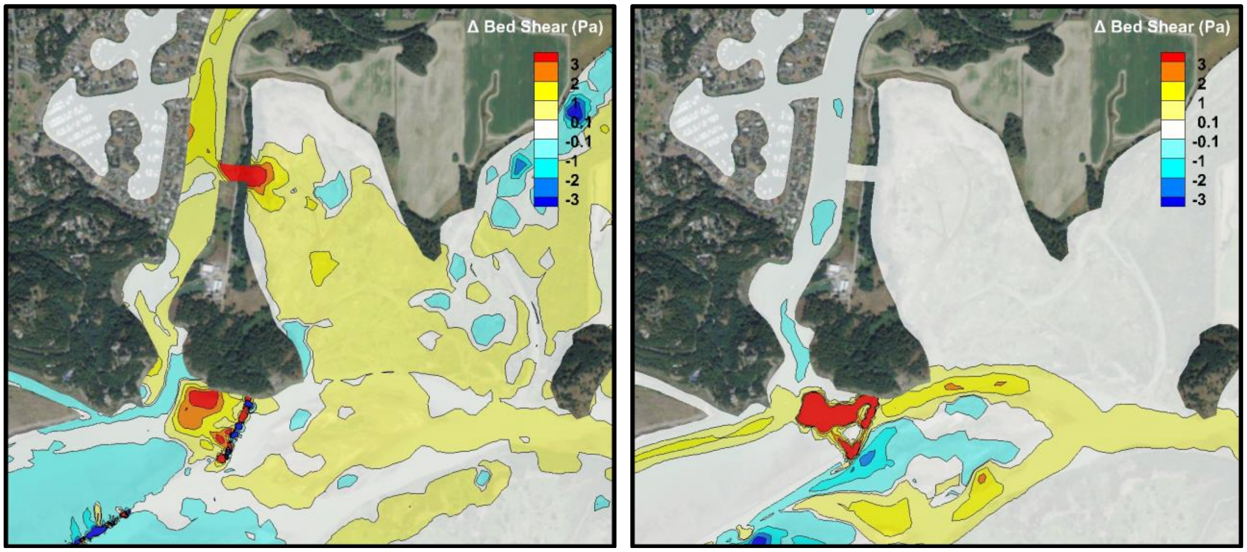


Figure B.54. Contour map of change in shear stress from the Baseline to Small Projects simulation for McGlinn Causeway with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

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).

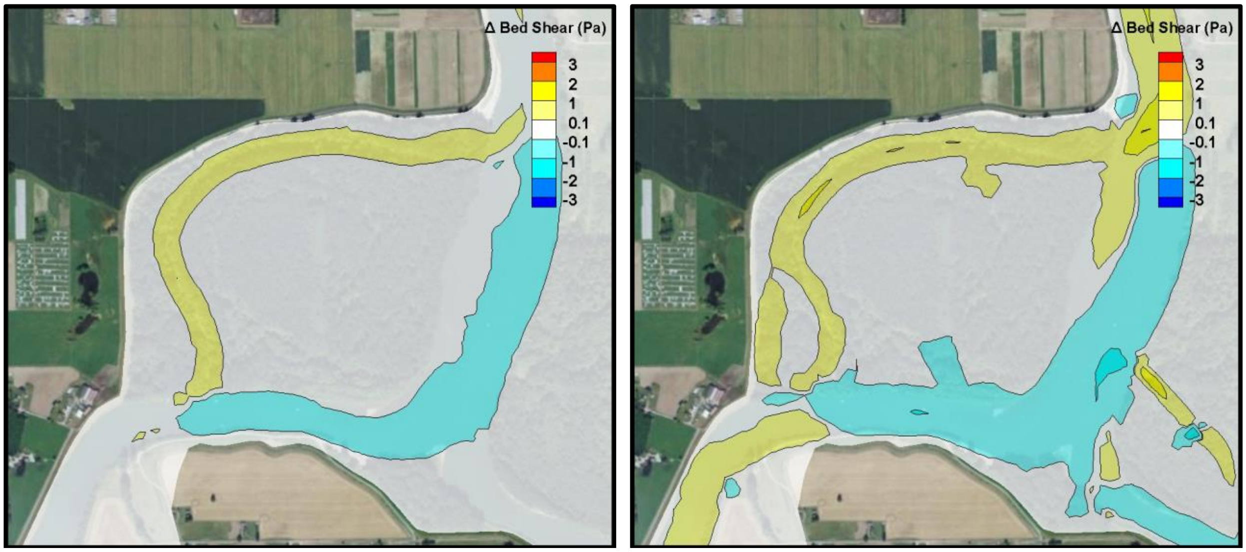


Figure B.56. Contour map of change in shear stress from the Baseline to Small Projects simulation for Cottonwood Island with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

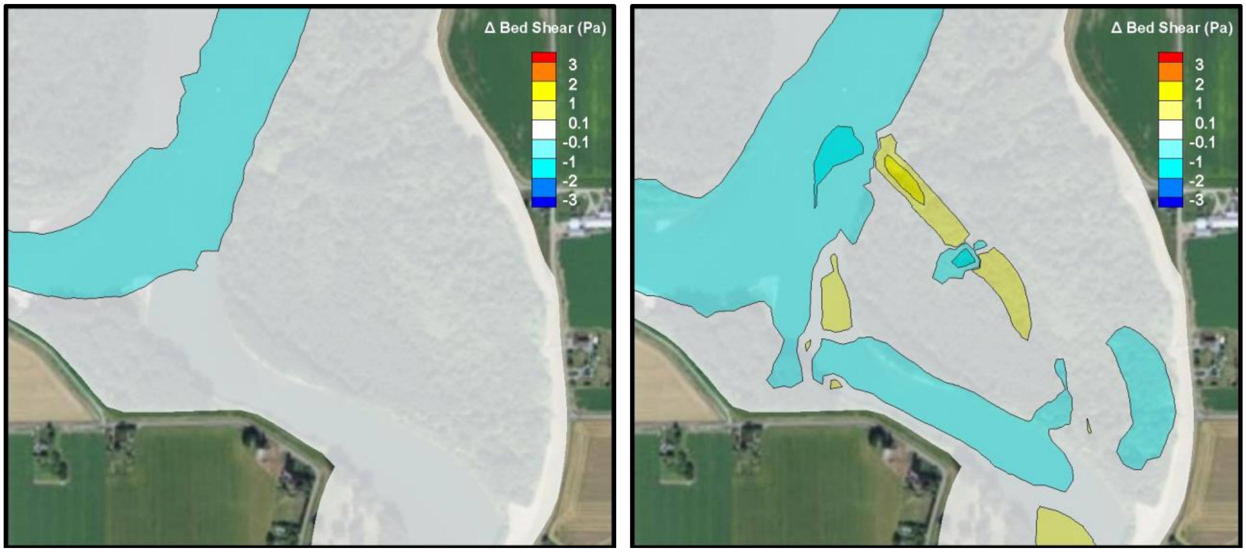


Figure B.57. Contour map of change in shear stress from the Baseline to Small Projects simulation for East Cottonwood with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

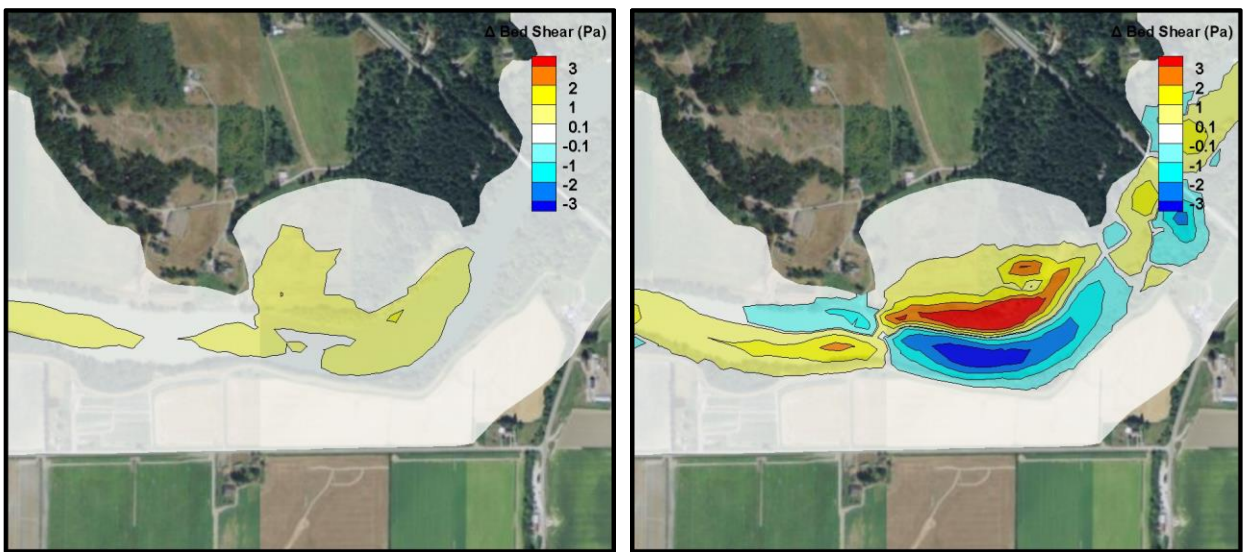


Figure B.58. Contour map of change in shear stress from the Baseline to Small Projects simulation for Pleasant Ridge South with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

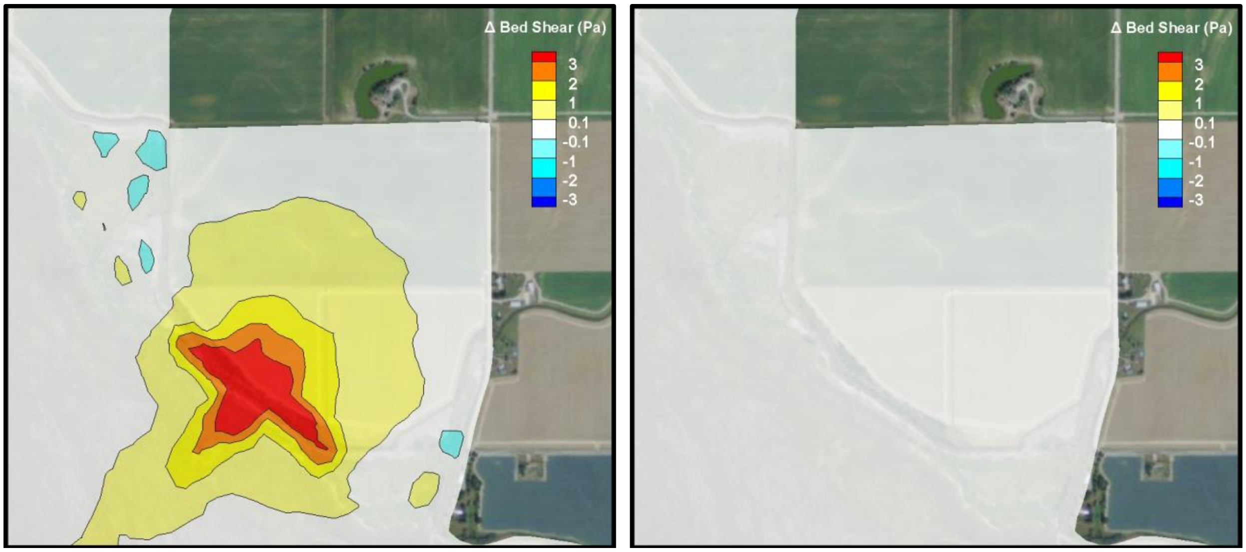


Figure B.59. Contour map of change in shear stress from the Baseline to Small Projects simulation for Hall Slough with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

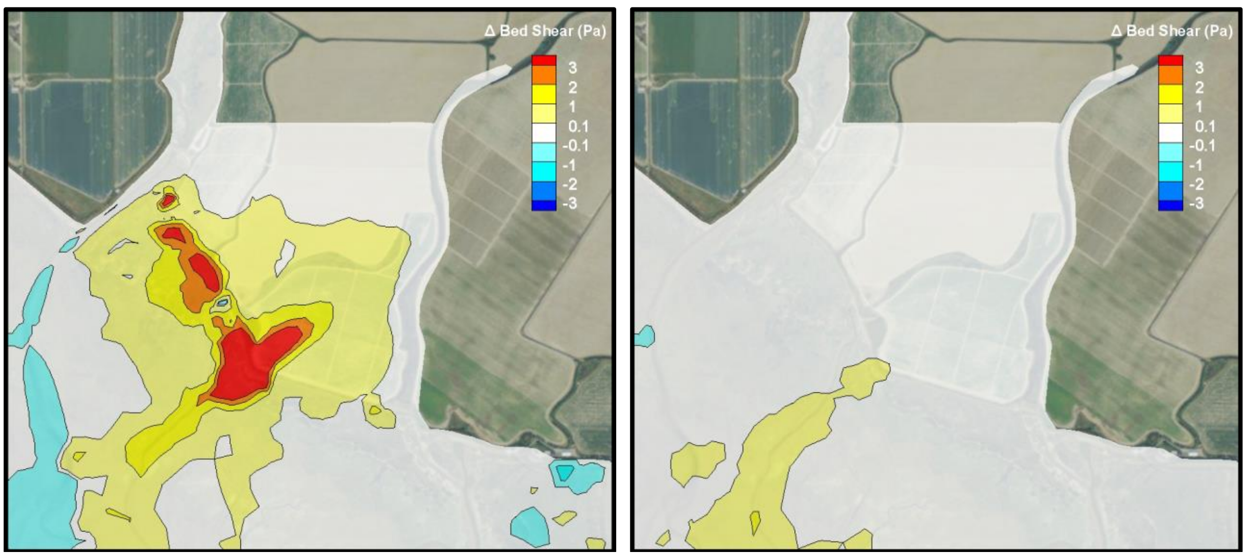


Figure B.60. Contour map of change in shear stress from the Baseline to Small Projects simulation for Fir Island Farm with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

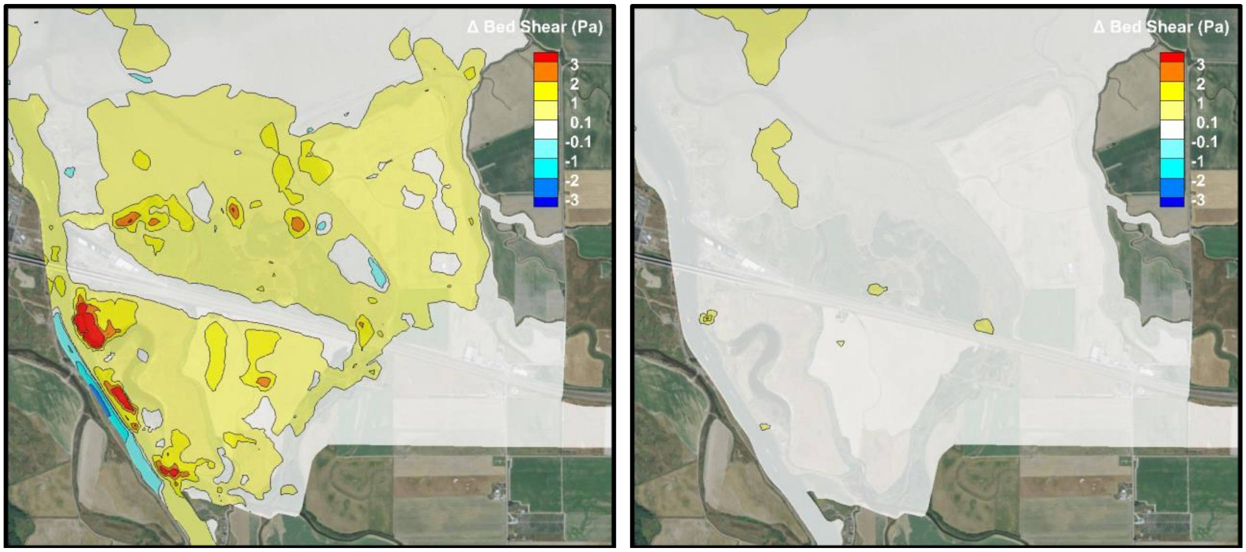


Figure B.61. Contour map of change in shear stress from the Baseline to Small Projects simulation for Fir Island Farm with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

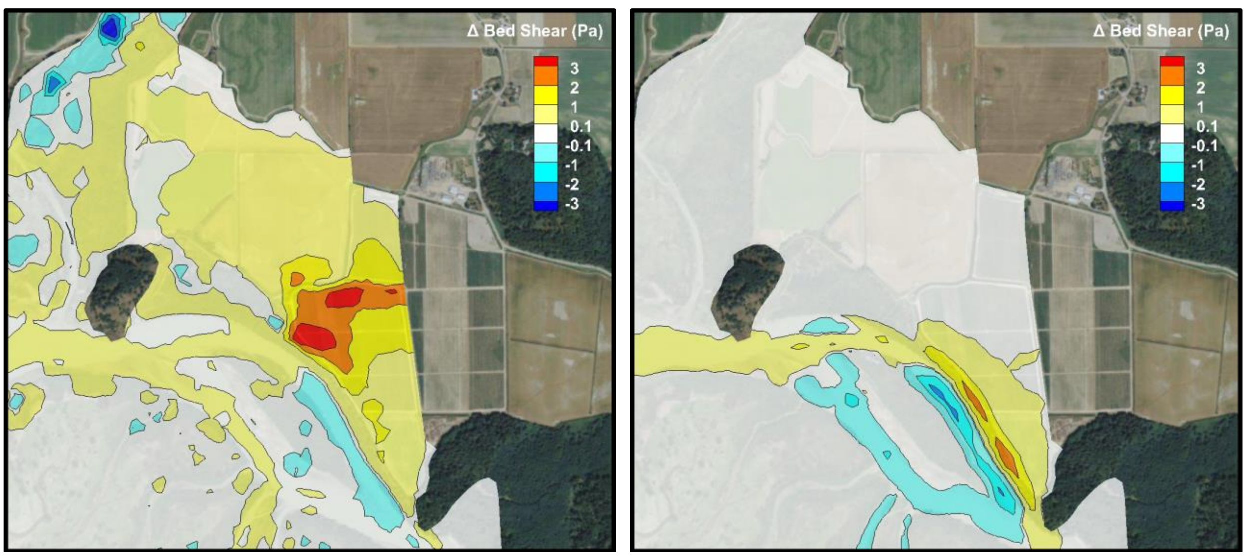


Figure B.62. Contour map of change in shear stress from the Baseline to Small Projects simulation for Sullivan Hacienda with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

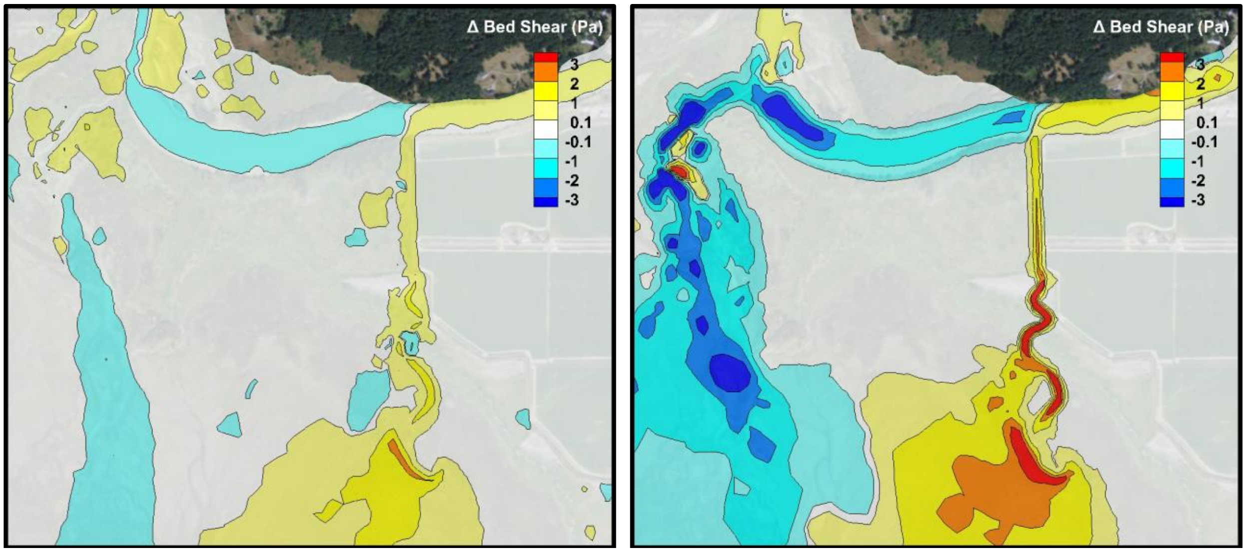


Figure B.63. Contour map of change in shear stress from the Baseline to Small Projects simulation for Rawlins Road Distributary Channel with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

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.

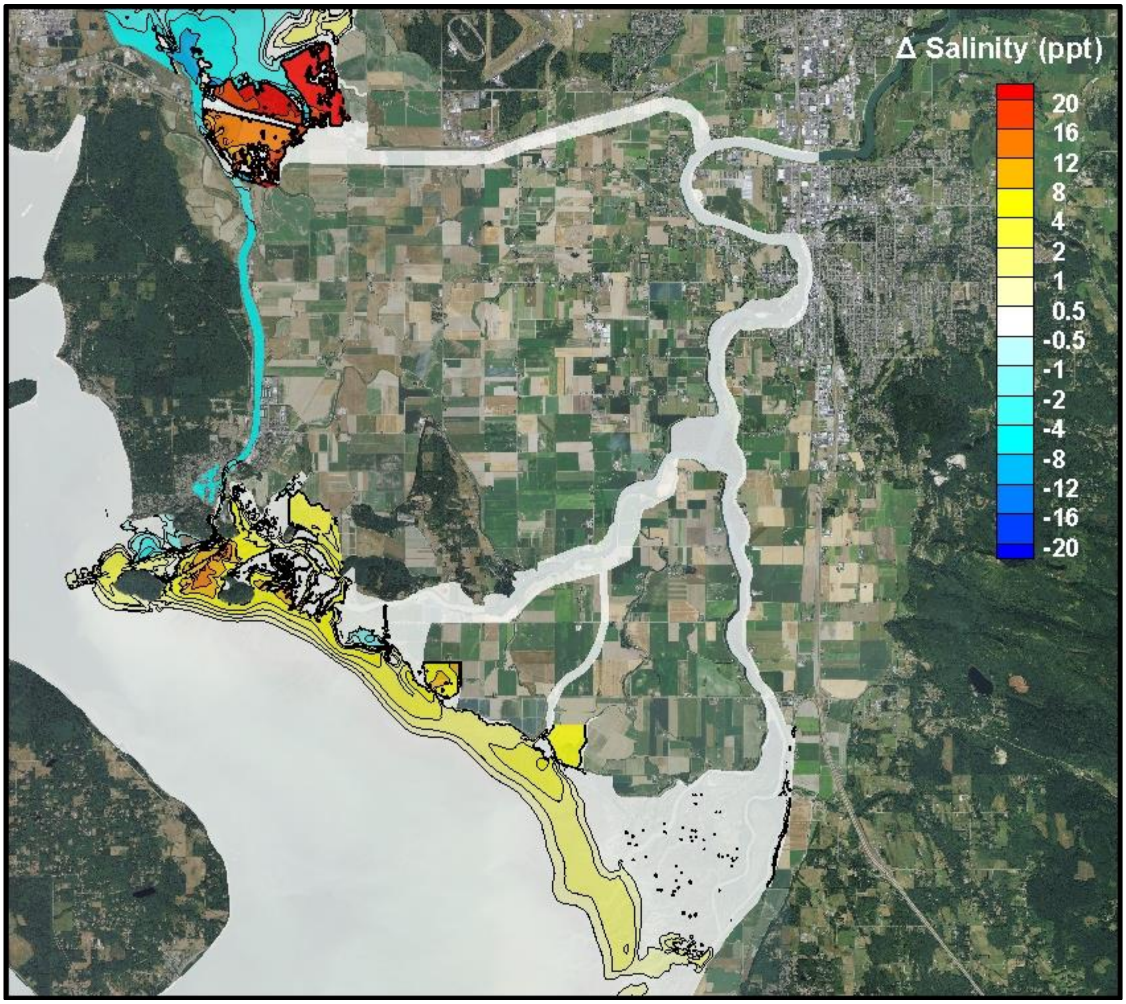


Figure B.64. Contour map of change in salinity from the Baseline to Small Projects simulation with low flow and high tide.

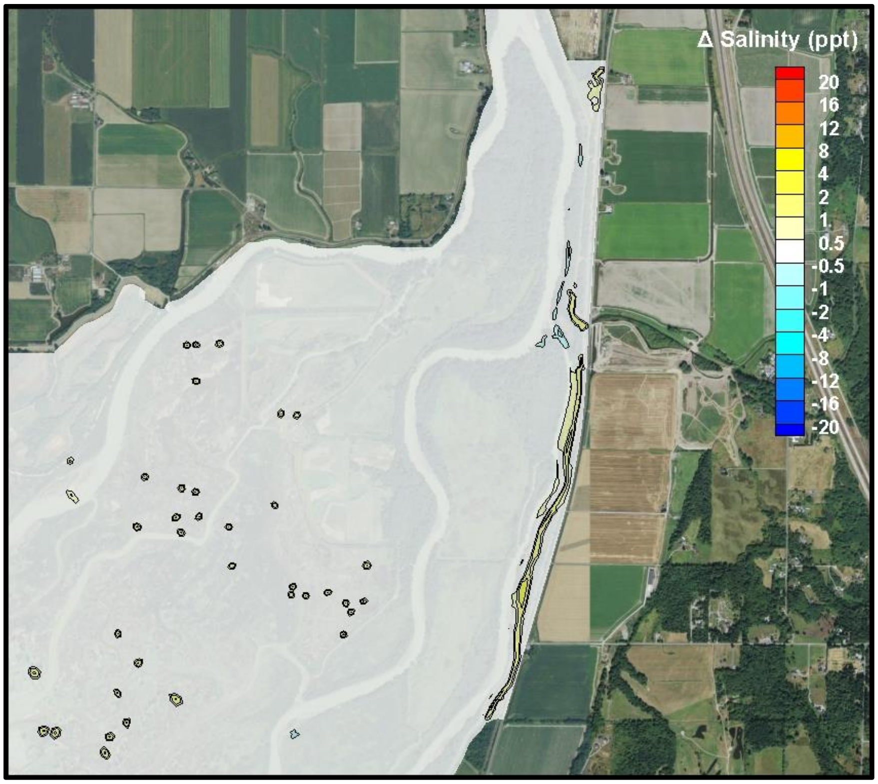


Figure B.65. Contour map of change in salinity from the Baseline to Small Projects simulation for SF Levee Setbacks 2, 3, and 4 with low flow and high tide.

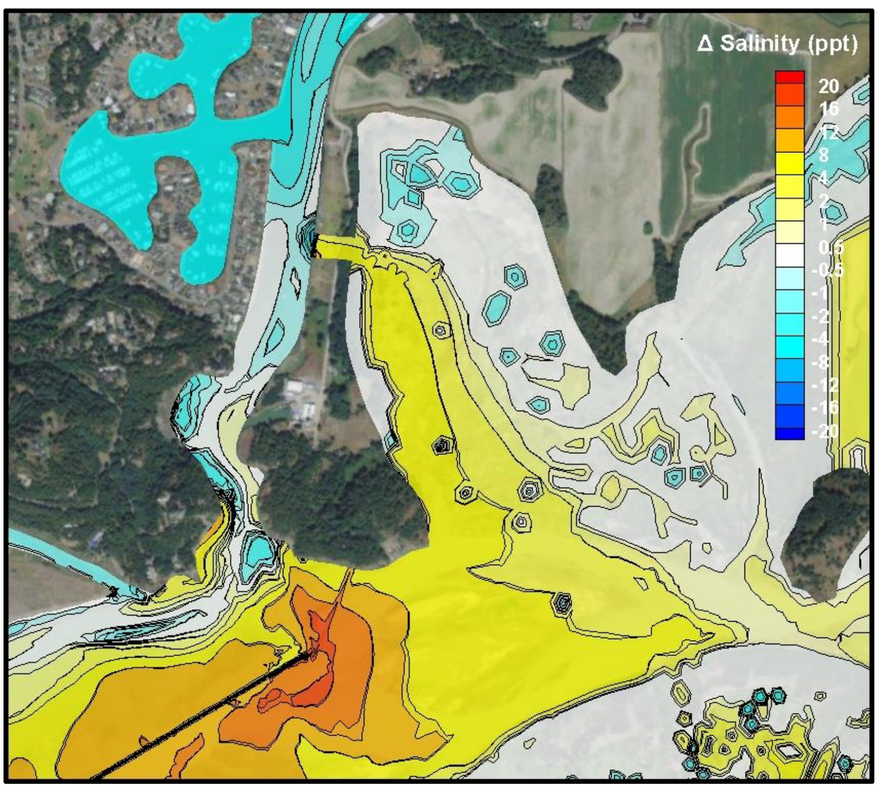


Figure B.66. Contour map of change in salinity from the Baseline to Small Projects simulation for McGlinn Causeway with low flow and high tide.

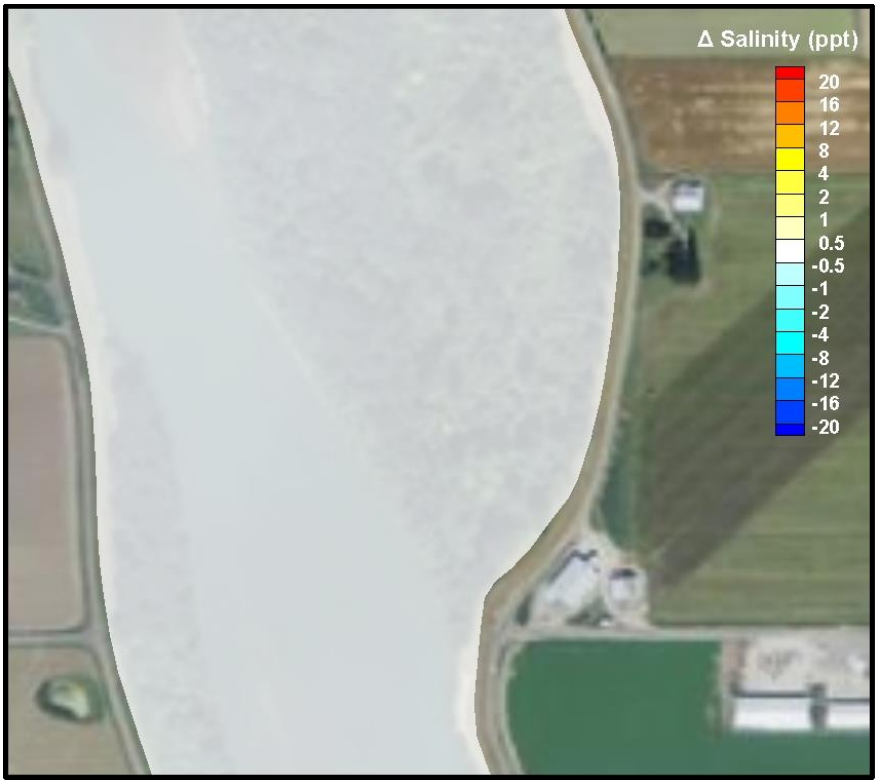


Figure B.67. Contour map of change in salinity from the Baseline to Small Projects simulation for TNC South Fork with low flow and high tide.

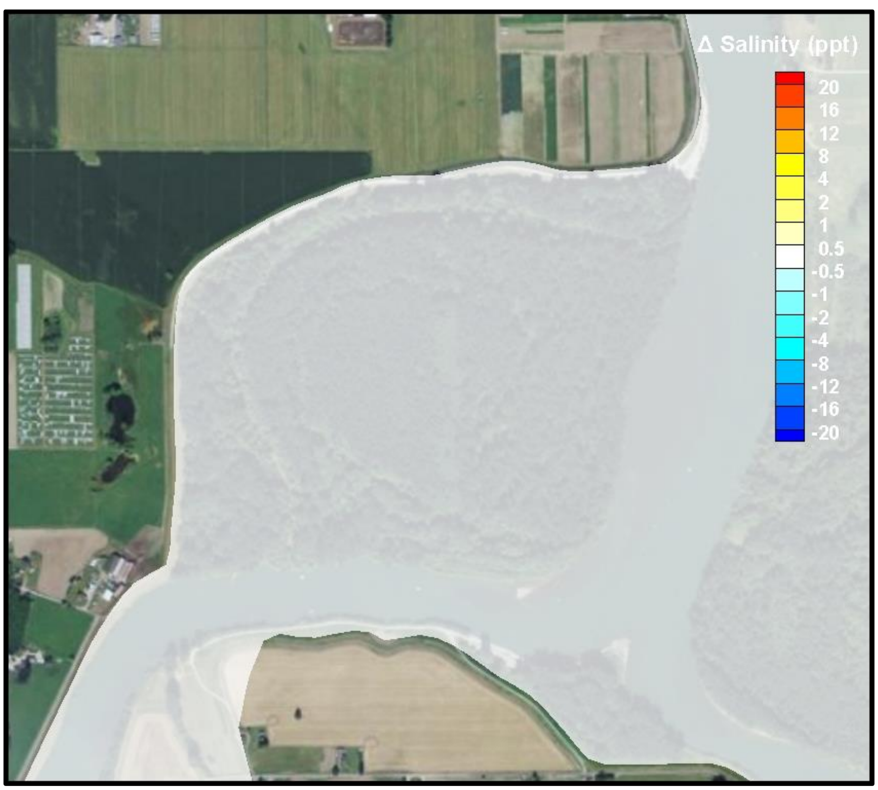


Figure B.68. Contour map of change in salinity from the Baseline to Small Projects simulation for Cottonwood Island with low flow and high tide.

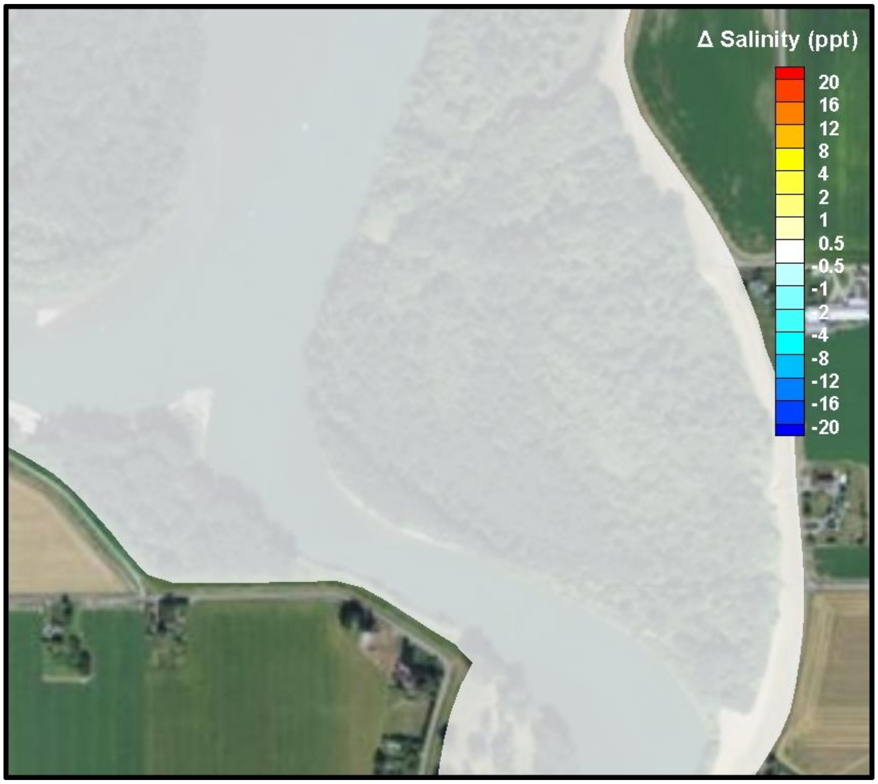


Figure B.69. Contour map of change in salinity from the Baseline to Small Projects simulation for East Cottonwood with low flow and high tide.

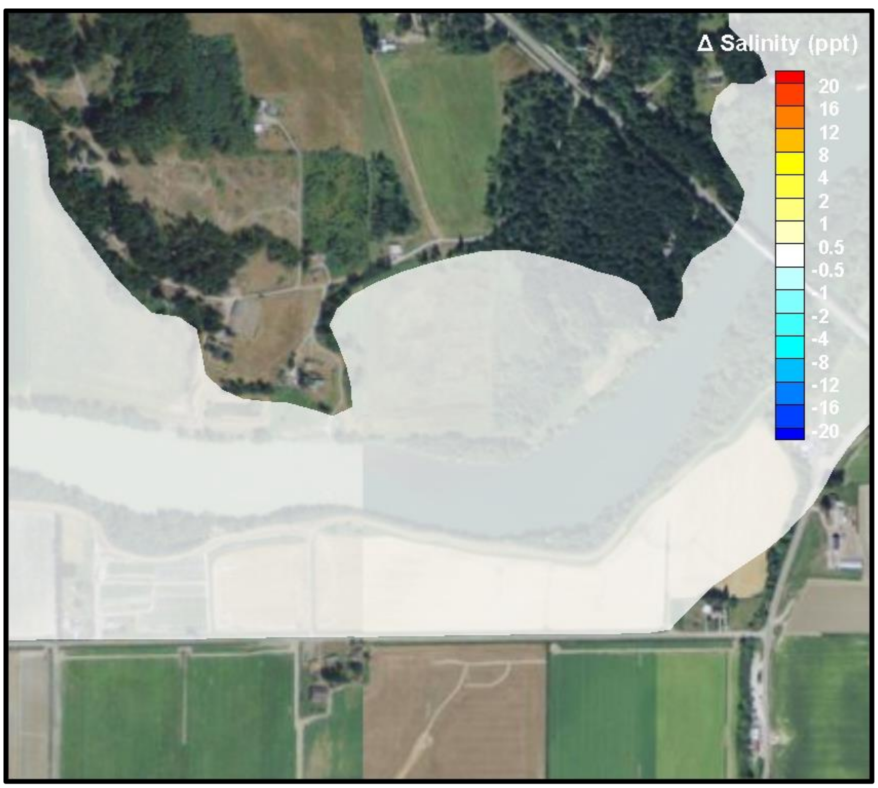


Figure B.70. Contour map of change in salinity from the Baseline to Small Projects simulation for Pleasant Ridge South with low flow and high tide.

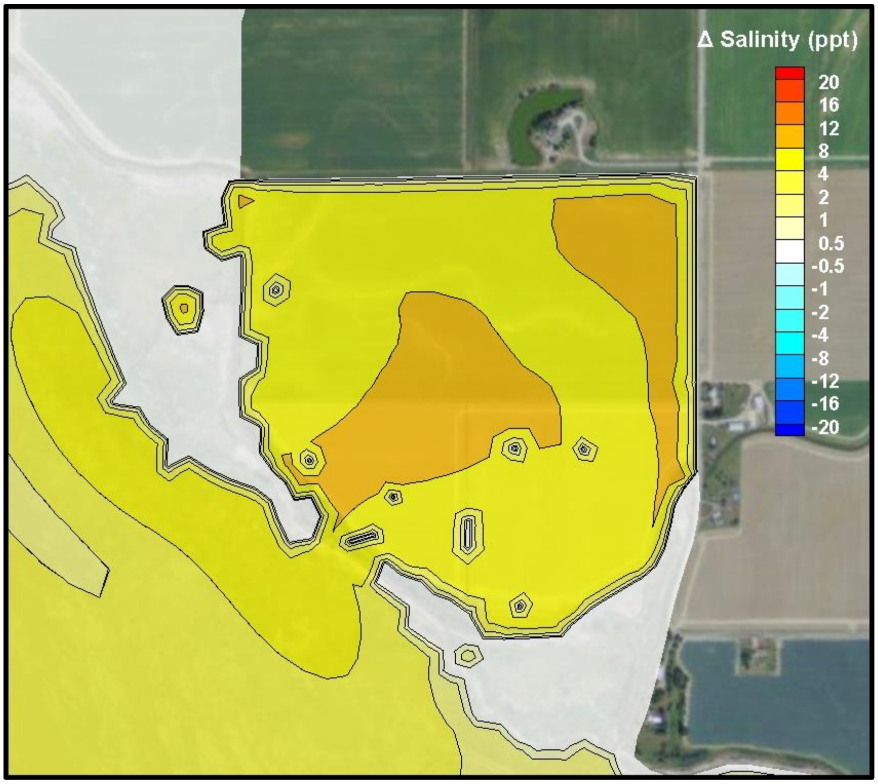


Figure B.71. Contour map of change in salinity from the Baseline to Small Projects simulation for Hall Slough with low flow and high tide.

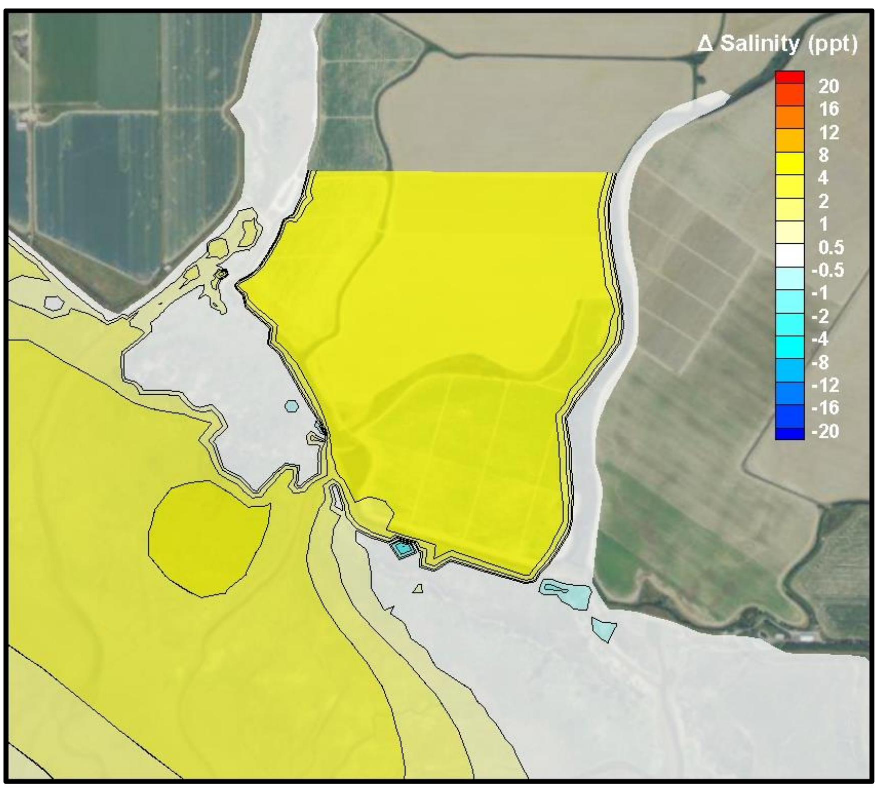


Figure B.72. Contour map of change in salinity from the Baseline to Small Projects simulation for Fir Island Farm with low flow and high tide.

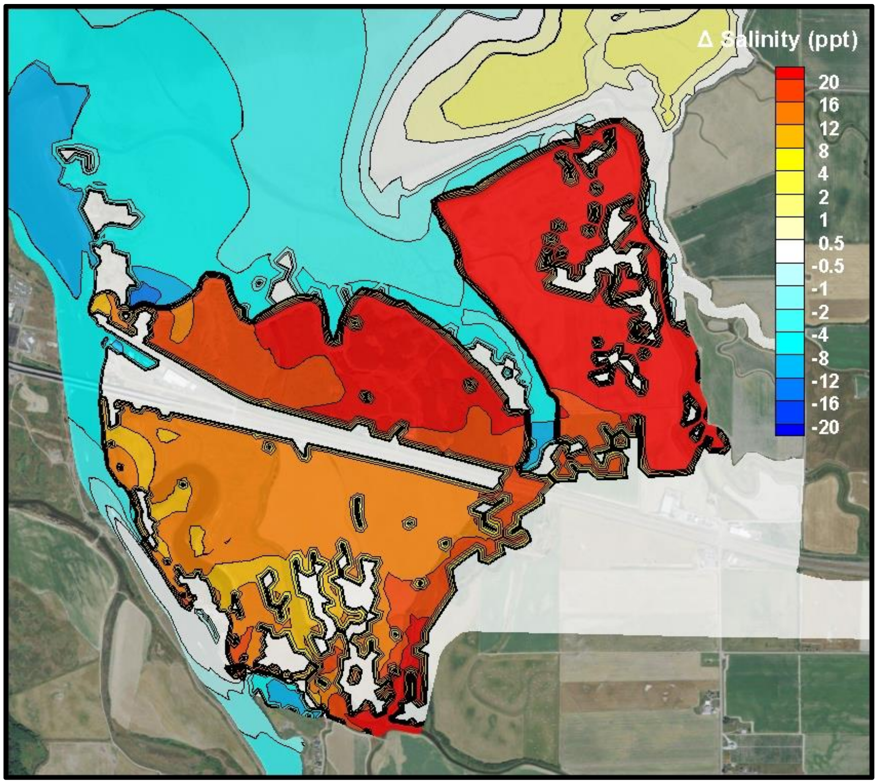


Figure B.73. Contour map of change in salinity from the Baseline to Small Projects simulation for Telegraph Slough Full with low flow and high tide.

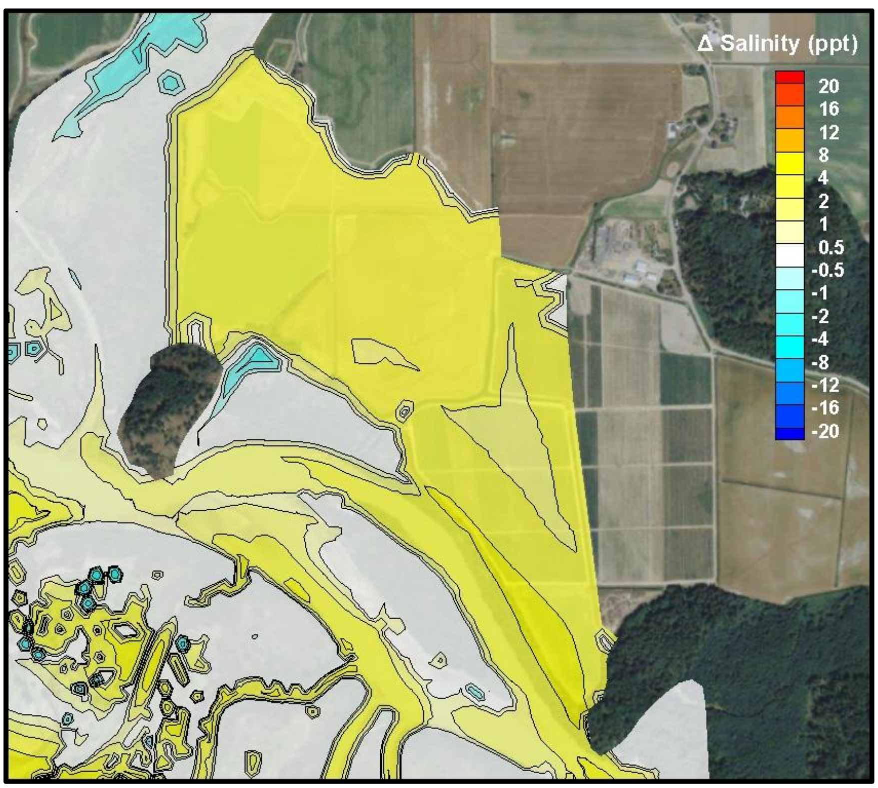


Figure B.74. Contour map of change in salinity from the Baseline to Small Projects simulation for Sullivan Hacienda with low flow and high tide.

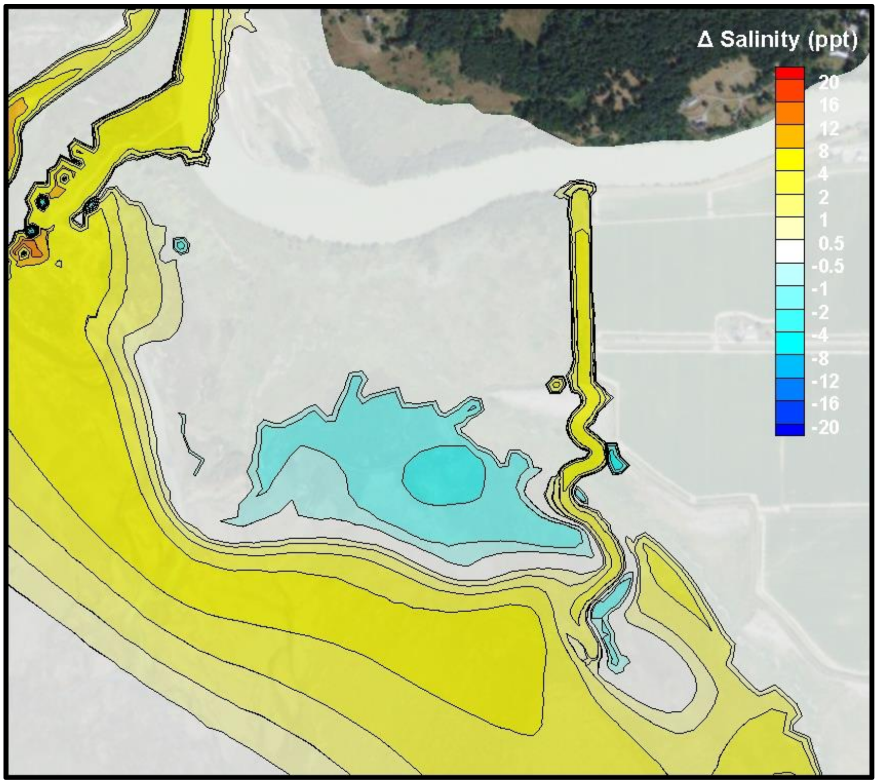


Figure B.75. Contour map of change in salinity from the Baseline to Small Projects simulation for Rawlins Distributary with low flow and high tide.

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.

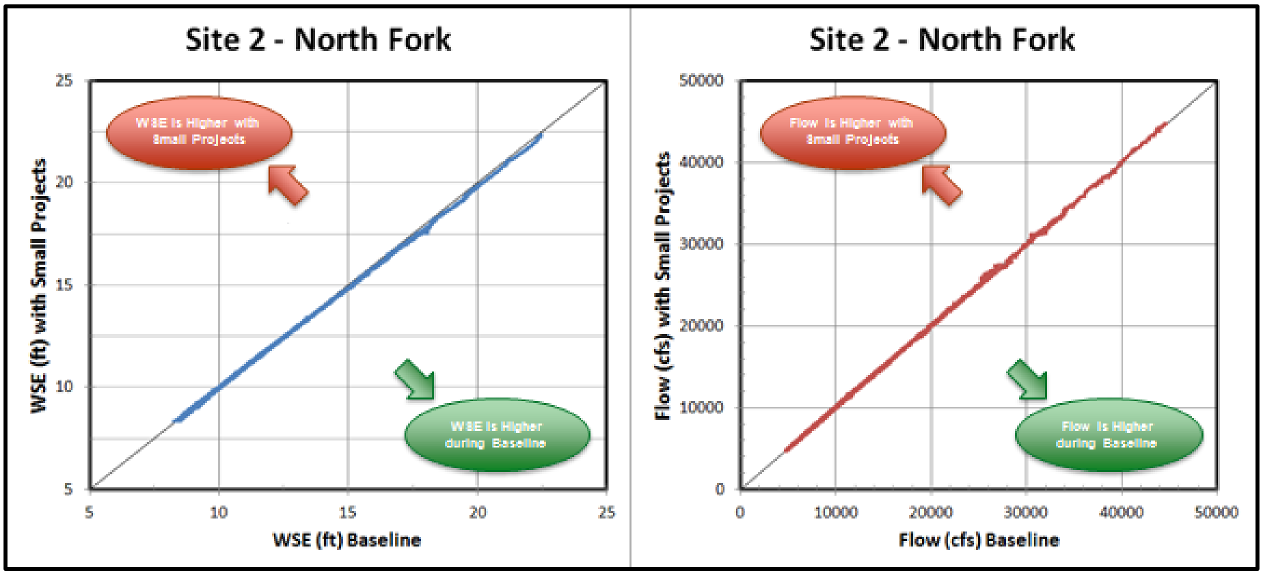


Figure B.76. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Small Projects simulation at the North Fork gauge location compared with the same information under baseline conditions.

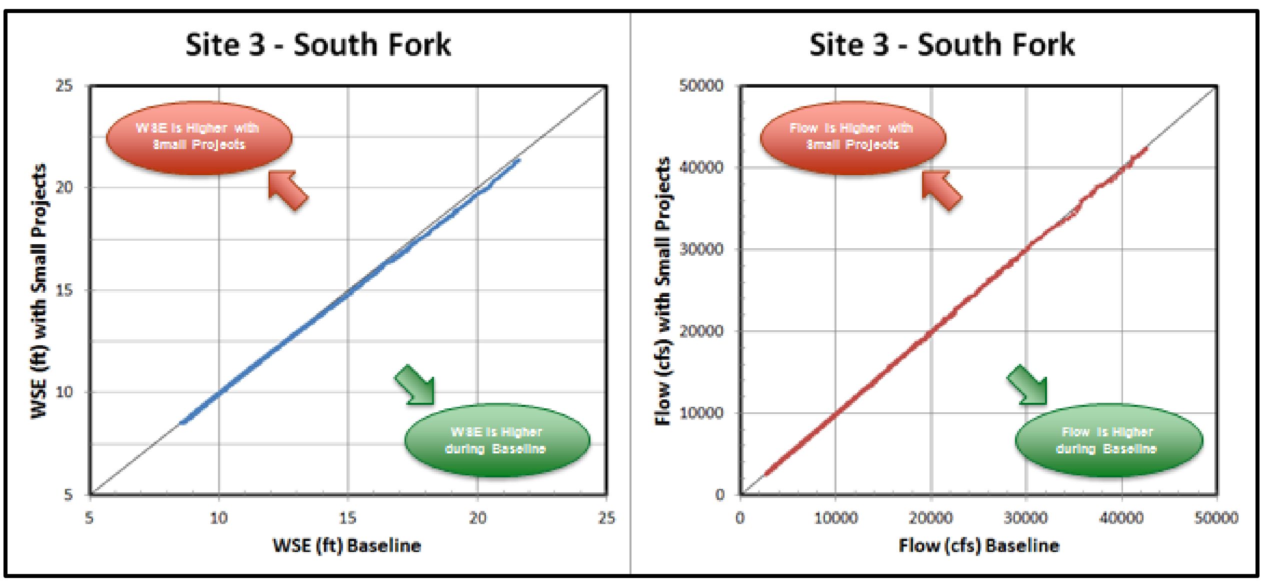


Figure B.77. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Small Projects simulation at the South Fork gauge location compared with the same information under baseline conditions.

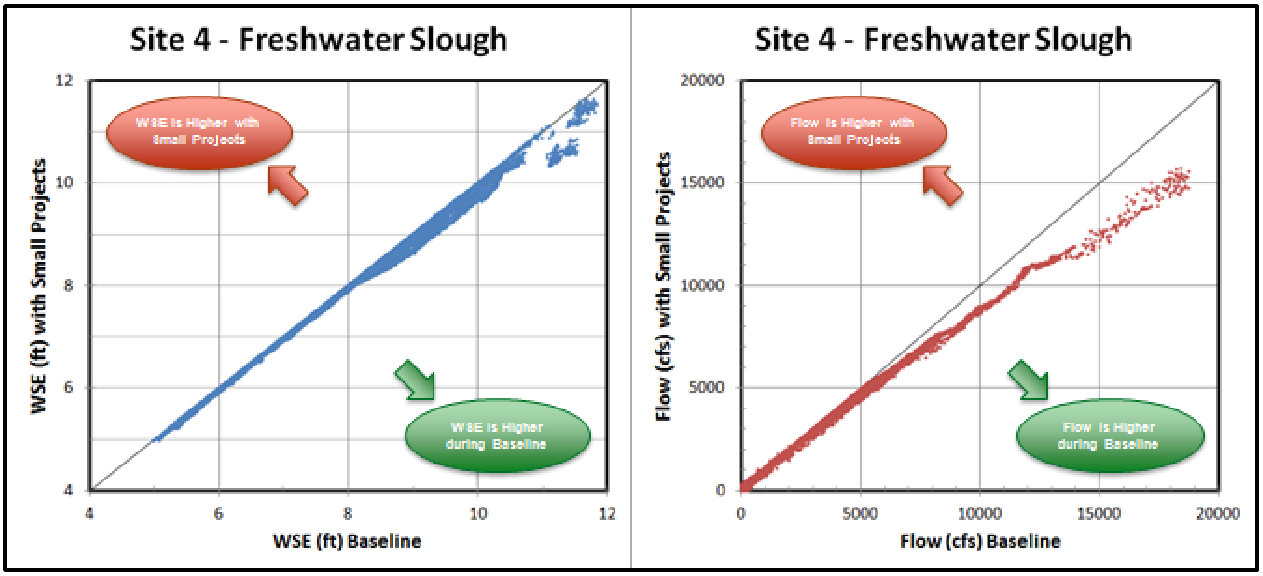


Figure B.78. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Small Projects simulation at the Freshwater Slough gauge location compared with the same information under baseline conditions.

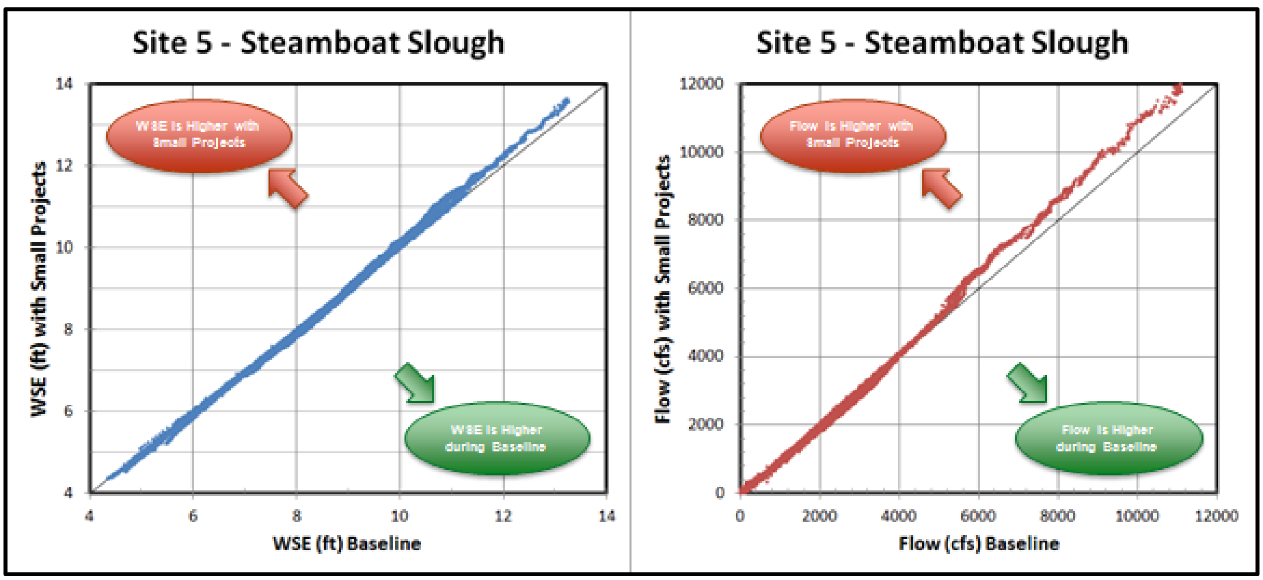


Figure B.79. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Small Projects simulation at the Steamboat Slough gauge location compared with the same information under baseline conditions.

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.

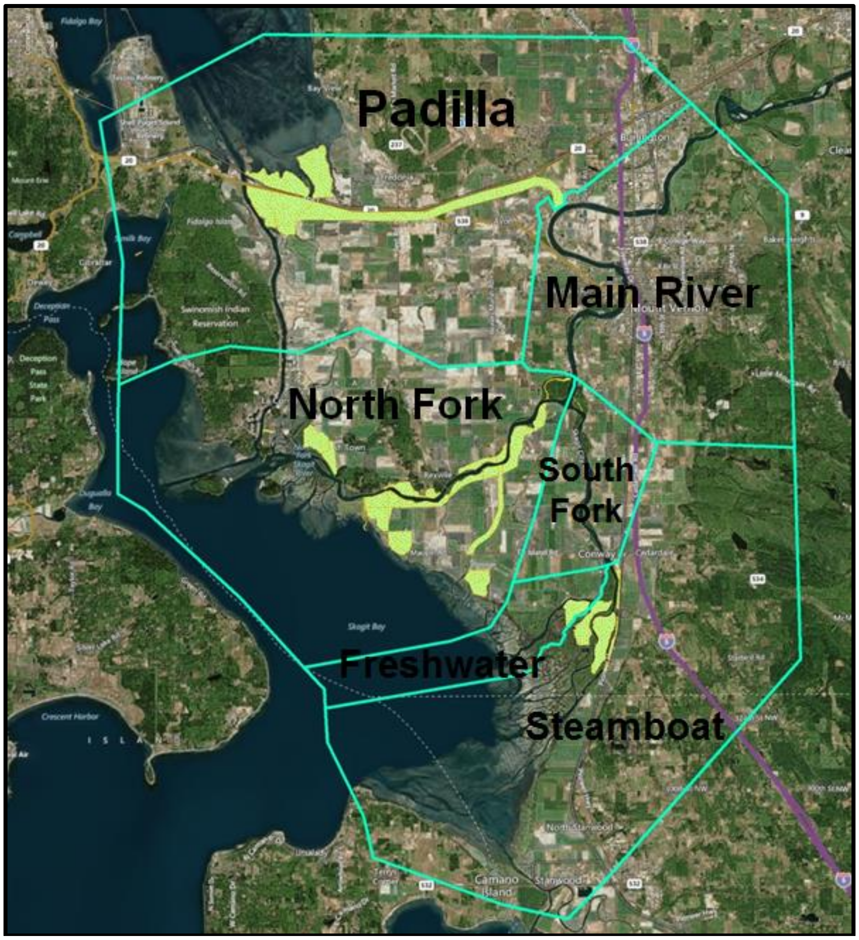


Figure C.2. Sub-basins within the Skagit region used for area calculations.

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.

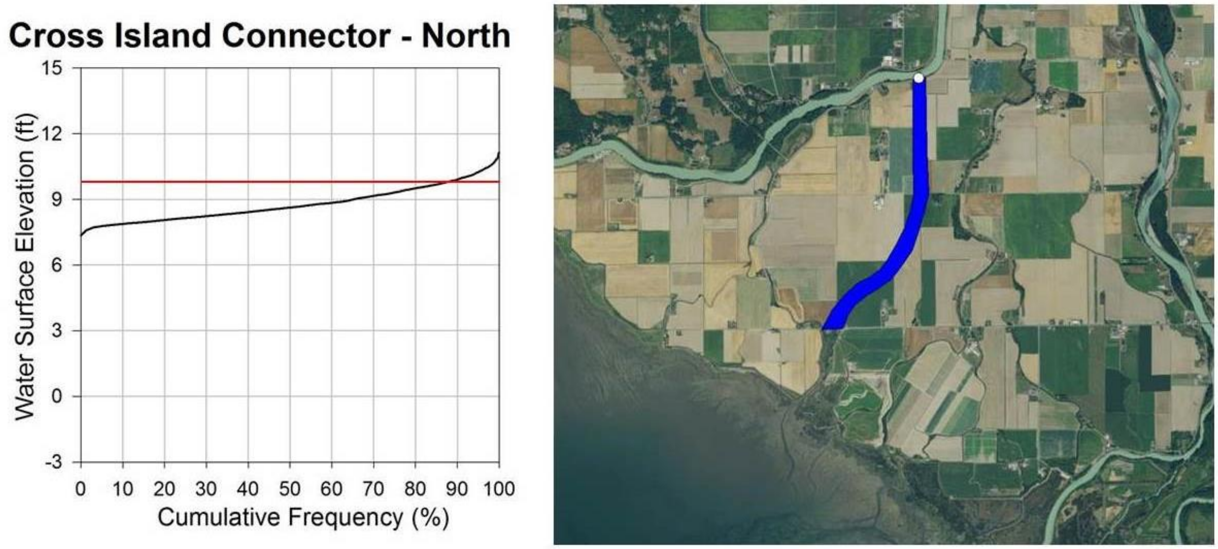


Figure C.3. Cumulative frequency plot and corresponding map for Cross Island Connector (north) during the Major Hydraulic Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

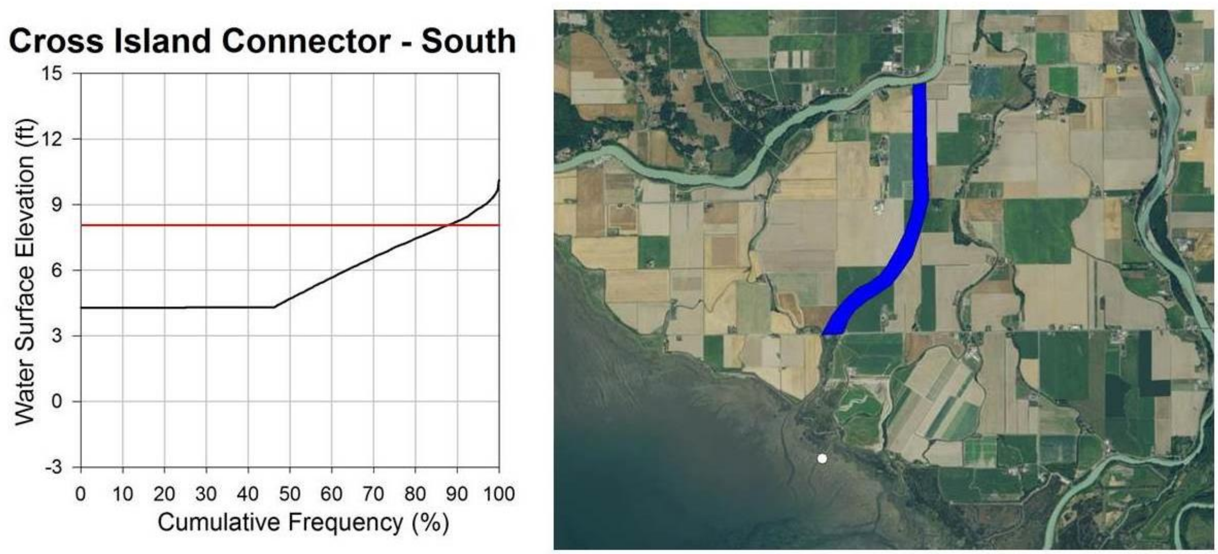


Figure C.4. Cumulative frequency plot and corresponding map for Cross Island Connector (south) during the Major Hydraulic Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

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.

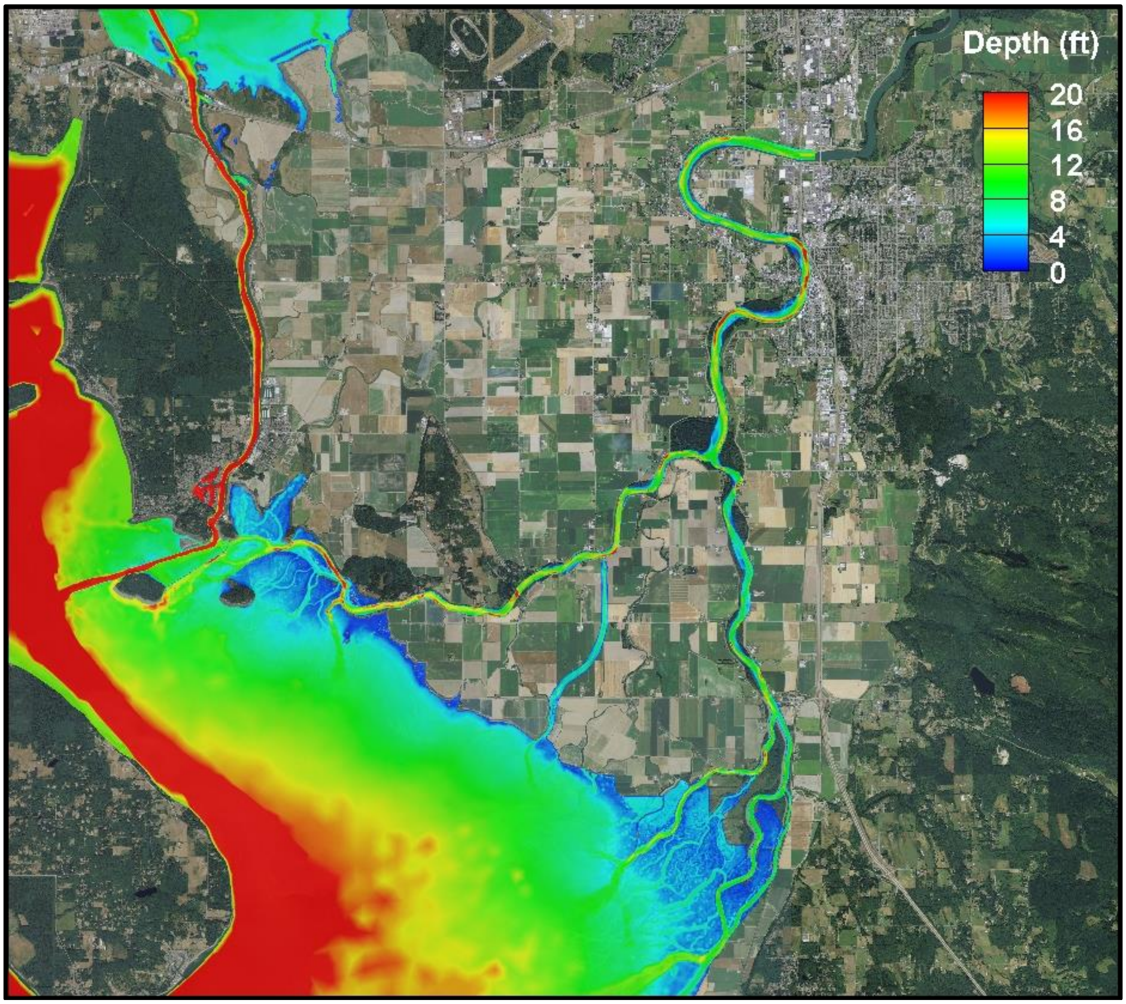


Figure C.5. Contour map of depths for the full domain during the Major Hydraulic Project Cross Island Connector simulation with May flow and high spring tide.

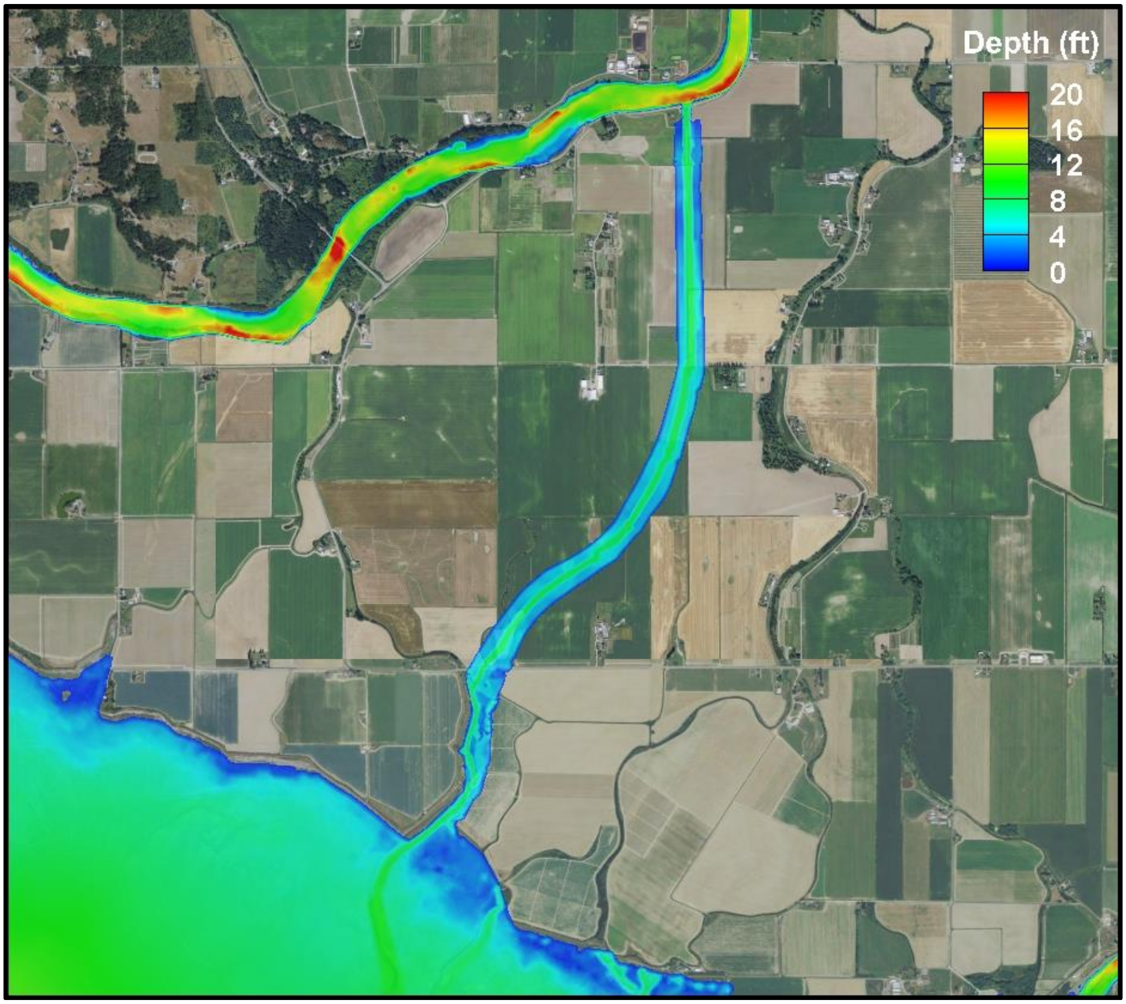


Figure C.6. Contour map of depths for Cross Island Connector during the Major Hydraulic Project simulation.

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.

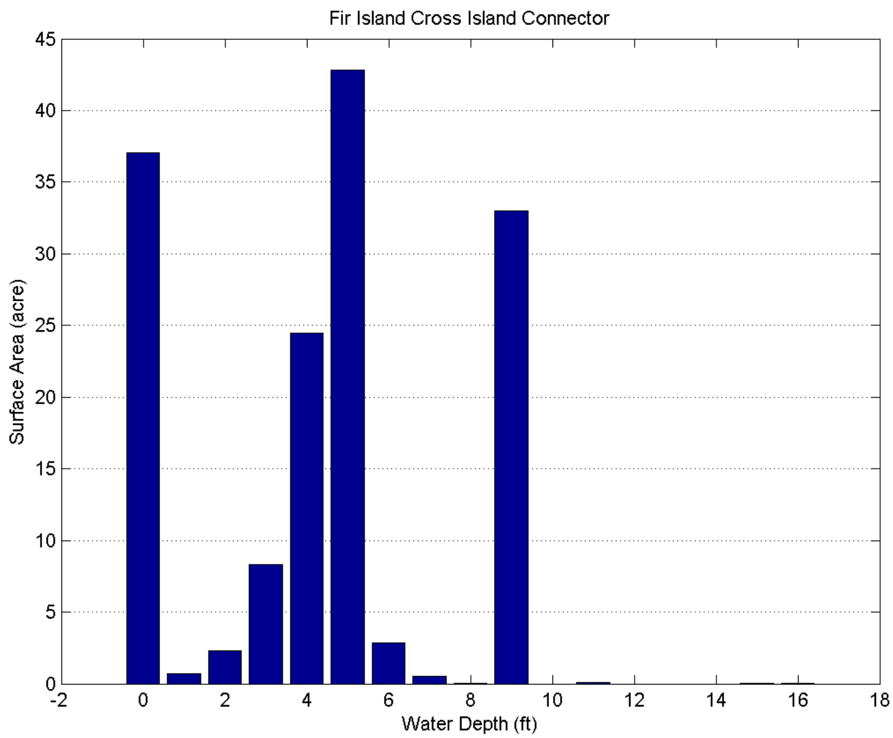


Figure C.7. Histogram of depths for Cross Island Connector.

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.

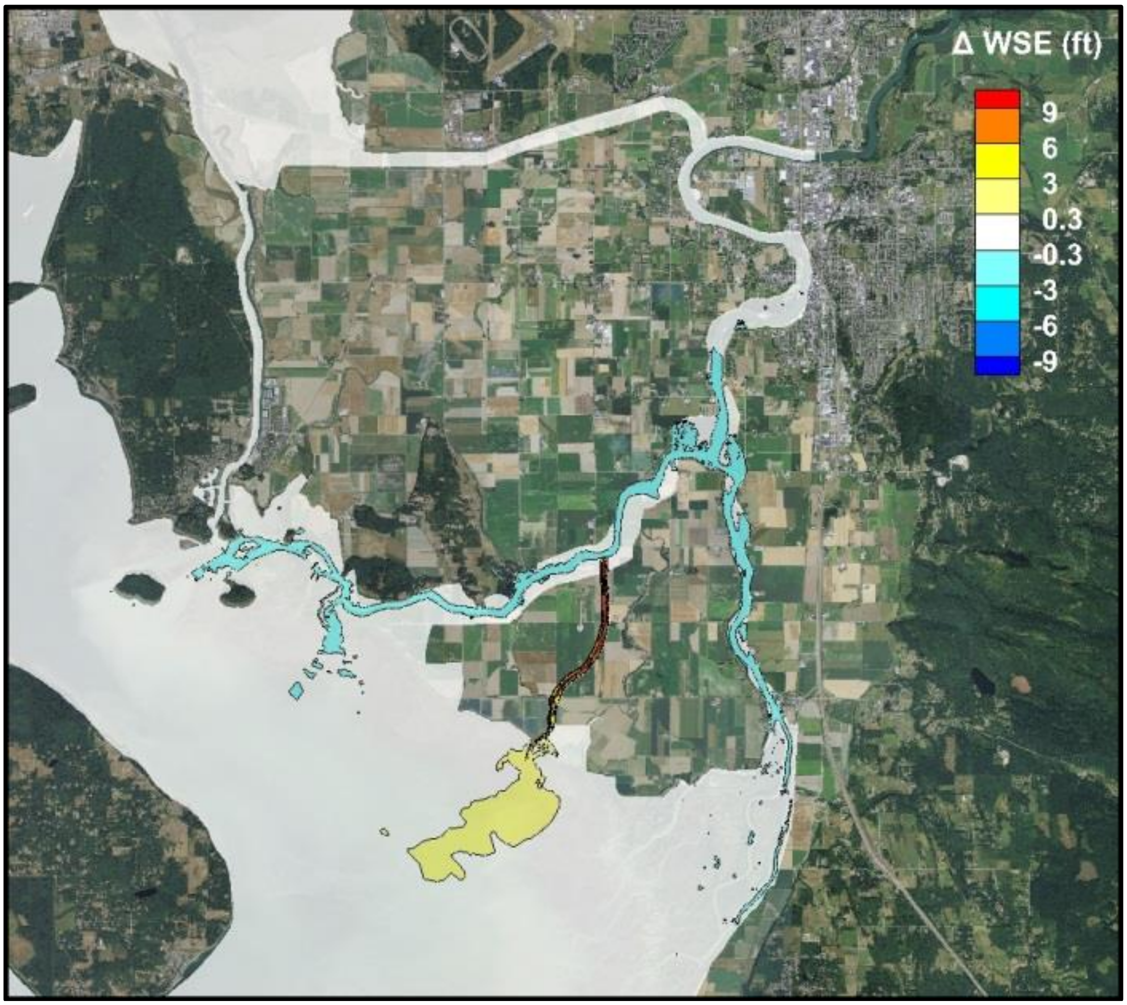


Figure C.8. Contour map of change in WSE from the Baseline to Cross Island Connector simulation with Q2 flow and low tide.

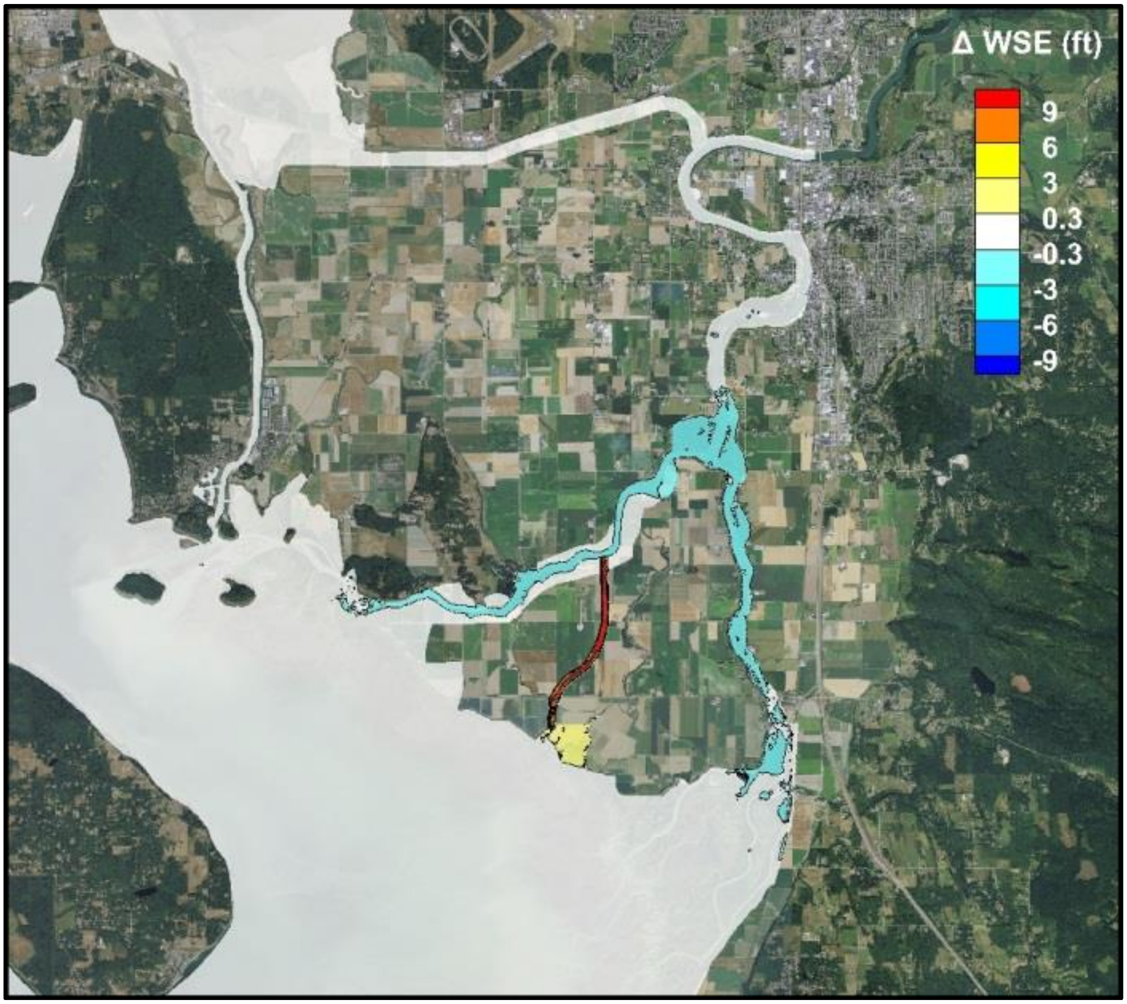


Figure C.9. Contour map of change in WSE from the Baseline to Cross Island Connector simulation with flood flow and high tide.

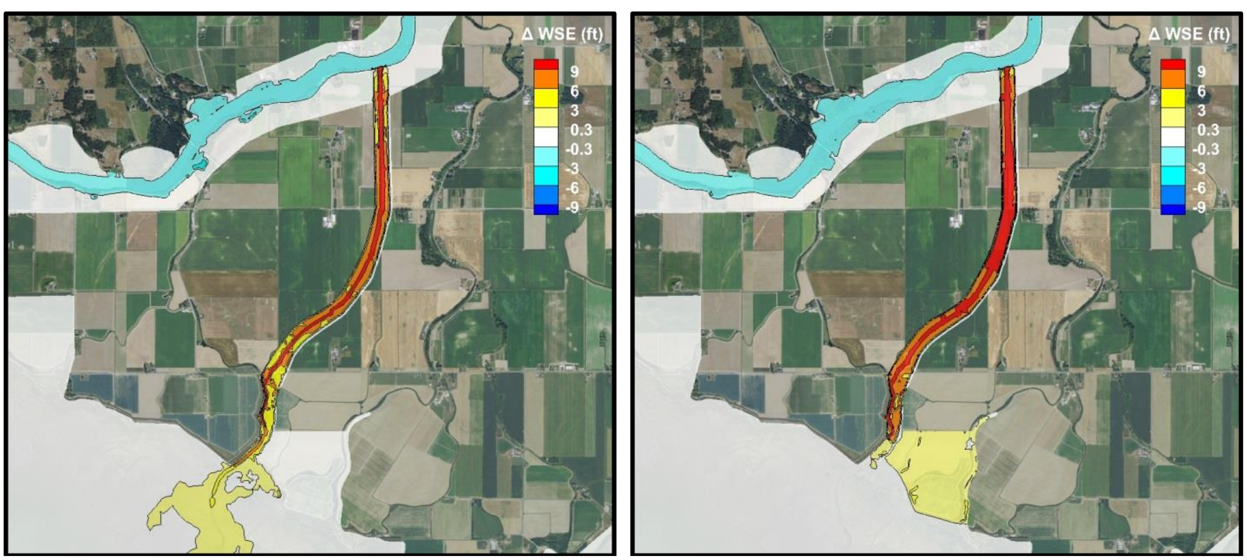


Figure C.10. Contour map of change in WSE from the Baseline simulation for Cross Island Connector with Q2 flow and low tide (left) and flood flow and high tide (right).

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.

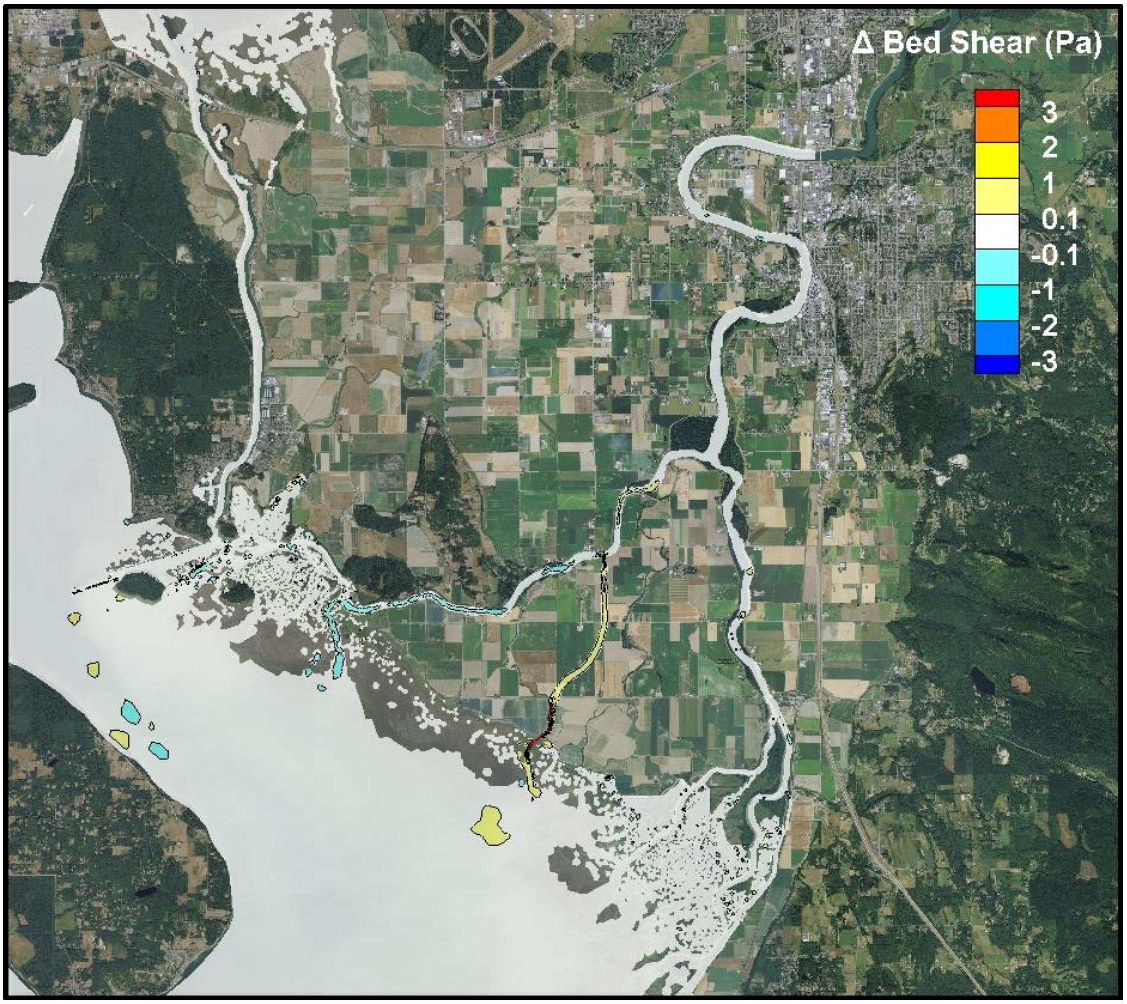


Figure C.11. Contour map of change in shear stress from the Baseline to Cross Island Connector simulation with peak shear across a full tidal cycle at low flow.

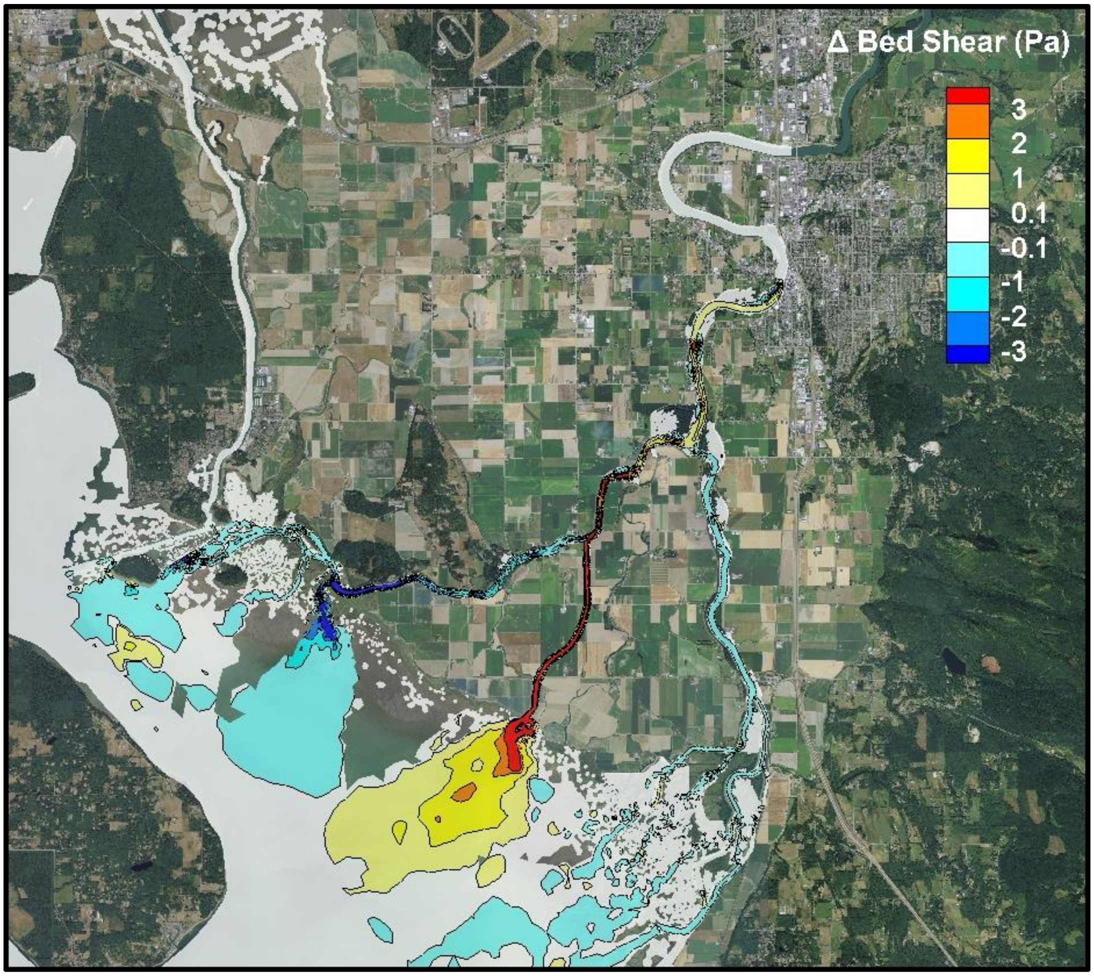


Figure C.12. Contour map of change in shear stress from the Baseline to Cross Island Connector simulation with Q2 flow and low tide.

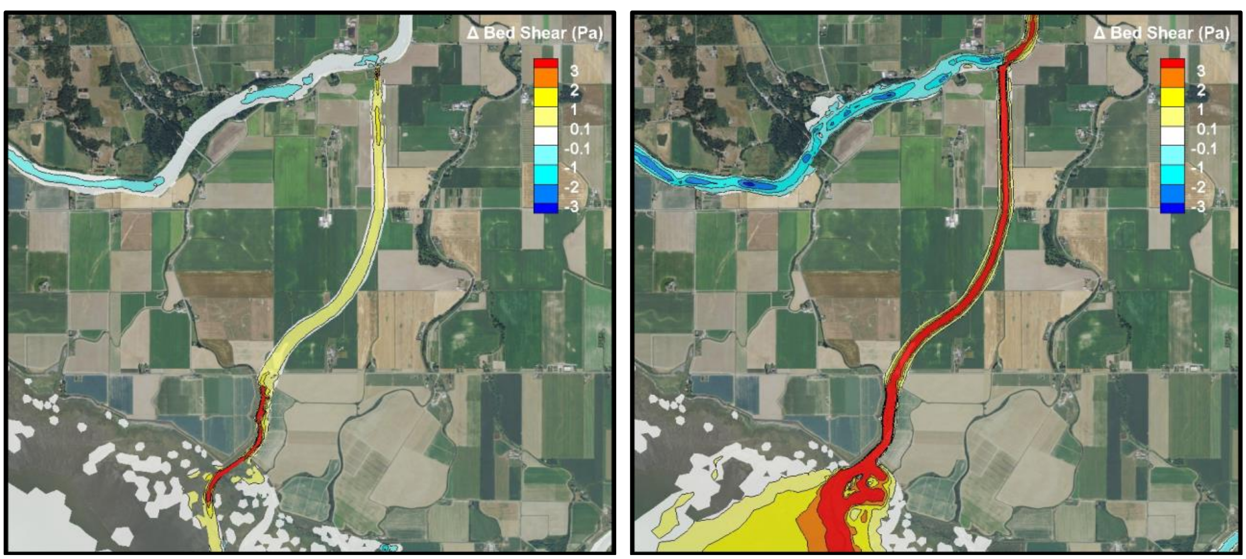


Figure C.13. Contour map of change in shear stress from the Baseline simulation for Cross Island Connector with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

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.

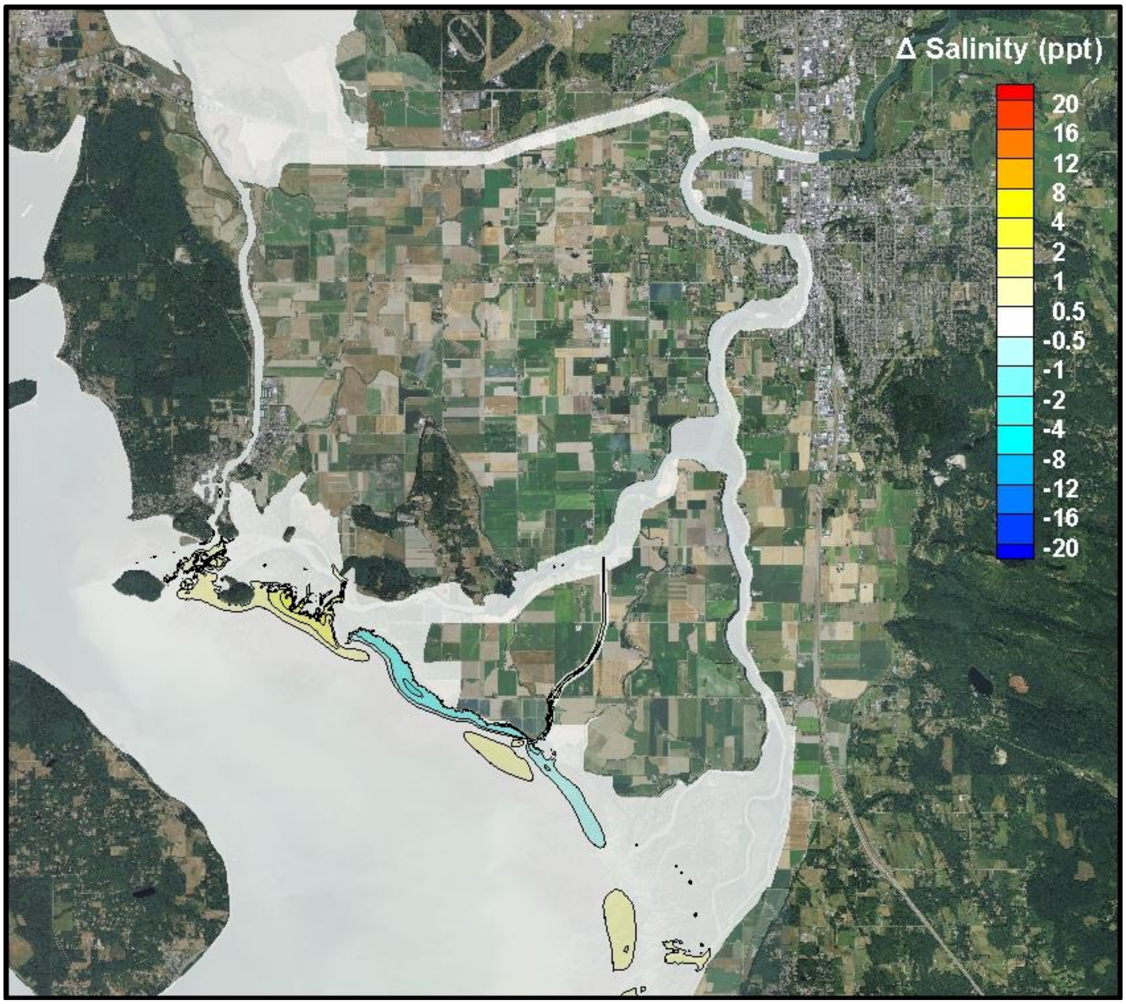


Figure C.14. Contour map of change in salinity from the Baseline to Cross Island Connector simulation with low flow and high tide.

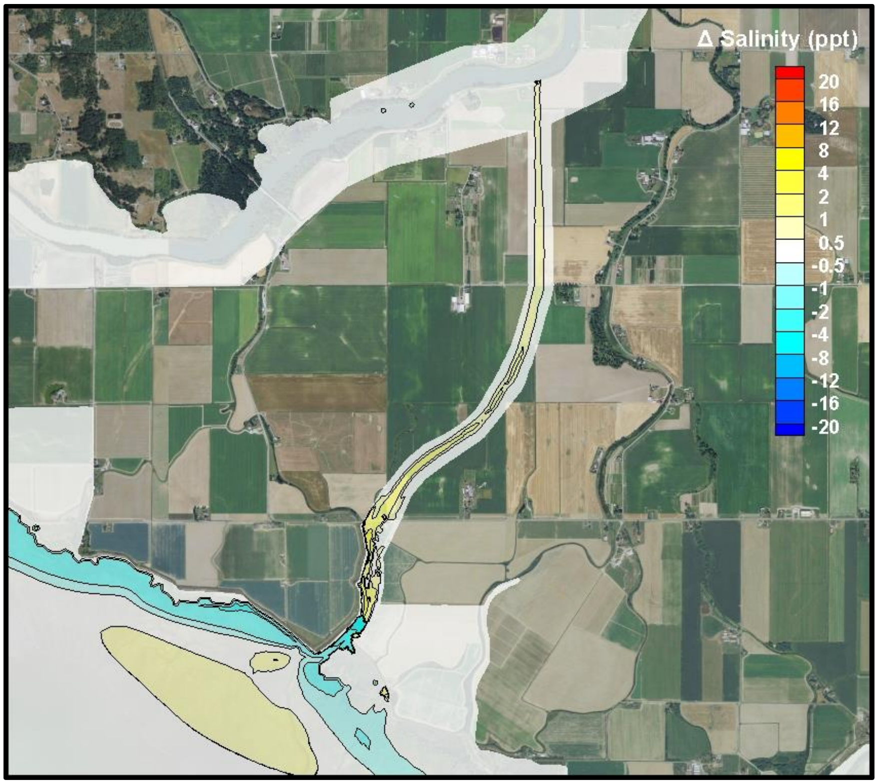


Figure C.15. Contour map of change in salinity from the Baseline to Cross Island Connector simulation for Cross Island Connector with low flow and high tide.

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.

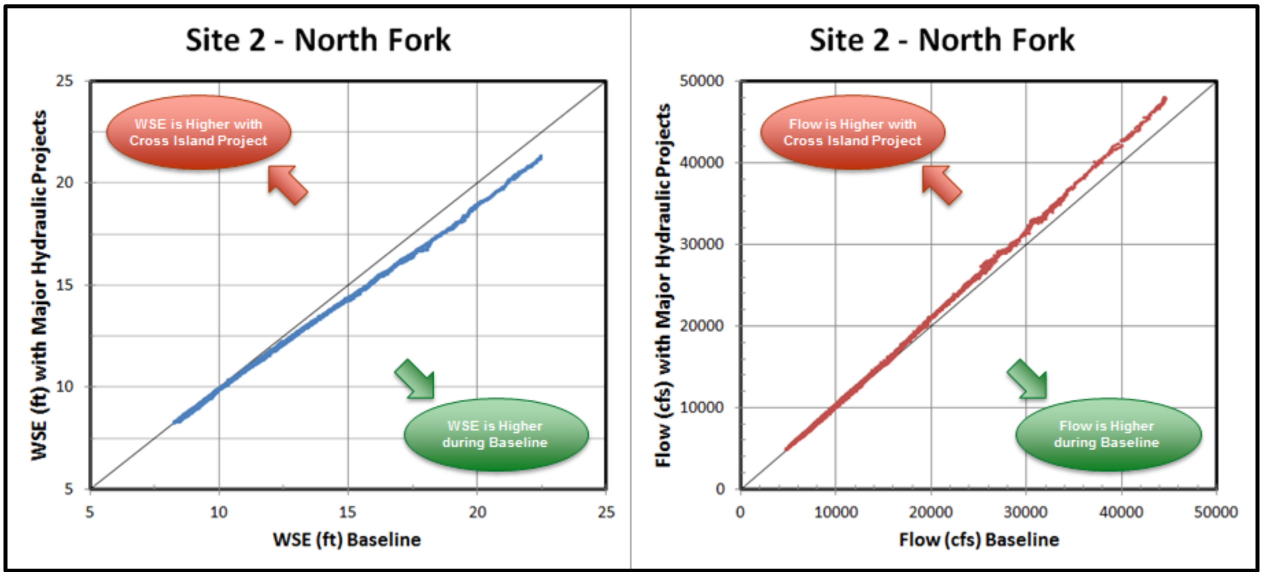


Figure C.16. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Hydraulic Project simulation at the North Fork gauge location compared with the same information under baseline conditions.

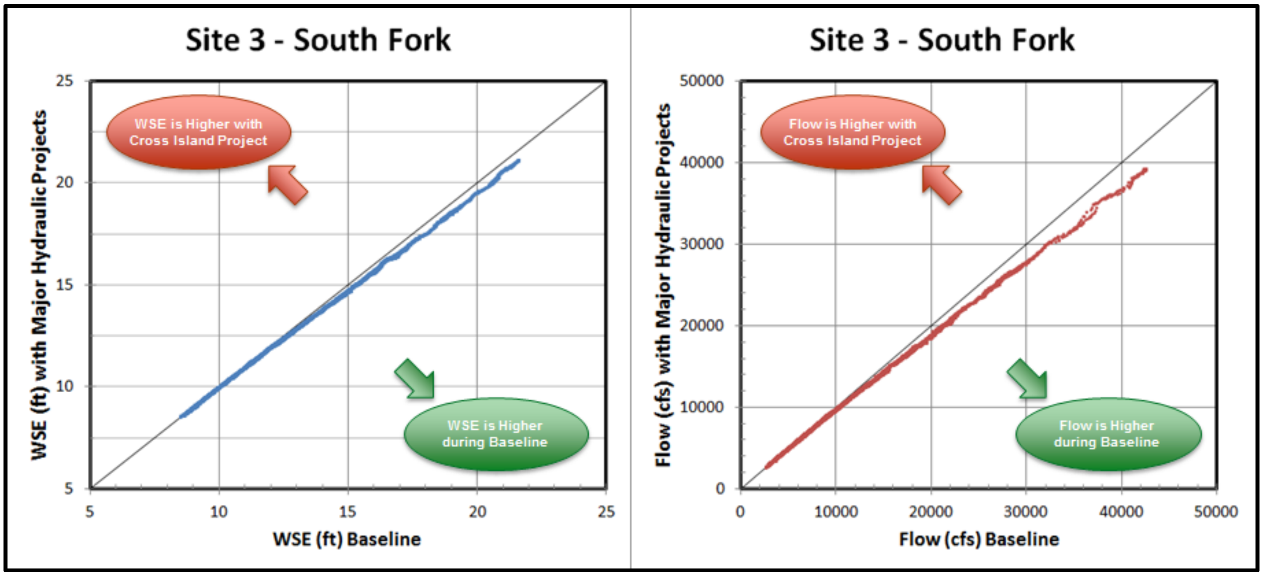


Figure C.17. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Hydraulic Project simulation at the South Fork gauge location compared with the same information under baseline conditions.

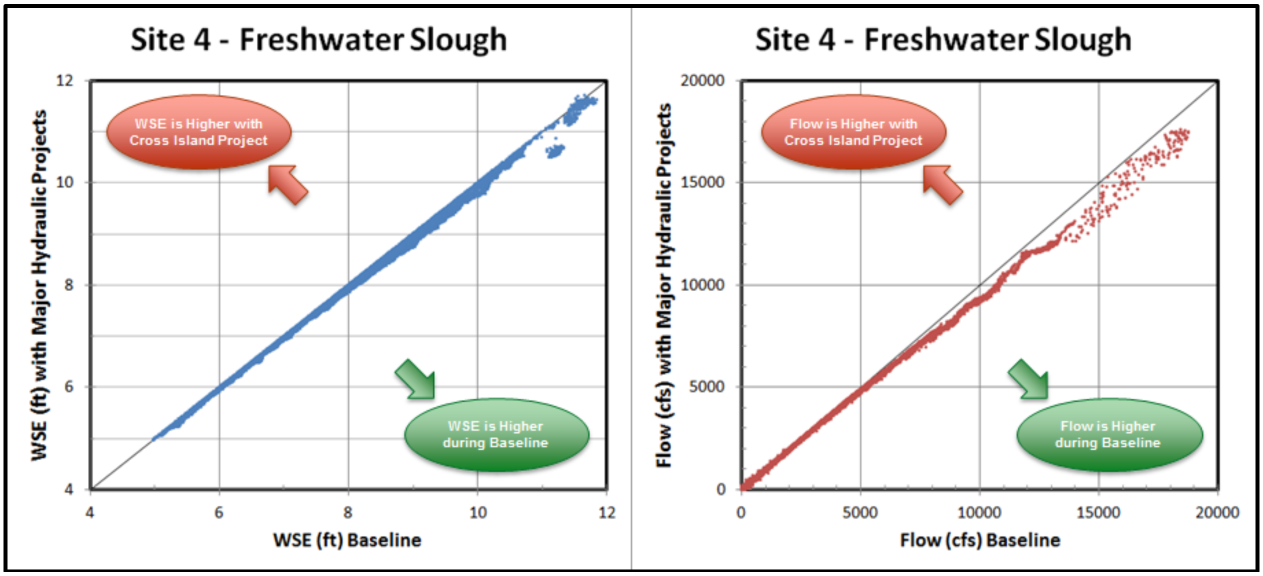


Figure C.18. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Hydraulic Project simulation at the Freshwater Slough gauge location compared with the same information under baseline conditions.

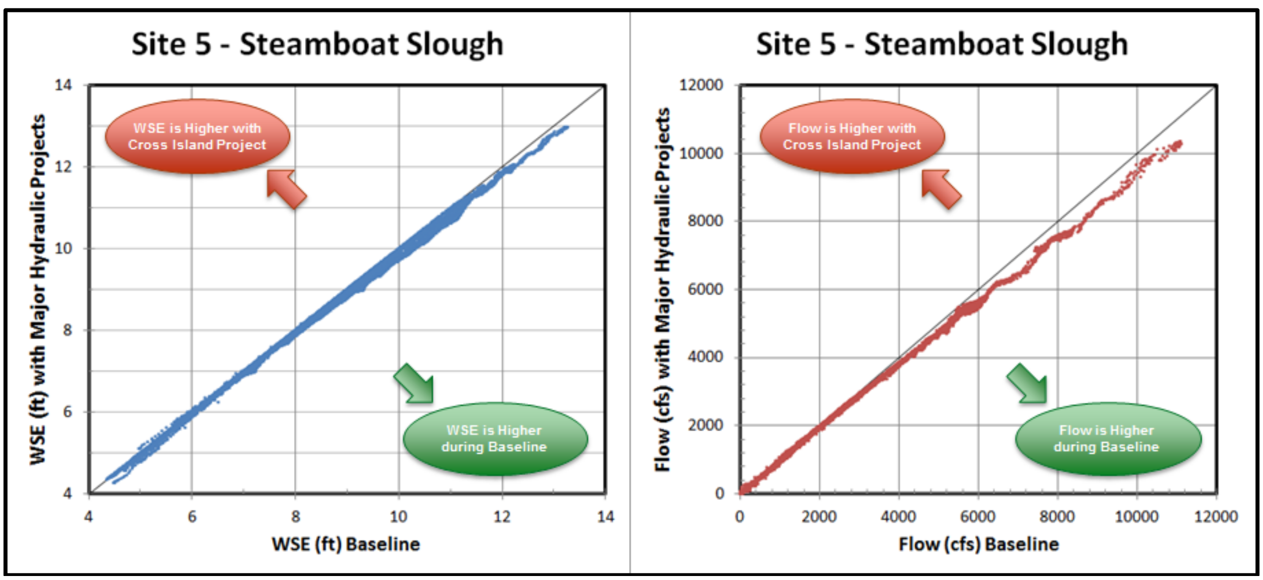


Figure C.19. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Hydraulic Project simulation at the Steamboat Slough gauge location compared with the same information under baseline conditions.

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.

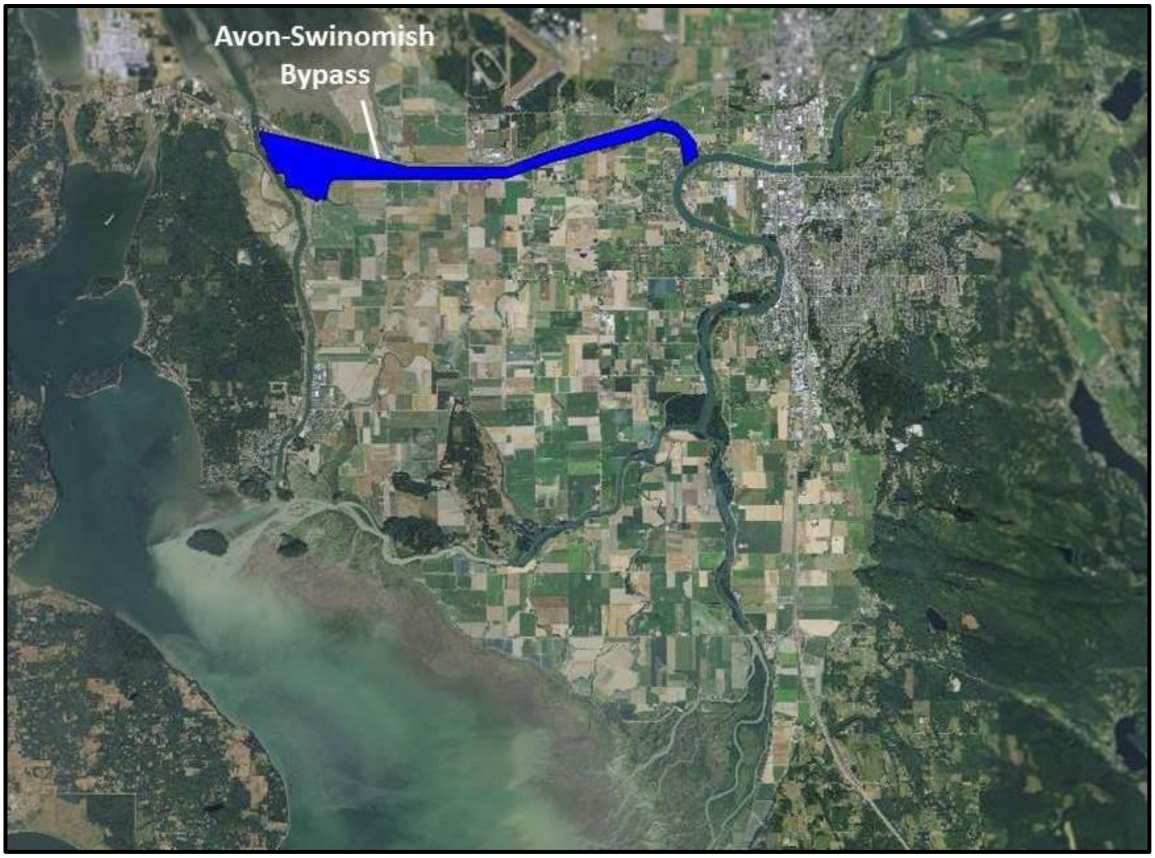


Figure D.1. A map of project area in the Major Hydraulic Project simulation: Avon-Swinomish Bypass.

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.

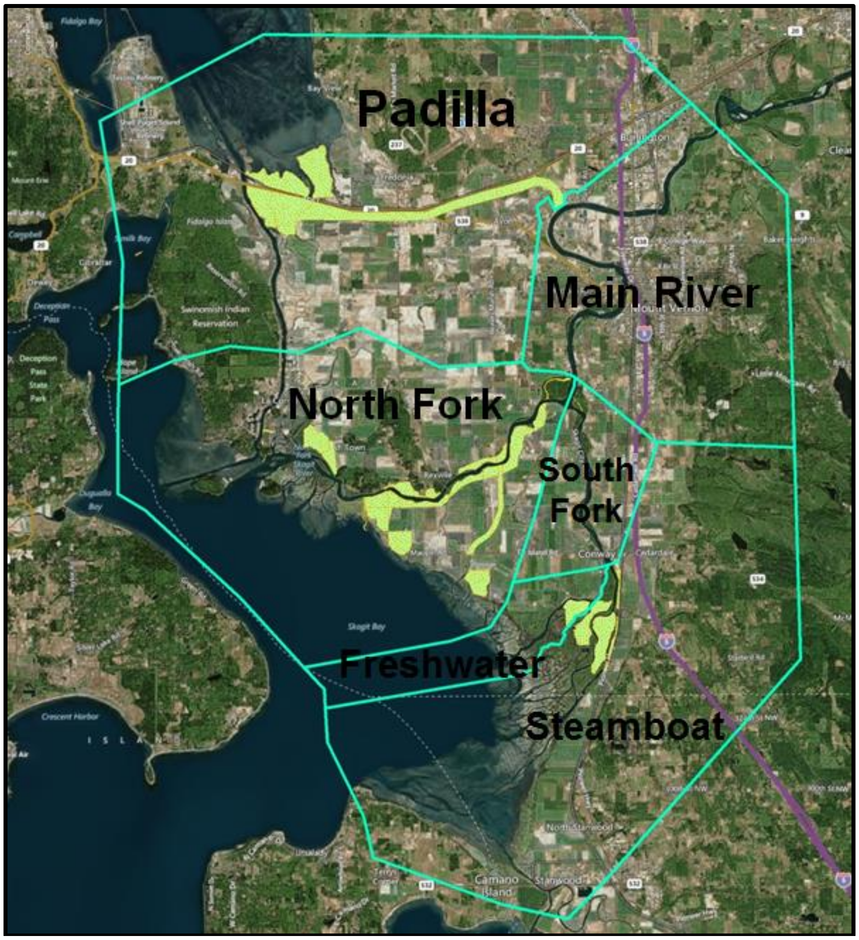


Figure D.2. Sub-basins within the Skagit region used for area calculations.

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.

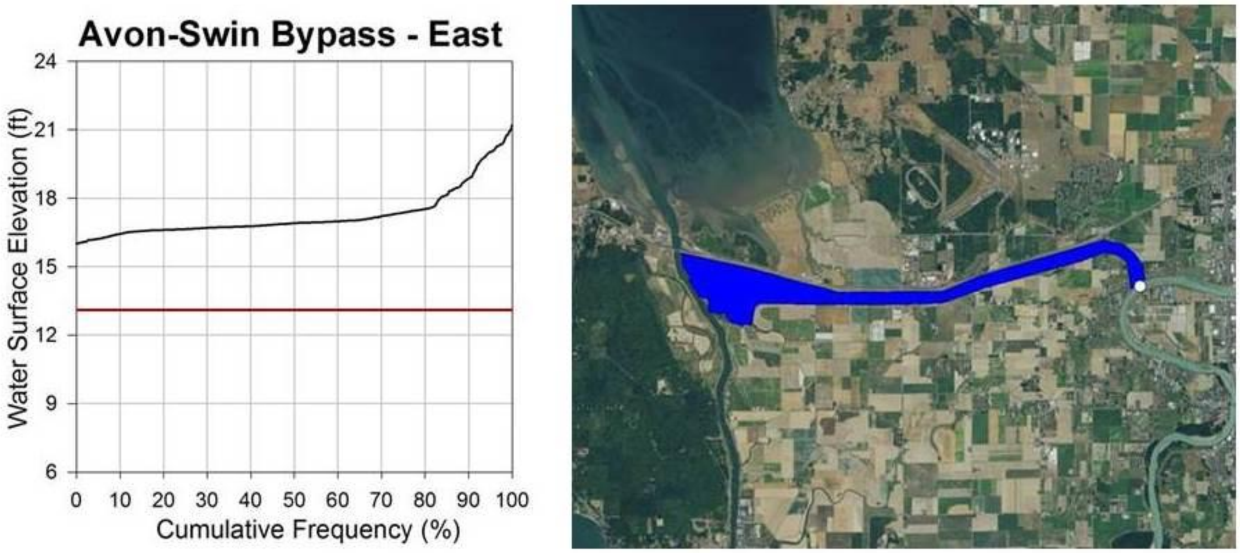


Figure D.3. Cumulative frequency plot and corresponding map for Avon-Swinomish Bypass (east) during the Major Hydraulic Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

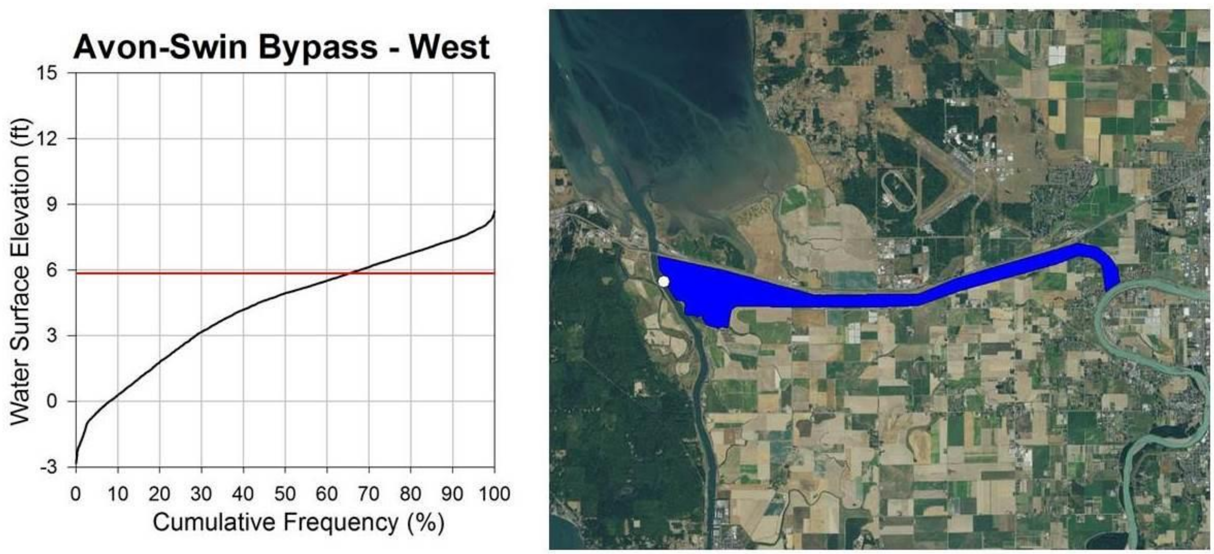


Figure D.4. Cumulative frequency plot and corresponding map for Avon-Swinomish Bypass (west) during the Major Hydraulic Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

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.

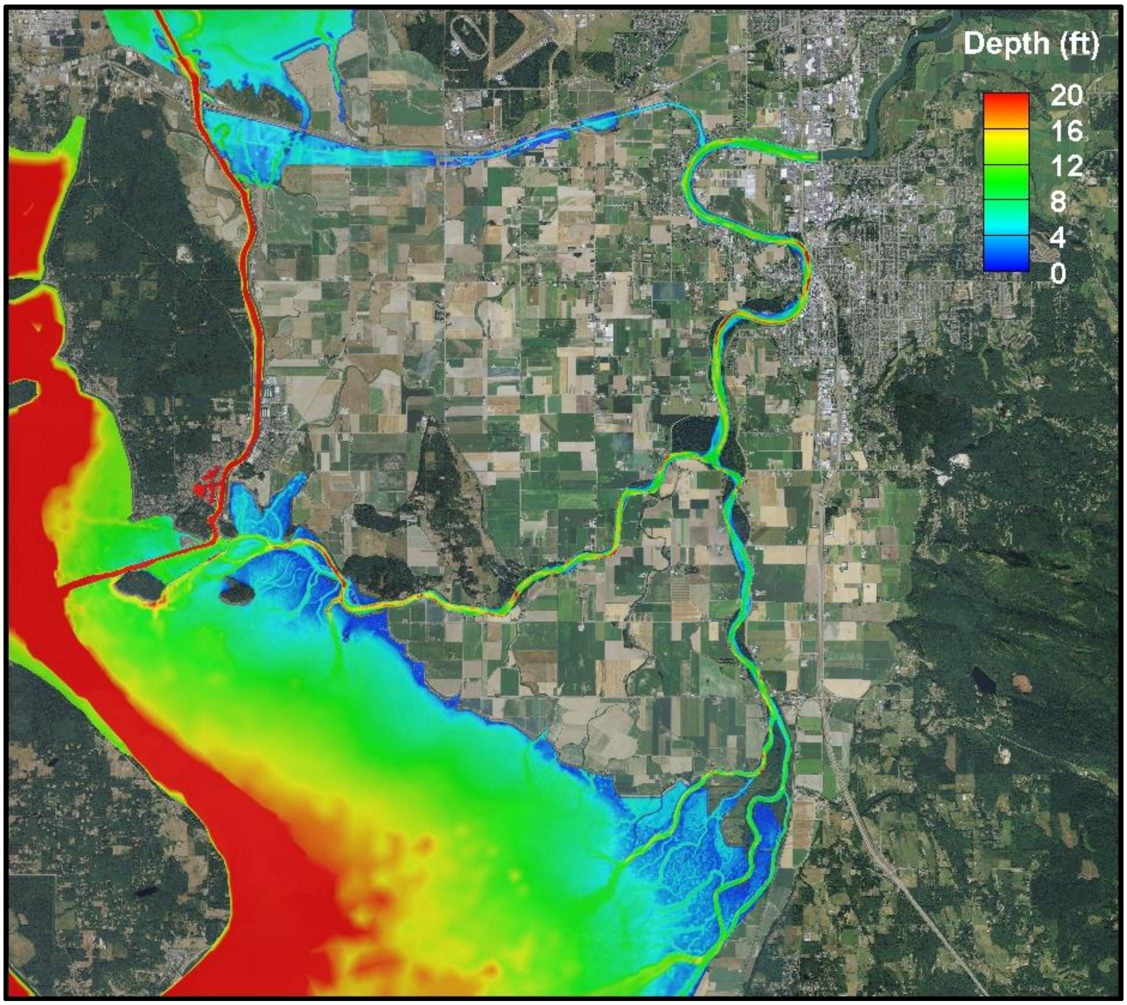


Figure D.5. Contour map of depths for the full domain during the Major Hydraulic Project Avon-Swinomish ByPass simulation with May flow and high spring tide.

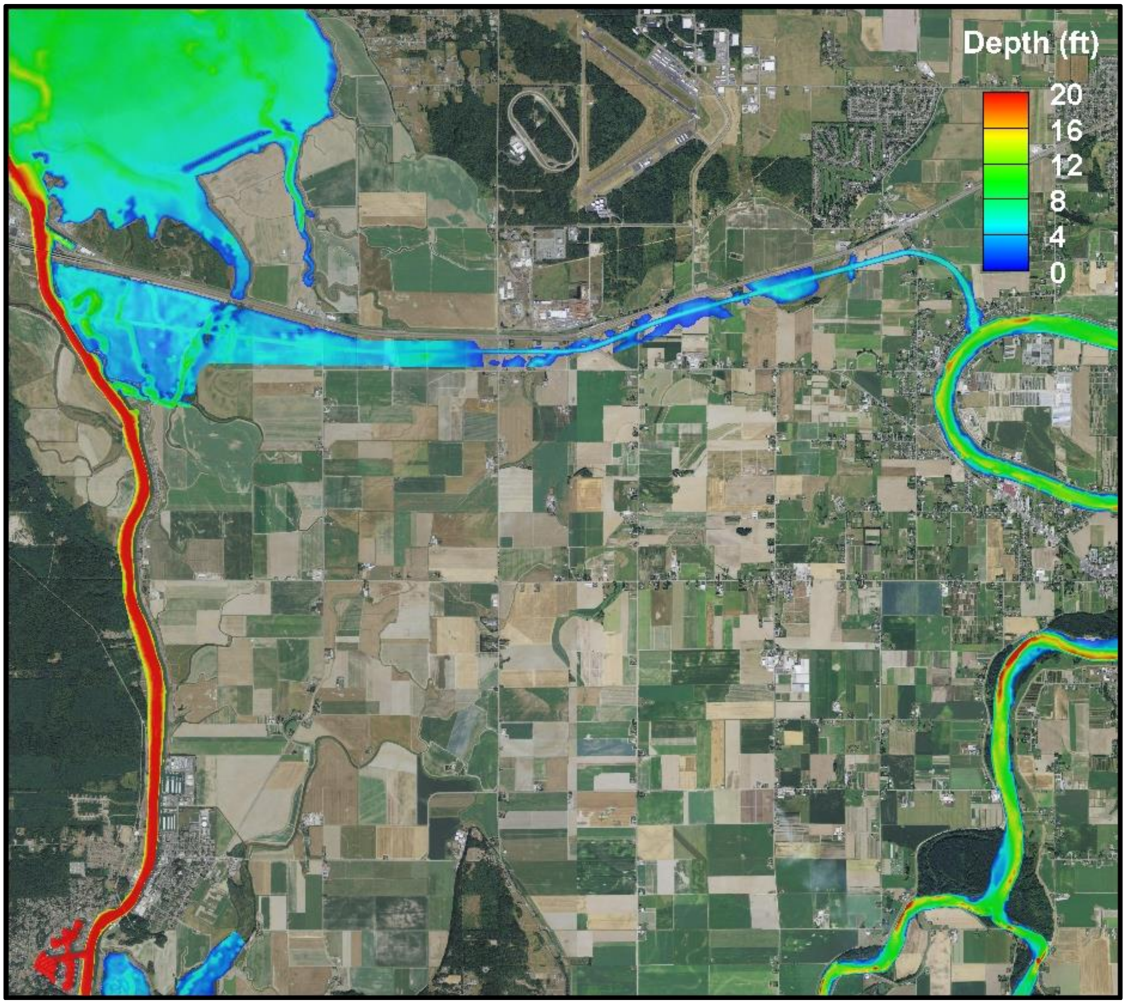


Figure D.6. Contour map of depths for Avon-Swinomish Bypass during the Major Hydraulic Project simulation.

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.

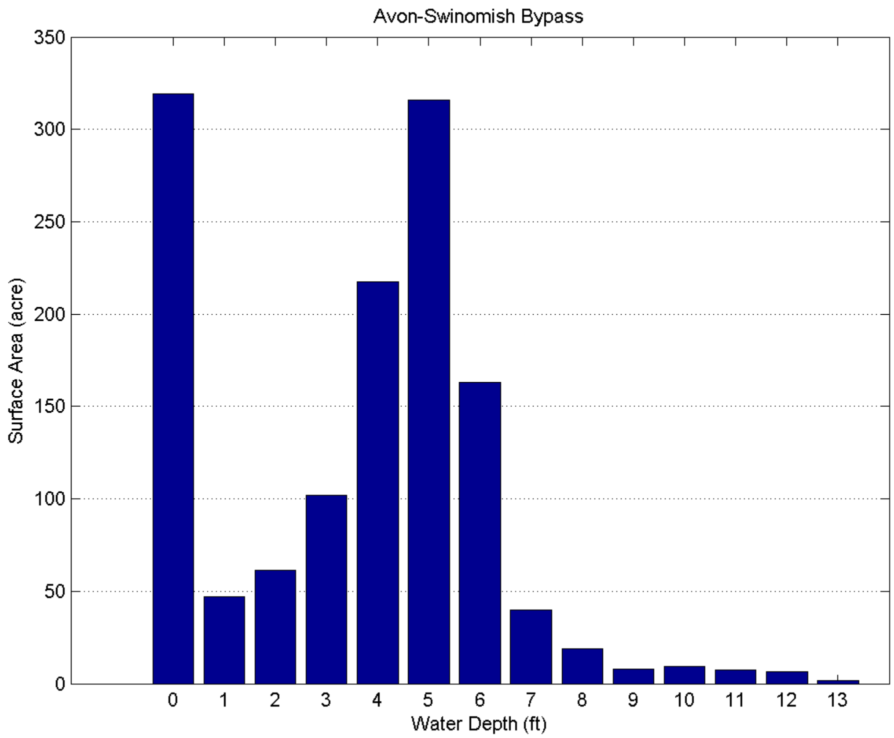


Figure D.7. Histogram of depths for Avon-Swinomish Bypass.

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.

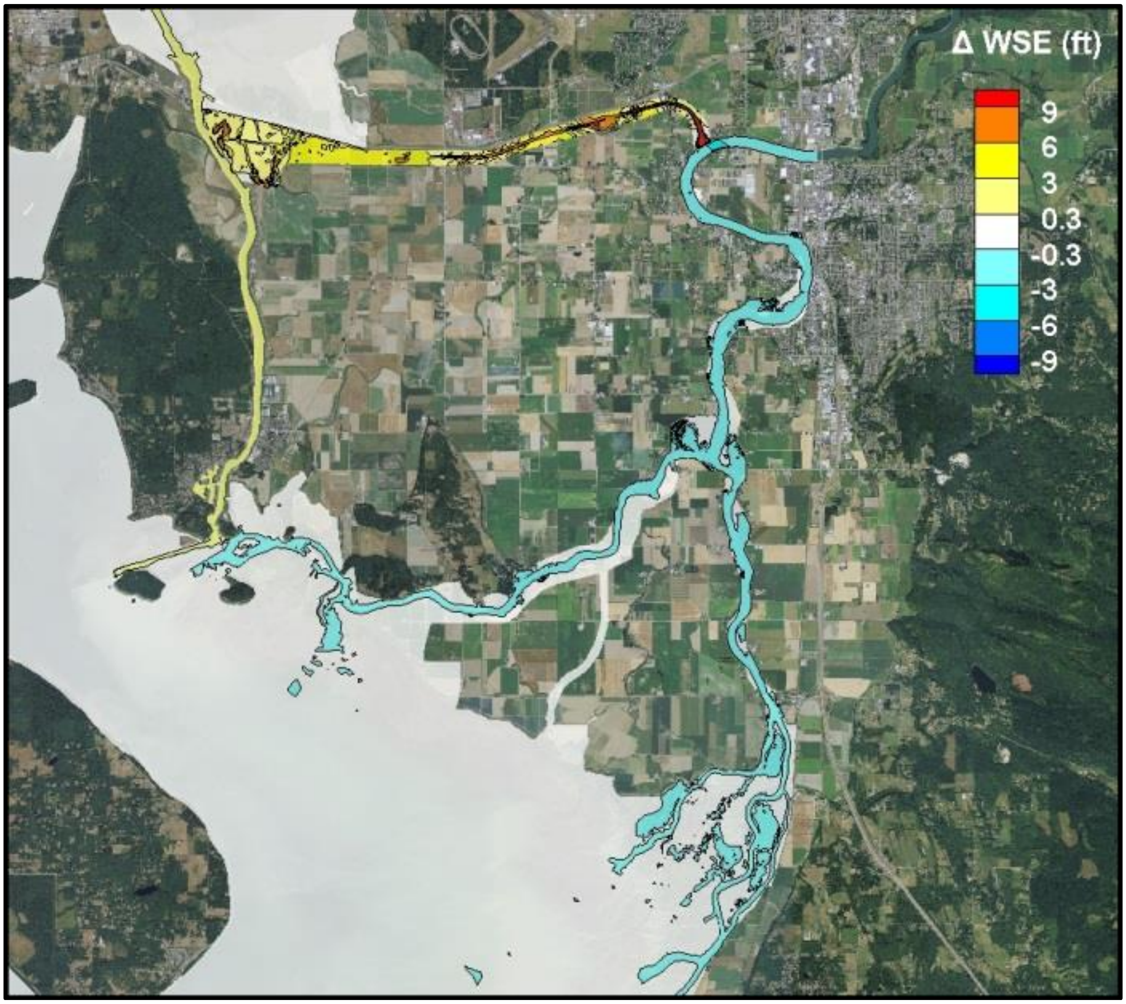


Figure D.8. Contour map of change in WSE from the Baseline to Avon-Swinomish Bypass simulation with Q2 flow and low tide.

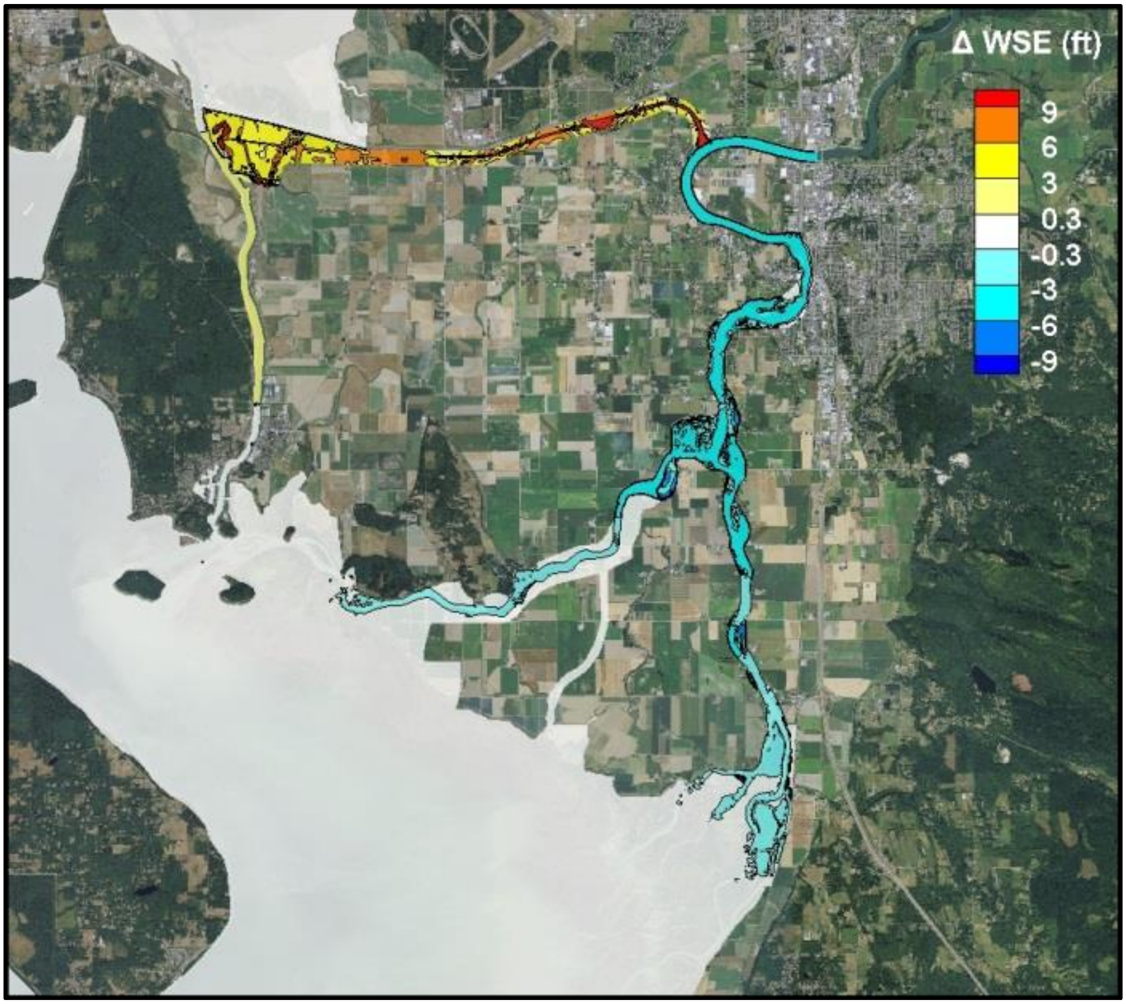


Figure D.9. Contour map of change in WSE from the Baseline to Avon-Swinomish Bypass simulation with flood flow and high tide.

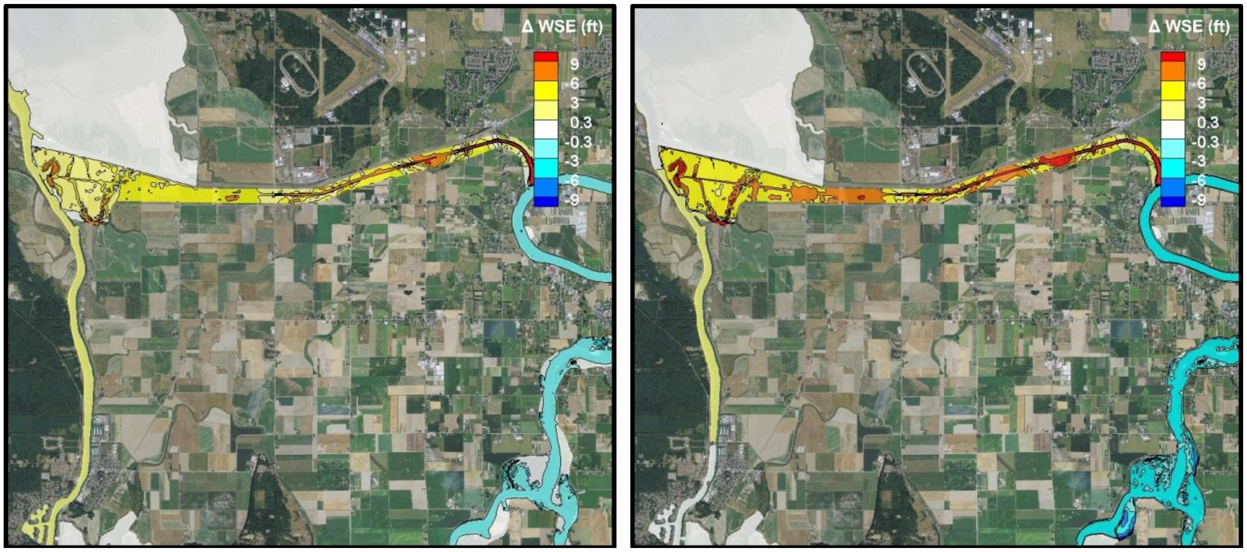


Figure D.10. Contour map of change in WSE from the Baseline simulation for Avon-Swinomish Bypass with Q2 flow and low tide (left) and flood flow and high tide (right).

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.

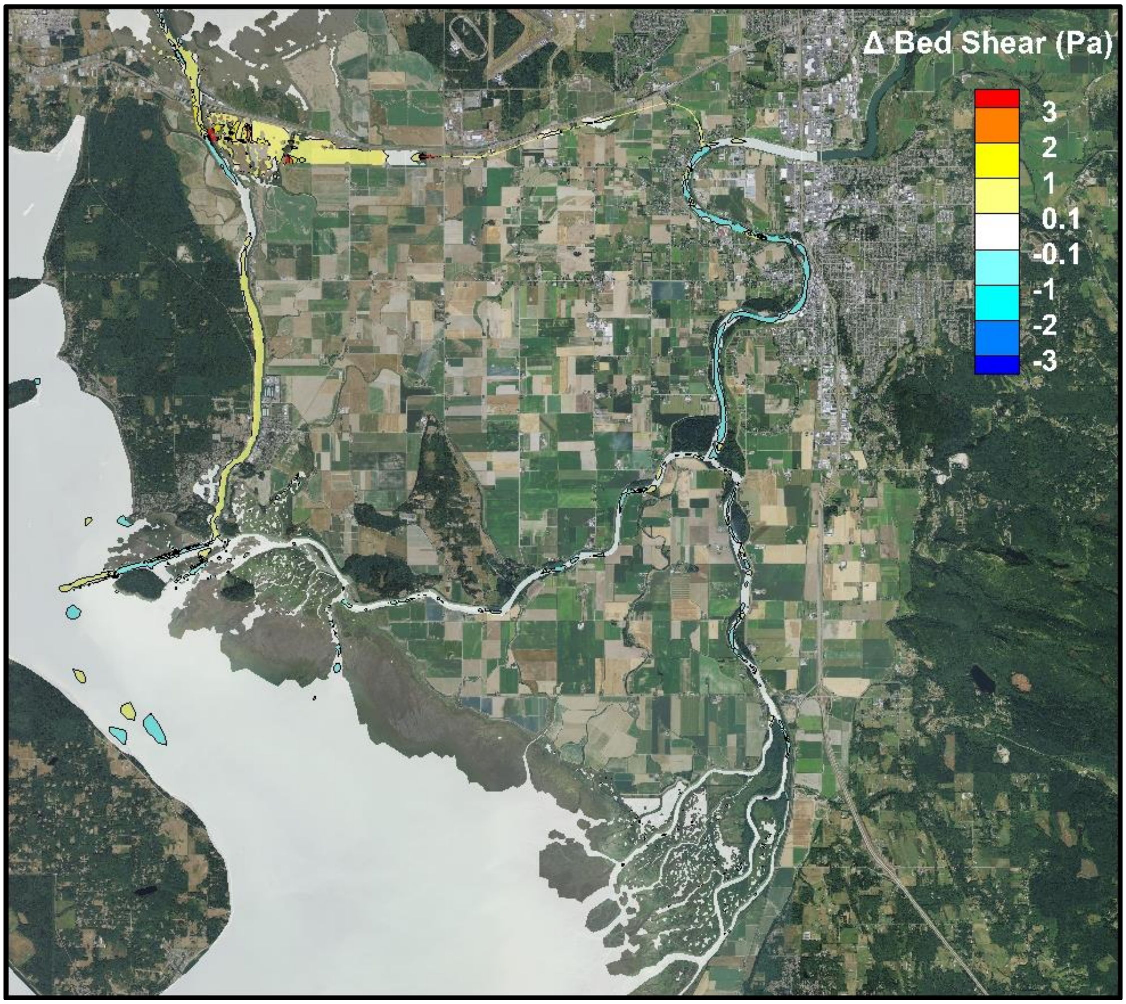


Figure D.11. Contour map of change in shear stress from the Baseline to Avon-Swinomish Bypass simulation with peak shear across a full tidal cycle at low flow.

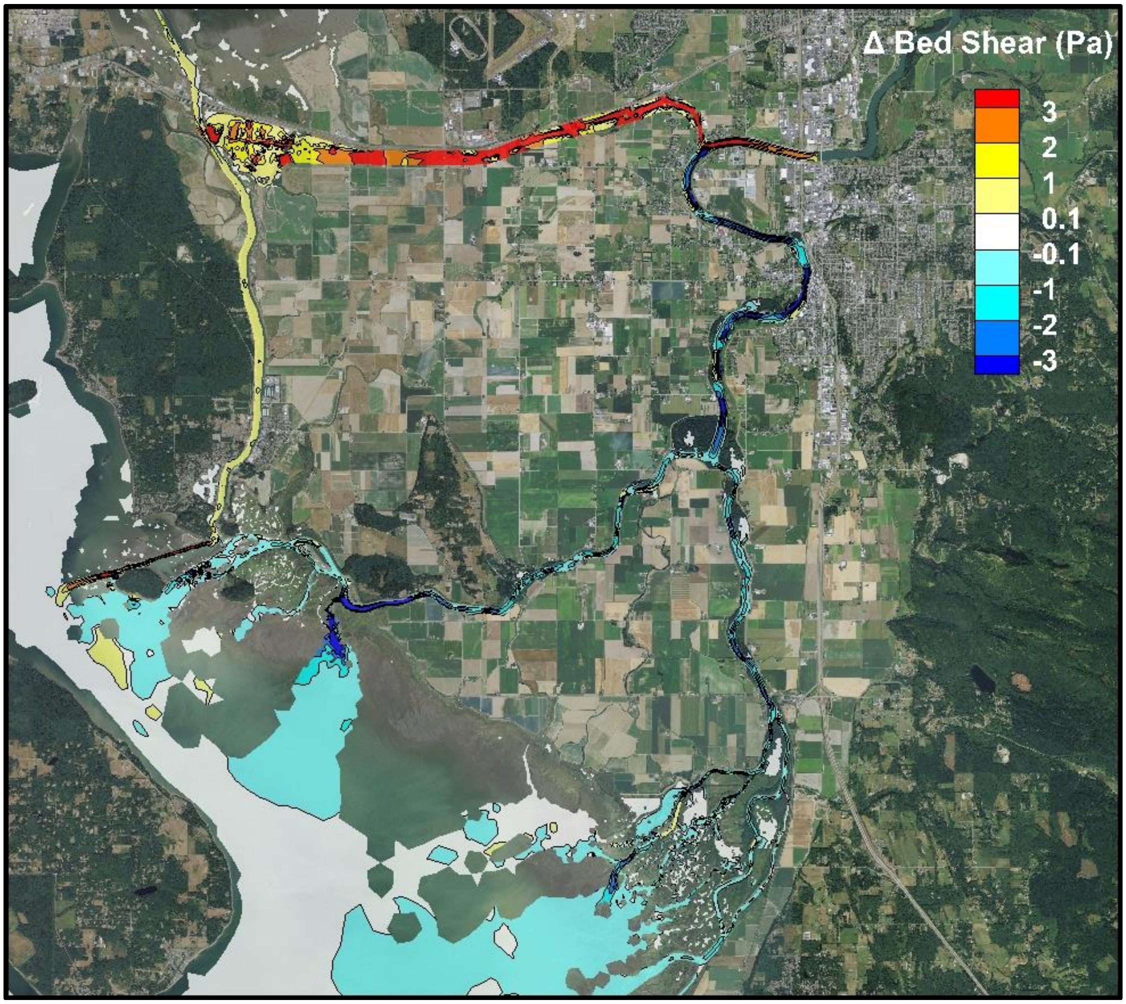


Figure D.12. Contour map of change in shear stress from the Baseline to Avon-Swinomish Bypass simulation with Q2 flow and low tide.

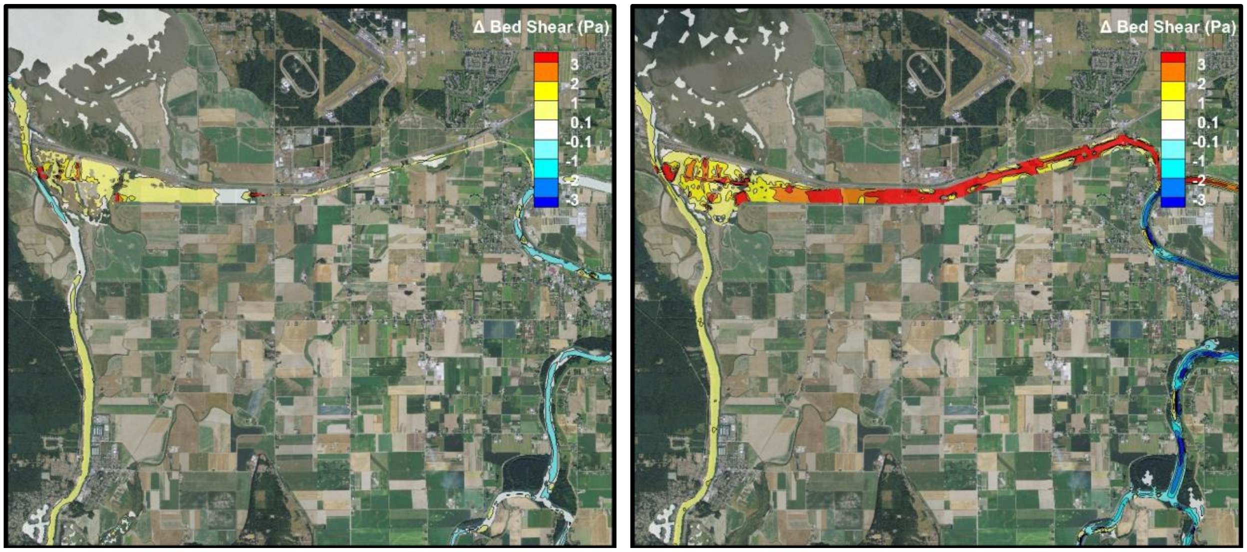


Figure D.13. Contour map of change in shear stress from the Baseline simulation for Avon-Swinomish Bypass with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

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.

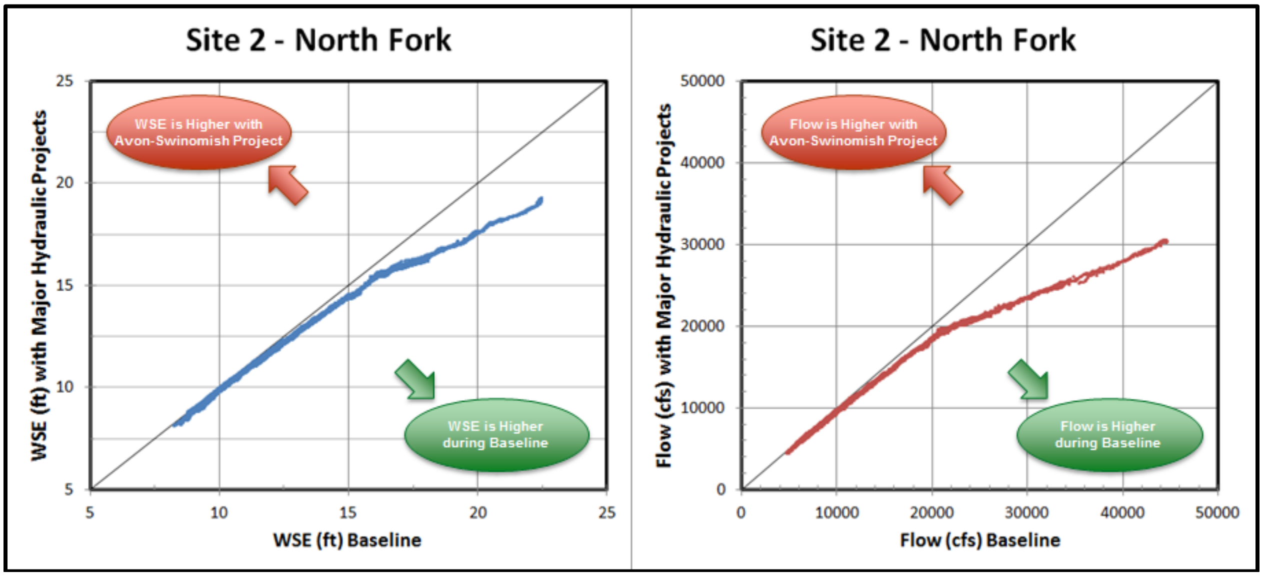


Figure D.14. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Hydraulic Project simulation at the North Fork gauge location compared with the same information under baseline conditions.

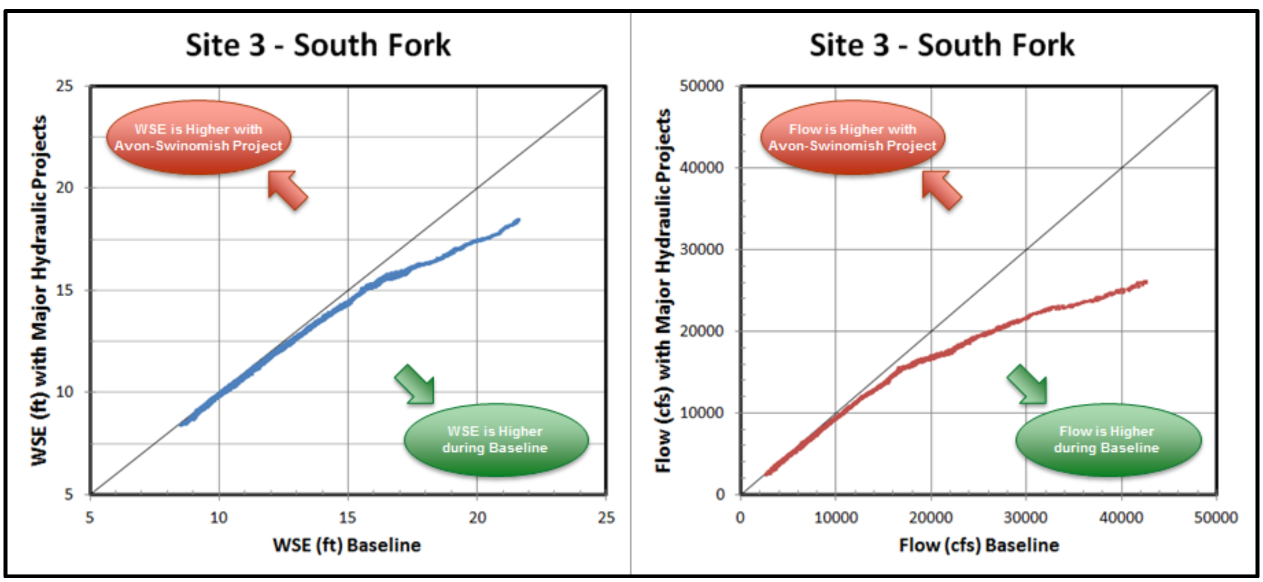


Figure D.15. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Hydraulic Project simulation at the South Fork gauge location compared with the same information under baseline conditions.

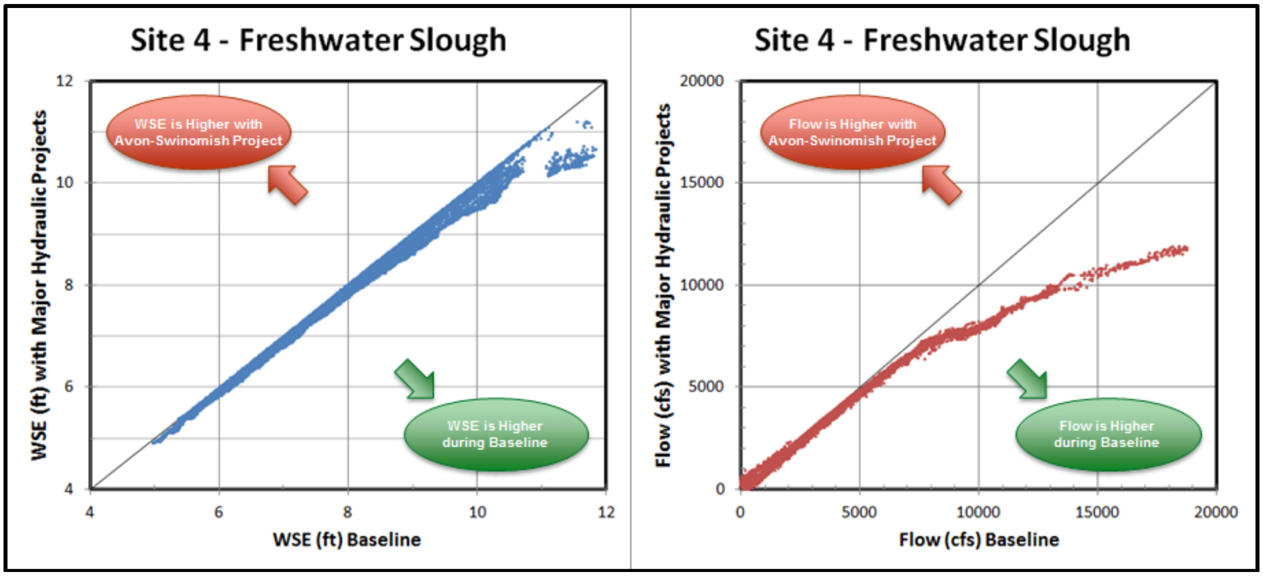


Figure D.16. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Hydraulic Project simulation at the Freshwater Slough gauge location compared with the same information under baseline conditions.

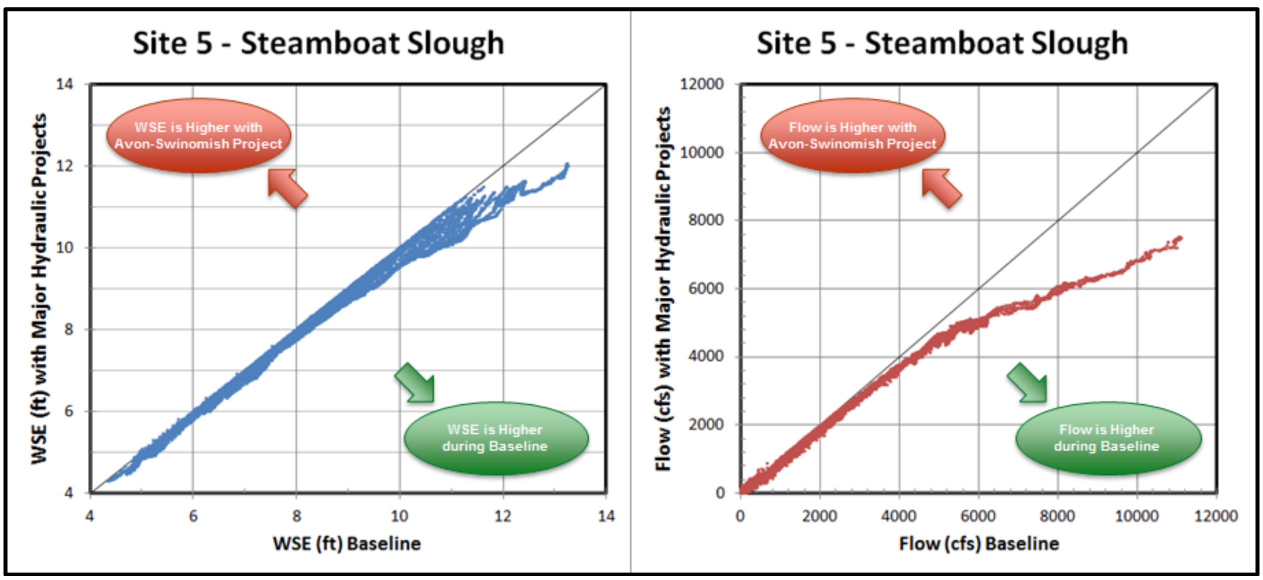


Figure D.17. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Hydraulic Project simulation at the Steamboat Slough gauge location compared with the same information under baseline conditions.

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.

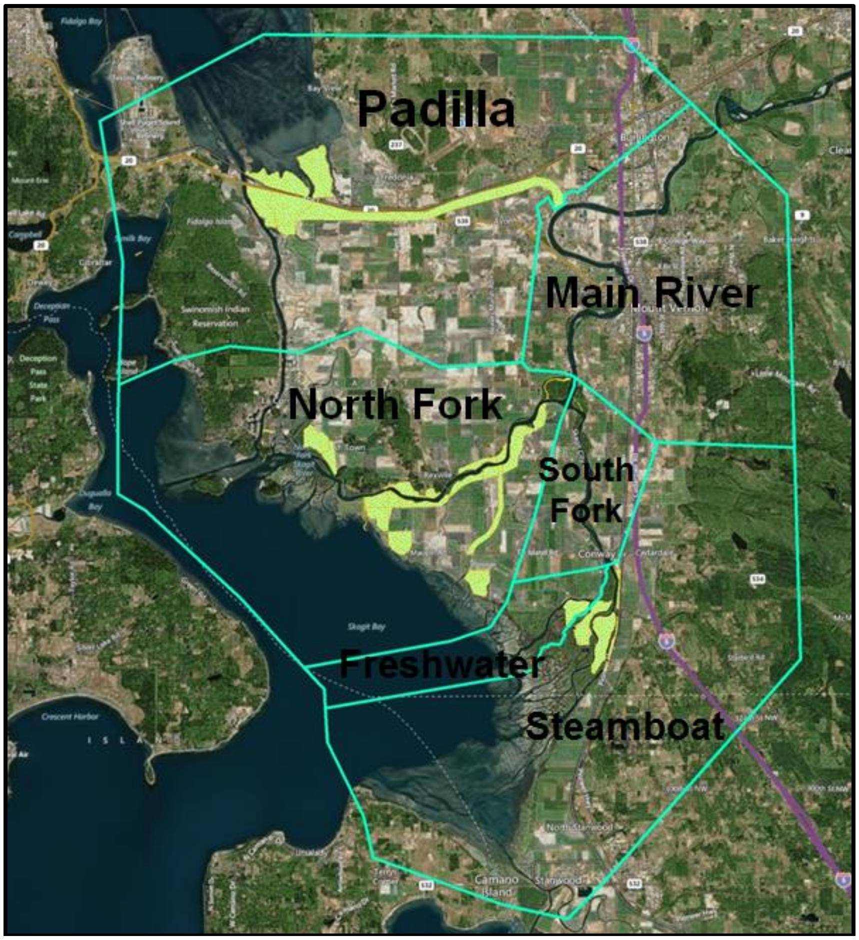


Figure E.2. Sub-basins within the Skagit region used for area calculations.

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.

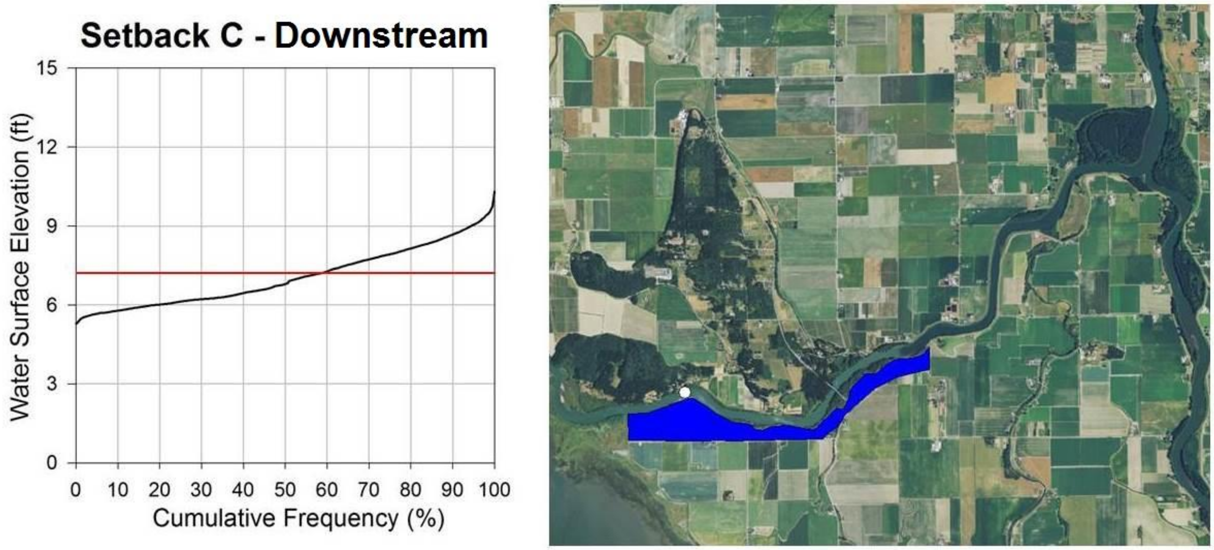


Figure E.3. Cumulative frequency plot and corresponding map for NF Levee Setback C (downstream) during the Major Setback Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

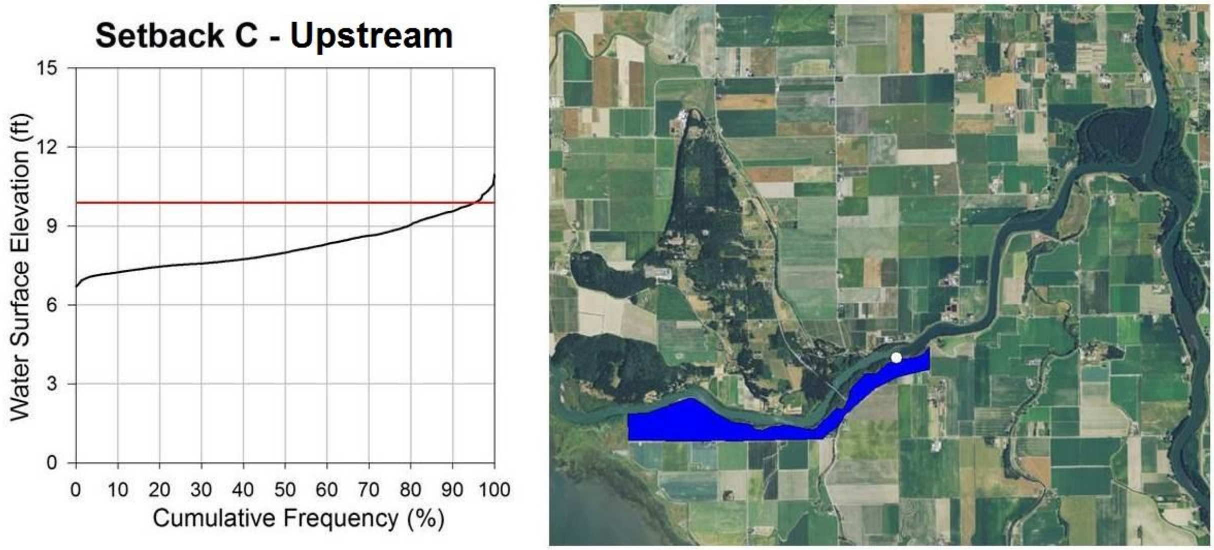


Figure E.4. Cumulative frequency plot and corresponding map for NF Levee Setback C (upstream) during the Major Setback Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

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.

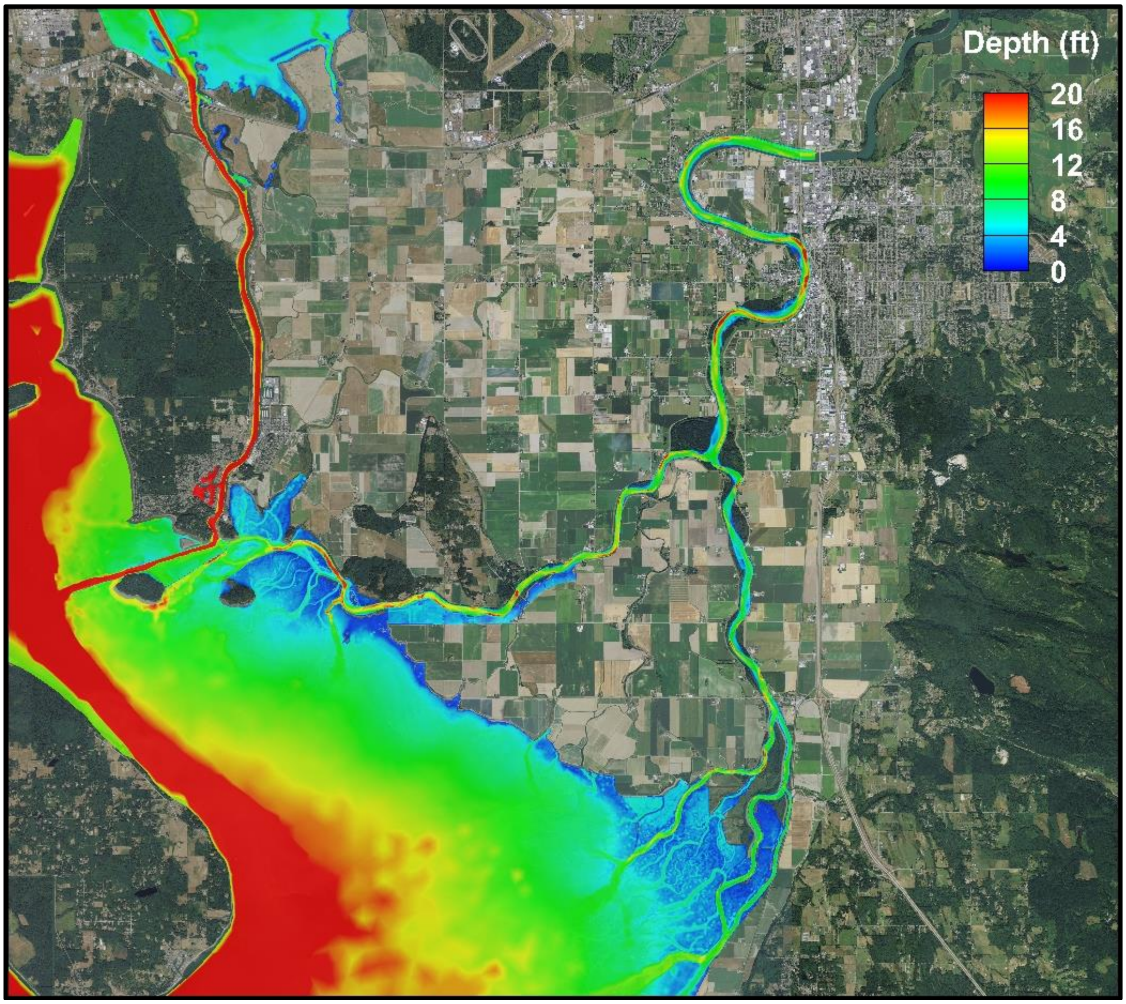


Figure E.5. Contour map of depths for the full domain during the Major Setback Project North Fork Levee Setback C simulation with May flow and high spring tide.

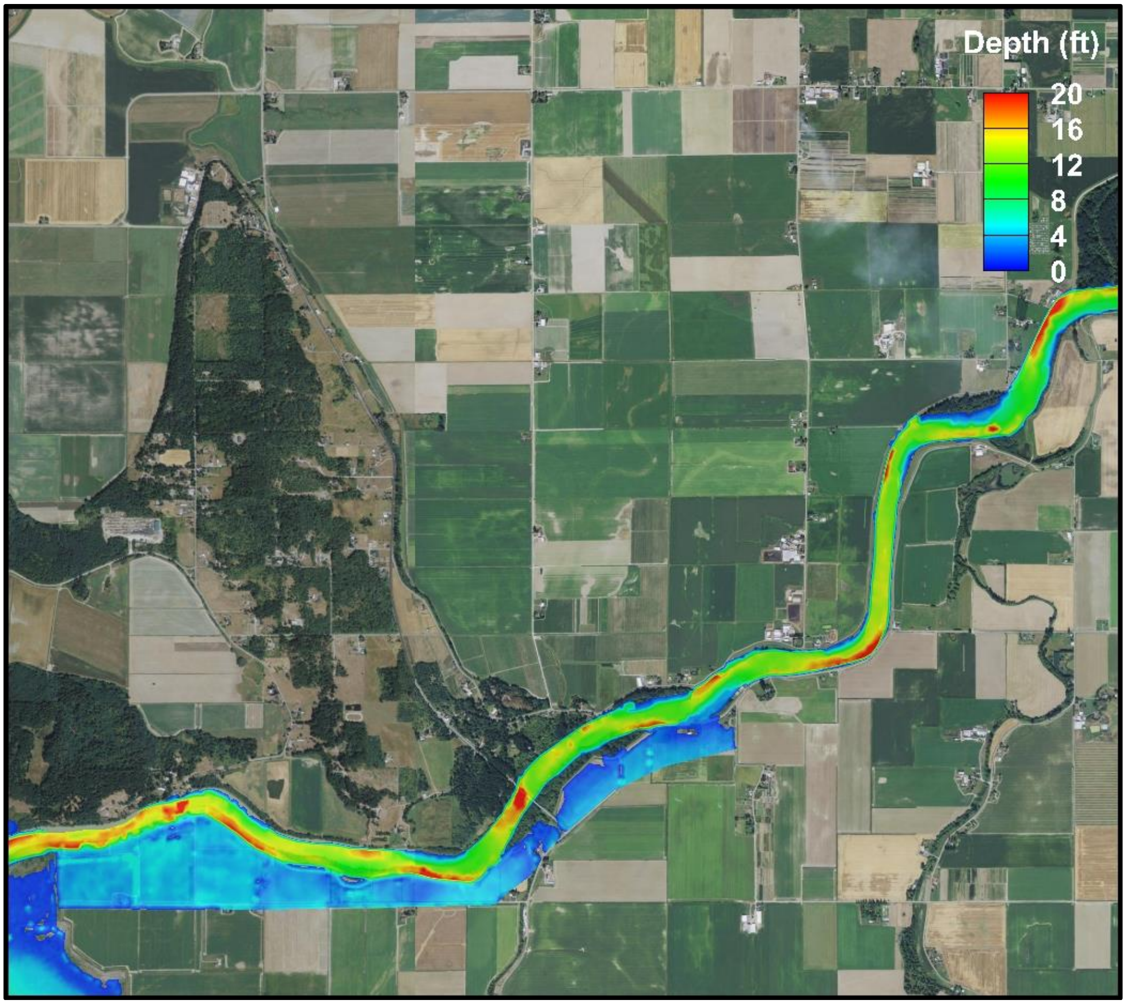


Figure E.6. Contour map of depths for NF Levee Setback C during the Major Setback Project simulation.

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.

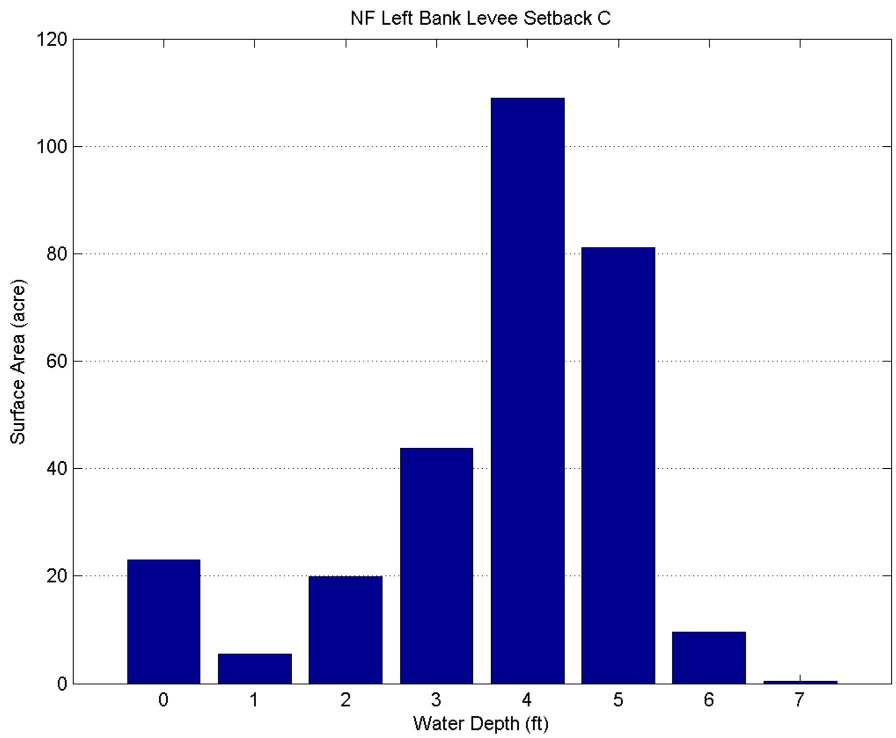


Figure E.7. Histogram of depths for NF Levee Setback C.

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.

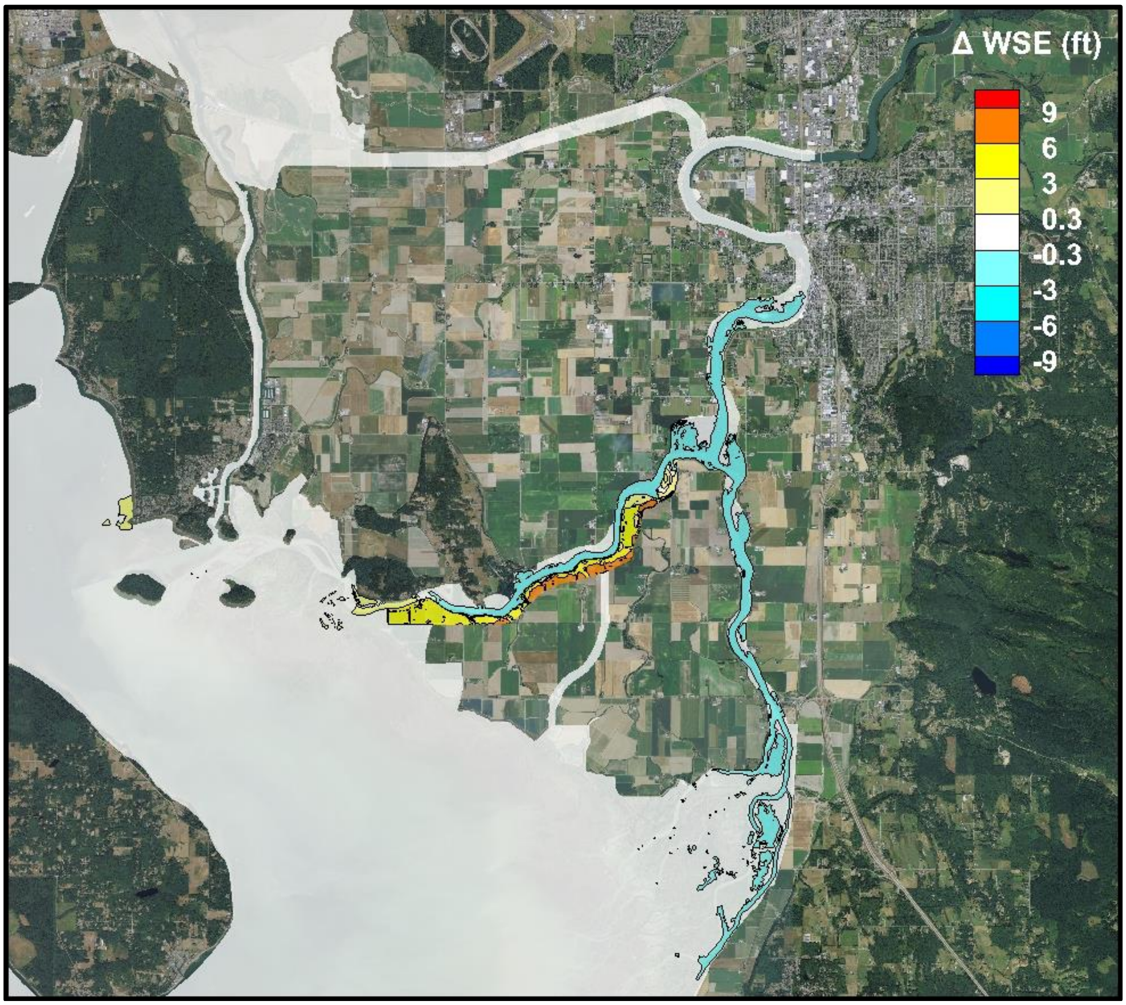


Figure E.8. Contour map of change in WSE from the Baseline to NF Levee Setback C simulation with Q2 flow and low tide.

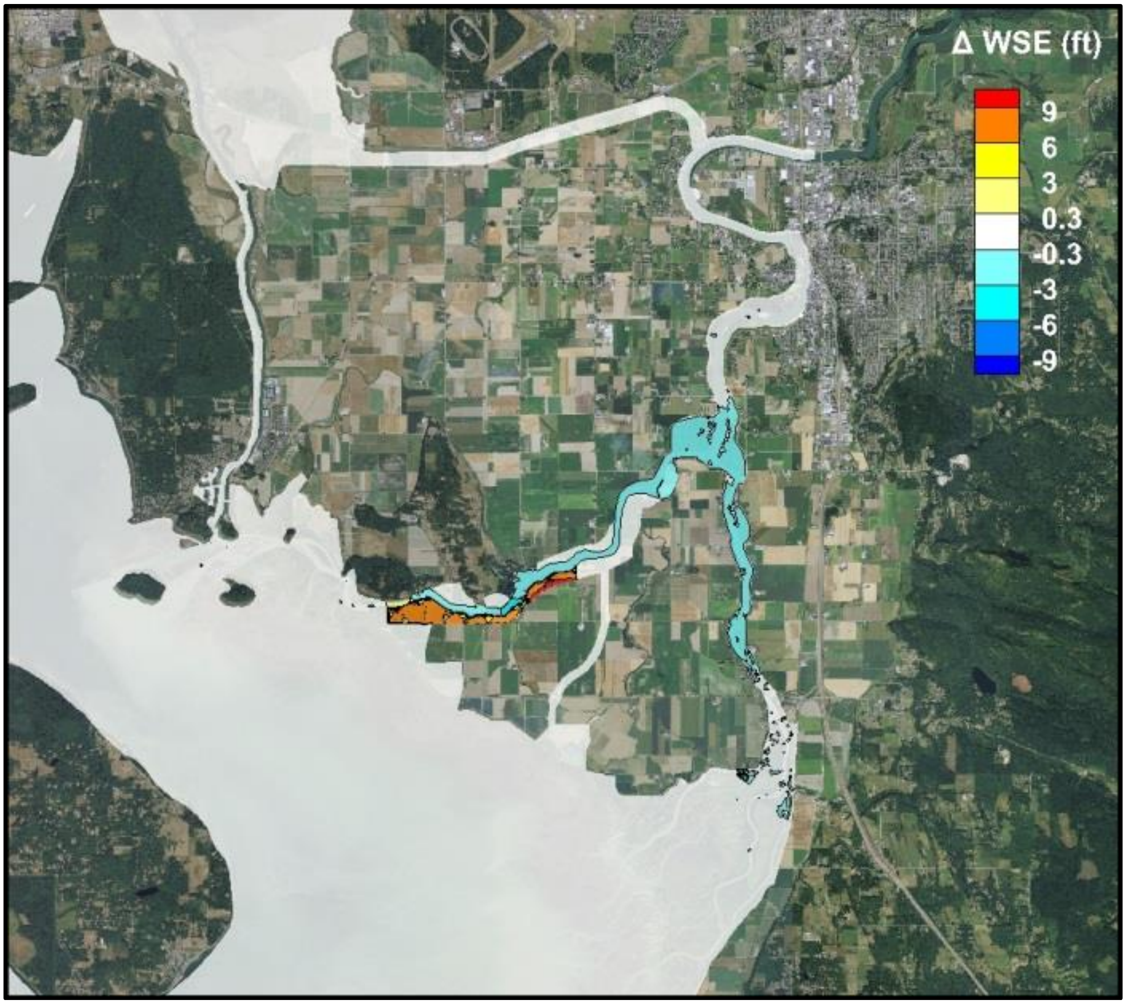


Figure E.9. Contour map of change in WSE from the Baseline to NF Levee Setback C simulation with flood flow and high tide.

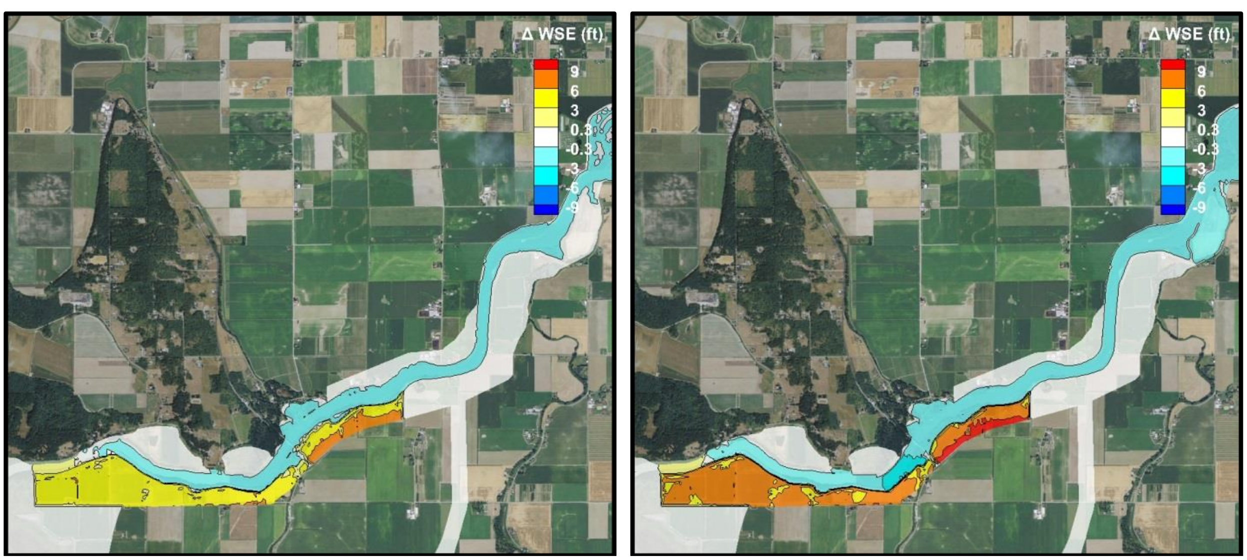


Figure E.10. Contour map of change in WSE from the Baseline simulation for NF Levee Setback C with Q2 flow and low tide (left) and flood flow and high tide (right).

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.

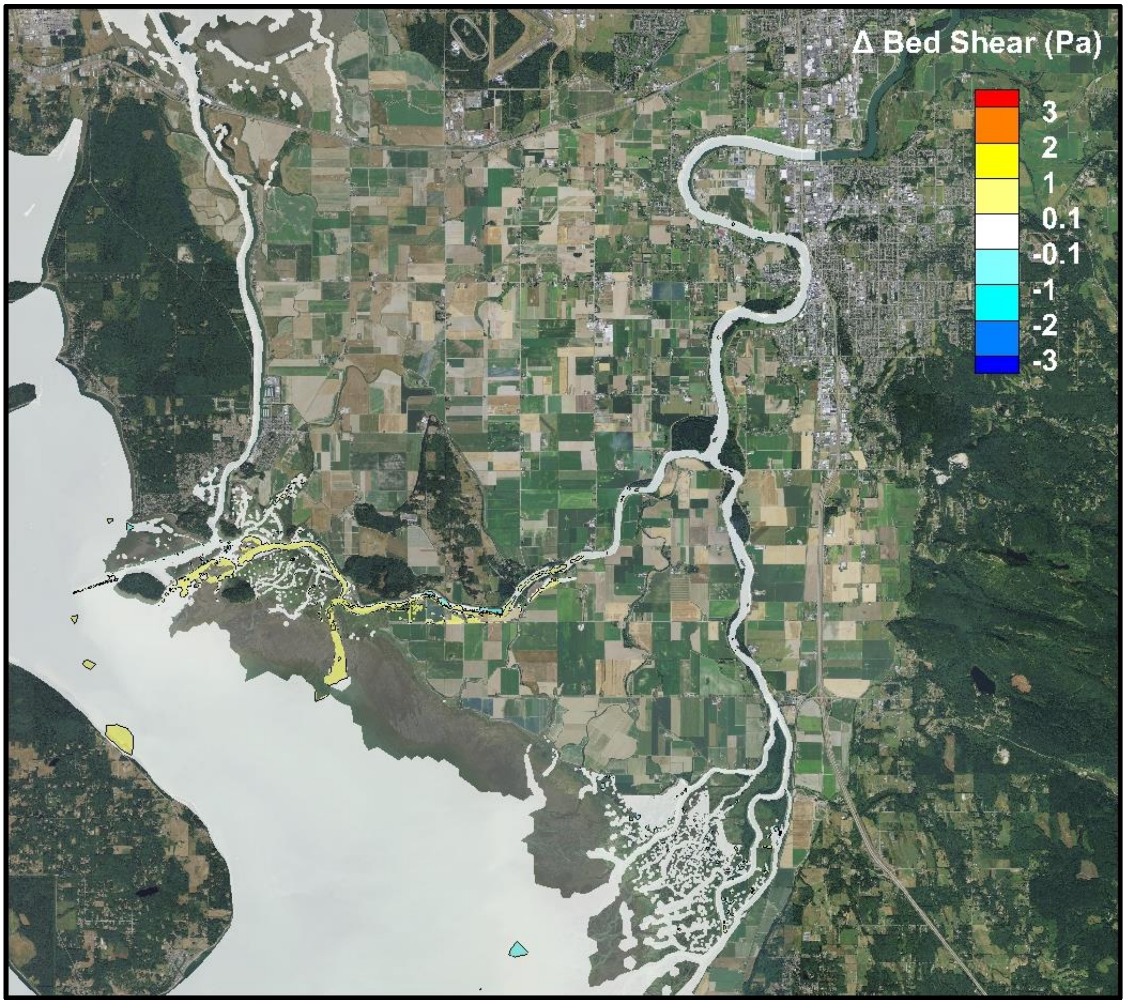


Figure E.11. Contour map of change in shear stress from the Baseline to NF Levee Setback C simulation with peak shear across a full tidal cycle at low flow**.**

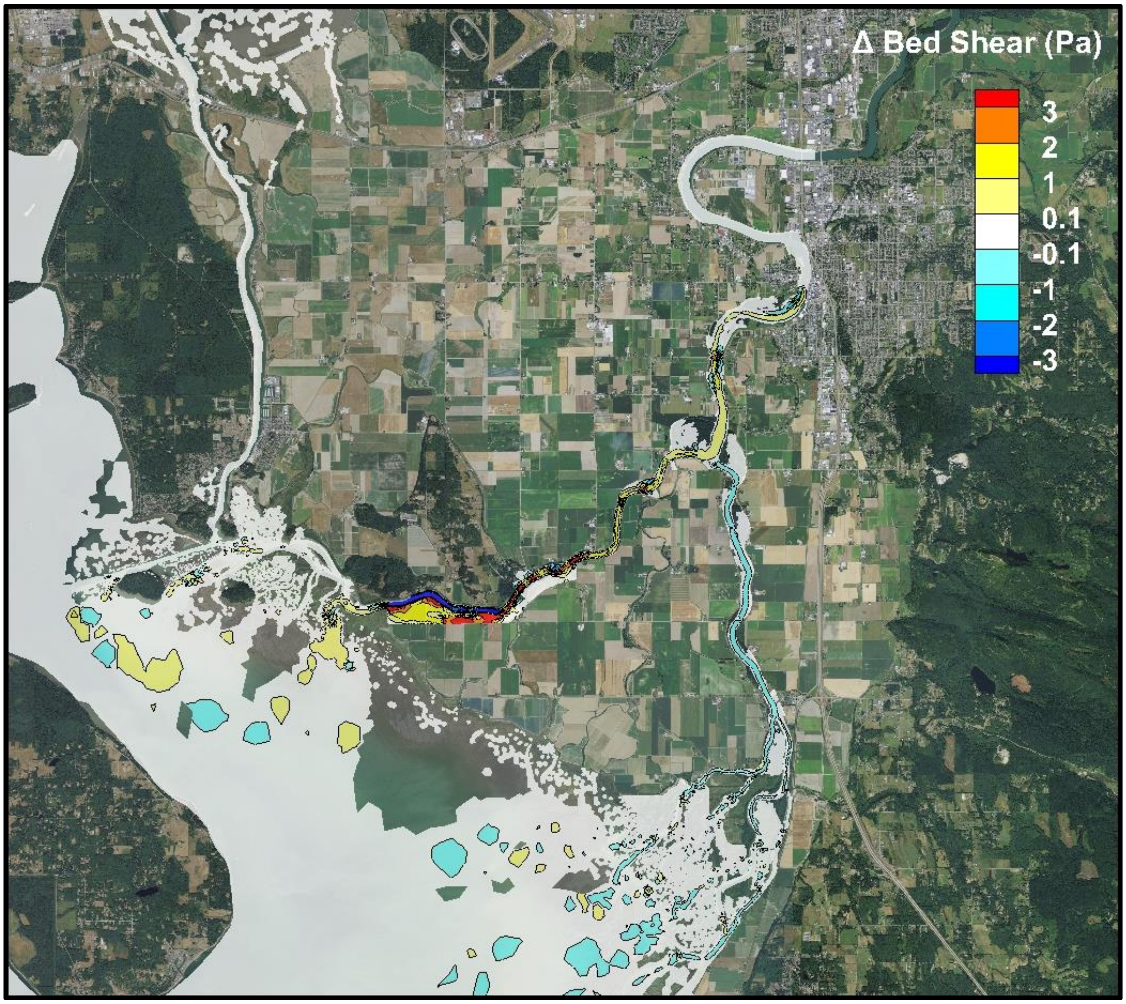


Figure E.12. Contour map of change in shear stress from the Baseline to NF Levee Setback C simulation with Q2 flow and low tide.

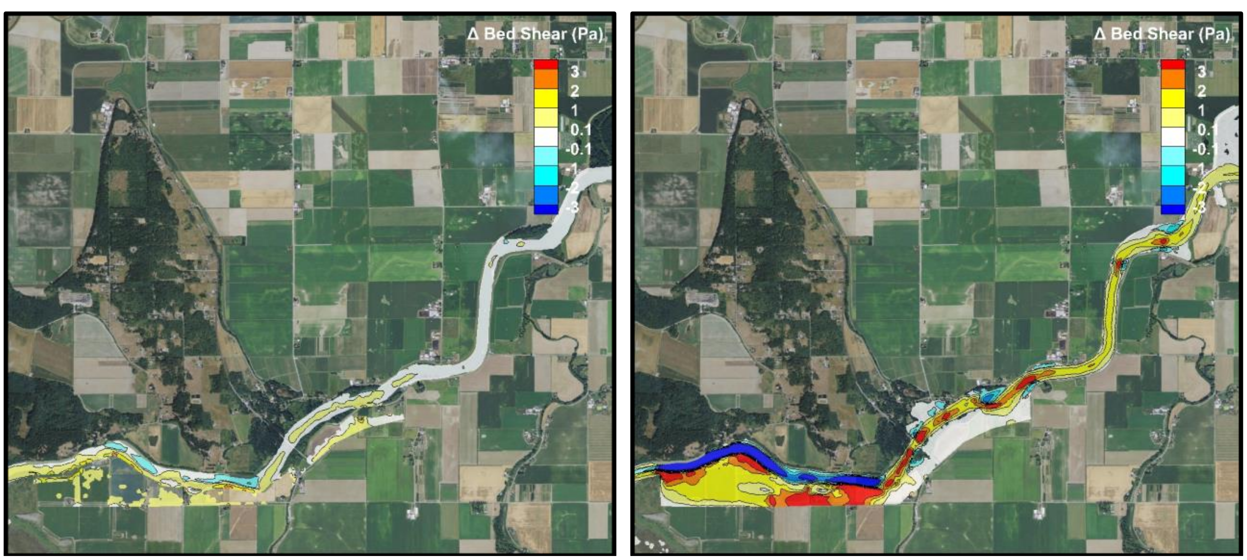


Figure E.13. Contour map of change in shear stress from Baseline for NF Levee Setback C with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

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.

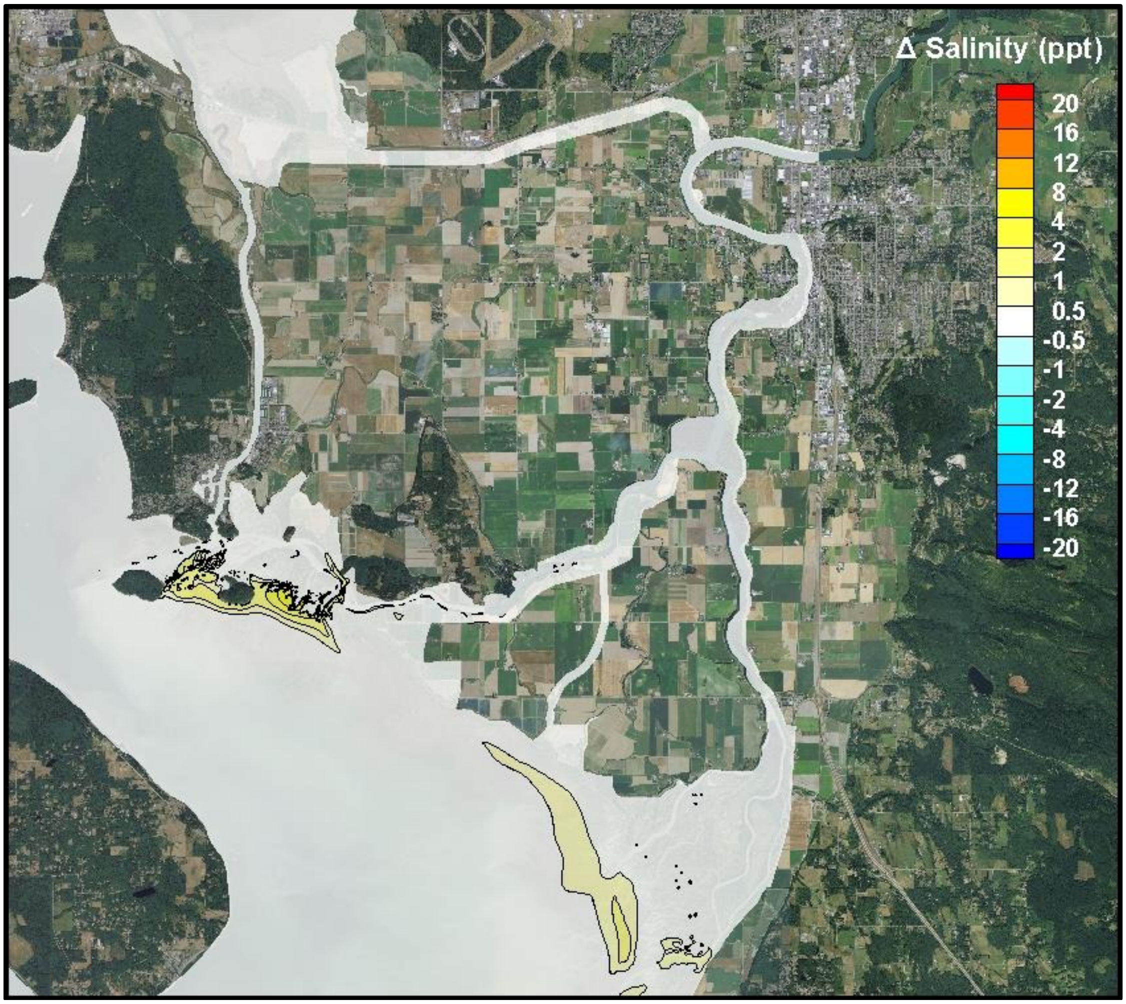


Figure E.14. Contour map of change in salinity from the Baseline to NF Levee Setback C simulation with low flow and high tide.

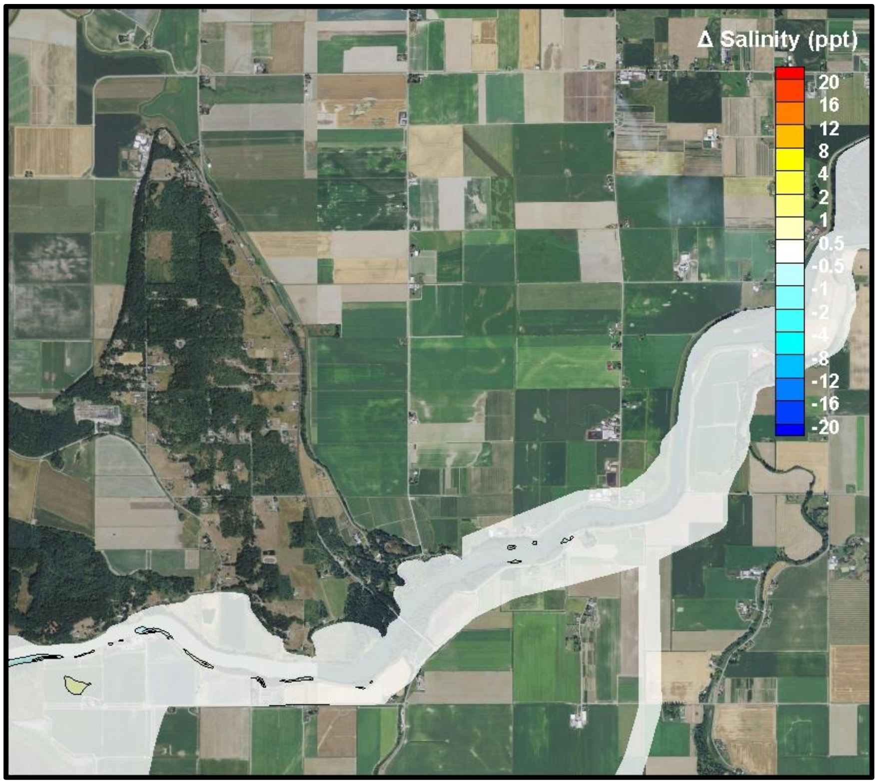


Figure E.15. Contour map of change in salinity from the Baseline simulation for NF Levee Setback C with low flow and high tide.

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.

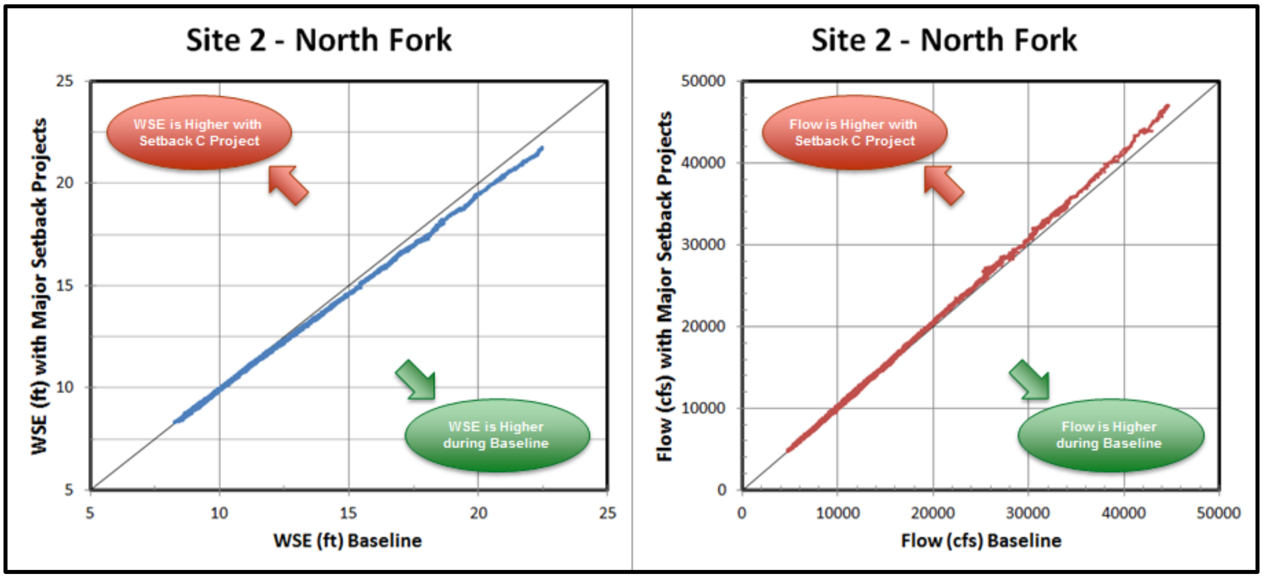


Figure E.16. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Setback Project simulation at the North Fork gauge location compared with the same information under baseline conditions.

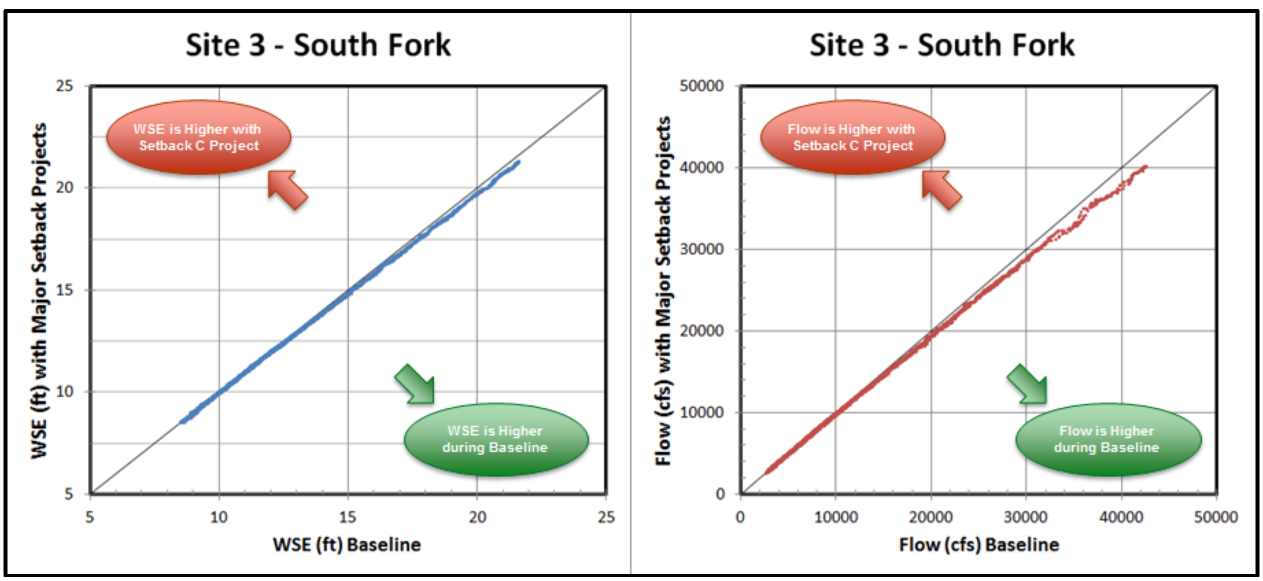


Figure E.17. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Setback Project simulation at the South Fork gauge location compared with the same information under baseline conditions.

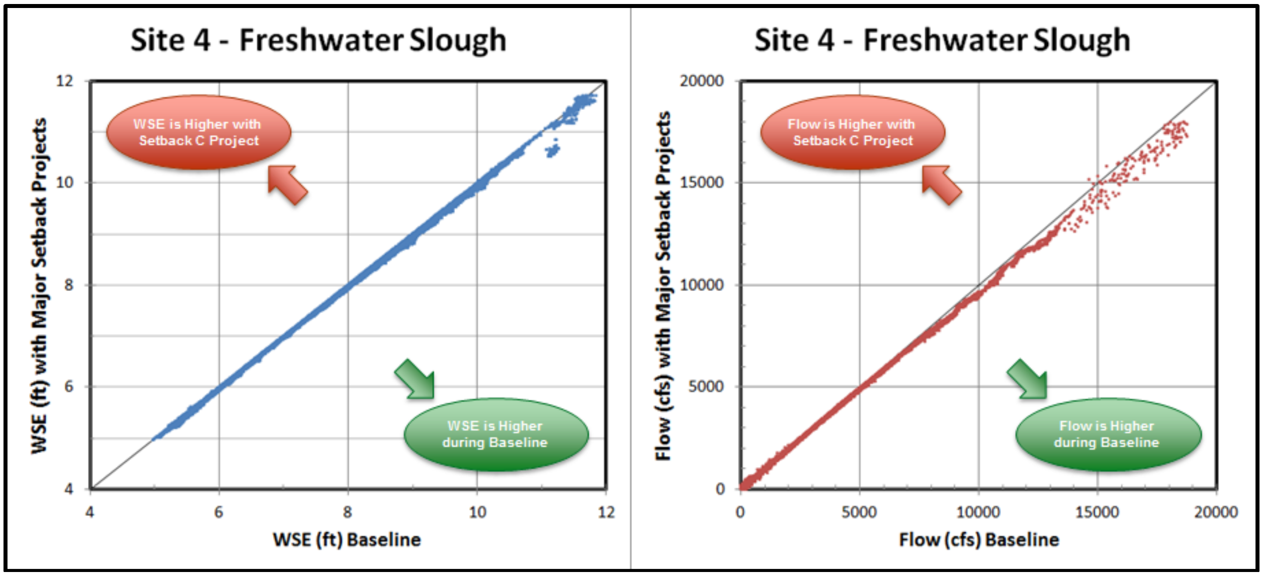


Figure E.18. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Setback Project simulation at the Freshwater Slough gauge location compared with the same information under baseline conditions.

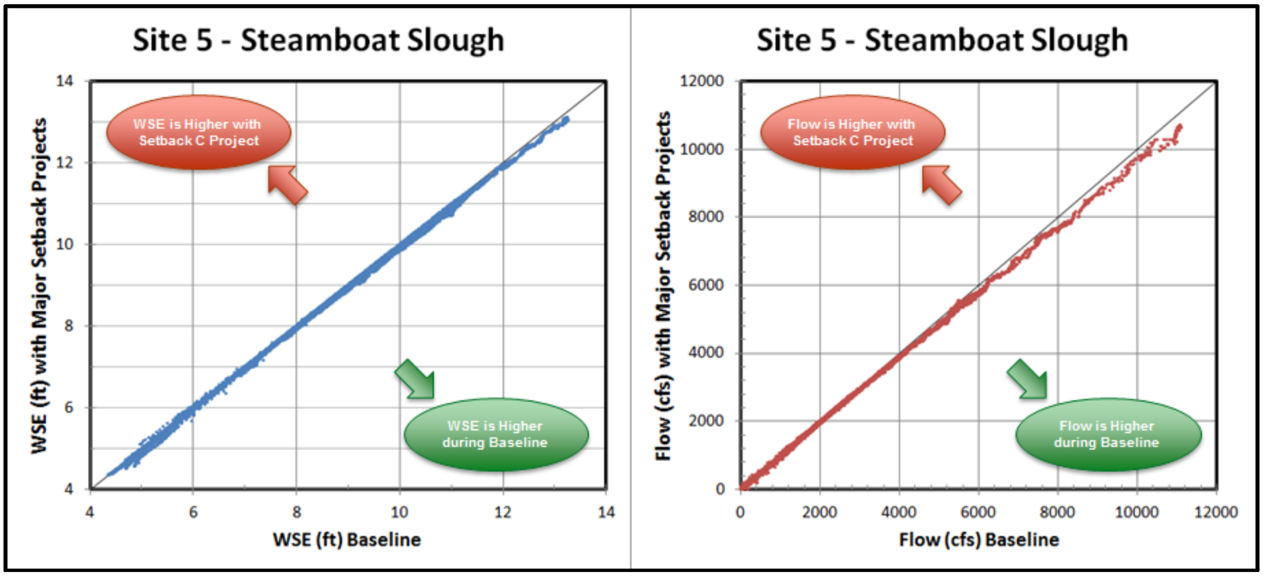


Figure E.19. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Setback Project simulation at the Steamboat Slough gauge location compared with the same information under baseline conditions.

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.

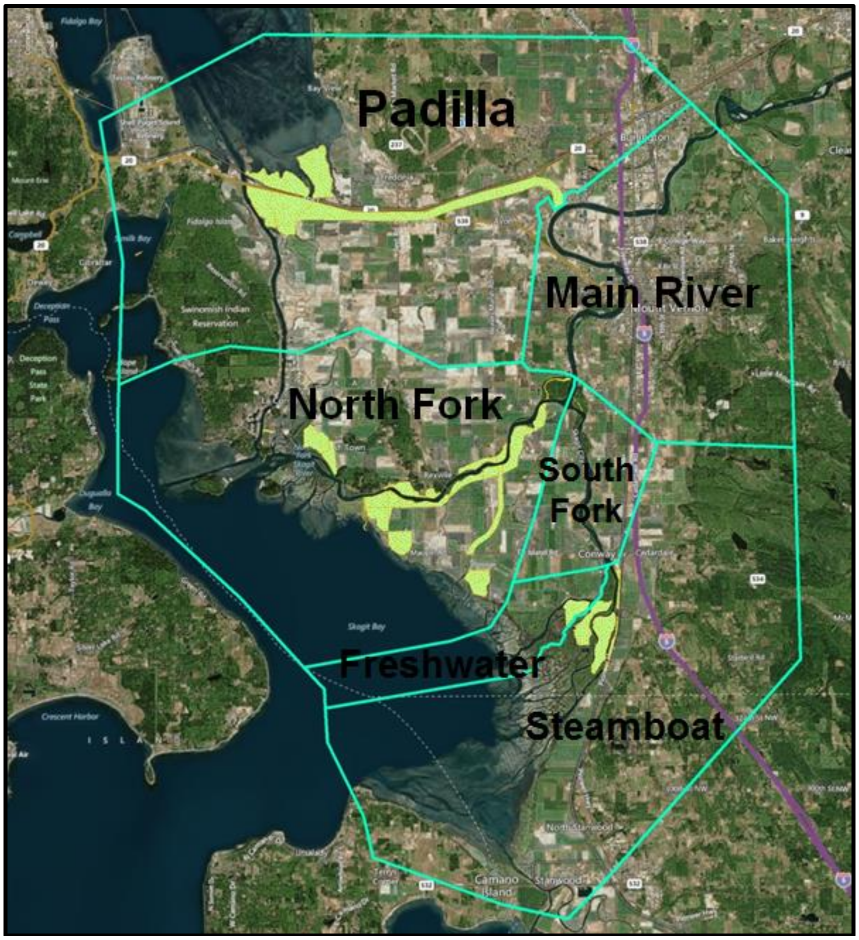


Figure F.2. Sub-basins within the Skagit region used for area calculations.

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.

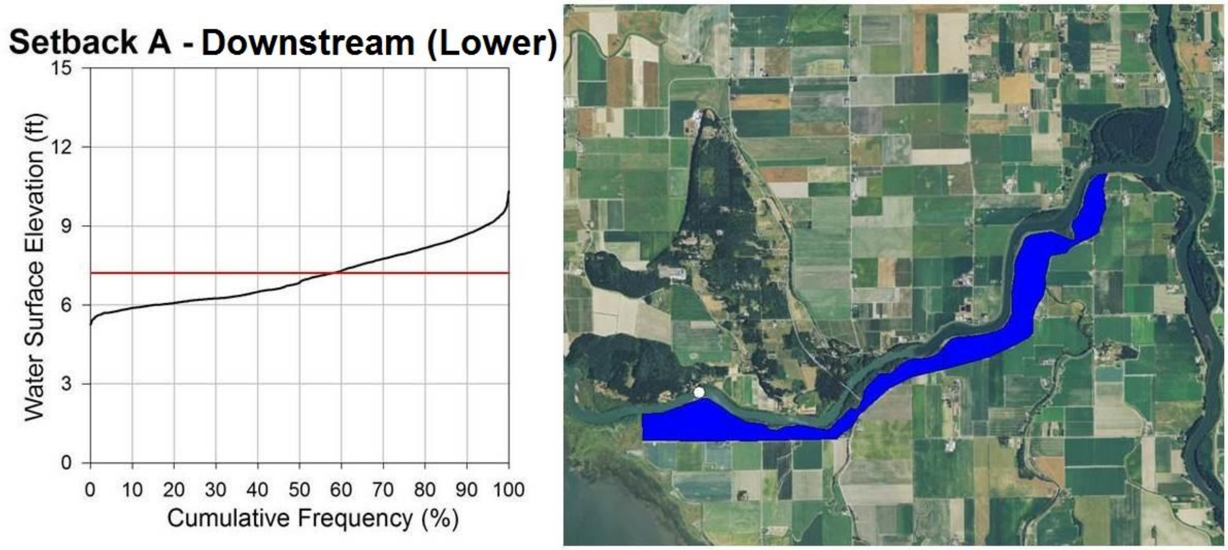


Figure F.3. Cumulative frequency plot and corresponding map for NF Levee Setback A - Downstream (Lower) during the Major Setback Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

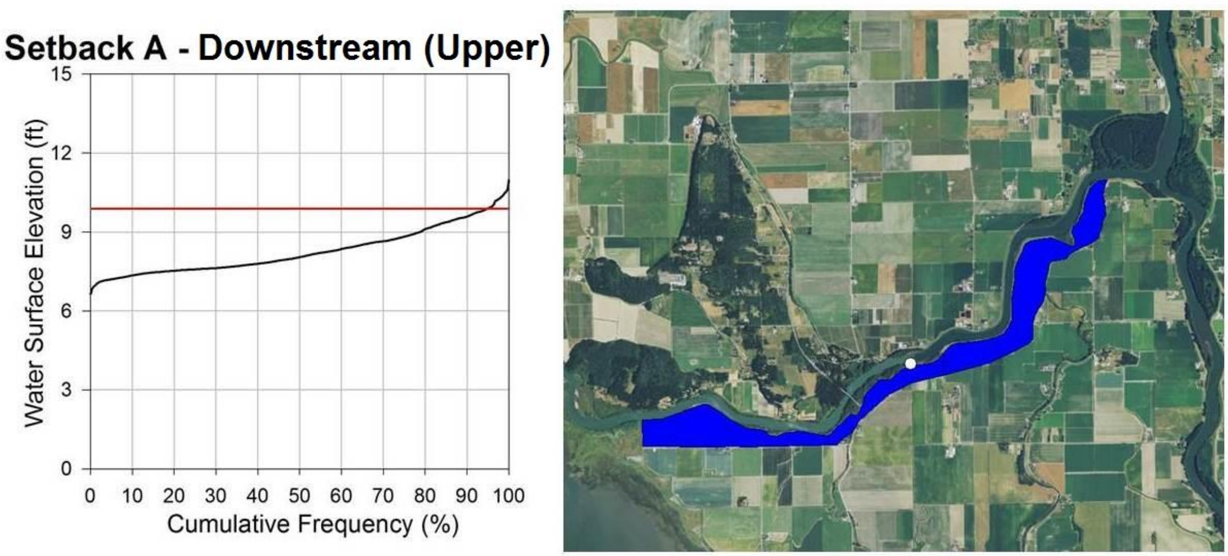


Figure F.4. Cumulative frequency plot and corresponding map for NF Levee Setback A - Downstream (Upper) during the Major Setback Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

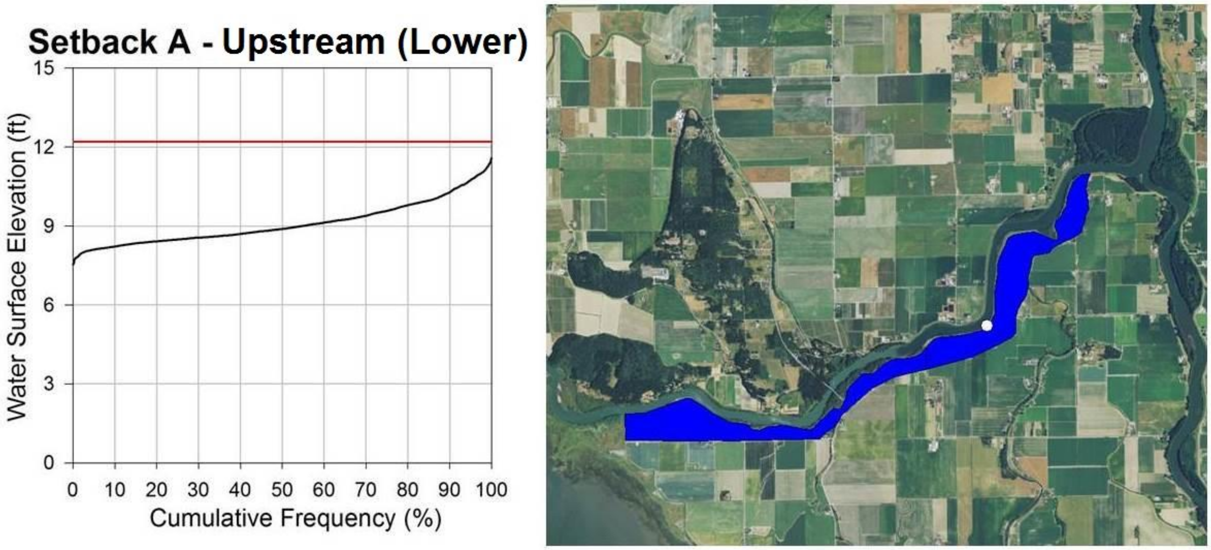


Figure F.5. Cumulative frequency plot and corresponding map for NF Levee Setback A - Upstream (Lower) during the Major Setback Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

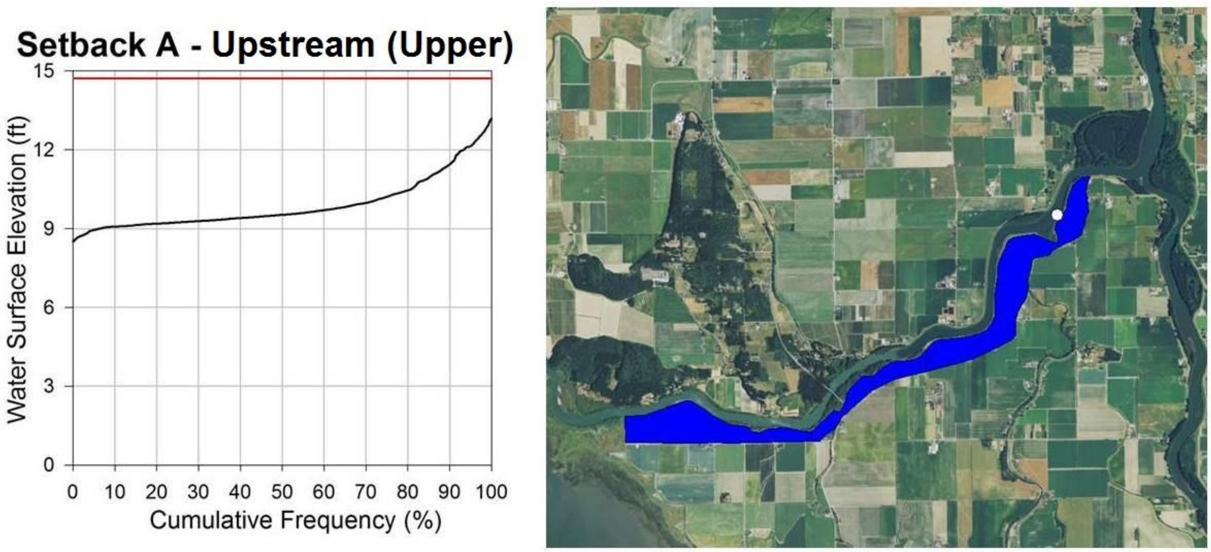


Figure F.6. Cumulative frequency plot and corresponding map for NF Levee Setback A - Upstream (Upper) during the Major Setback Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

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.

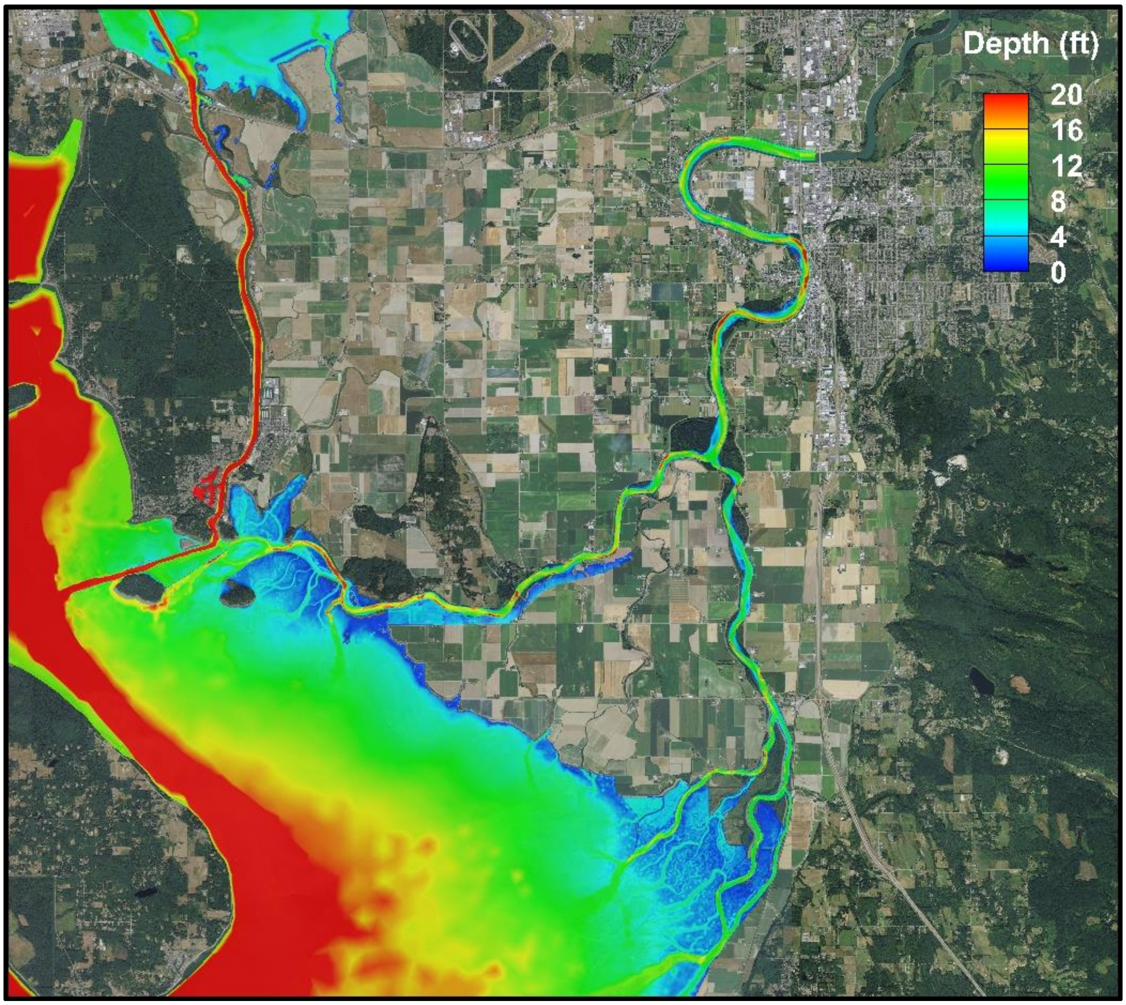


Figure F.7. Contour map of depths for the full domain during the Major Setback Project North Fork Levee Setback A simulation with May flow and high spring tide.

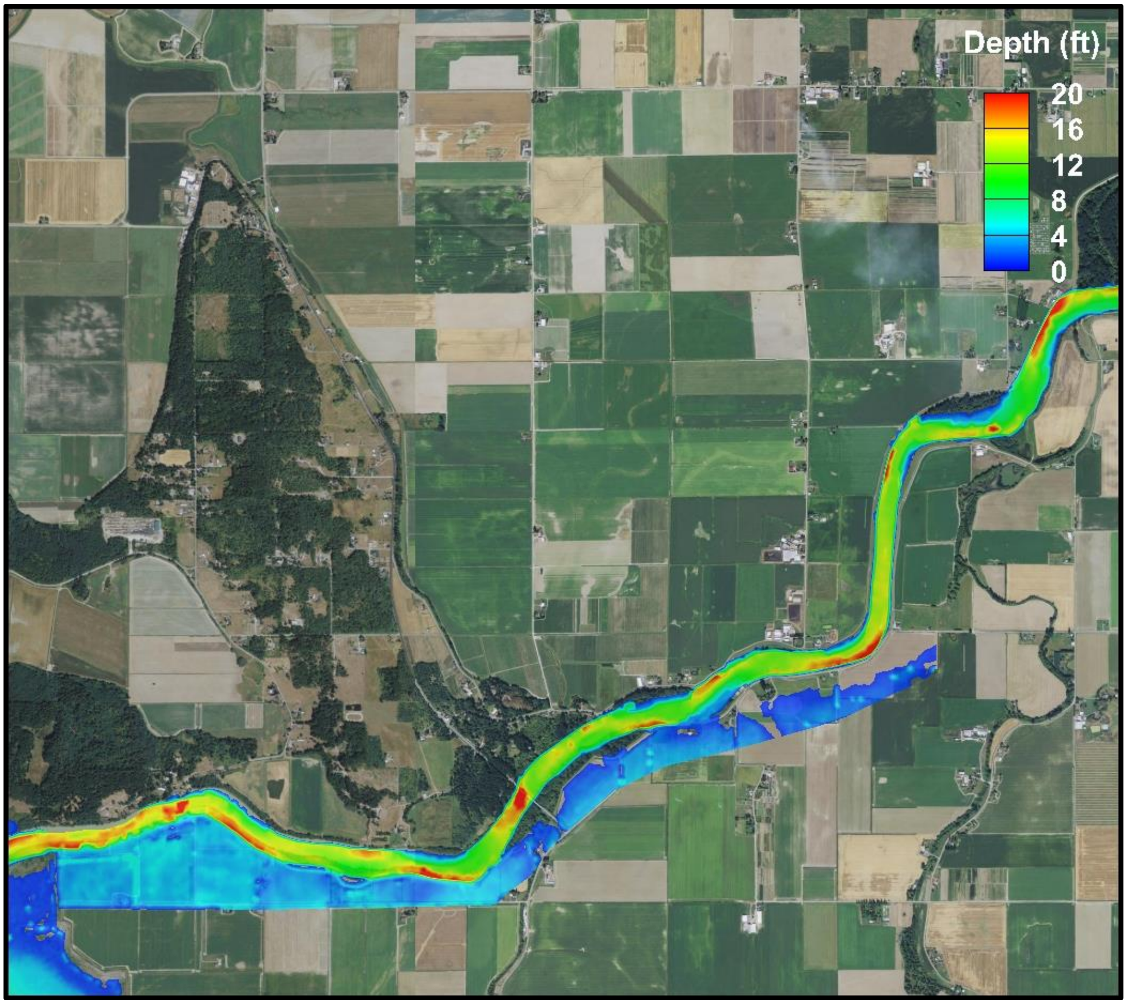


Figure F.8. Contour map of depths for NF Levee Setback A during the Major Setback Project simulation.

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.

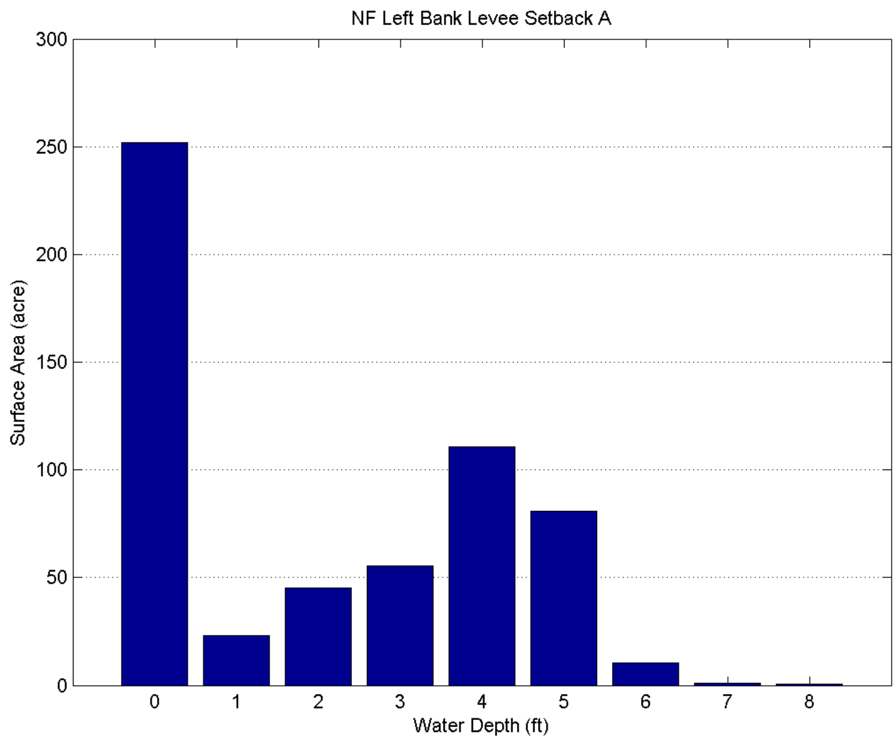


Figure F.9. Histogram of depths for NF Levee Setback A.

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.

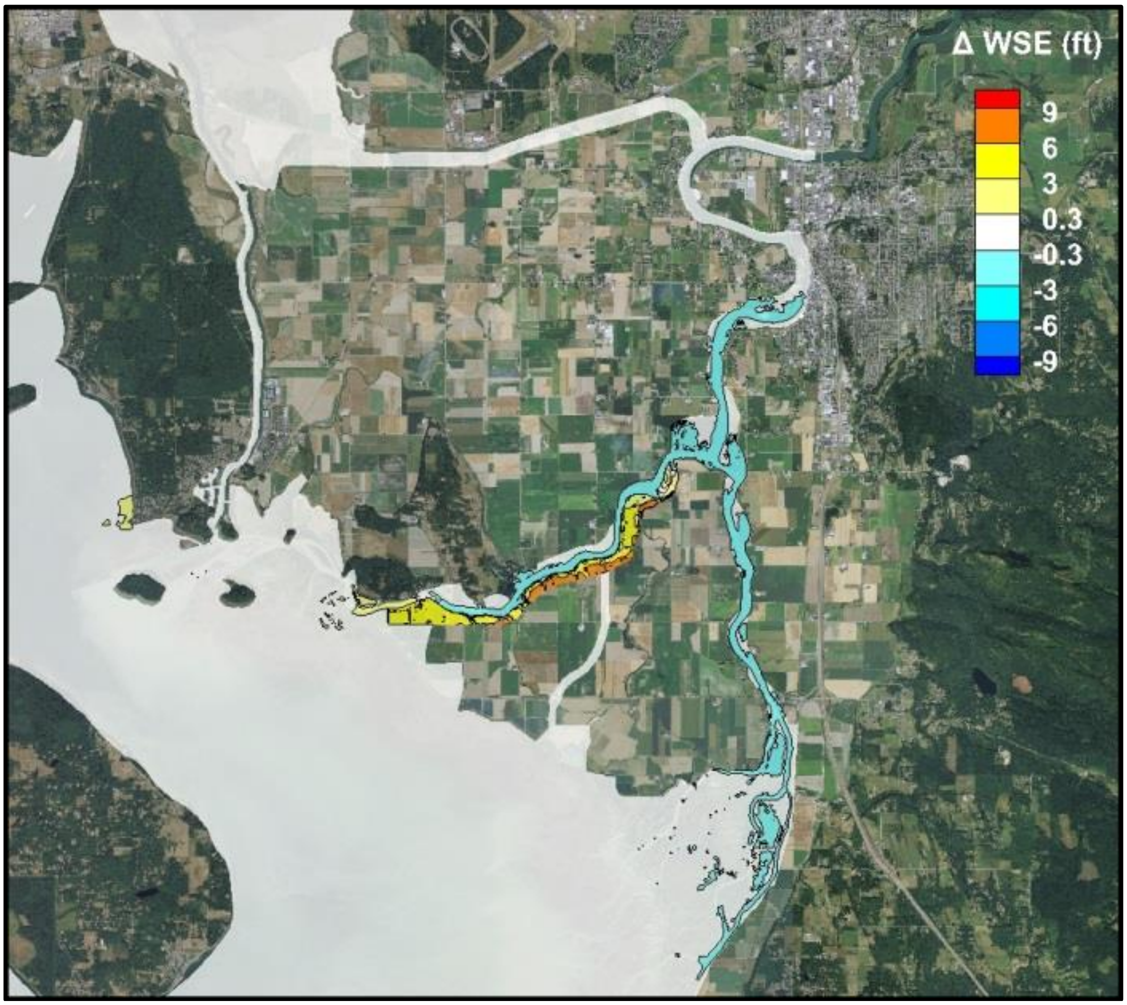


Figure F.10. Contour map of change in WSE from the Baseline to NF Levee Setback A simulation with Q2 flow and low tide.

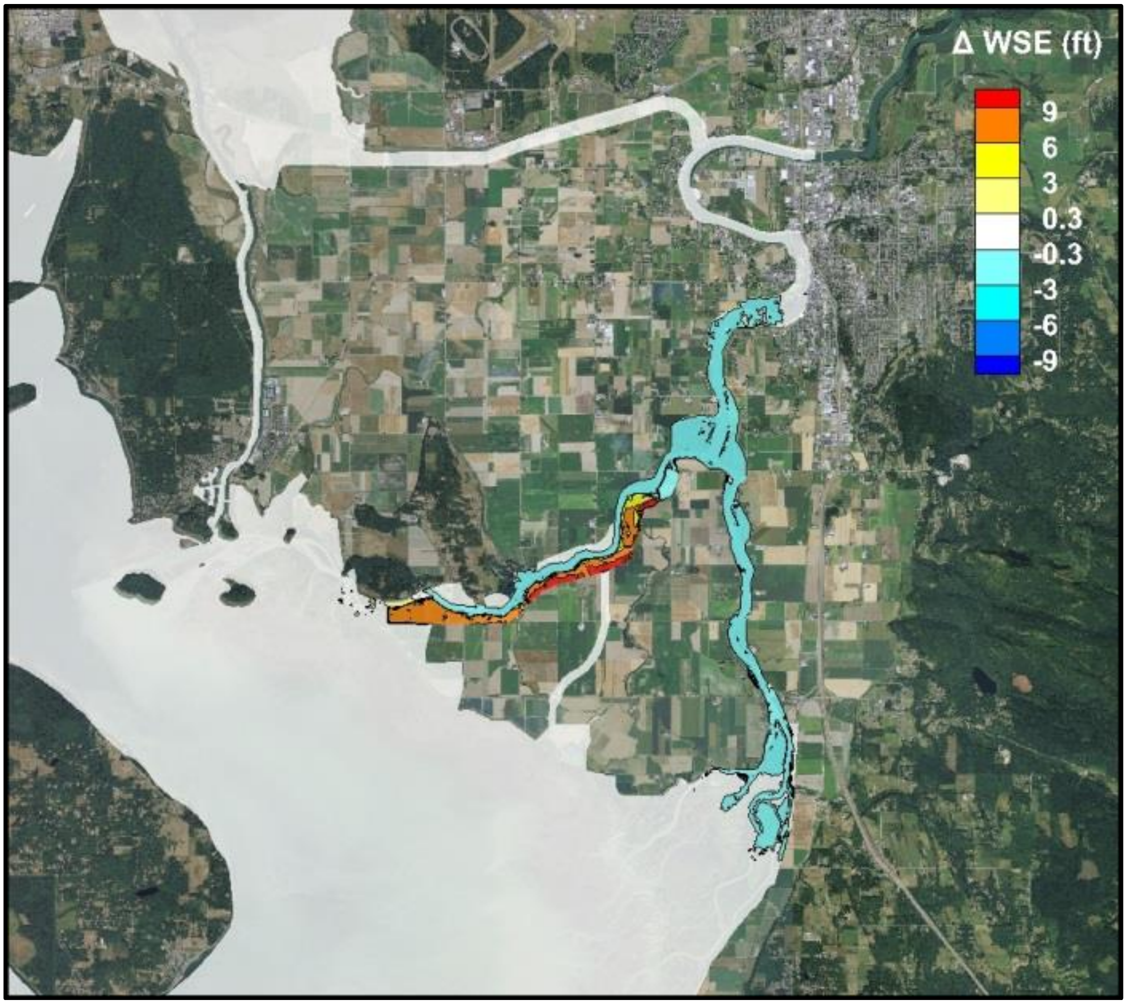


Figure F.11. Contour map of change in WSE from the Baseline to NF Levee Setback A simulation with flood flow and high tide.

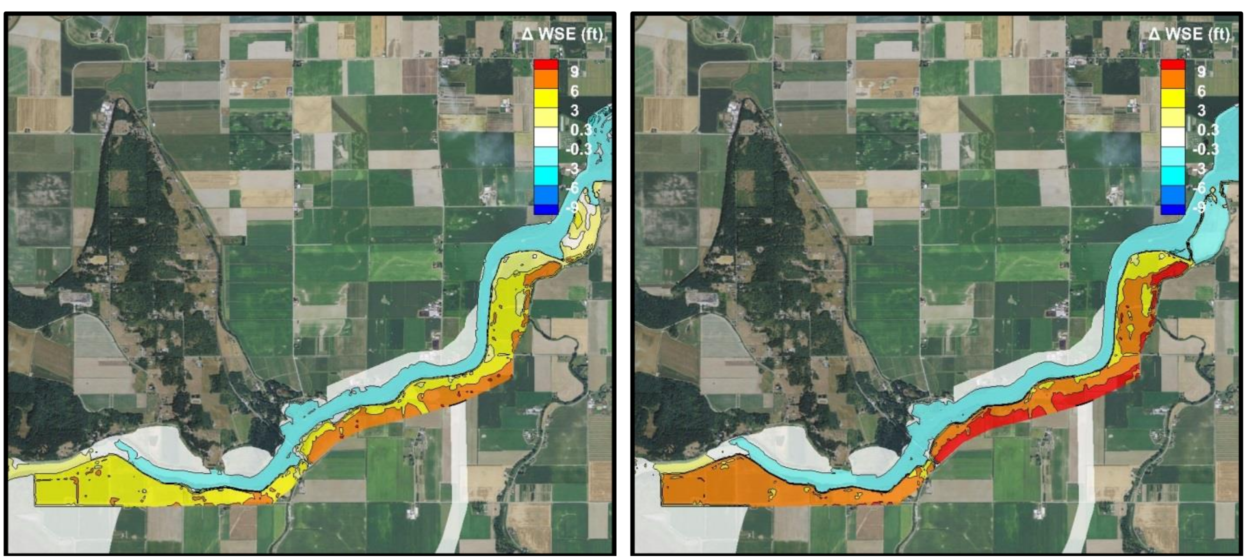


Figure F.12. Contour map of change in WSE from the Baseline simulation for NF Levee Setback A with Q2 flow and low tide (left) and flood flow and high tide (right).

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.

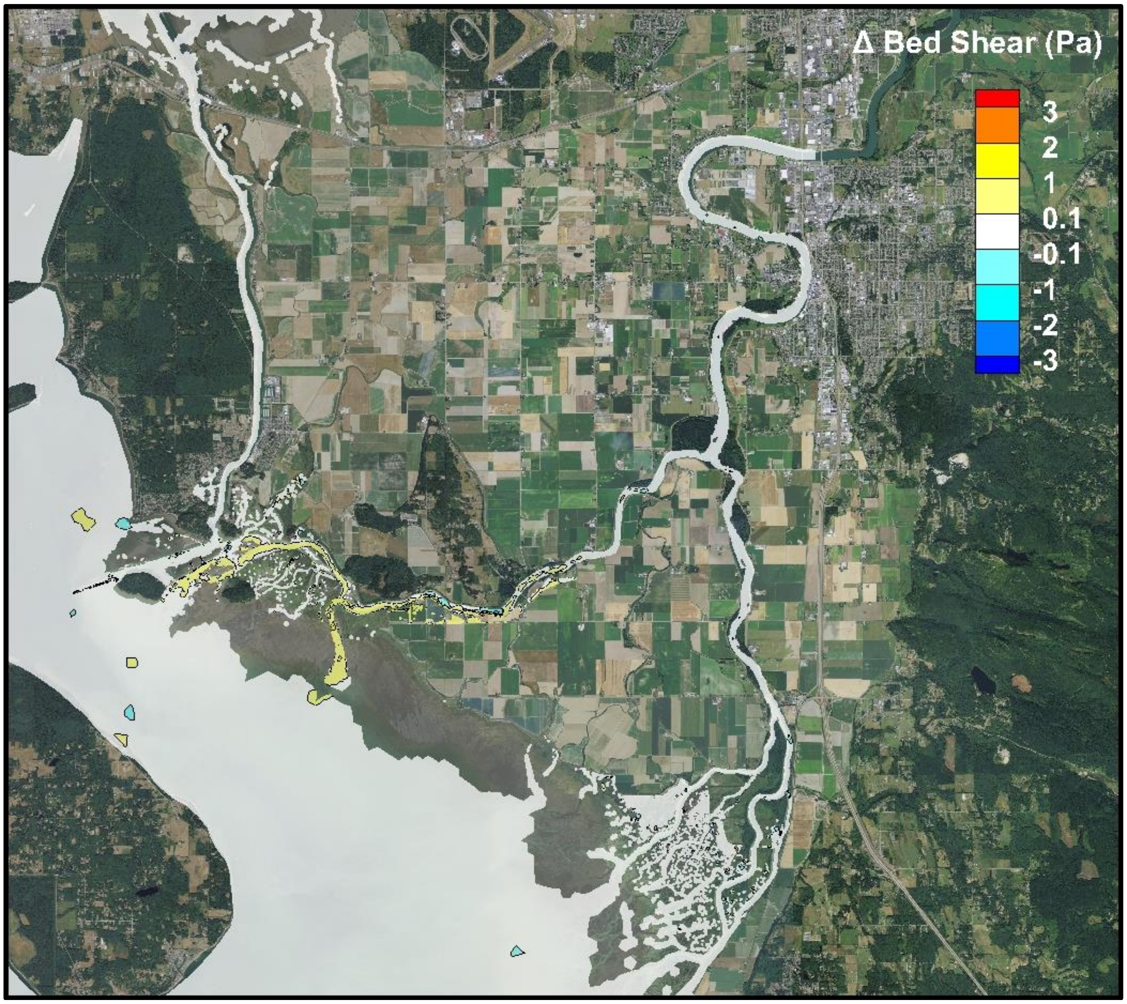


Figure F.13. Contour map of change in shear stress from the Baseline to NF Levee Setback A simulation with peak shear across a full tidal cycle at low flow.

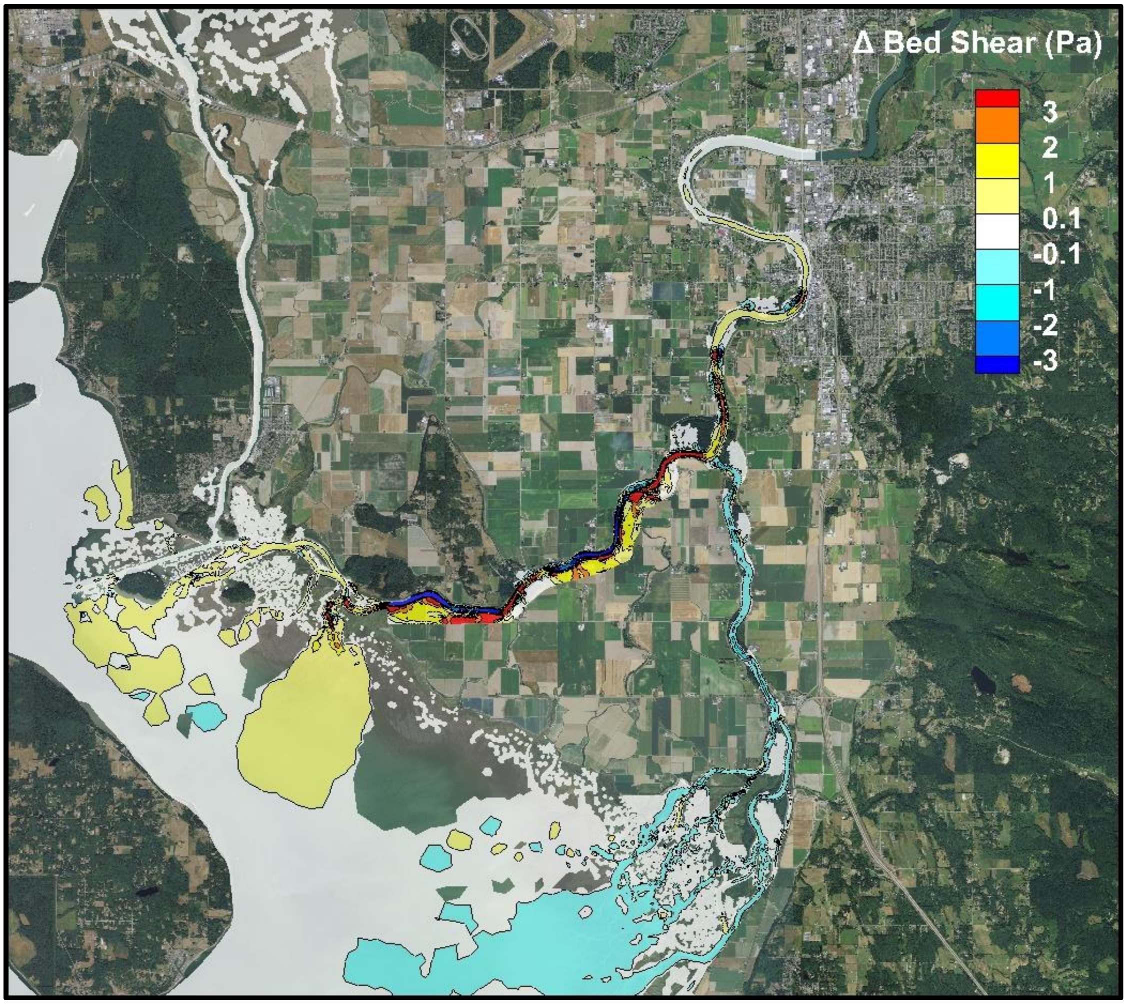


Figure F.14. Contour map of change in shear stress from the Baseline to NF Levee Setback A simulation with Q2 flow and low tide.

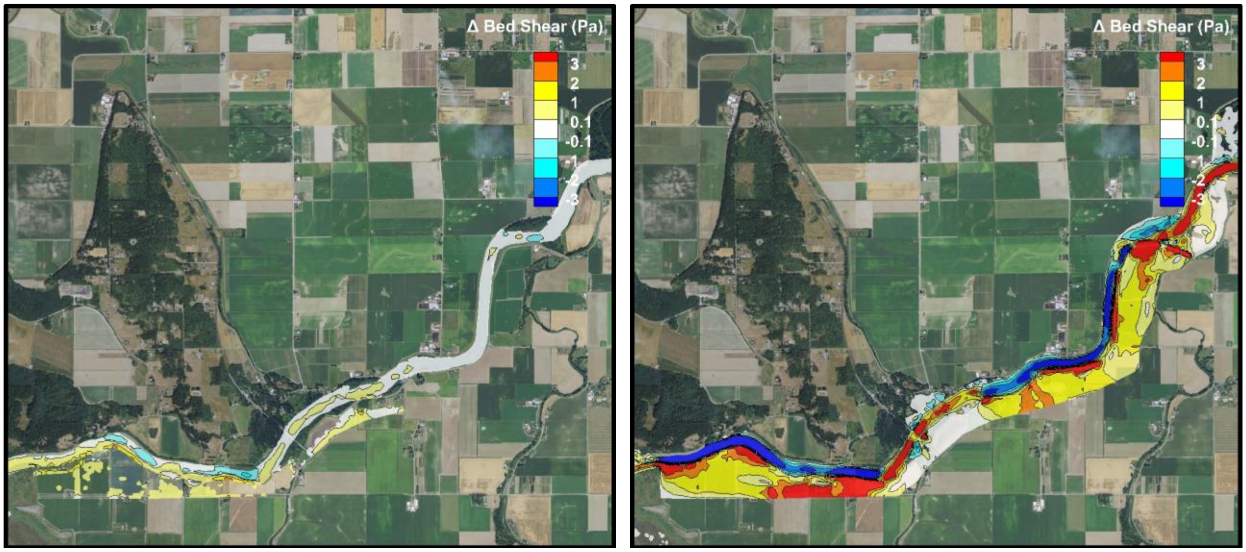


Figure F.15. Contour map of change in shear stress from Baseline for NF Levee Setback A with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

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.

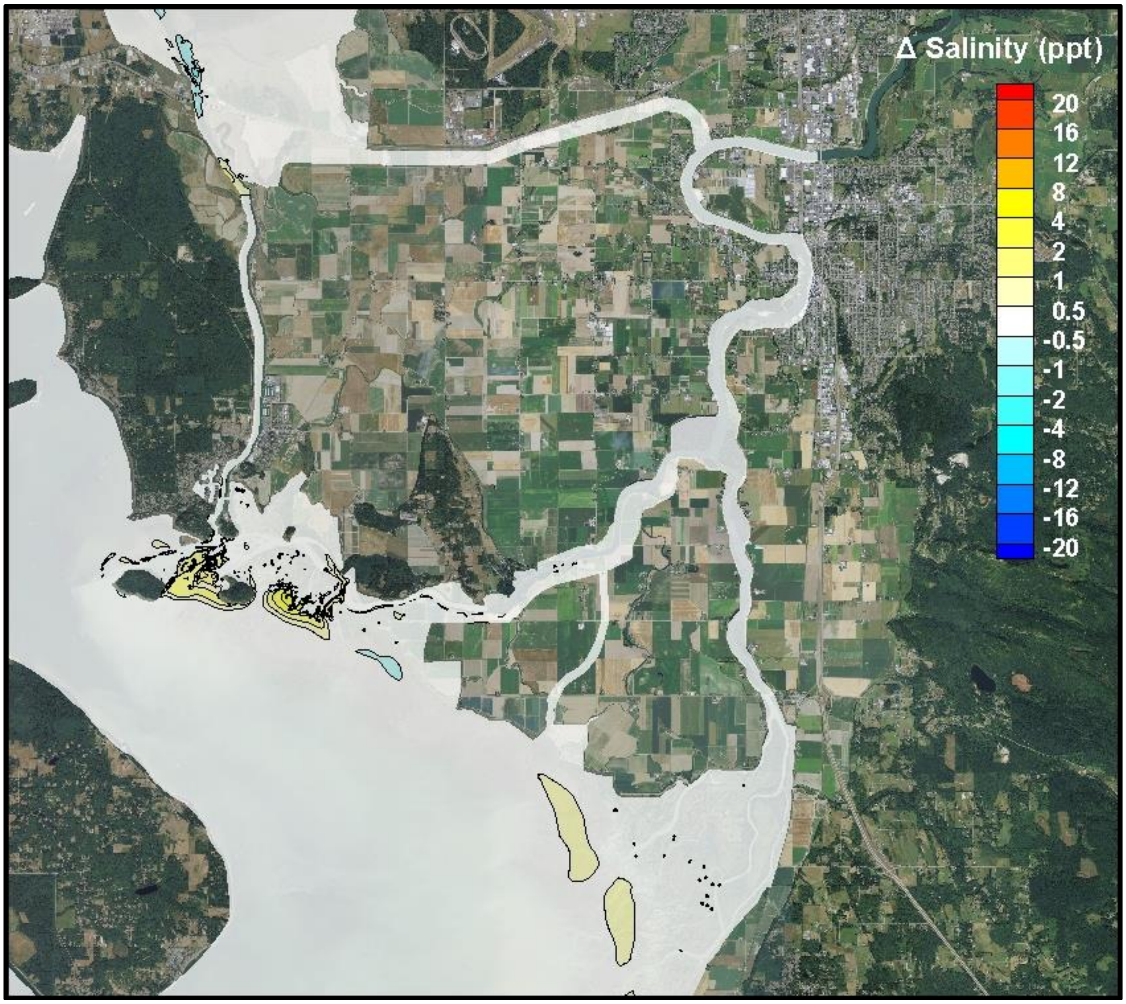


Figure F.16. Contour map of change in salinity from the Baseline to NF Levee Setback A simulation with low flow and high tide.

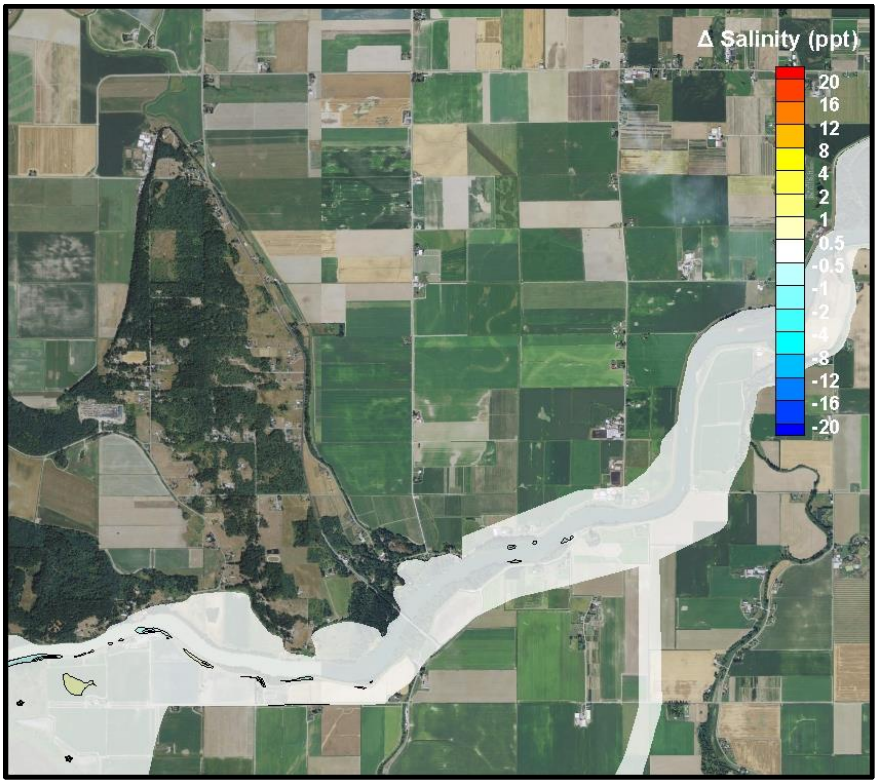


Figure F.17. Contour map of change in salinity from the Baseline simulation for NF Levee Setback A with low flow and high tide.

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.

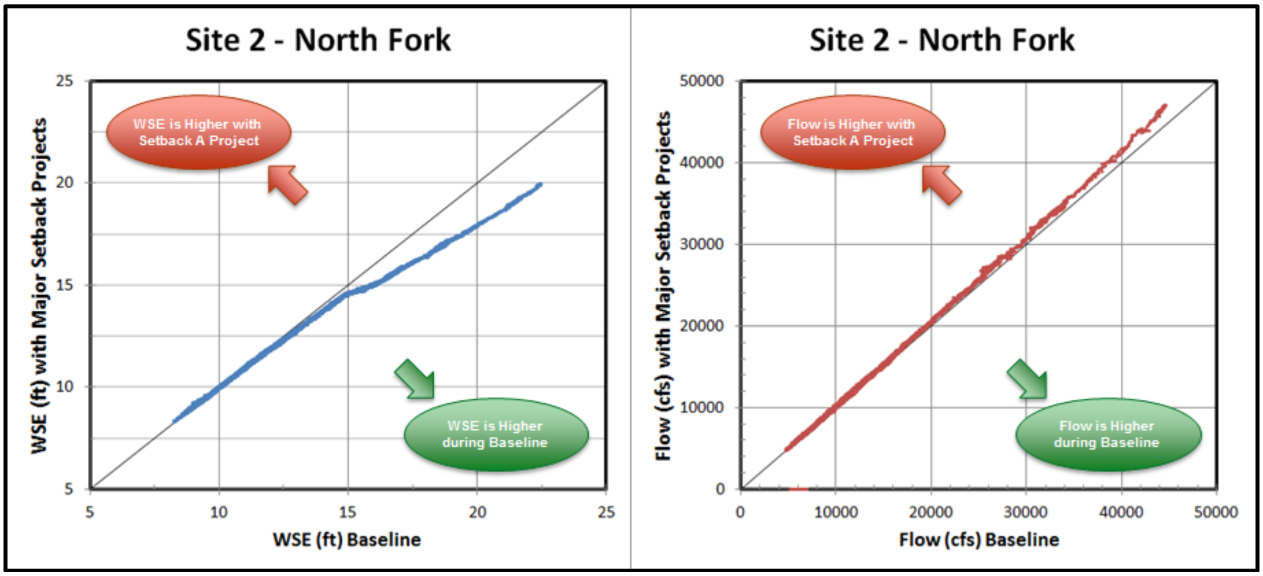


Figure F.18. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Setback Project simulation at the North Fork gauge location compared with the same information under baseline conditions.

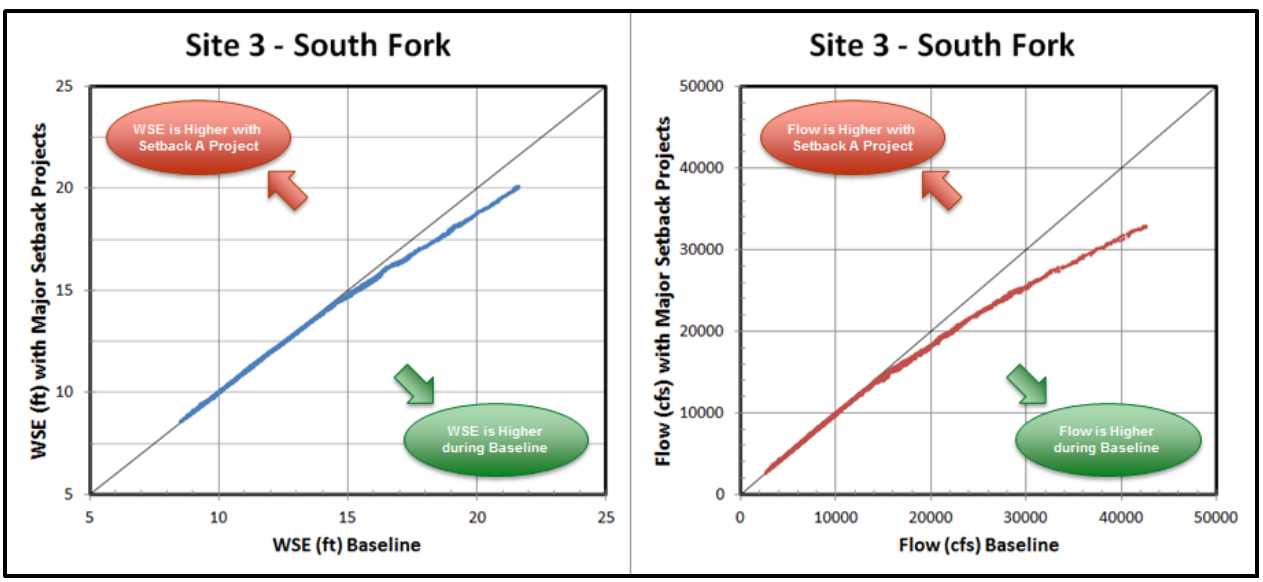


Figure F.19. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Setback Project simulation at the South Fork gauge location compared with the same information under baseline conditions.

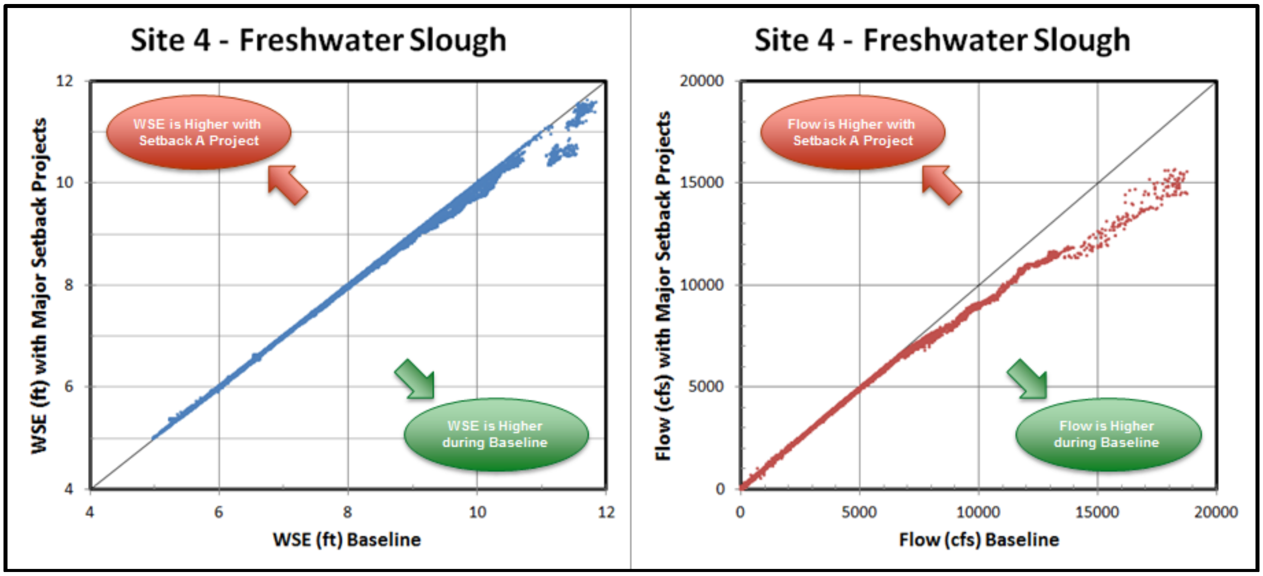


Figure F.20. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Setback Project simulation at the Freshwater Slough gauge location compared with the same information under baseline conditions.

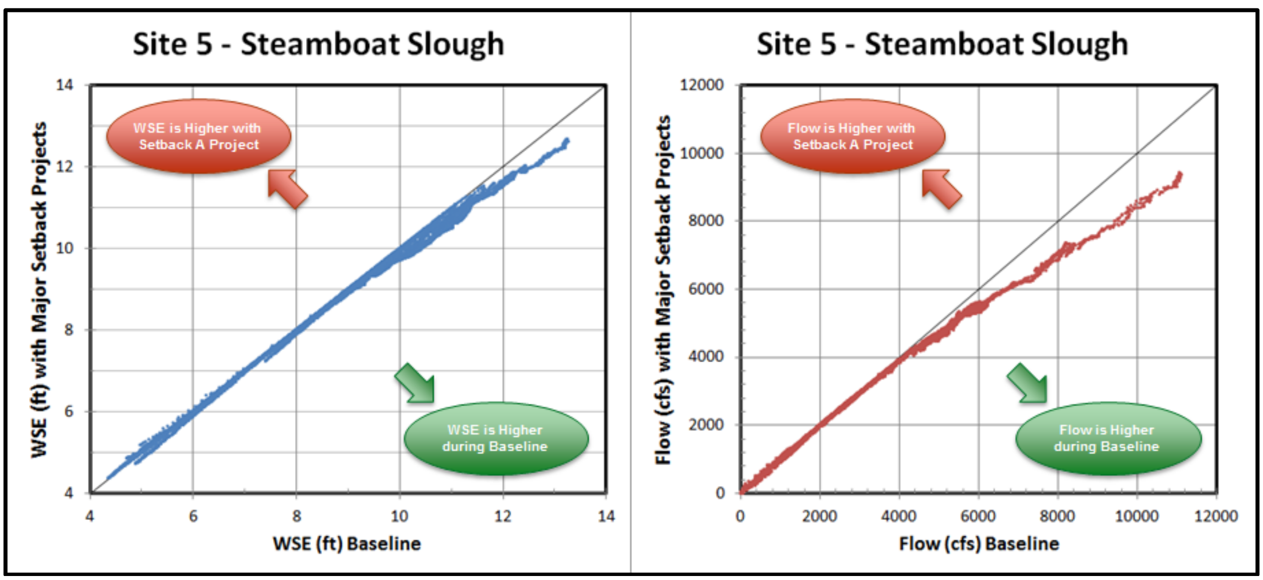


Figure F.21. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Major Setback Project simulation at the Steamboat Slough gauge location compared with the same information under baseline conditions.

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.

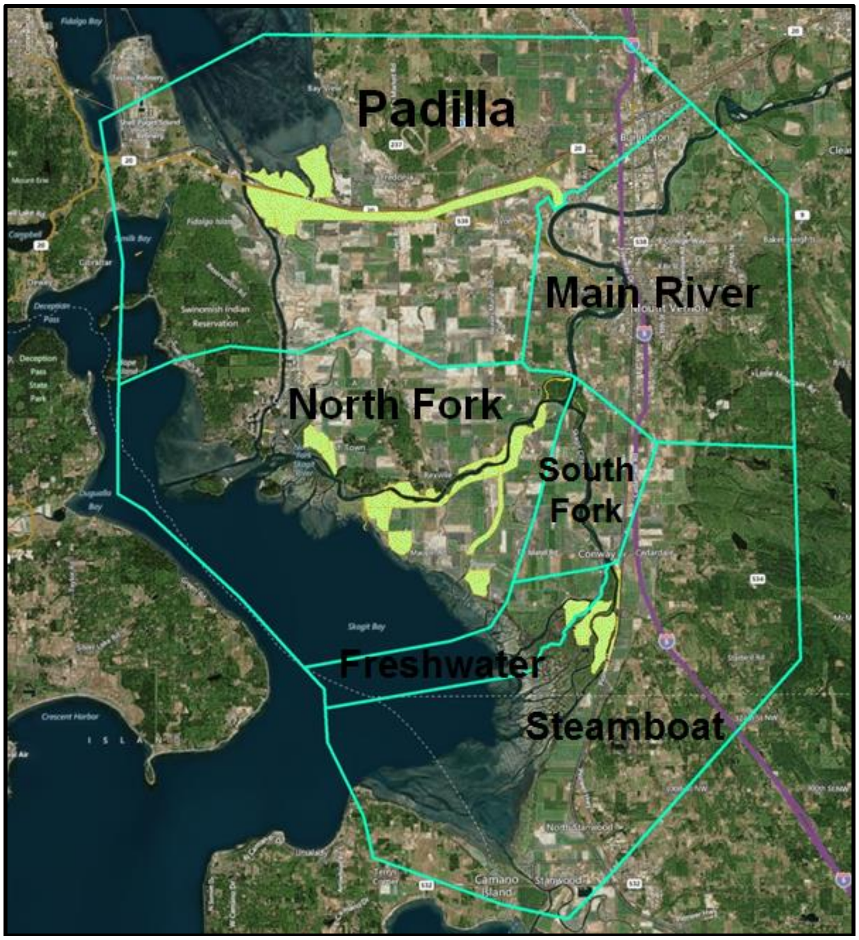


Figure G.2. Sub-basins within the Skagit region used for area calculations.

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.

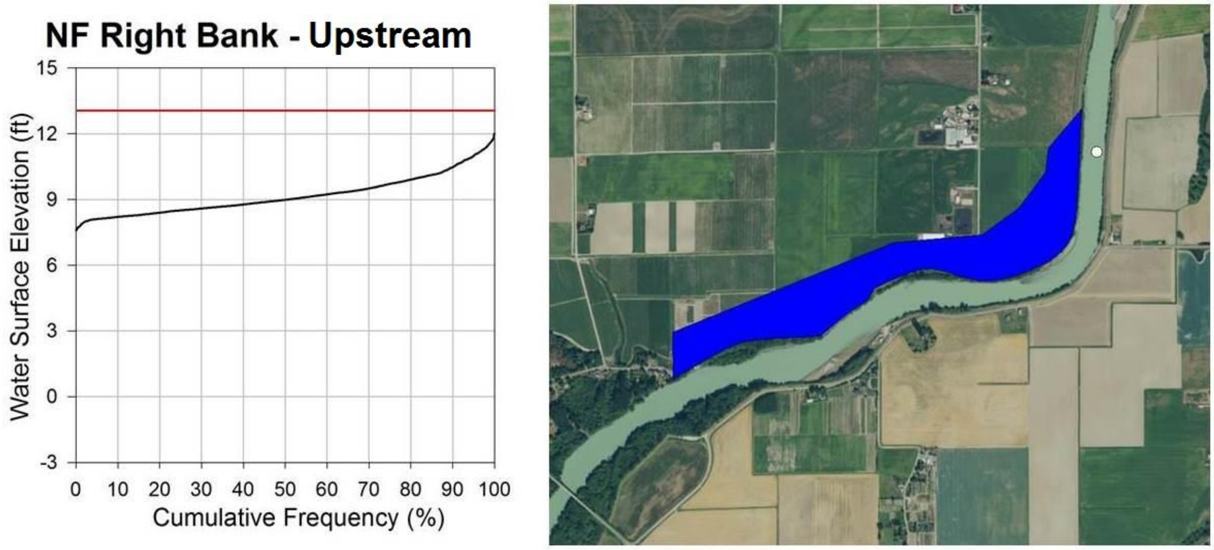


Figure G.3. Cumulative frequency plot and corresponding map for NF Right Bank Levee Setback (upstream) during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

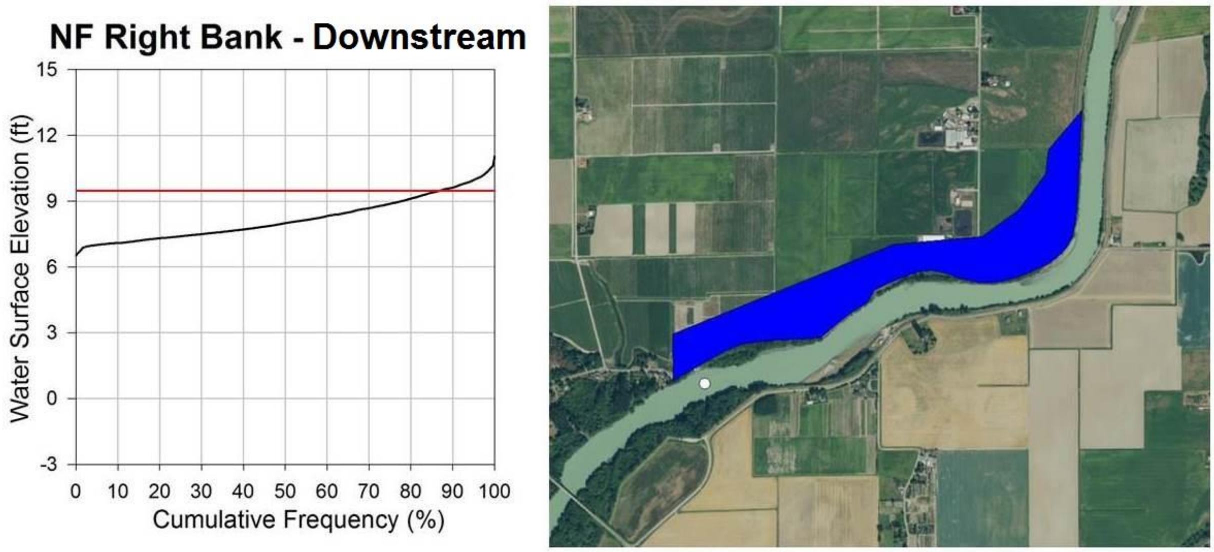


Figure G.4. Cumulative frequency plot and corresponding map for NF Right Bank Levee Setback (downstream) during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

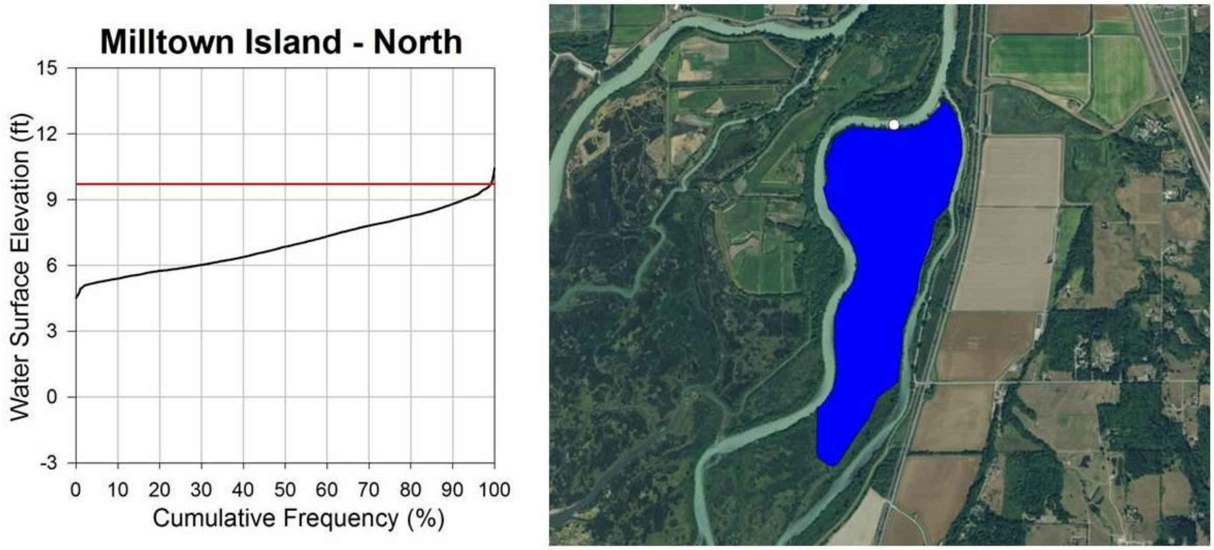


Figure G.5. Cumulative frequency plot and corresponding map for Milltown Island (north) during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

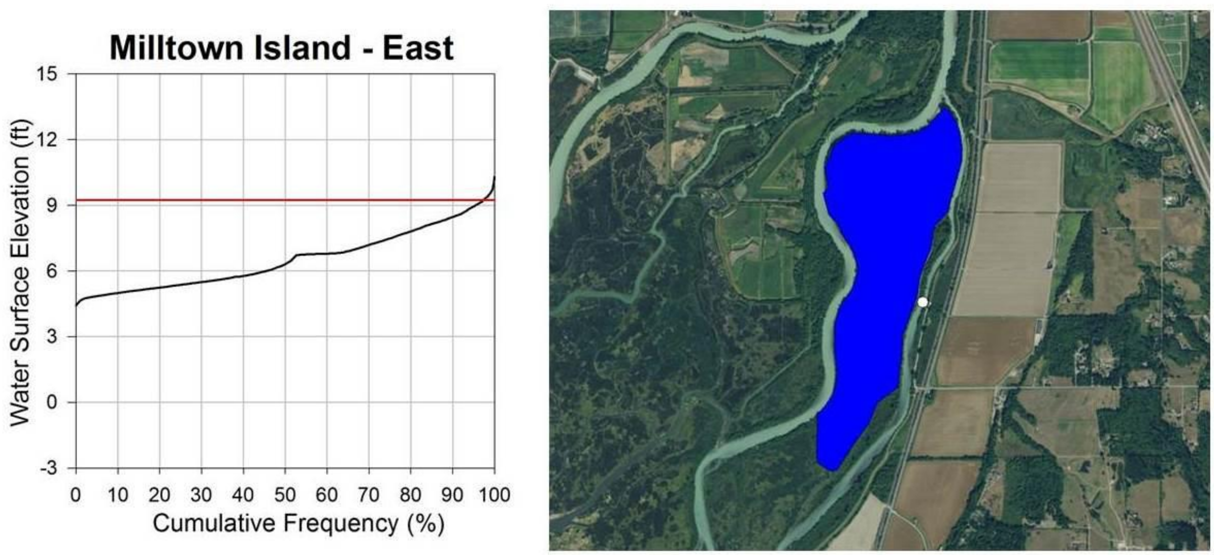


Figure G.6. Cumulative frequency plot and corresponding map for Milltown Island (east) during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

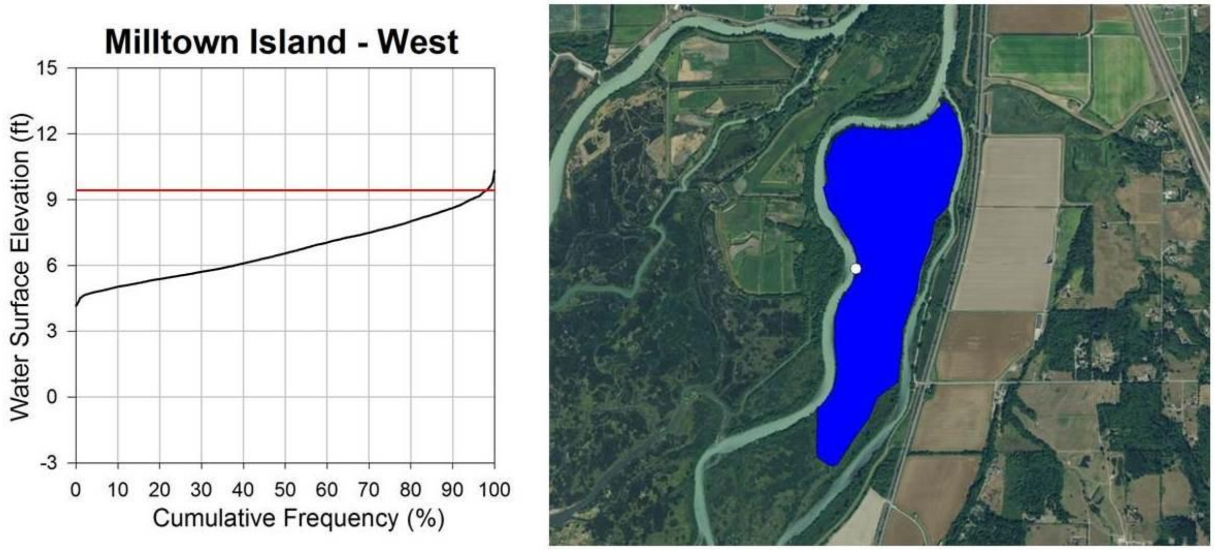


Figure G.7. Cumulative frequency plot and corresponding map for Milltown Island (west) during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

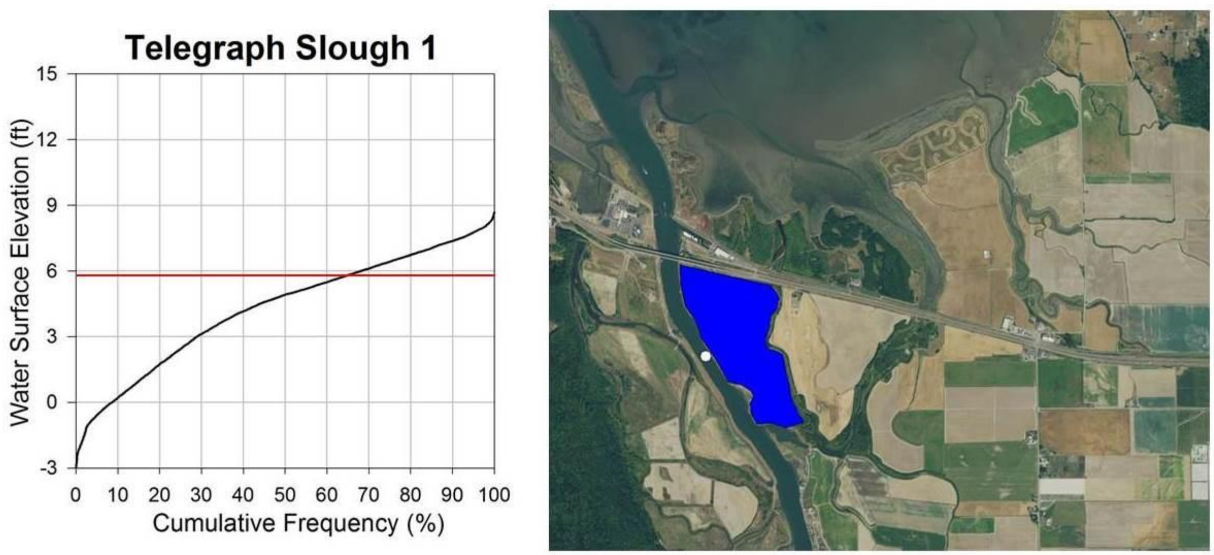


Figure G.8. Cumulative frequency plot and corresponding map for Telegraph Slough 1 during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

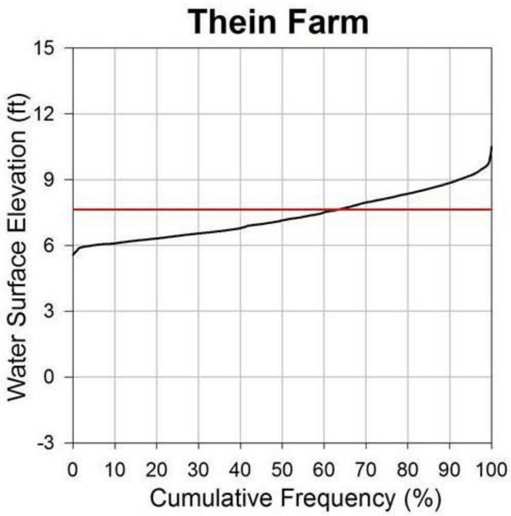


Figure G.9. Cumulative frequency plot and corresponding map for Thein Farm during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

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.

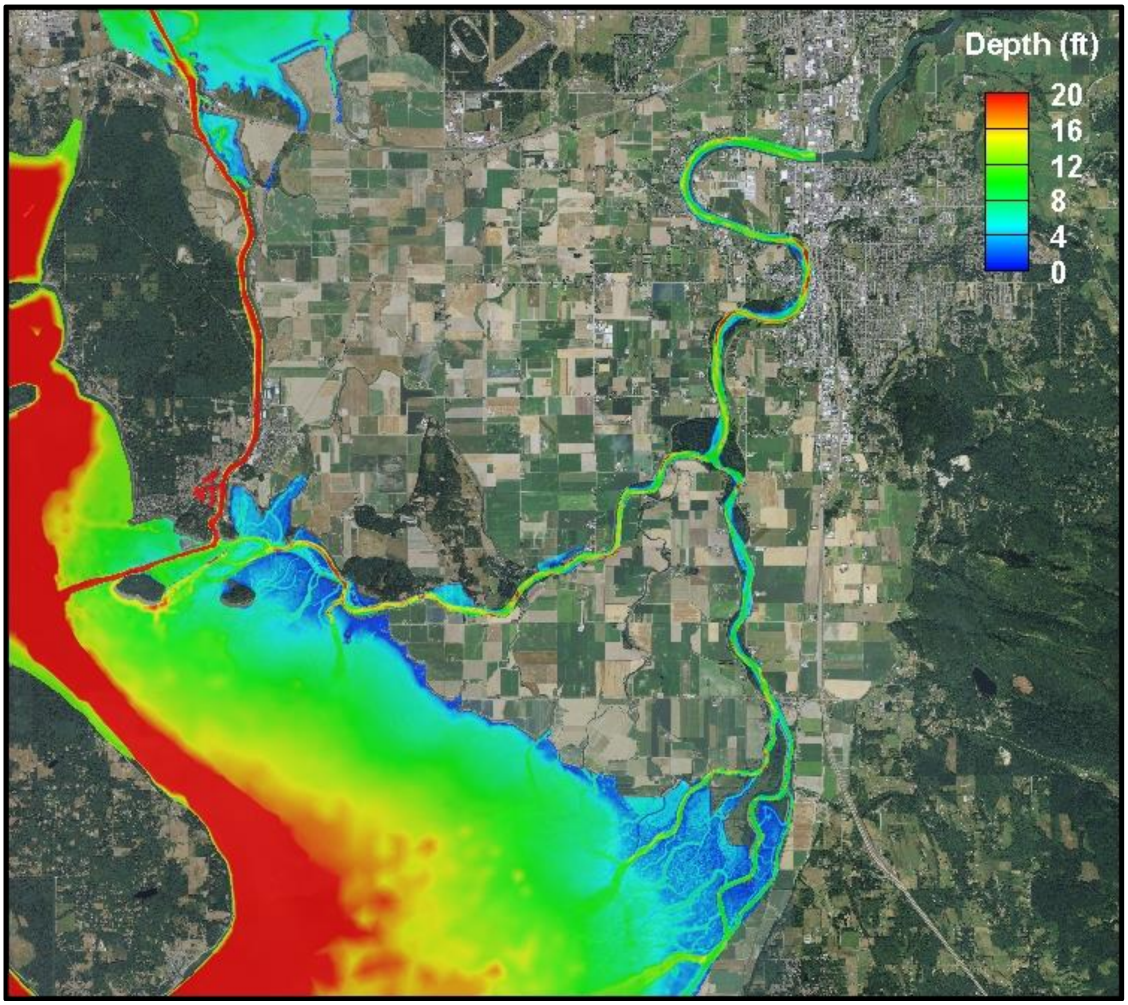


Figure G.10. Contour map of depths for the full domain during the Moderate Influence Projects simulation with May flow and high spring tide.

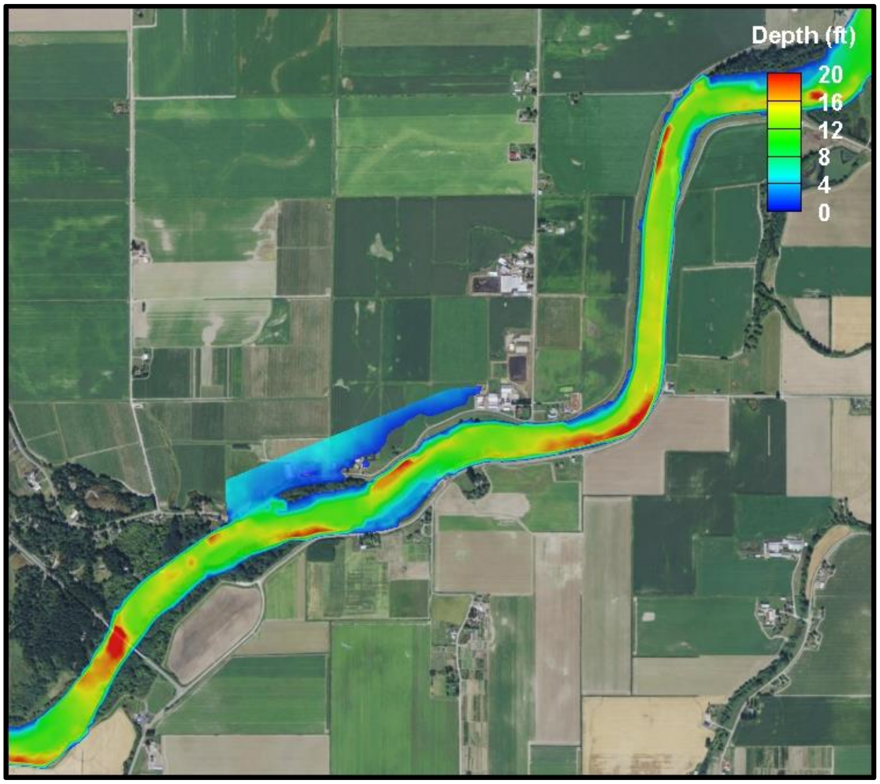


Figure G.11. Contour map of depths for NF Right Bank Levee Setback during the Moderate Influence Projects simulation.

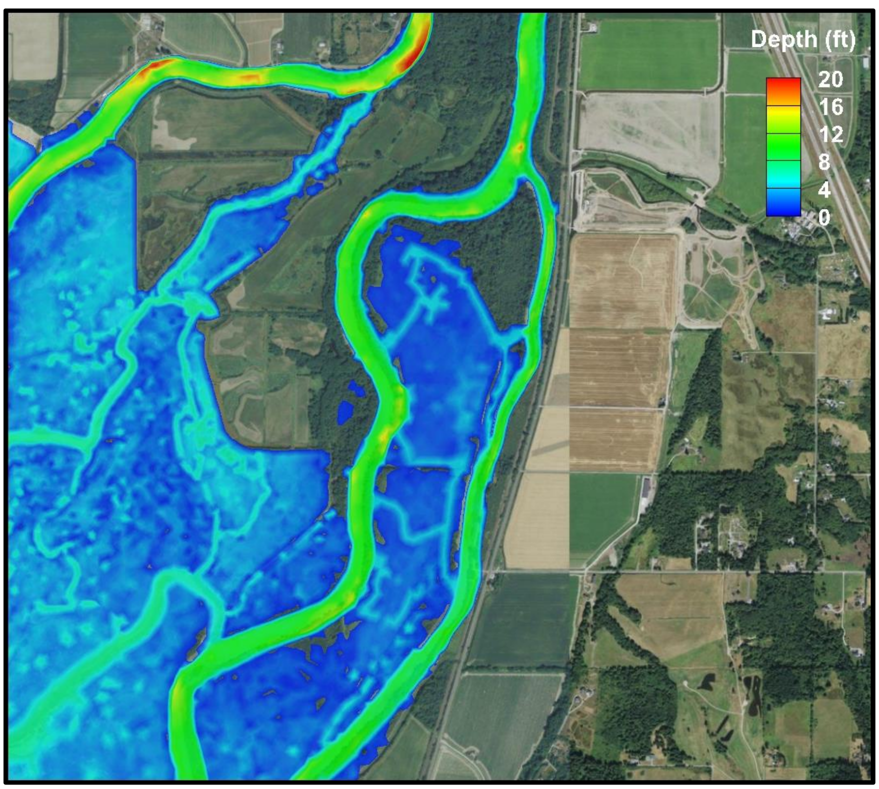


Figure G.12. Contour map of depths for Milltown Island during the Moderate Influence Projects simulation.

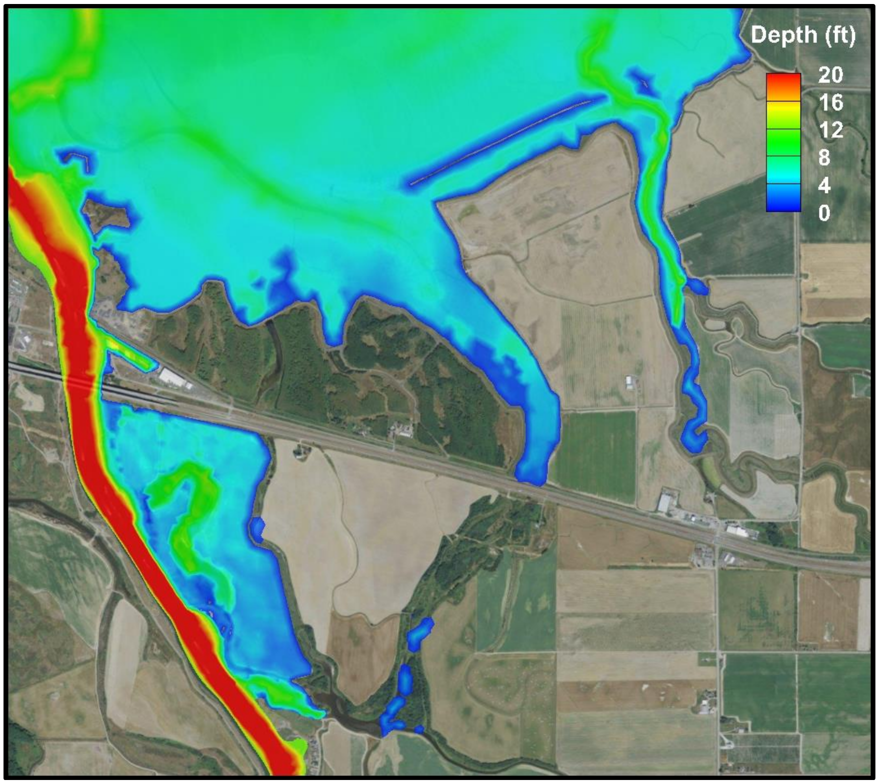


Figure G.13. Contour map of depths for Telegraph Slough 1 during the Moderate Influence Projects simulation.

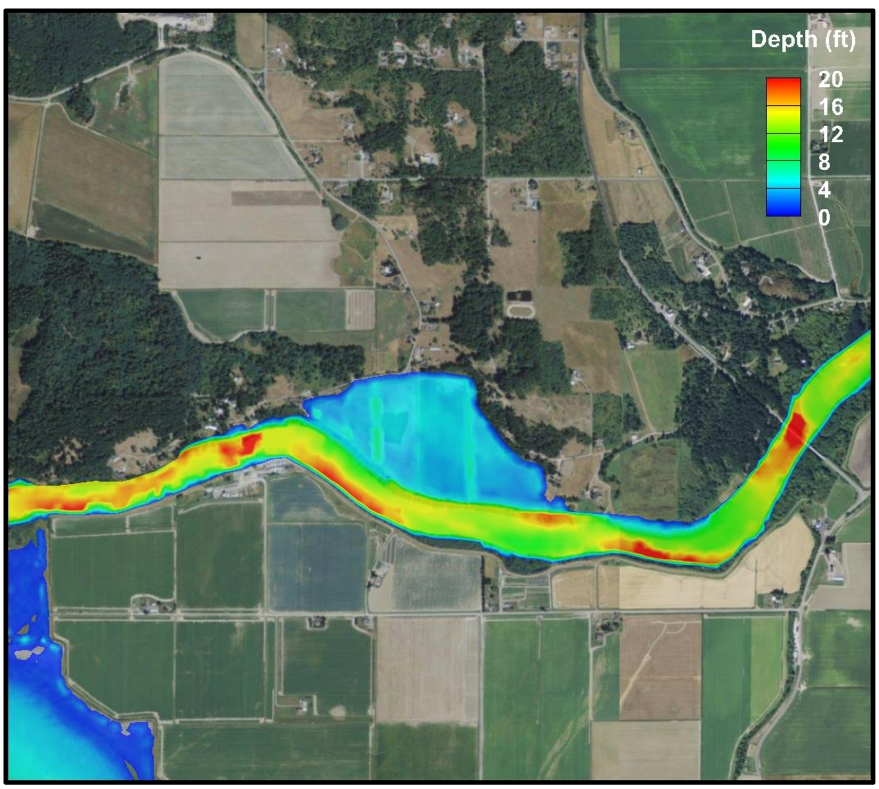


Figure G.14. Contour map of depths for Thein Farm during the Moderate Influence Projects simulation.

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.

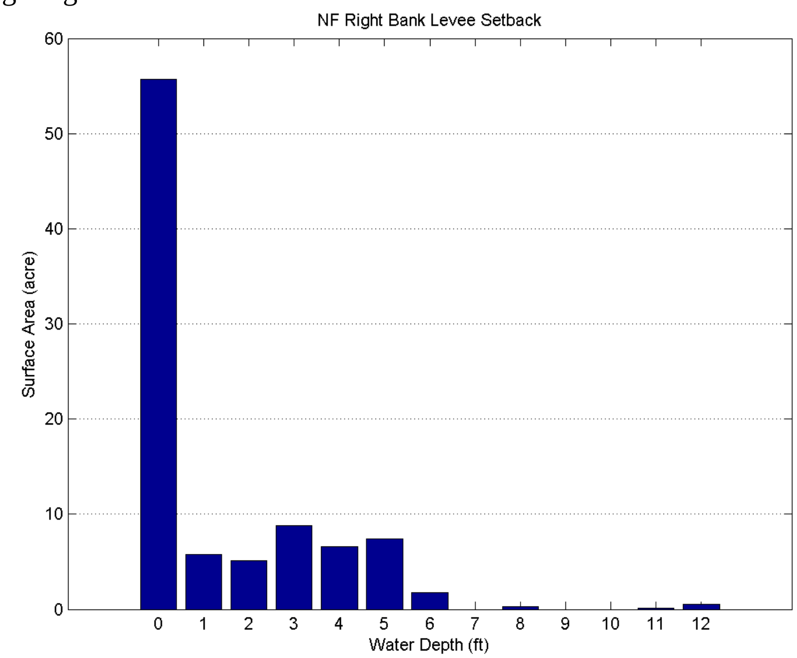


Figure G.15. Histogram of depths for NF Right Bank Levee Setback.

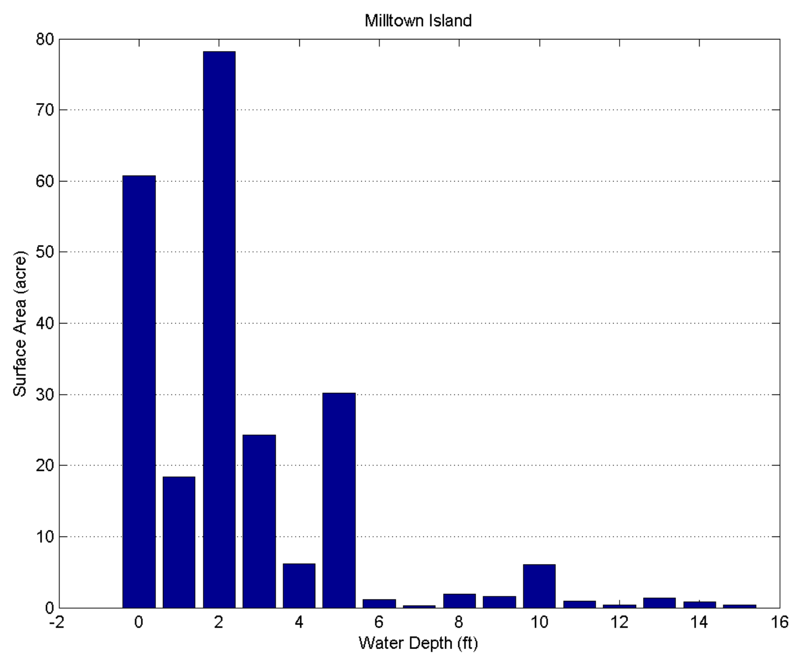


Figure G.16. Histogram of depths for Milltown Island.

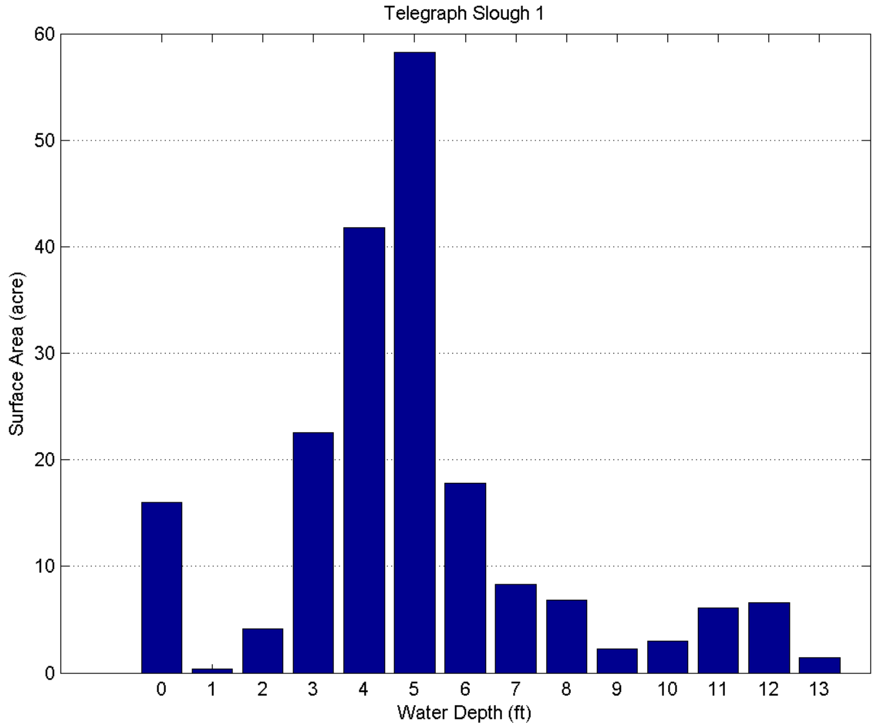


Figure G.17. Histogram of depths for Telegraph Slough 1.

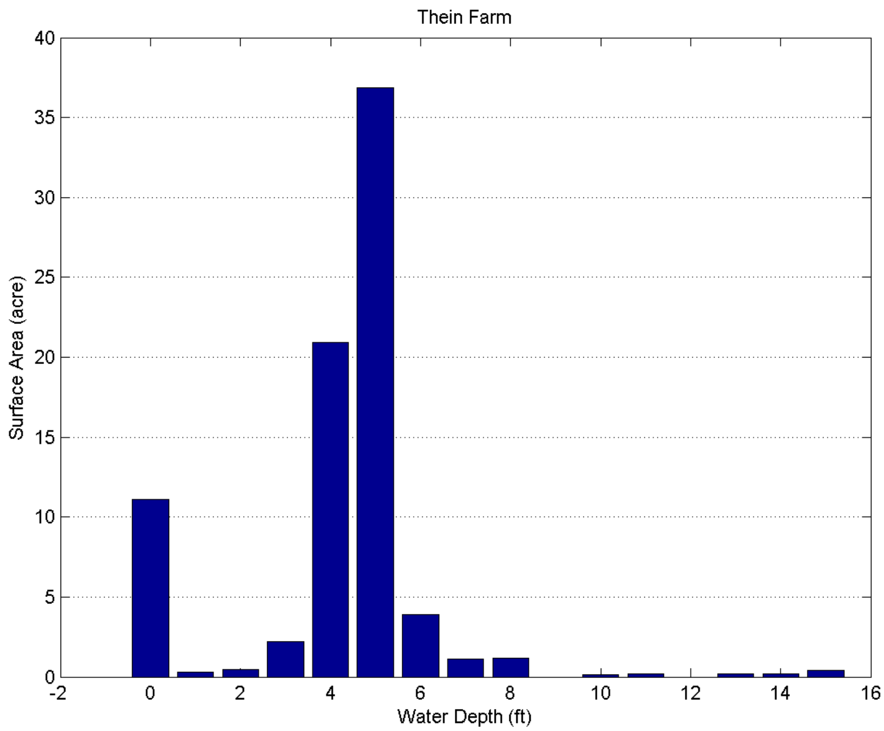


Figure G.18. Histogram of depths for Thein Farm.

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.

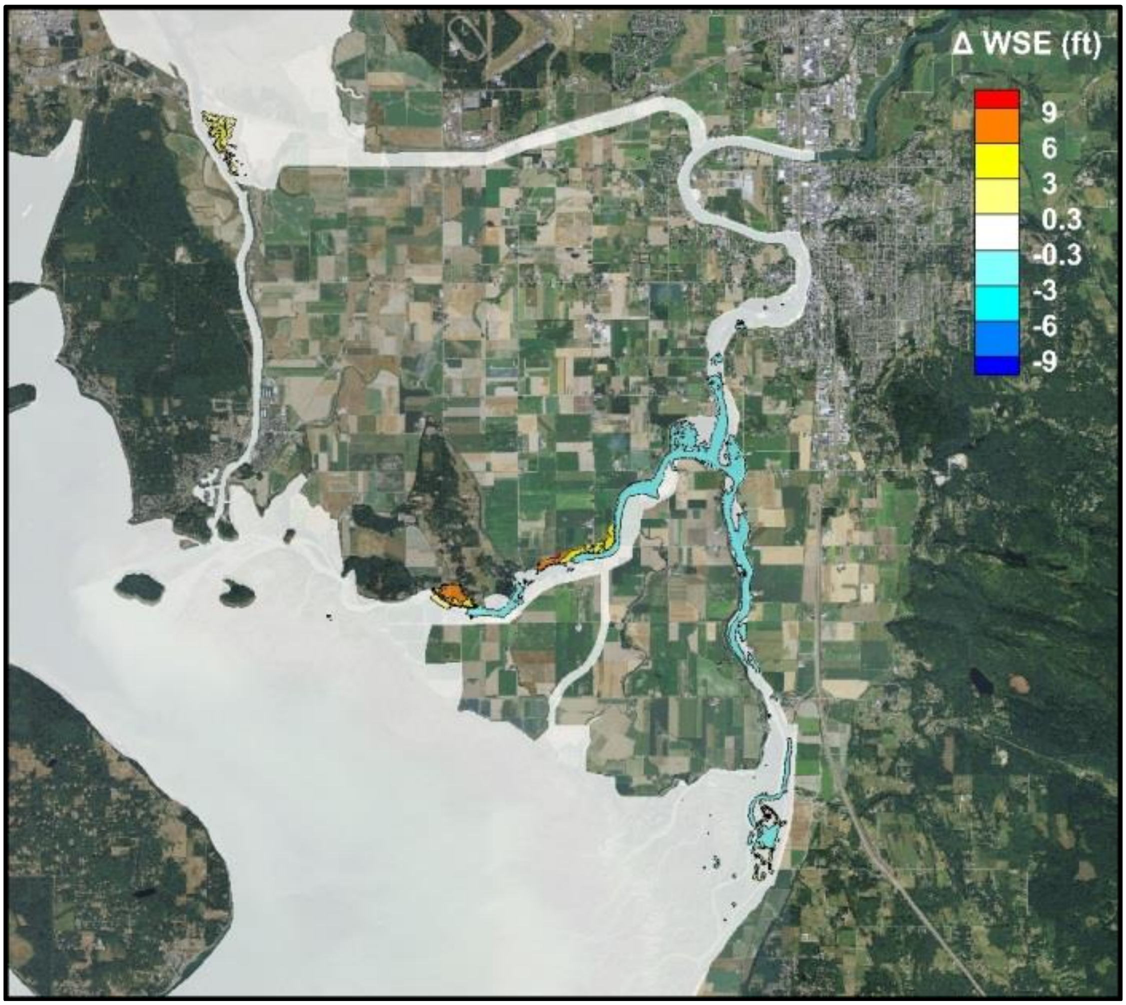


Figure G.19. Contour map of change in WSE from the Baseline to Moderate Influence Projects #1 simulation with Q2 flow and low tide.

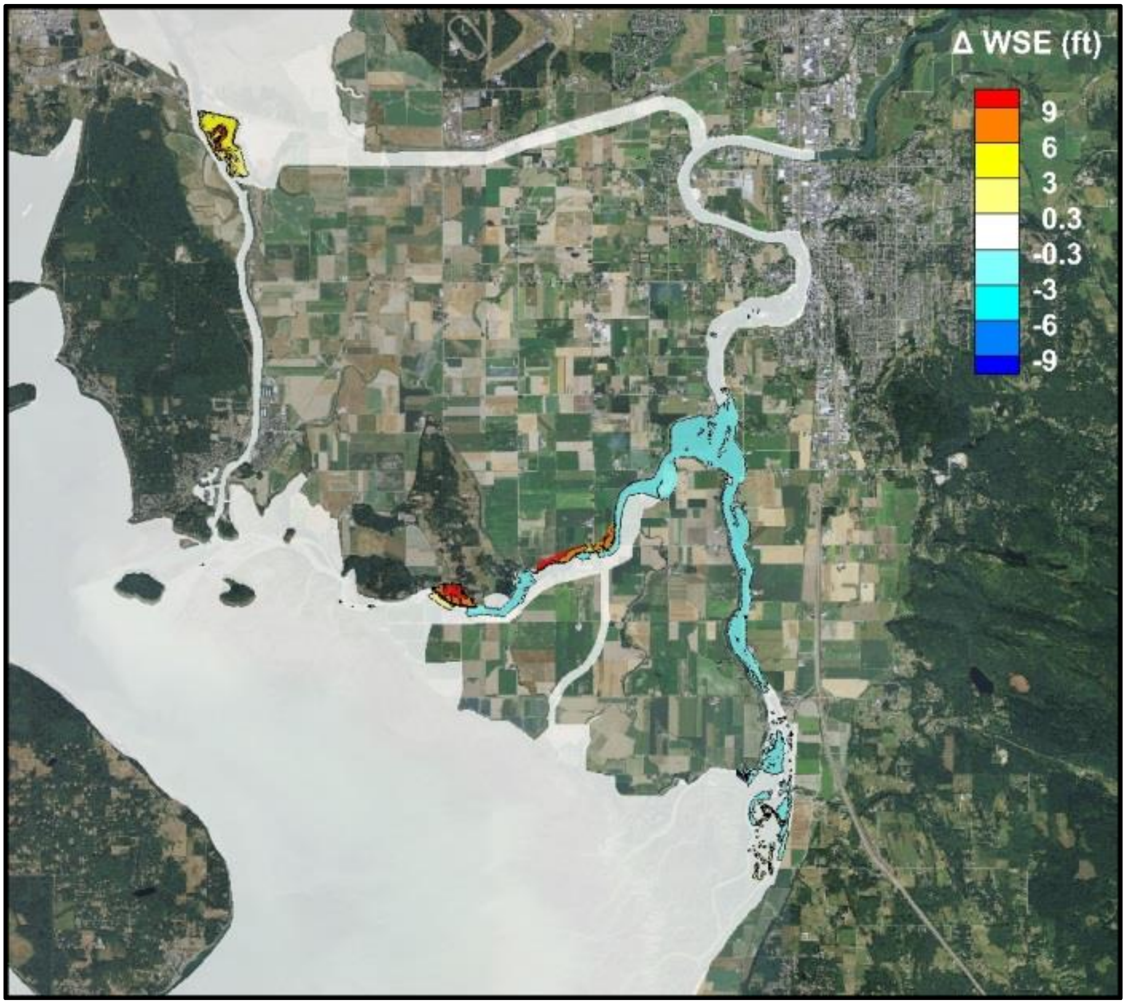


Figure G.20. Contour map of change in WSE from the Baseline to Moderate Influence Projects #1 simulation with flood flow and high tide.

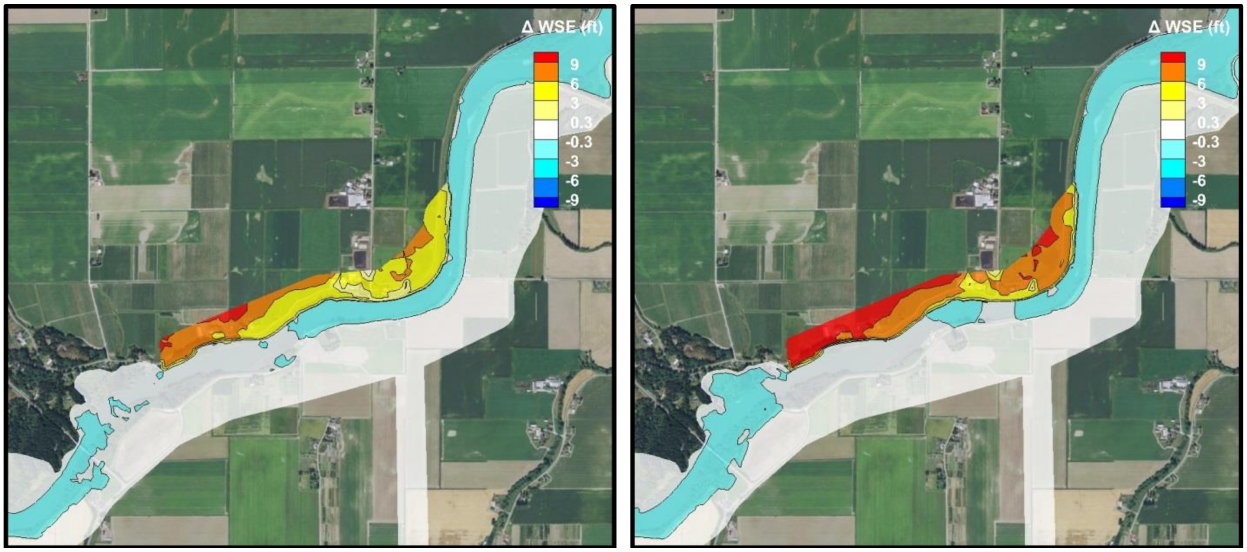


Figure G.21. Contour map of change in WSE from the Baseline simulation for NF Right Bank Levee Setback with Q2 flow and low tide (left) and flood flow and high tide (right).

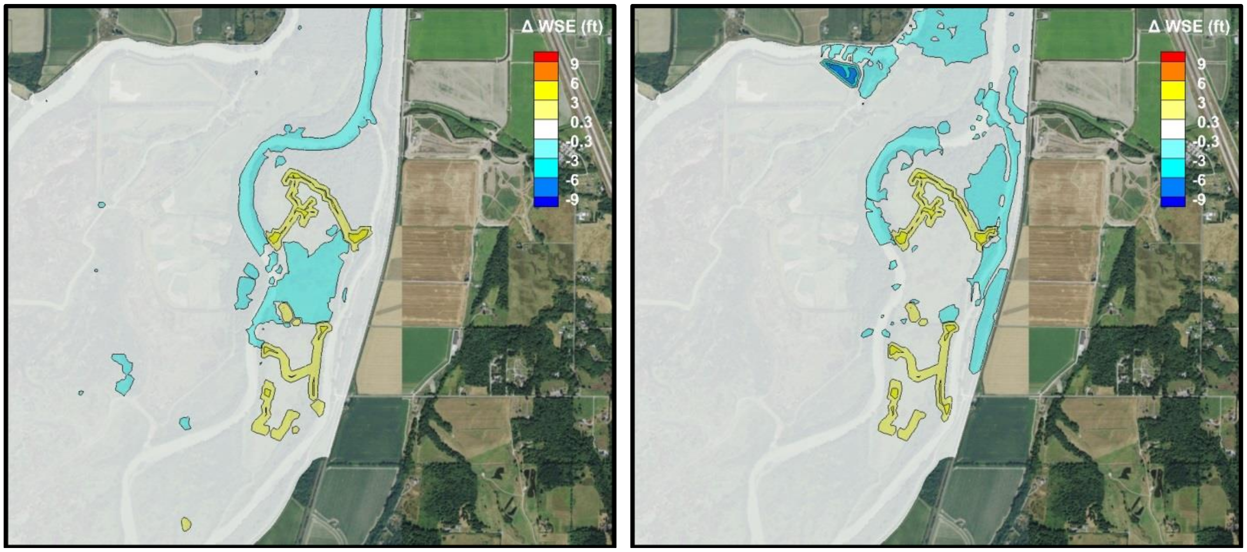


Figure G.22. Contour map of change in WSE from the Baseline simulation for Milltown Island with Q2 flow and low tide (left) and flood flow and high tide (right).

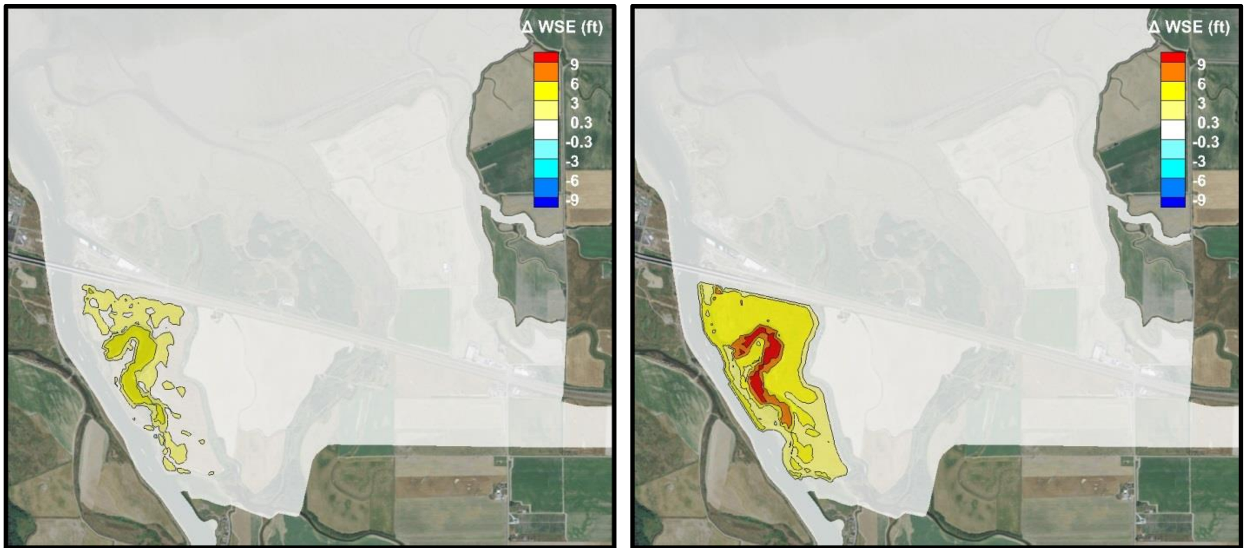


Figure G.23. Contour map of change in WSE from the Baseline simulation for Telegraph Slough 1 with Q2 flow and low tide (left) and flood flow and high tide (right).

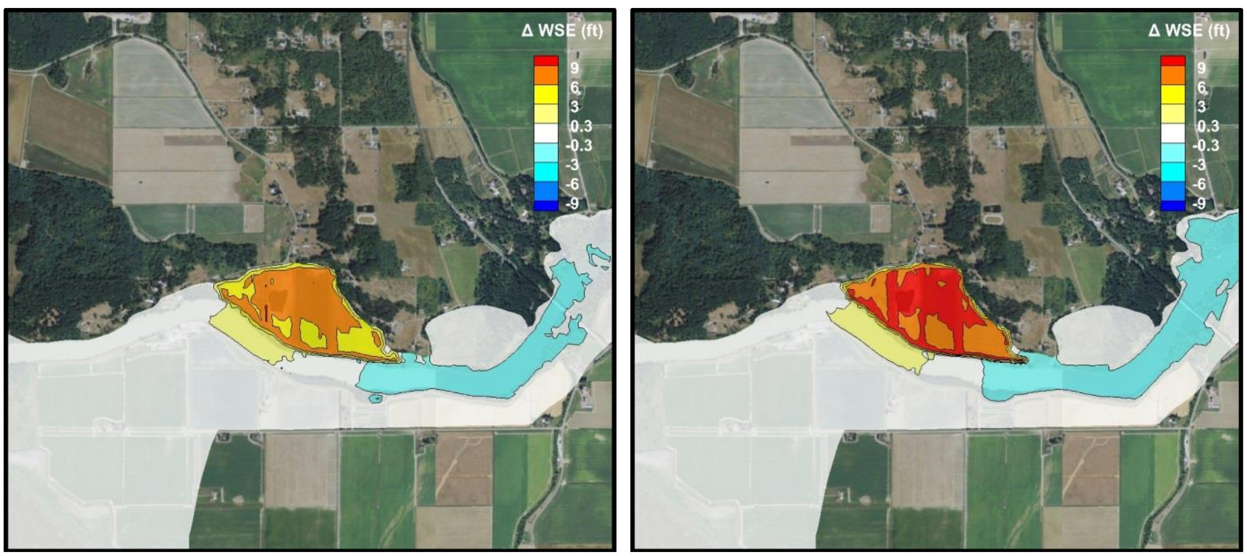


Figure G.24. Contour map of change in WSE from the Baseline simulation for Thein Farm with Q2 flow and low tide (left) and flood flow and high tide (right).

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.

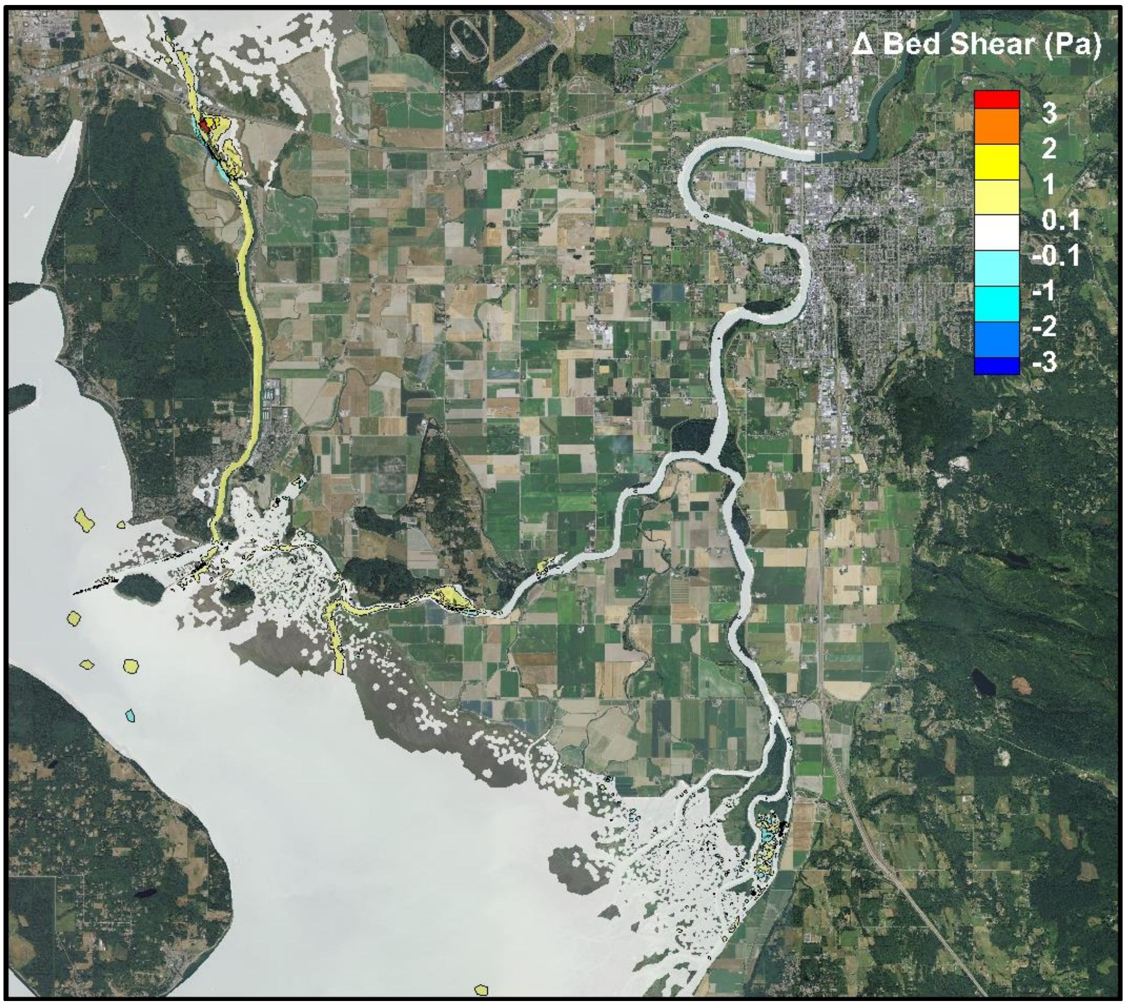


Figure G.25. Contour map of change in shear stress from the Baseline to Moderate Influence Projects #1 simulation with peak shear across a full tidal cycle at low flow.

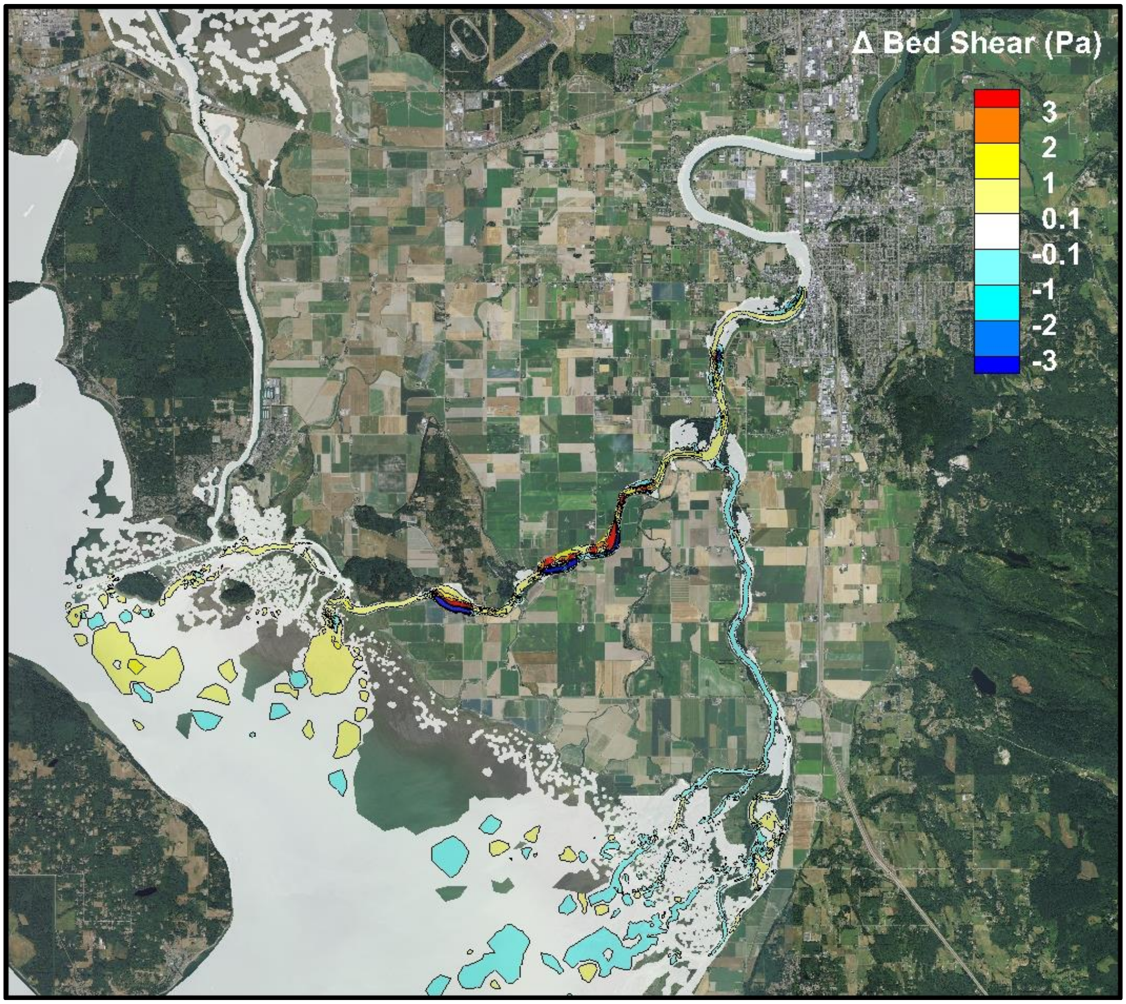


Figure G.26. Contour map of change in shear stress from the Baseline to Moderate Influence Projects #1 simulation with Q2 flow and low tide.

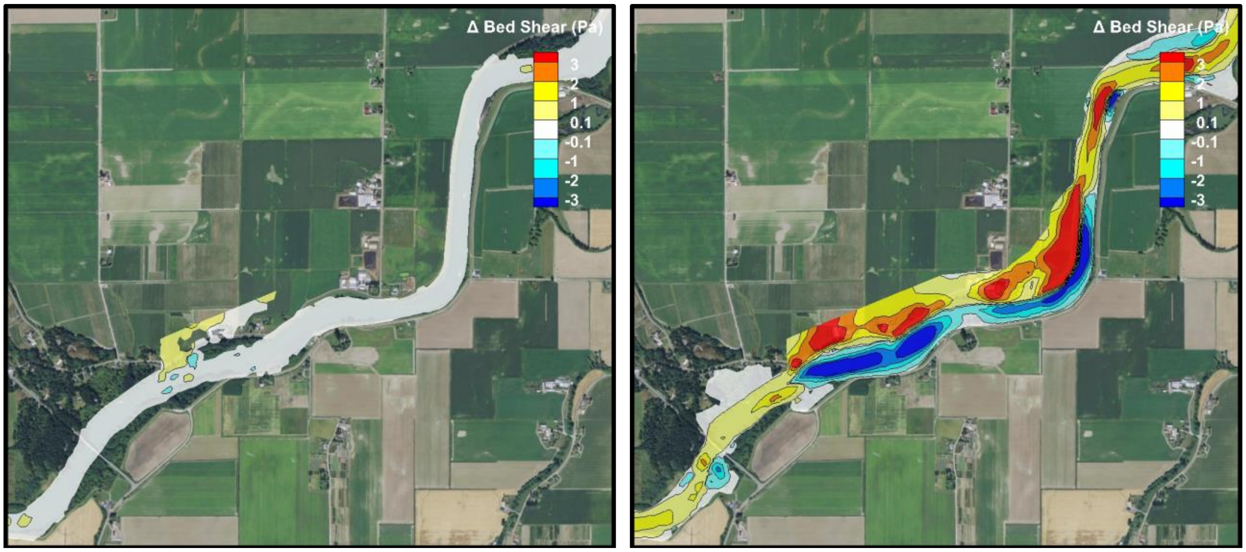


Figure G.27. Contour map of change in shear stress from the Baseline simulation for NF Right Bank Levee Setback with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

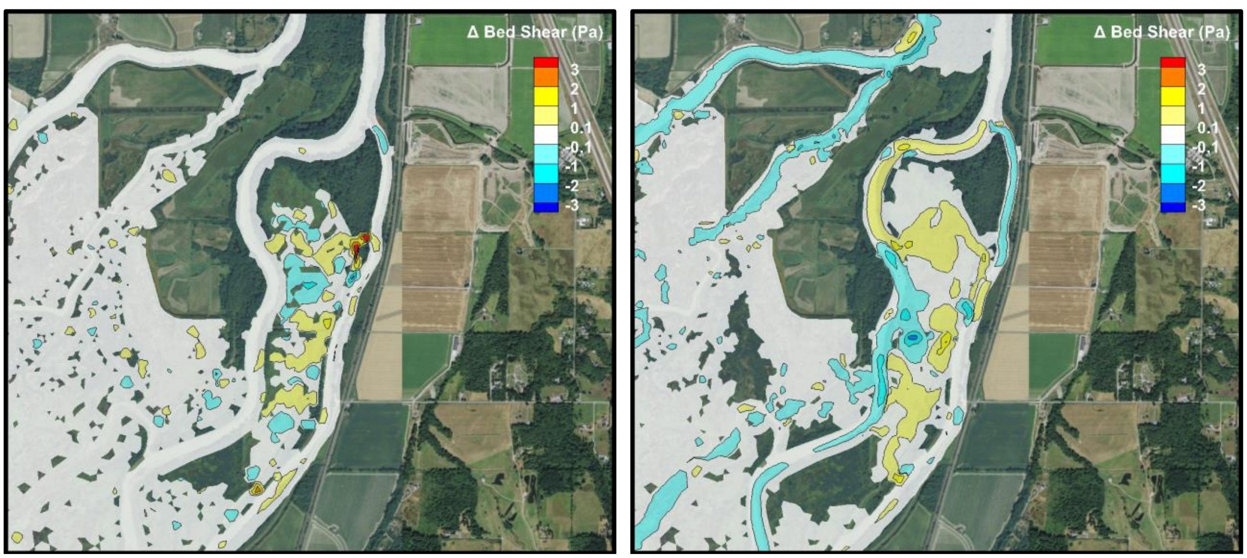


Figure G.28. Contour map of change in shear stress from the Baseline simulation for Milltown Island with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

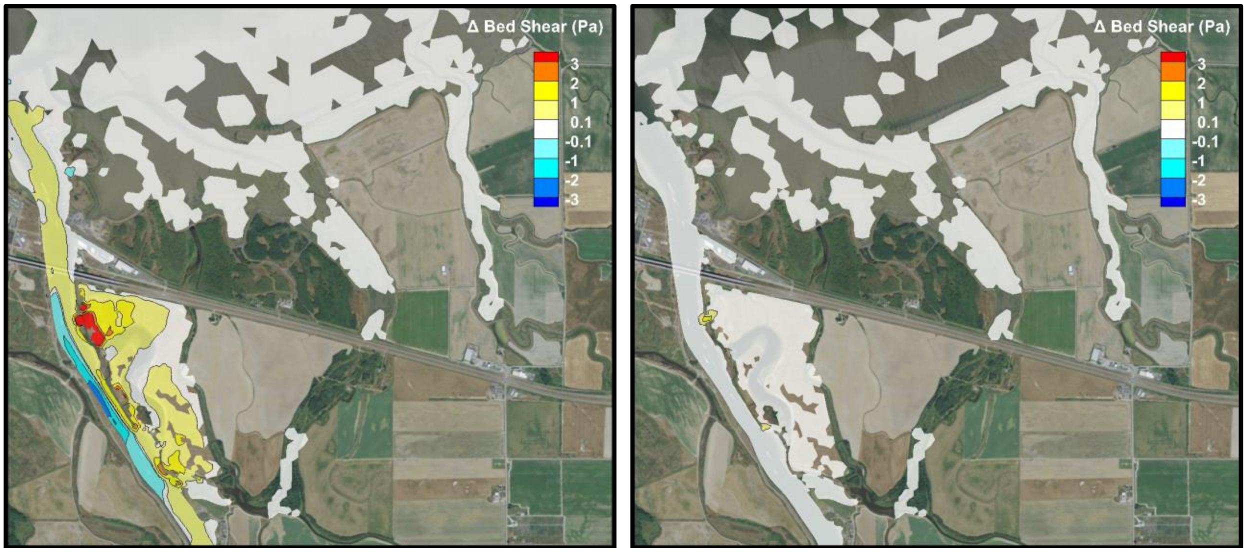


Figure G.29. Contour map of change in shear stress from the Baseline simulation for Telegraph Slough 1 with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

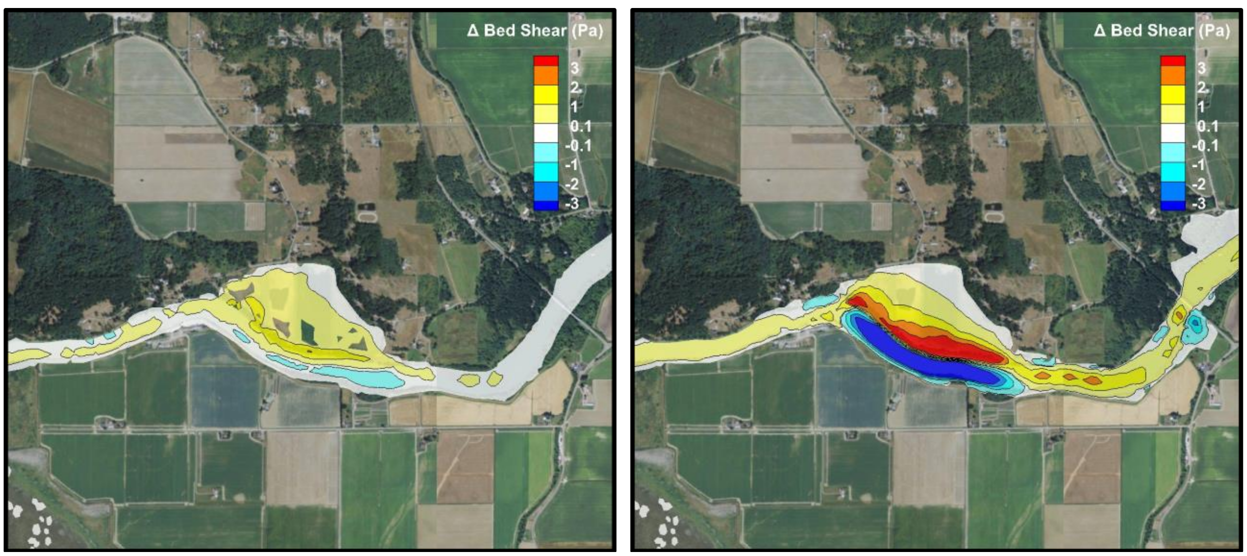


Figure G.30. Contour map of change in shear stress from the Baseline simulation for Thein Farm with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

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.

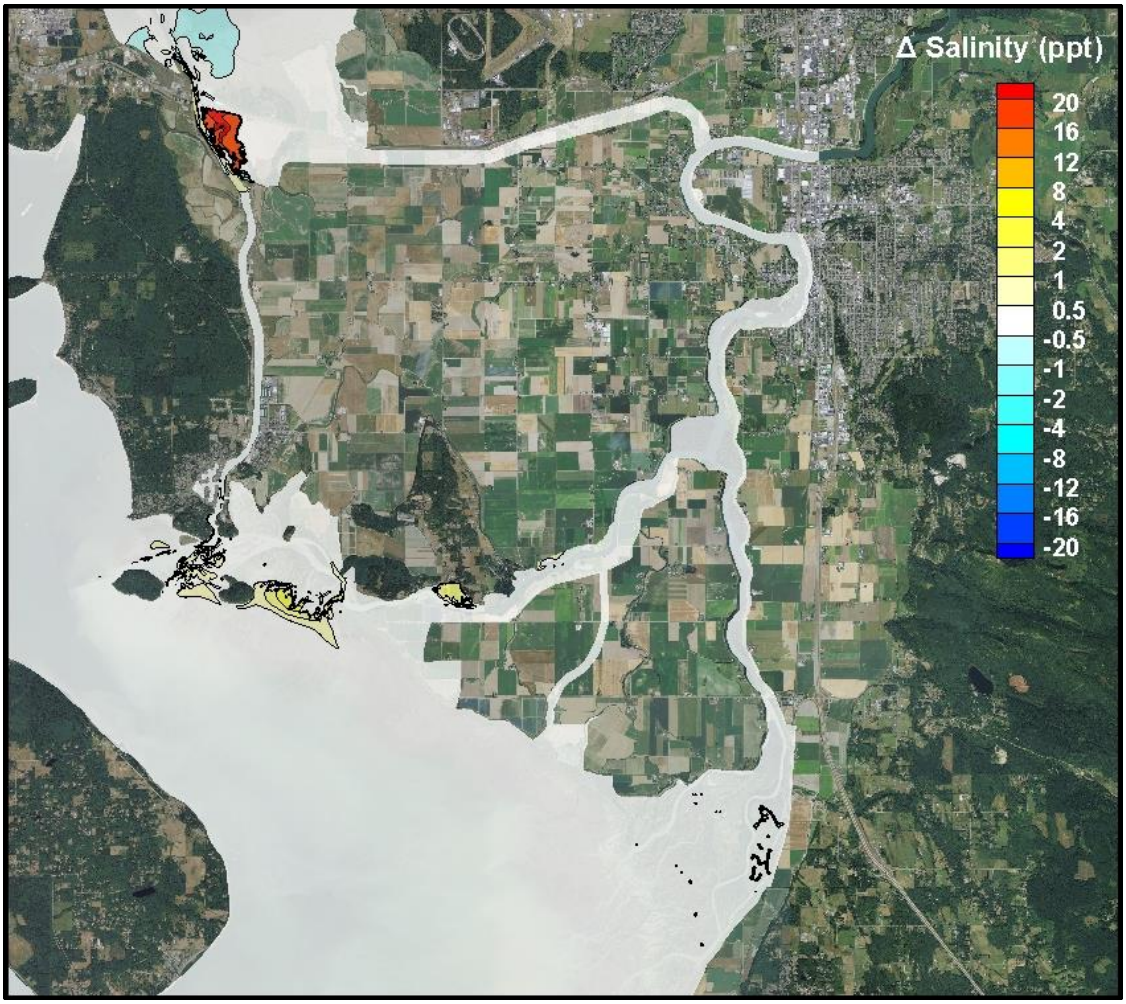


Figure G.31. Contour map of change in salinity from the Baseline to Moderate Influence Projects #1 simulation with low flow and high tide.

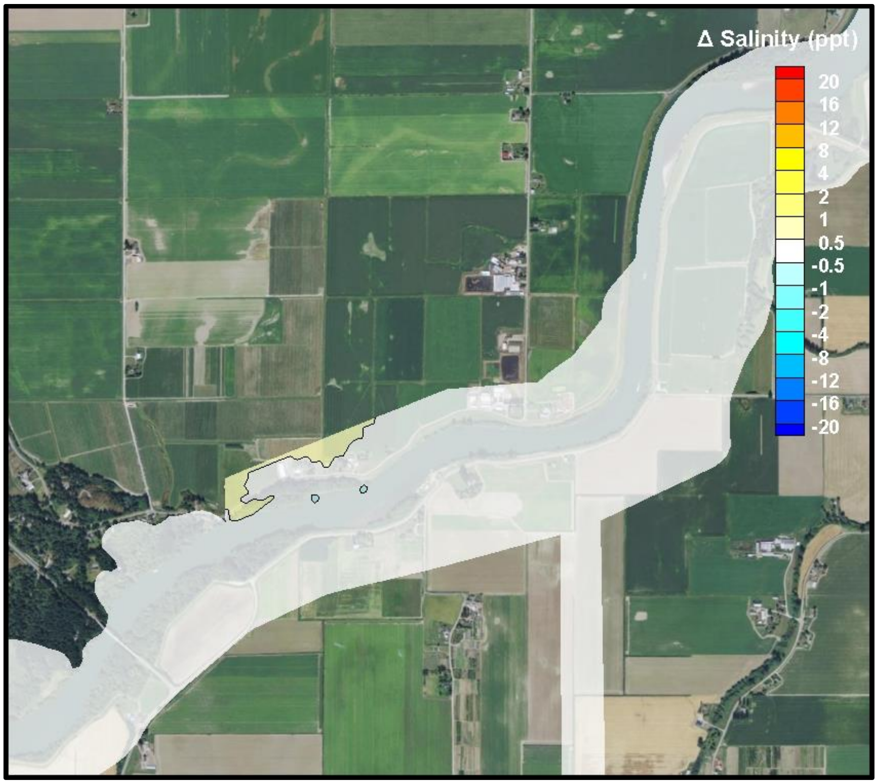


Figure G.32. Contour map of change in salinity from the Baseline simulation for NF Right Bank Levee Setback with low flow and high tide.

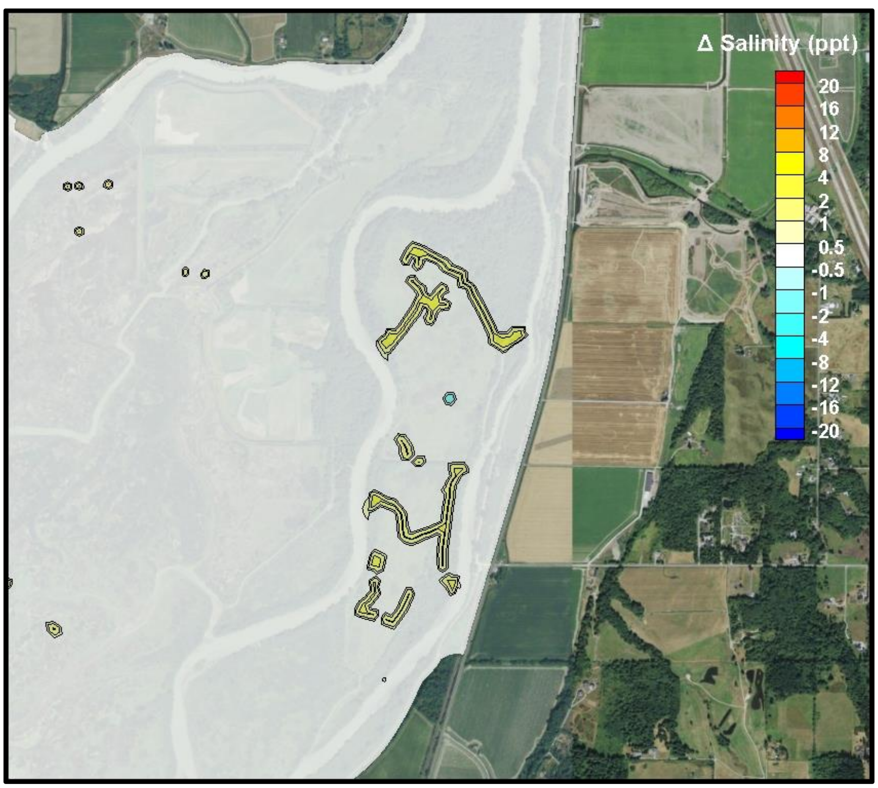


Figure G.33. Contour map of change in salinity from the Baseline simulation for Milltown Island with low flow and high tide.

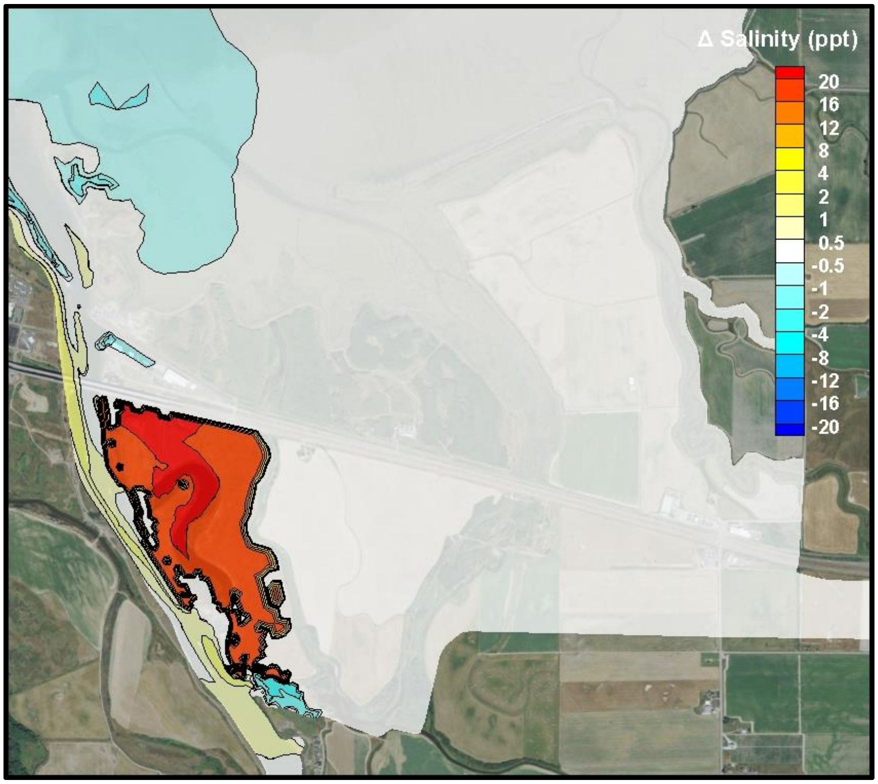


Figure G.34. Contour map of change in salinity from the Baseline simulation for Telegraph Slough 1 with low flow and high tide.

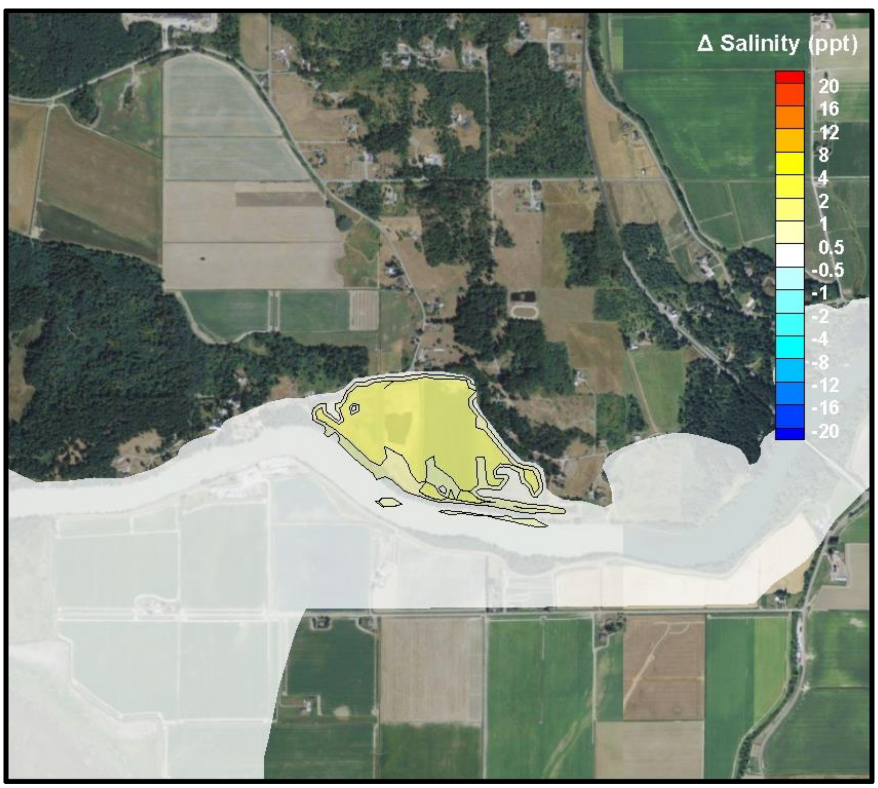


Figure G.35. Contour map of change in salinity from the Baseline simulation for Thein Farm with low flow and high tide.

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.

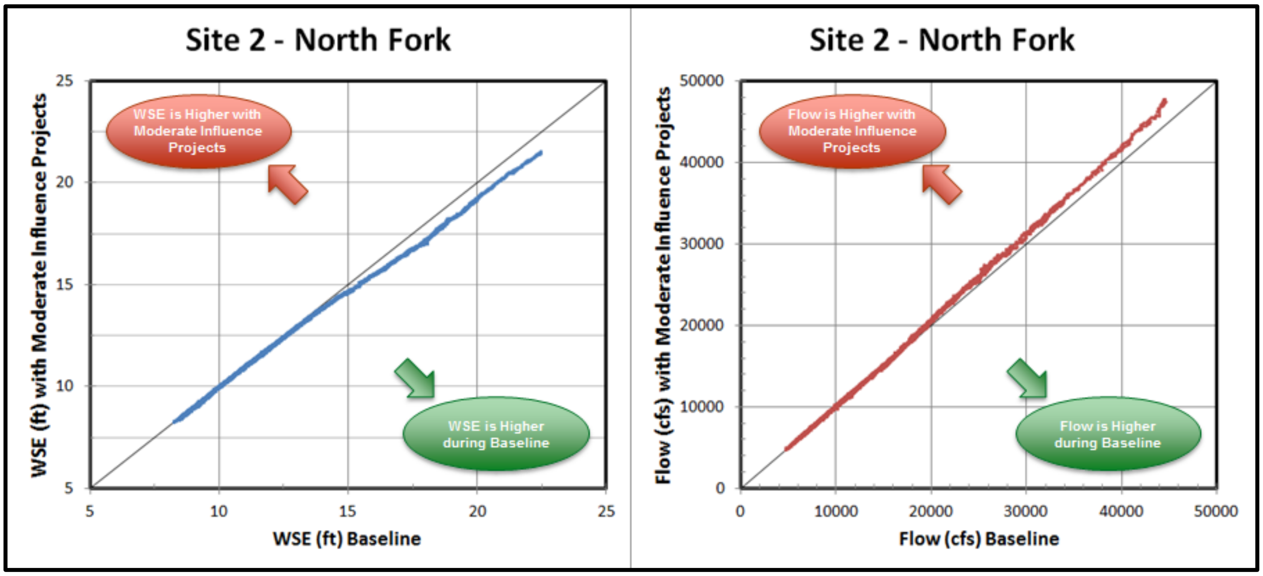


Figure G.36. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Moderate Influence Projects simulation at the North Fork gauge location compared with the same information under baseline conditions.

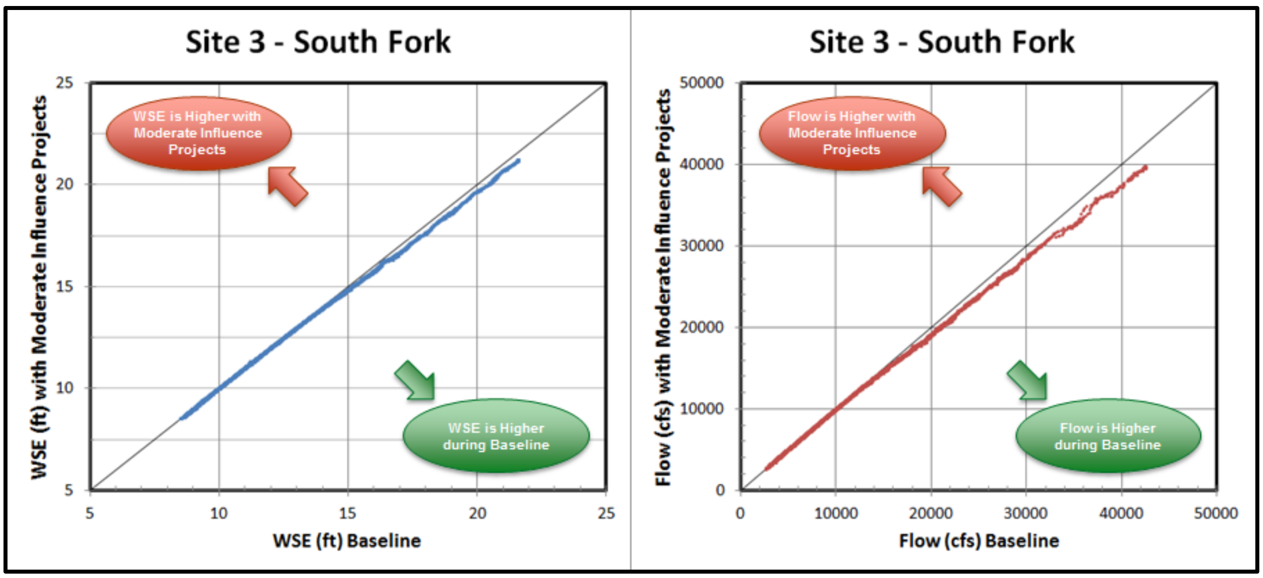


Figure G.37. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Moderate Influence Projects simulation at the South Fork gauge location compared with the same information under baseline conditions.

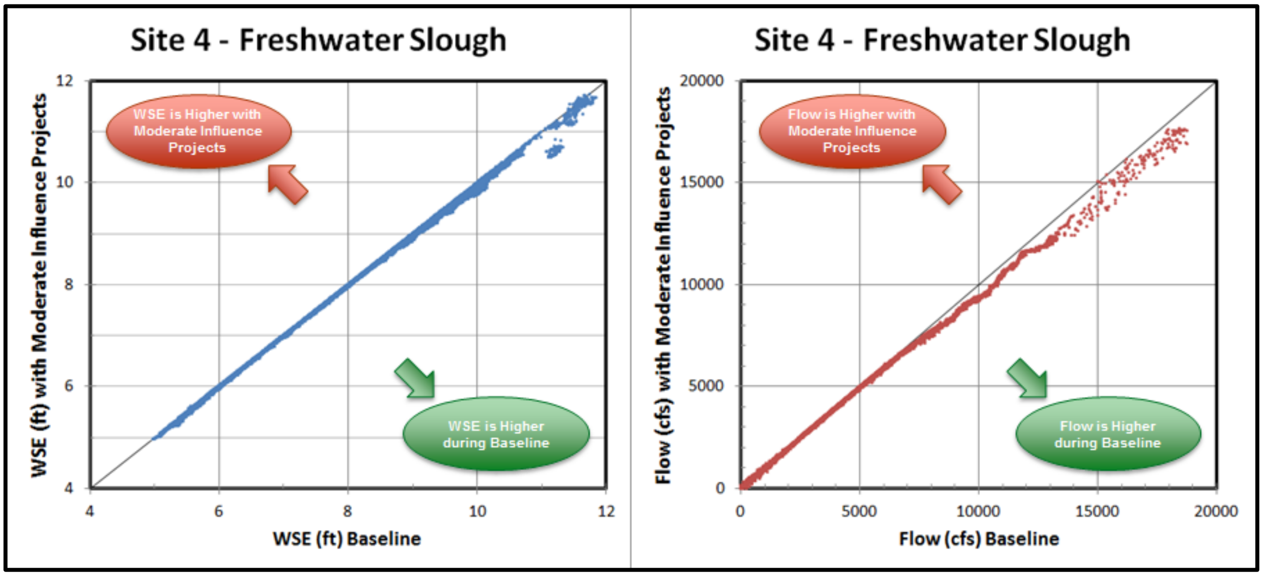


Figure G.38. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Moderate Influence Projects simulation at the Freshwater Slough gauge location compared with the same information under baseline conditions.

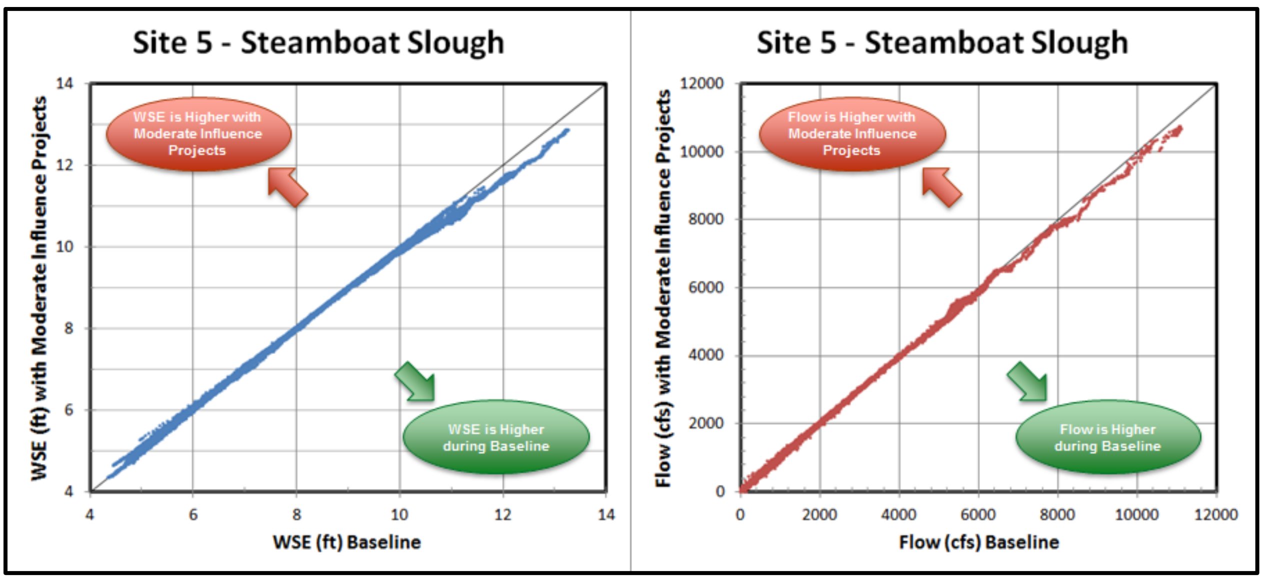


Figure G.39. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Moderate Influence Projects simulation at the Steamboat Slough gauge location compared with the same information under baseline conditions.

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.

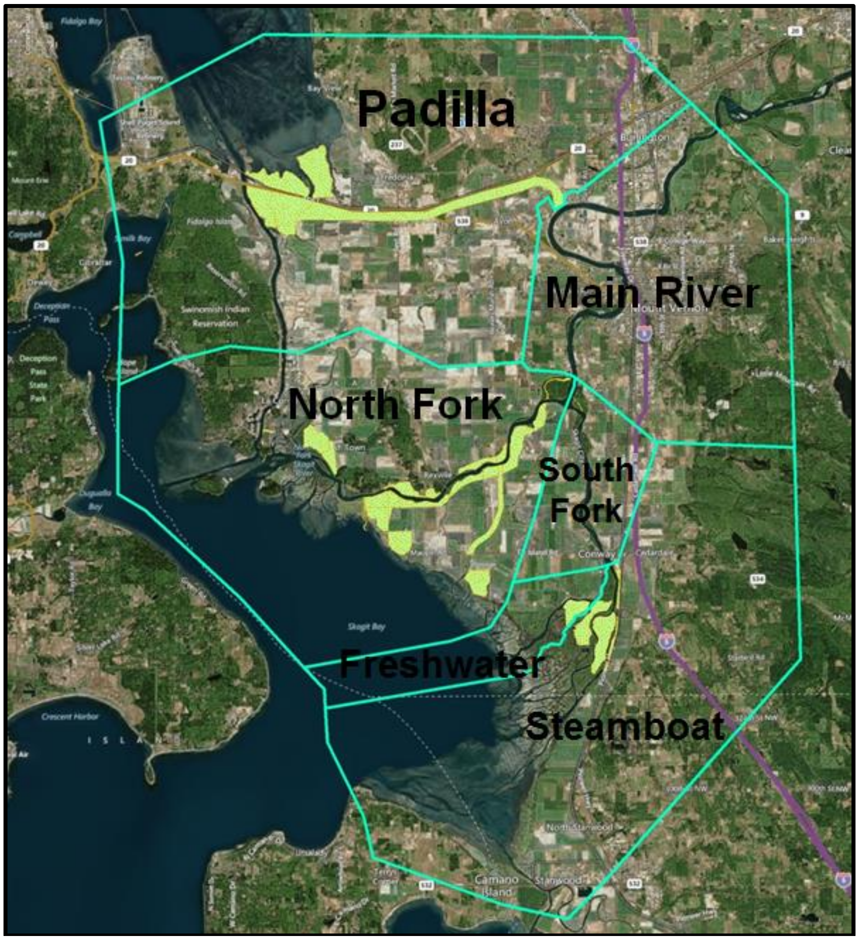


Figure H.2. Sub-basins within the Skagit region used for area calculations.

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.

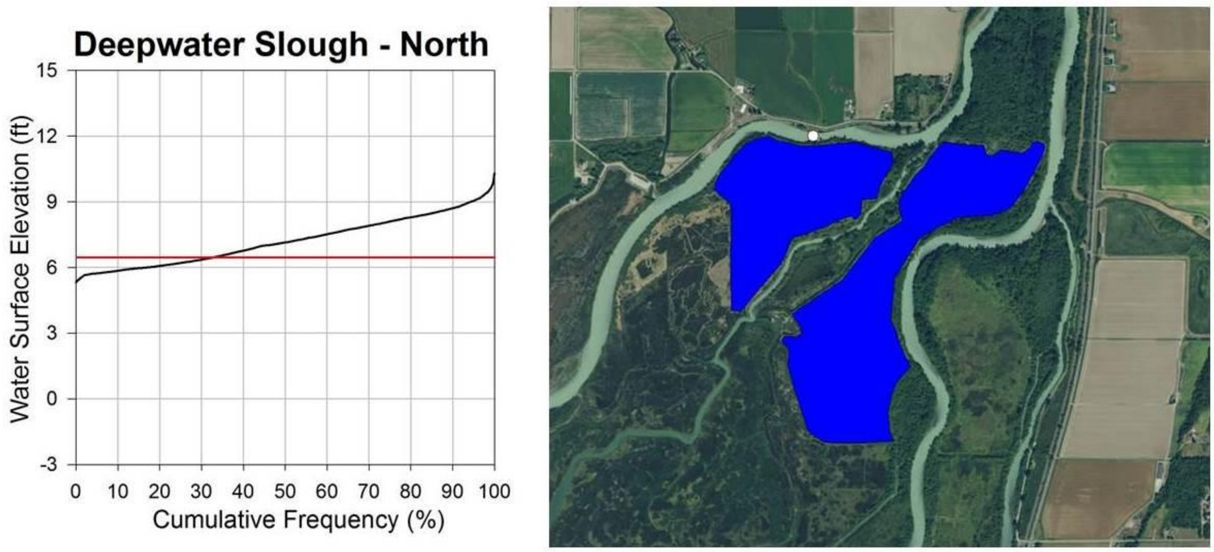


Figure H.3. Cumulative frequency plot and corresponding map for Deepwater Slough Phase 2 (north) during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

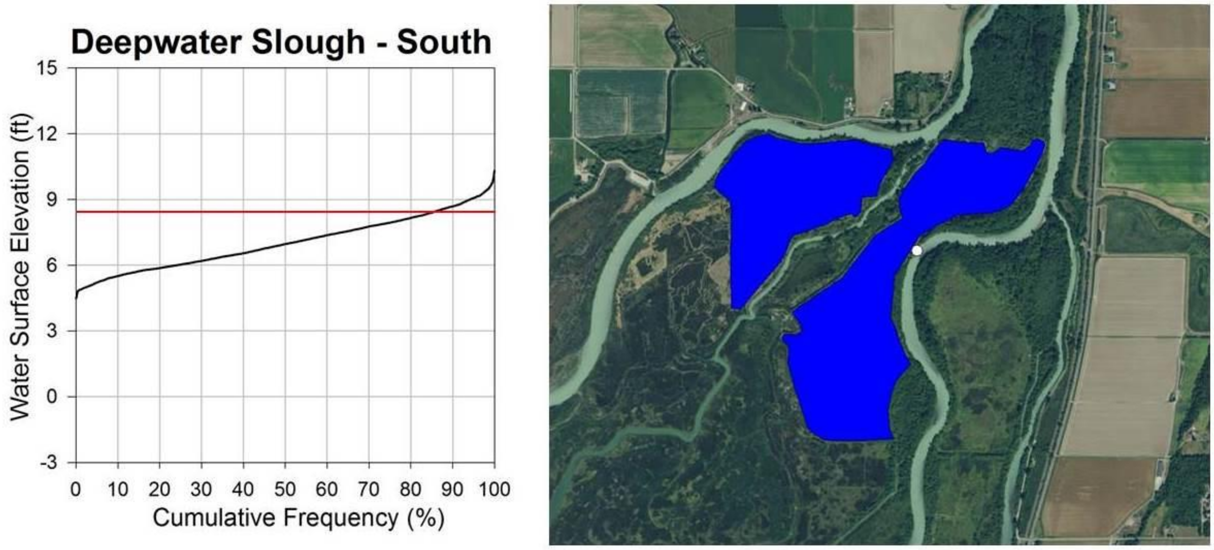


Figure H.4. Cumulative frequency plot and corresponding map for Deepwater Slough Phase 2 (south) during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

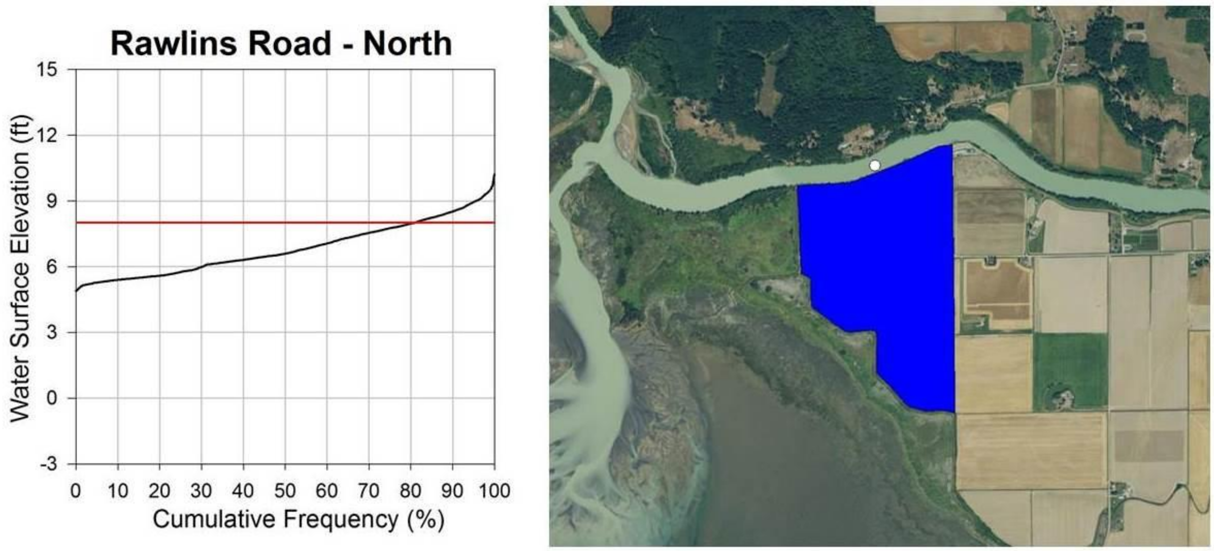


Figure H.5. Cumulative frequency plot and corresponding map for Rawlins Road (north) during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

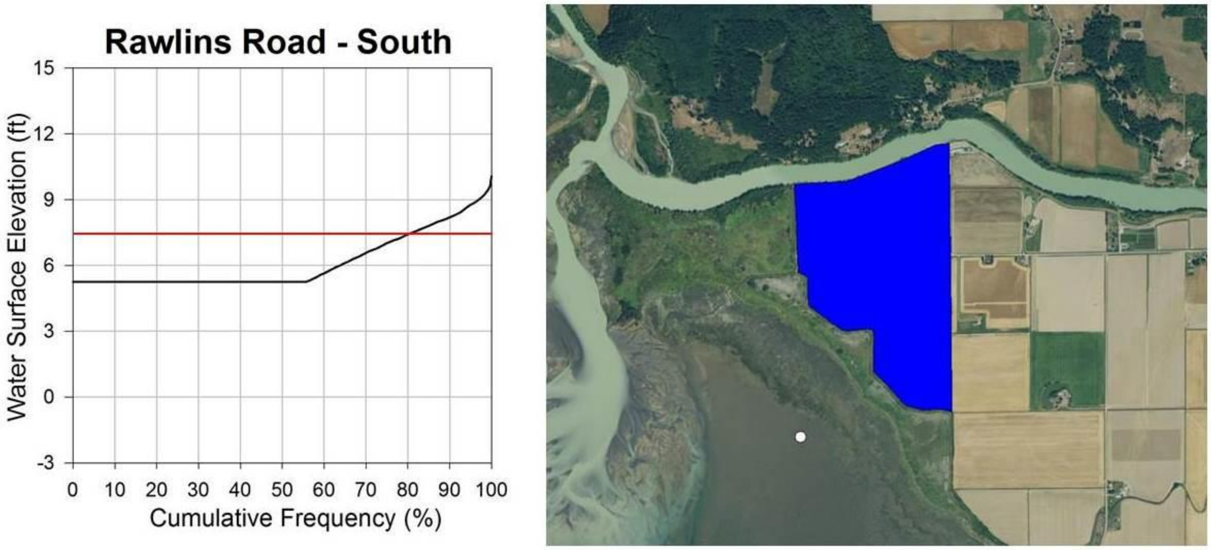


Figure H.6. Cumulative frequency plot and corresponding map for Rawlins Road (south) during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

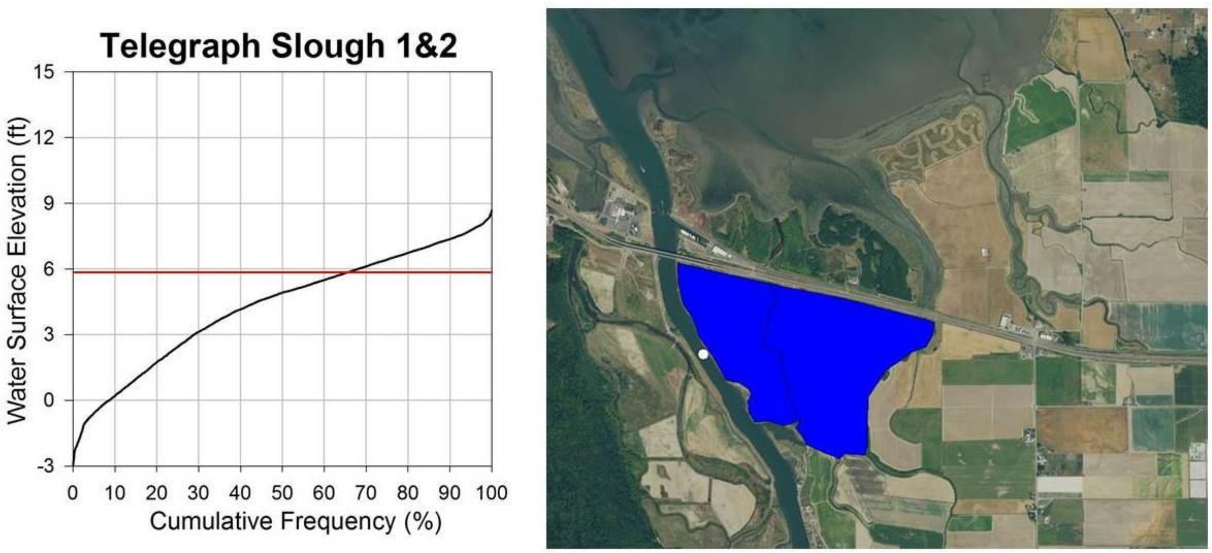


Figure H.7. Cumulative frequency plot and corresponding map for Telegraph Slough 1&2 during the Moderate Influence Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

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.

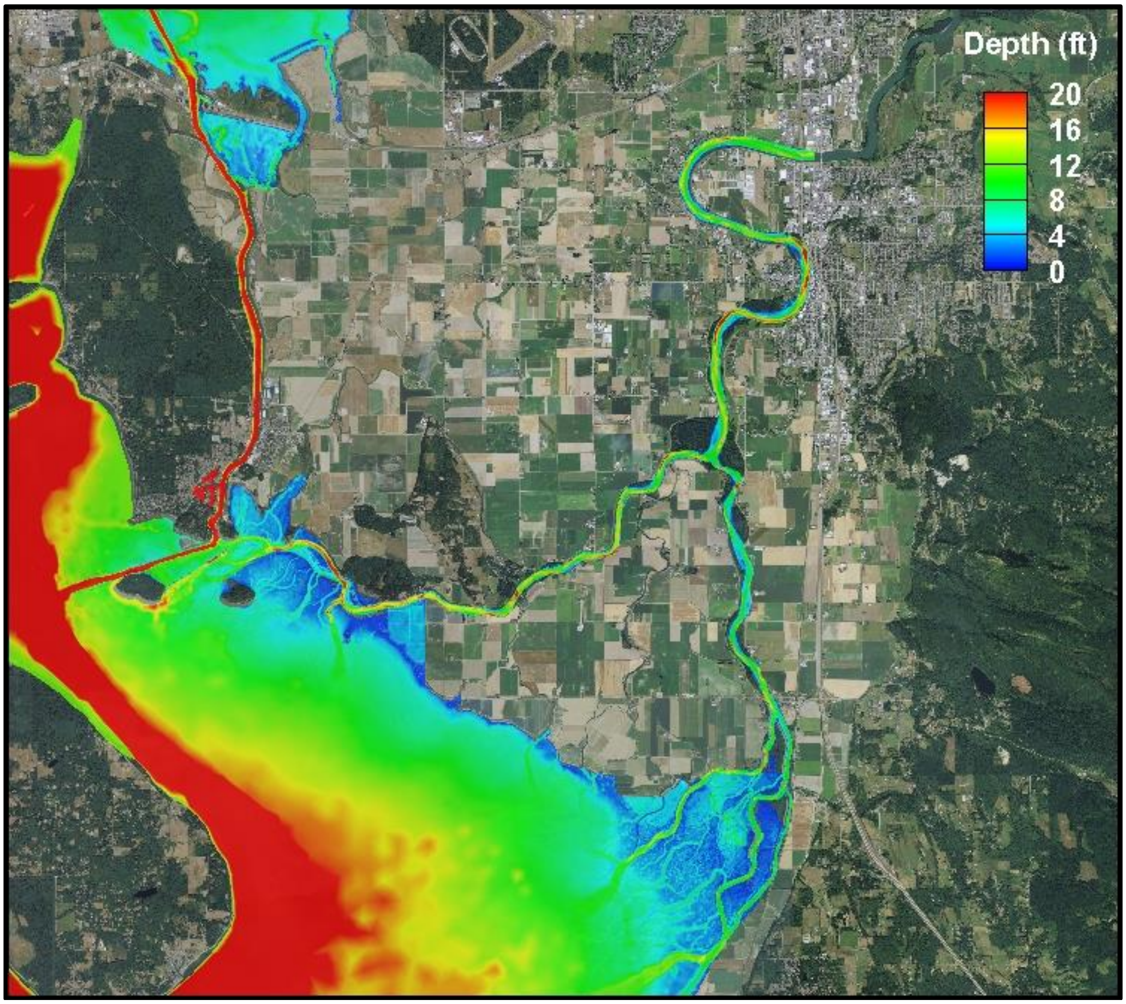


Figure H.8. Contour map of depths for the full domain during the Moderate Influence Projects simulation with May flow and high spring tide.

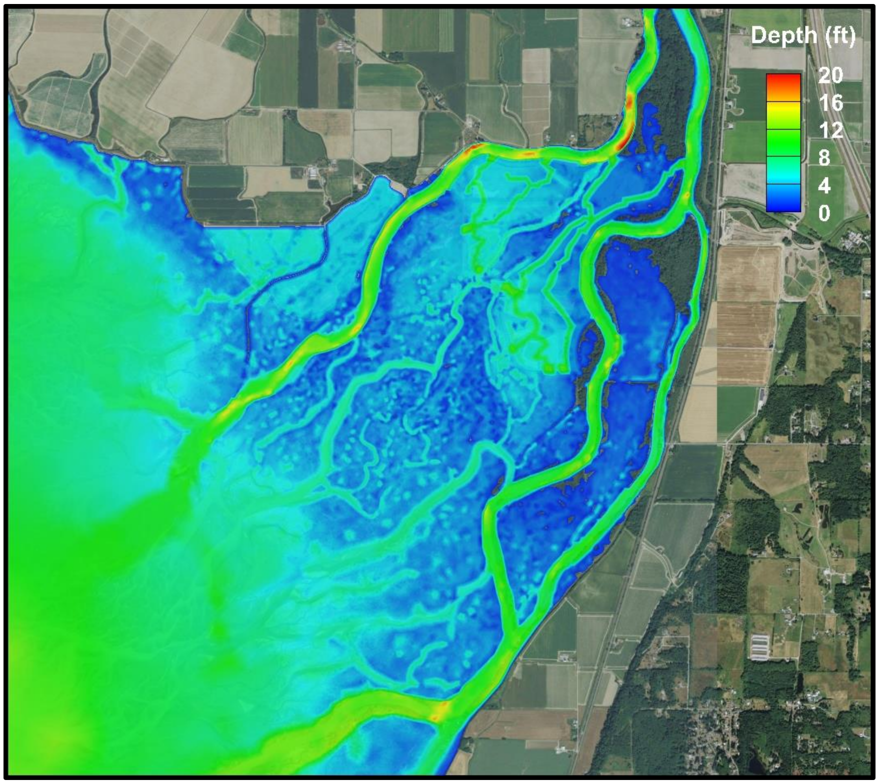


Figure H.9. Contour map of depths for Deepwater Slough Phase 2 during the Moderate Influence Projects simulation.

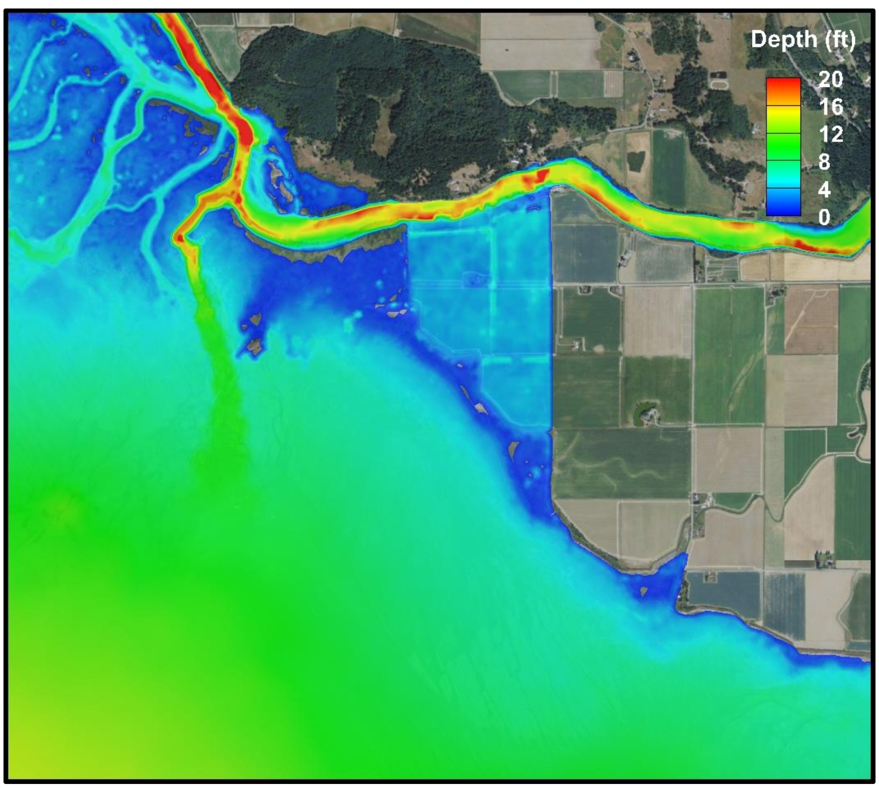


Figure H.10. Contour map of depths for Rawlins Road during the Moderate Influence Projects simulation.

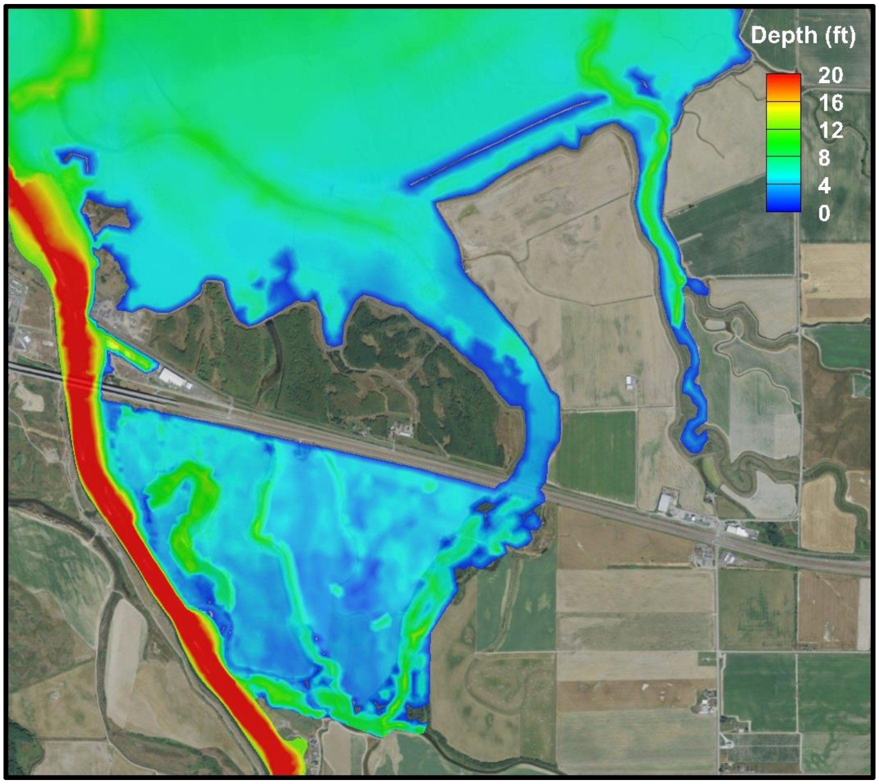


Figure H.11. Contour map of depths for Telegraph Slough 1&2 during the Moderate Influence Projects simulation.

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.

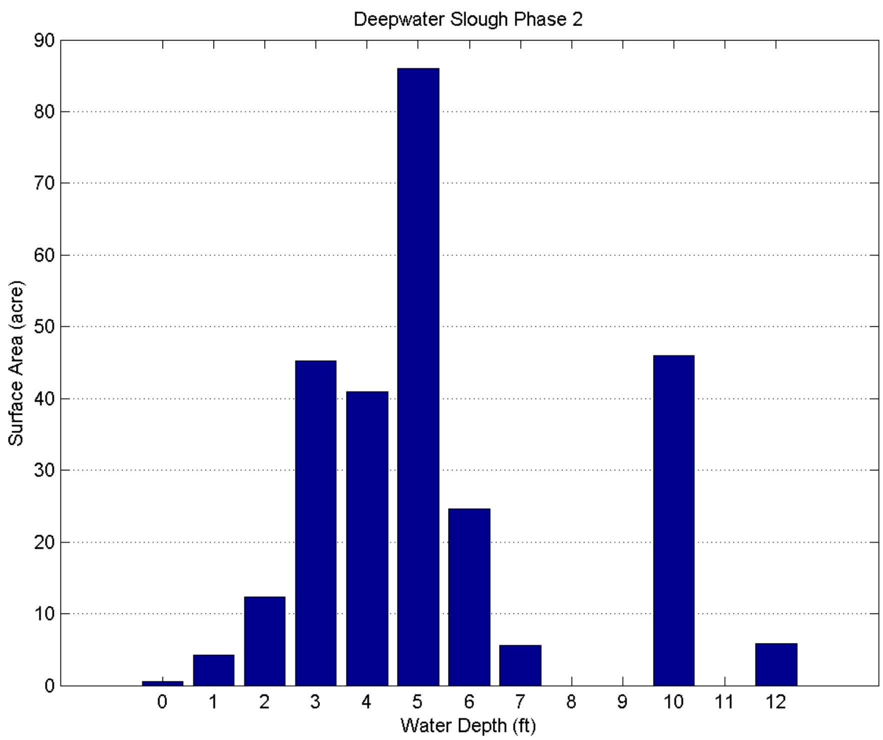


Figure H.12. Histogram of depths for Deepwater Slough Phase 2.

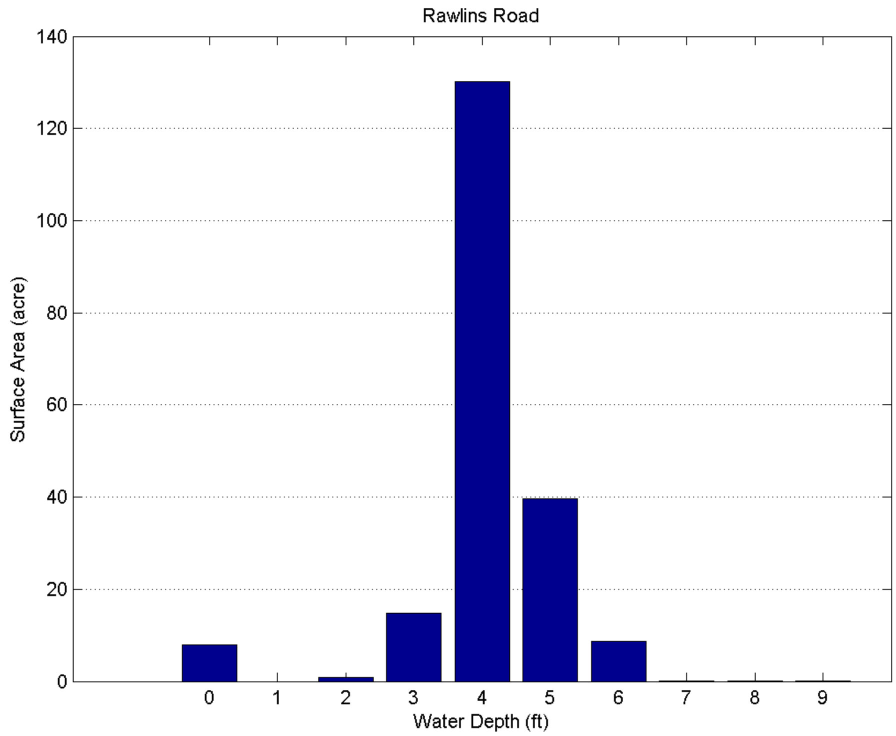


Figure H.13. Histogram of depths for Rawlins Road.

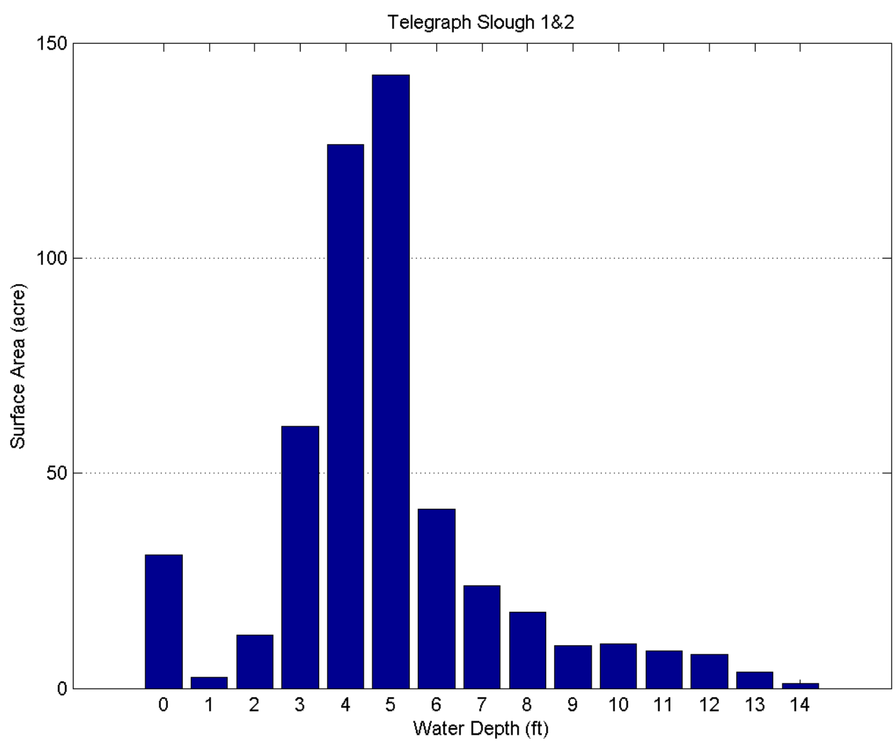


Figure H.14. Histogram of depths for Telegraph Sloughs 1 & 2.

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.

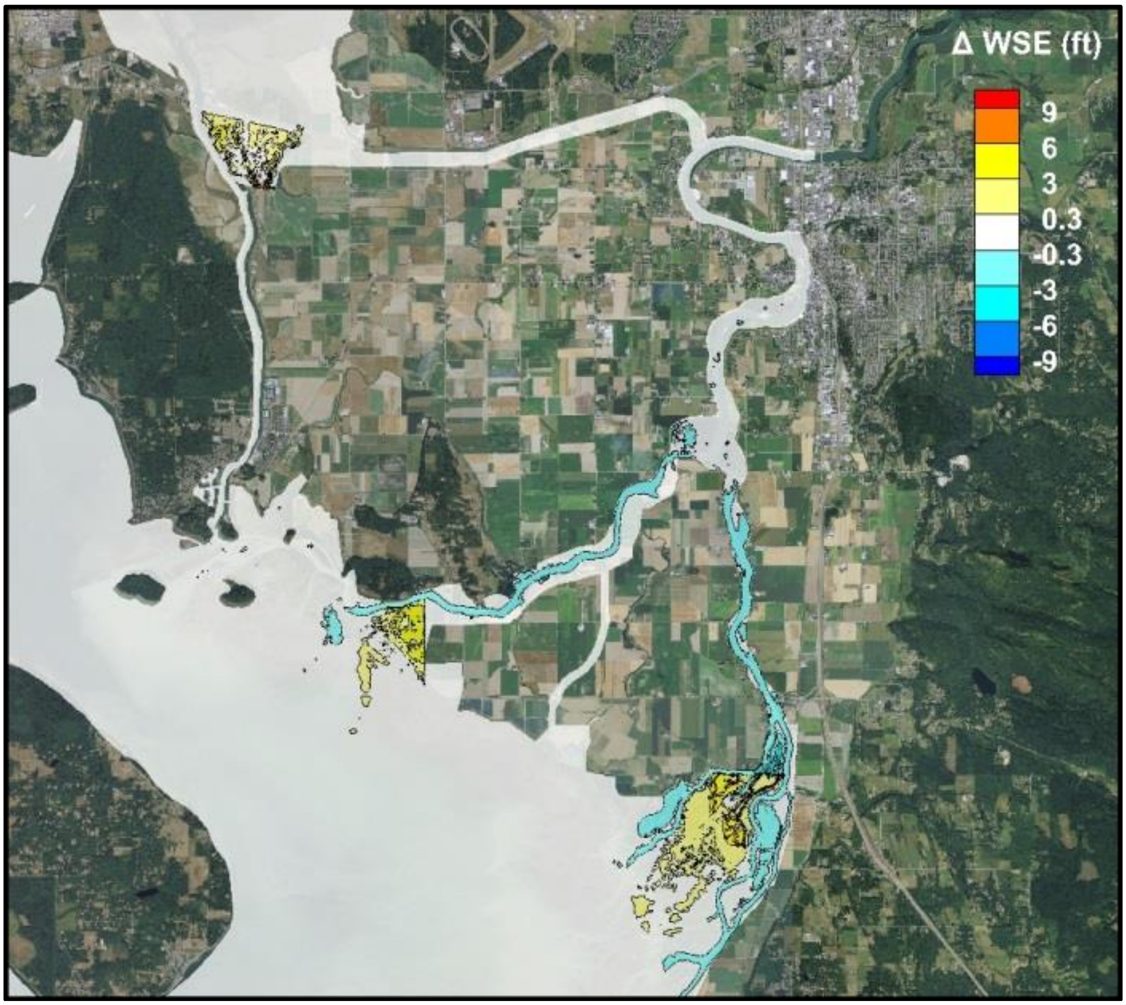


Figure H.15. Contour map of change in WSE from the Baseline to Moderate Influence Projects #2 simulation with Q2 flow and low tide.

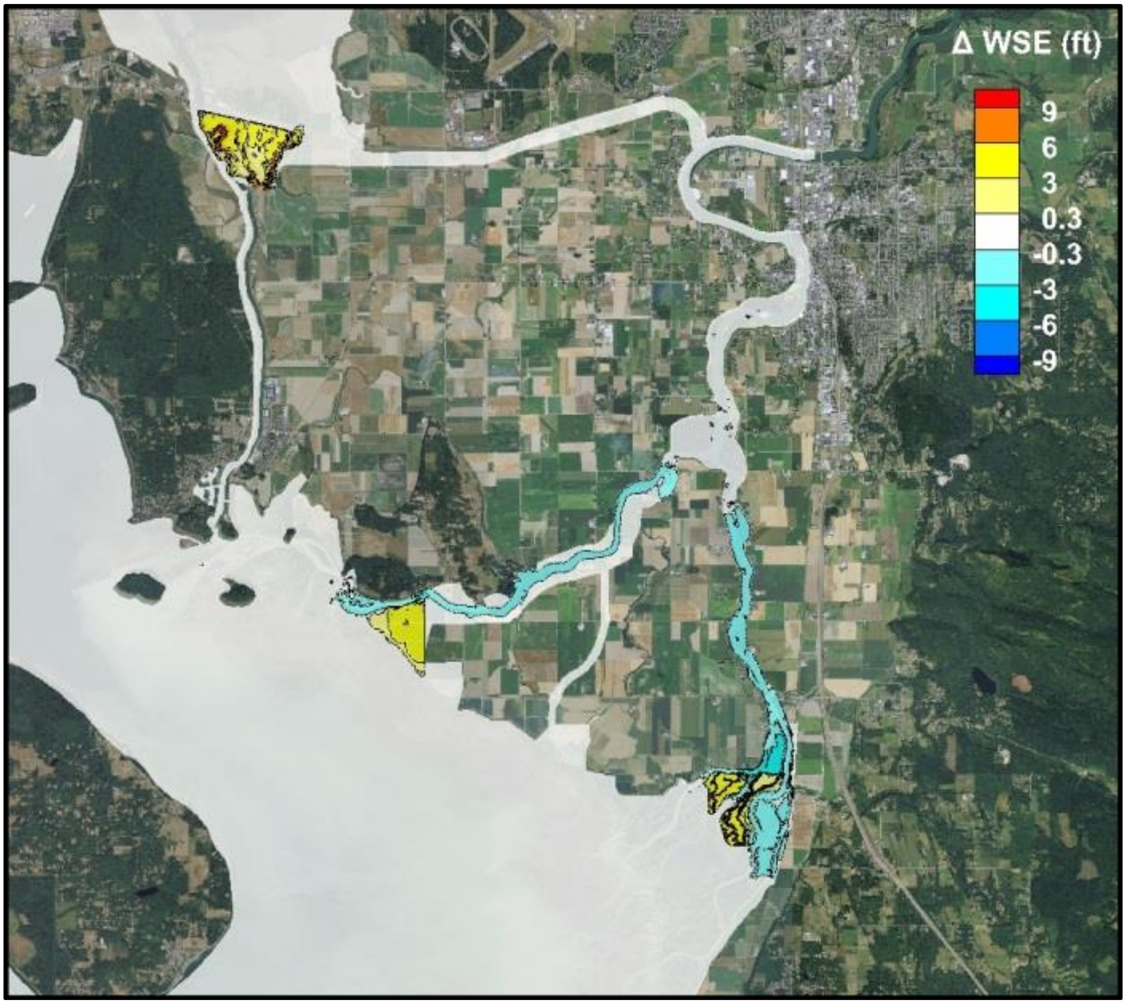


Figure H.16. Contour map of change in WSE from the Baseline to Moderate Influence Projects #2 simulation with flood flow and high tide.

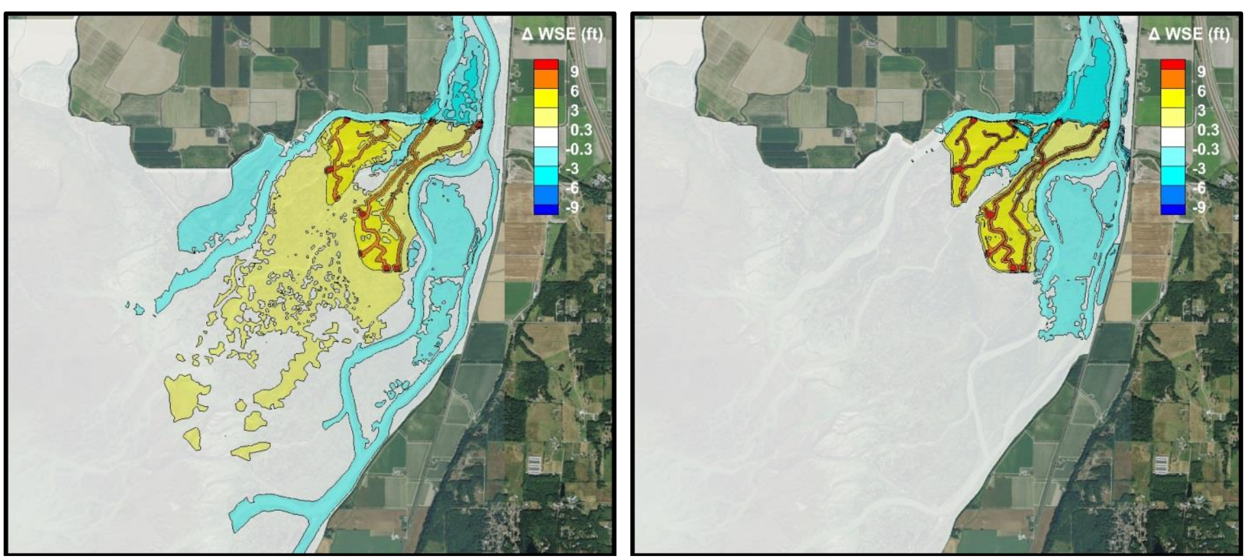


Figure H.17. Contour map of change in WSE from the Baseline simulation for Deepwater Slough Phase 2 with Q2 flow and low tide (left) and flood flow and high tide (right).

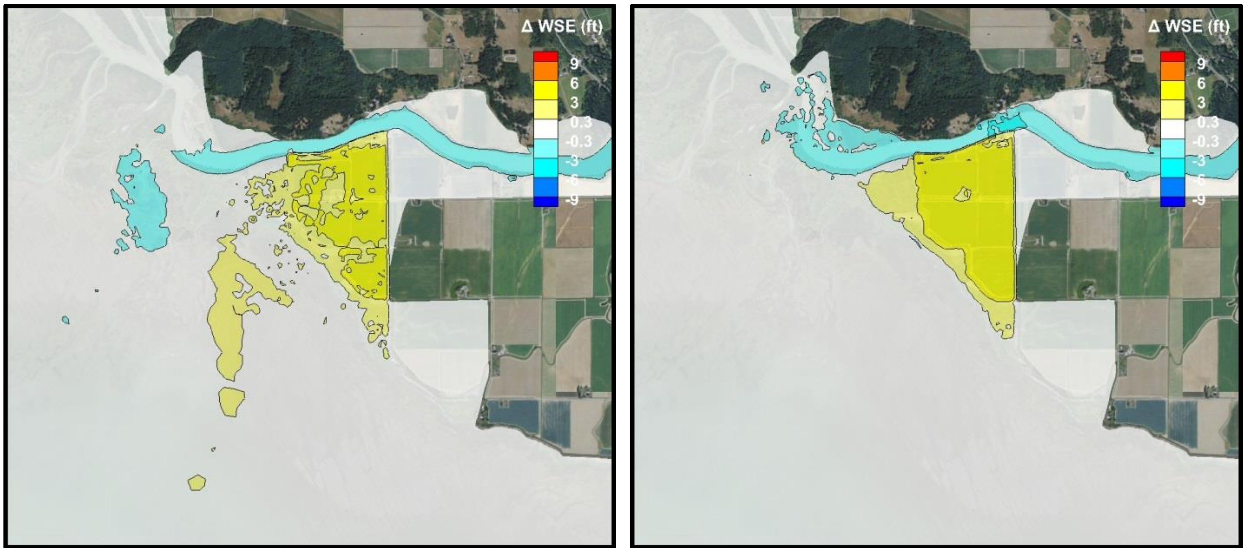


Figure H.18. Contour map of change in WSE from the Baseline simulation for Rawlins Road with Q2 flow and low tide (left) and flood flow and high tide (right).

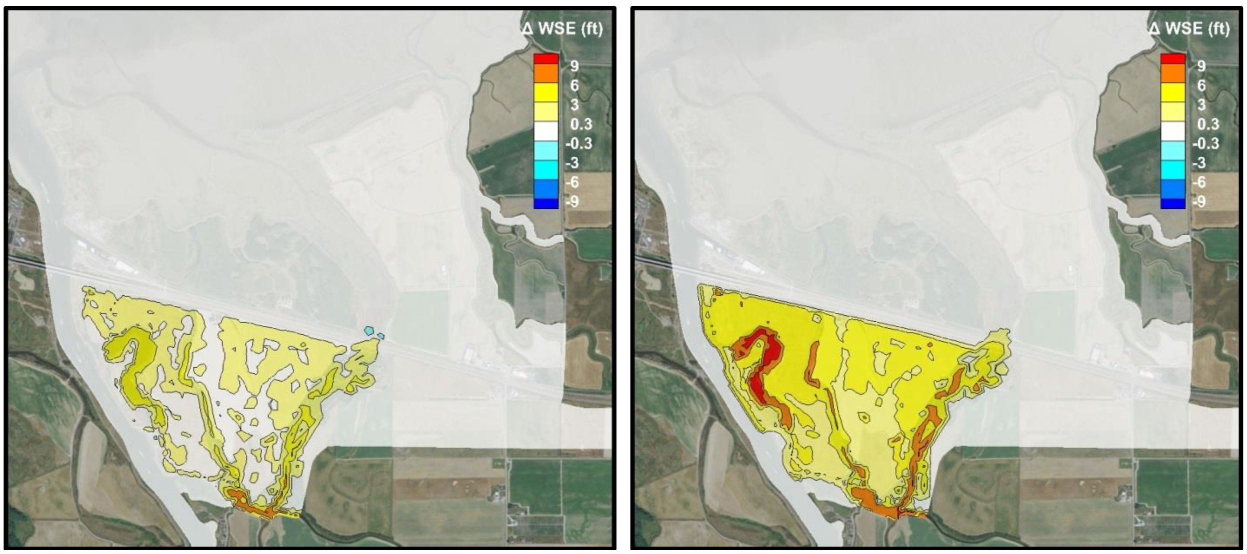


Figure H.19. Contour map of change in WSE from the Baseline simulation for Telegraph Slough 1&2 with Q2 flow and low tide (left) and flood flow and high tide (right).

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.

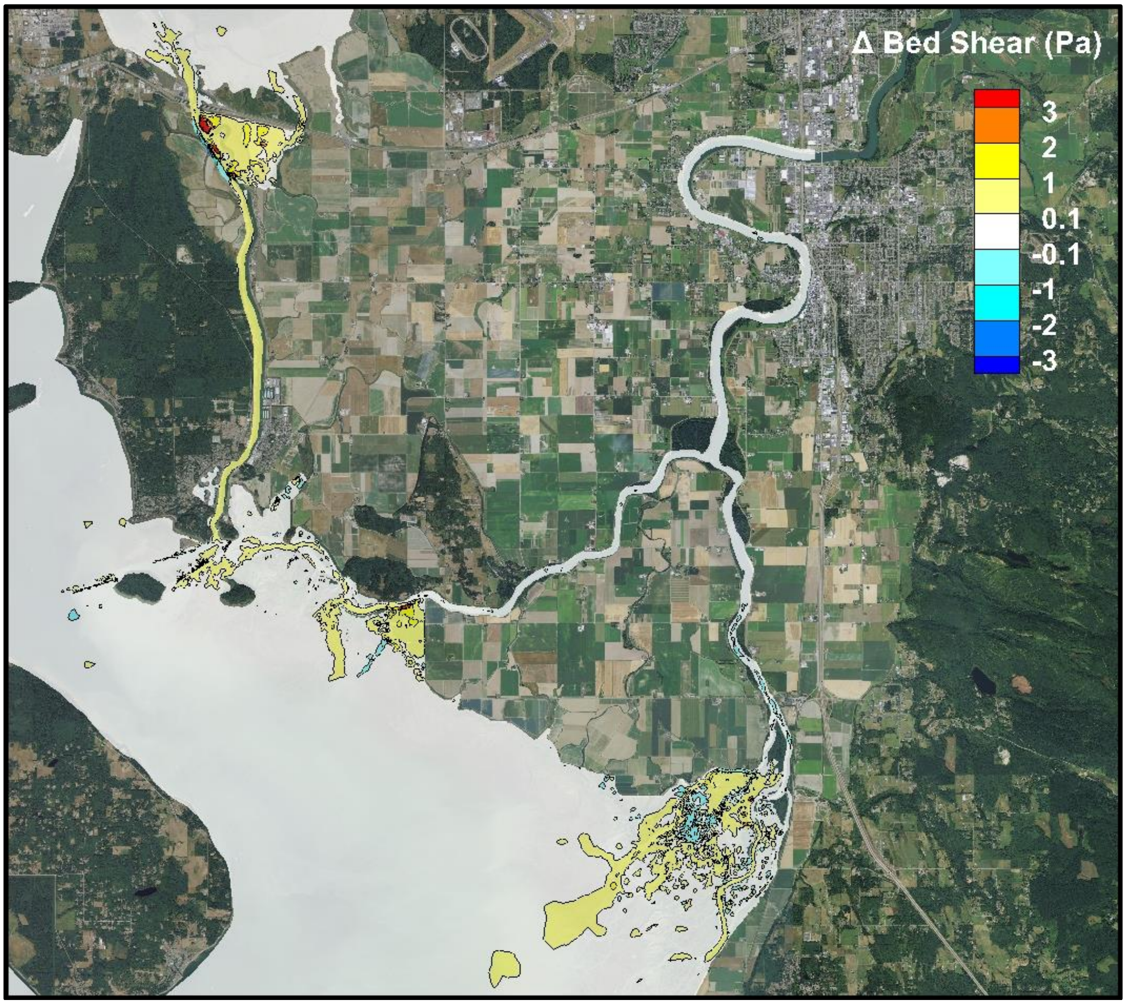


Figure H.20. Contour map of change in shear stress from the Baseline to Moderate Influence Projects #2 simulation with peak shear across a full tidal cycle at low flow.

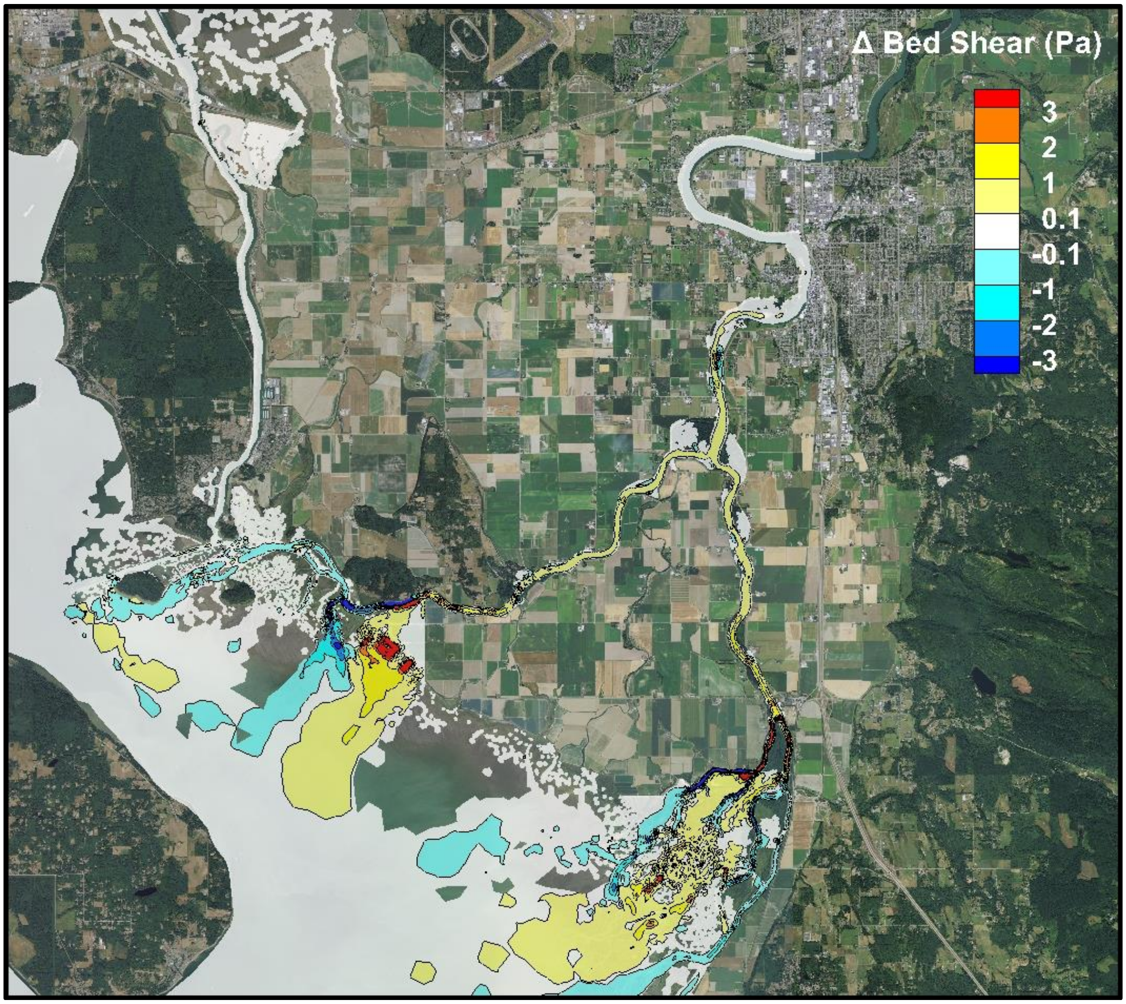


Figure H.21. Contour map of change in shear stress from the Baseline to Moderate Influence Projects #2 simulation with Q2 flow and low tide.

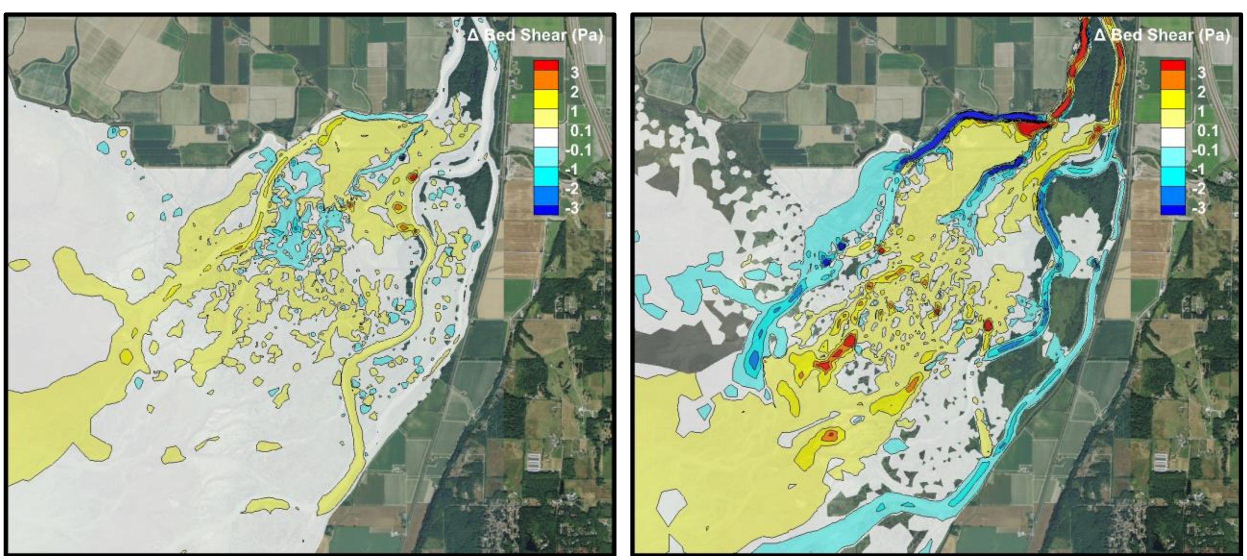


Figure H.22. Contour map of change in shear stress from Baseline for Deepwater Slough Phase 2 with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

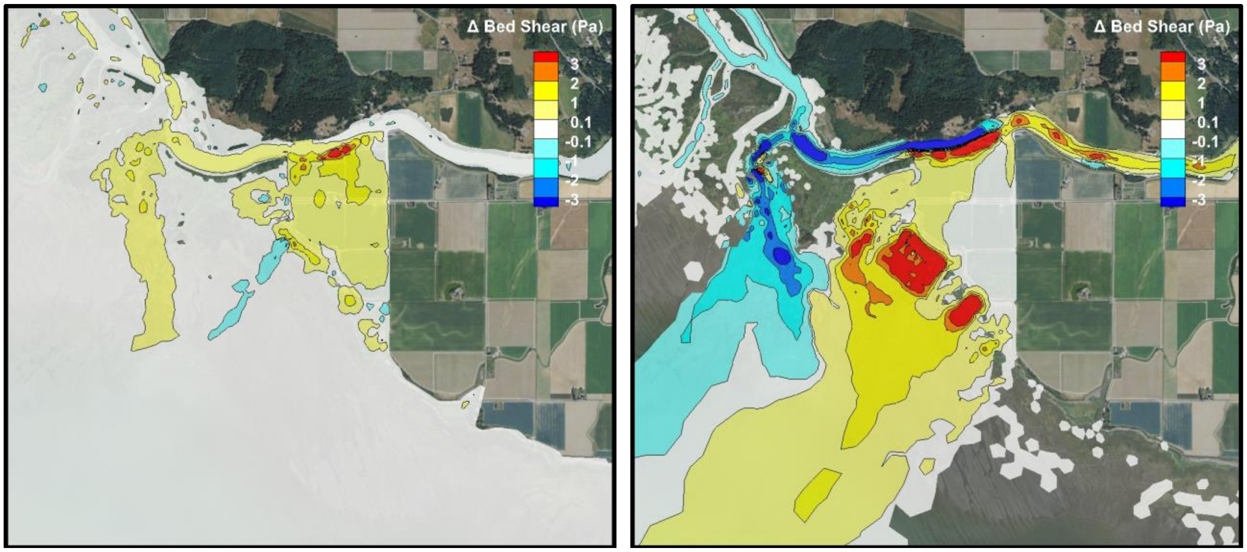


Figure H.23. Contour map of change in shear stress from the Baseline simulation for Rawlins Road with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

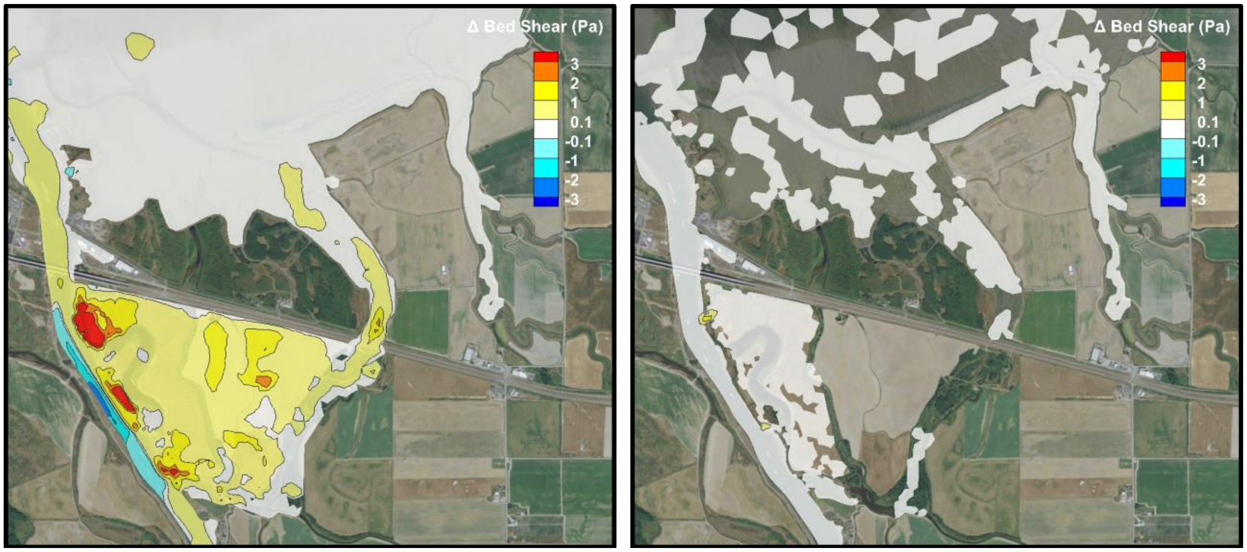


Figure H.24. Contour map of change in shear stress from the Baseline simulation for Telegraph Slough 1&2 with peak shear across a full tidal cycle at low flow (left) and Q2 flow and low tide (right).

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.

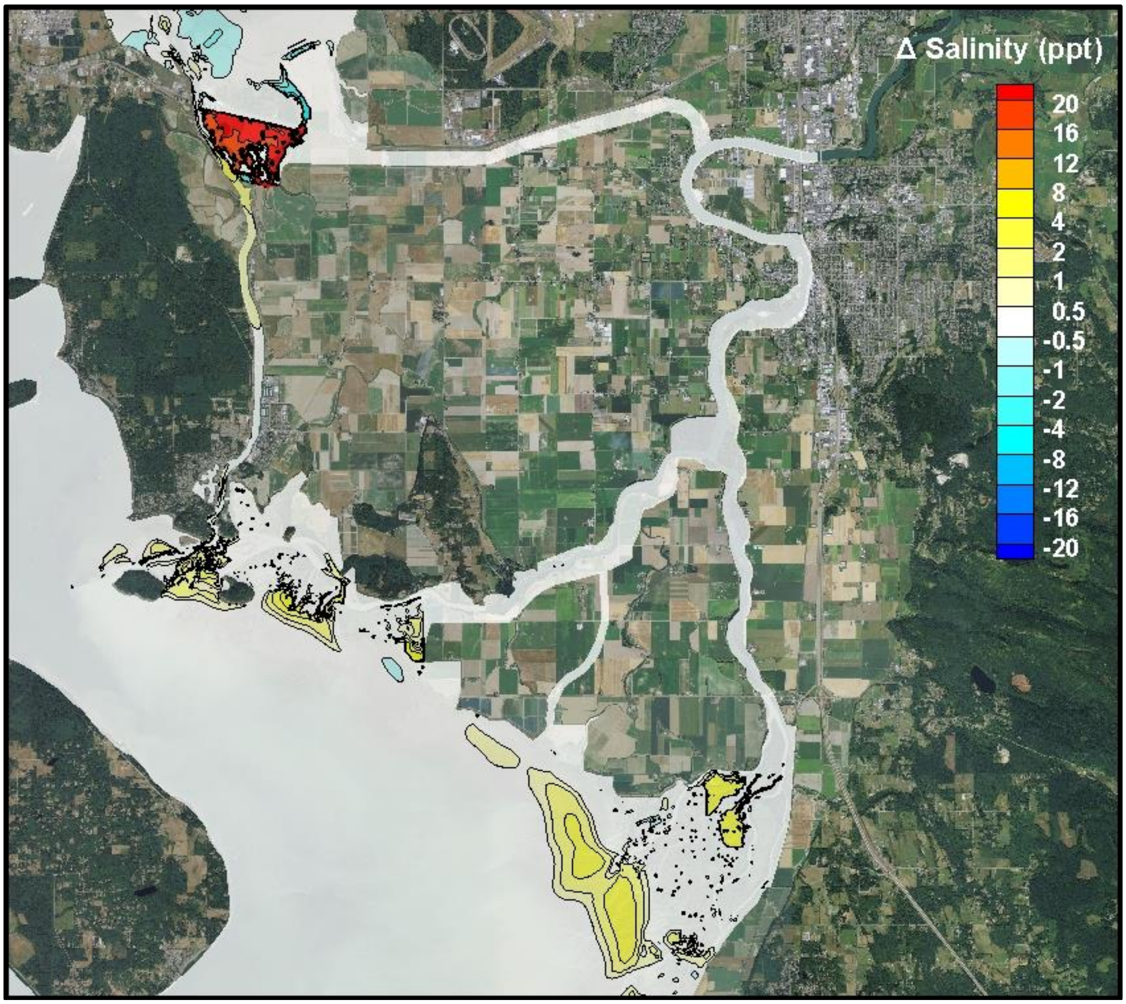


Figure H.25. Contour map of change in salinity from the Baseline to Moderate Influence Projects #2 simulation with low flow and high tide.

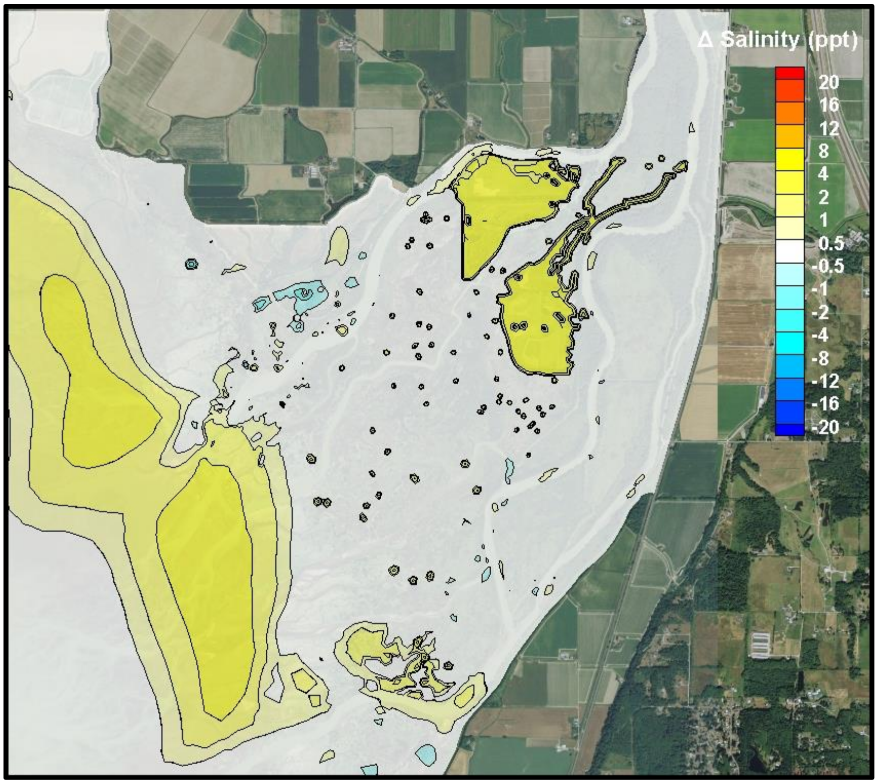


Figure H.26. Contour map of change in salinity from the Baseline simulation for Deepwater Slough Phase 2 with low flow and high tide.

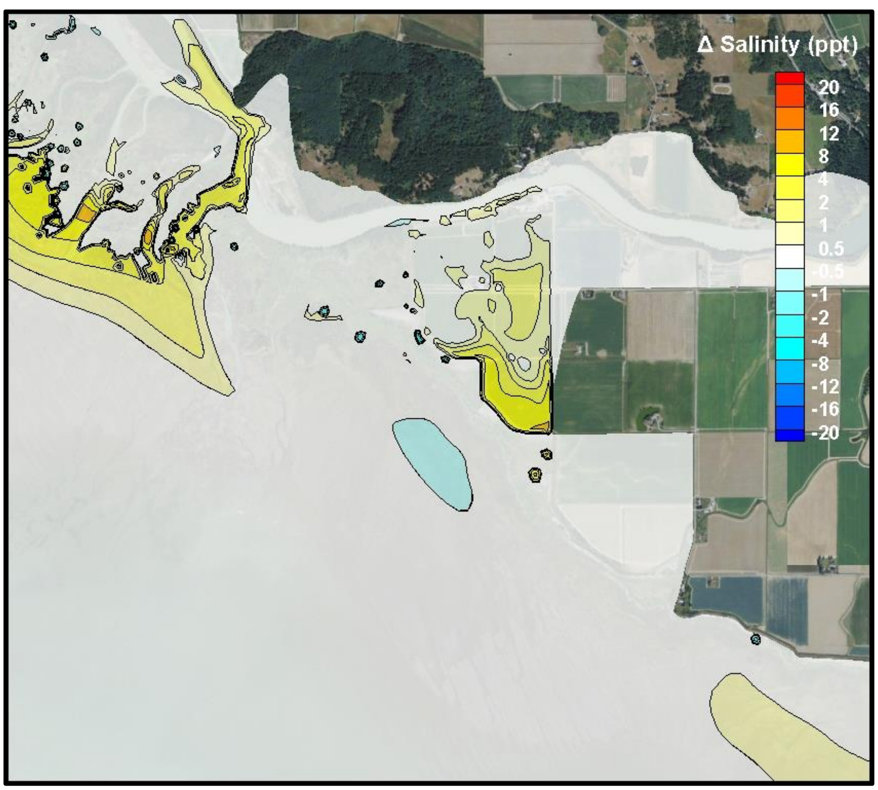


Figure H.27. Contour map of change in salinity from the Baseline simulation for Rawlins Road with low flow and high tide.

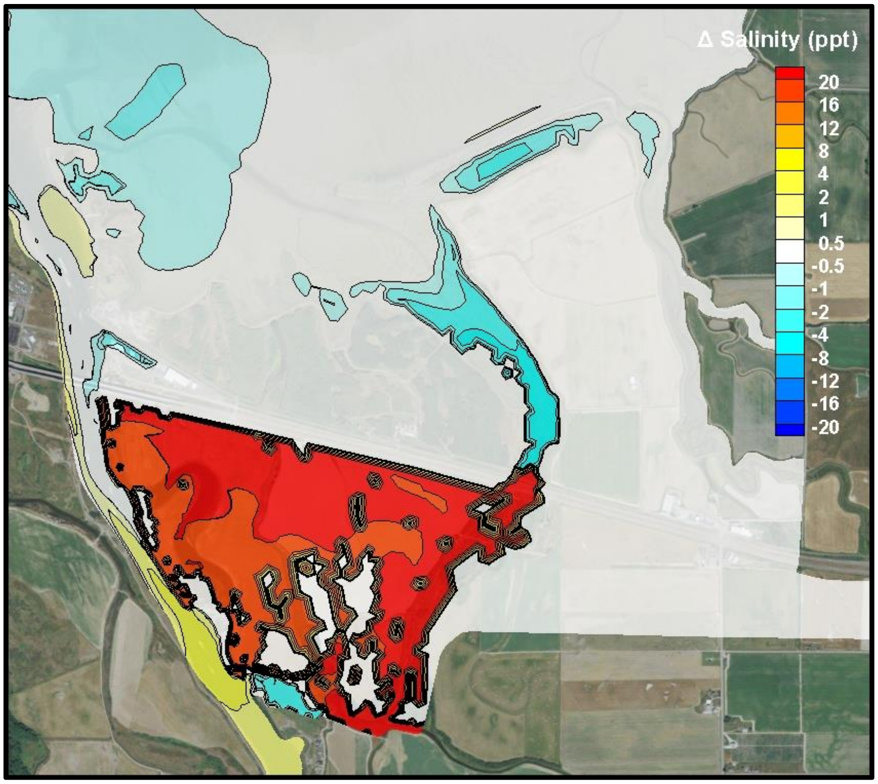


Figure H.28. Contour map of change in salinity from the Baseline simulation for Telegraph Slough 1&2 with low flow and high tide.

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.

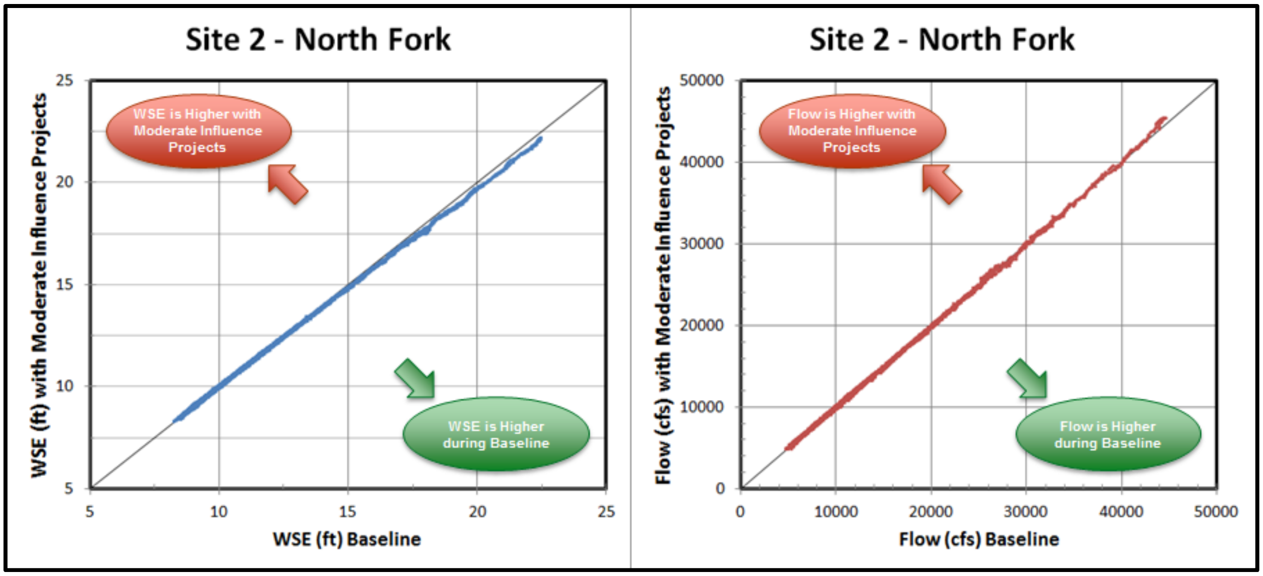


Figure H.29. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Moderate Influence Projects simulation at the North Fork gauge location compared with the same information under baseline conditions.

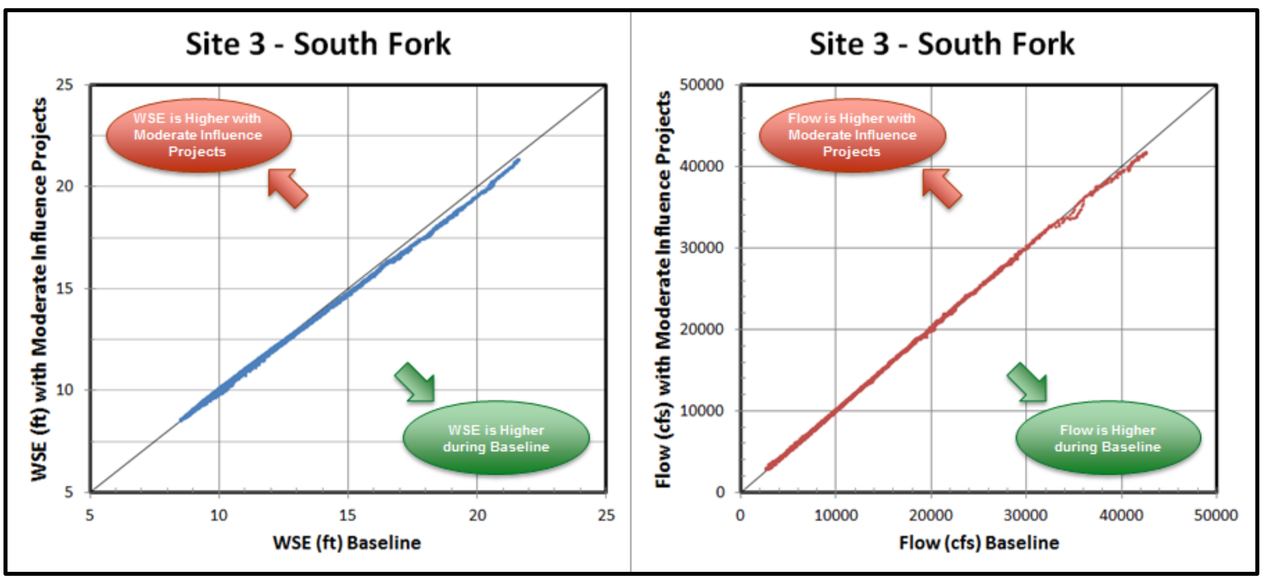


Figure H.30. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Moderate Influence Projects simulation at the South Fork gauge location compared with the same information under baseline conditions.

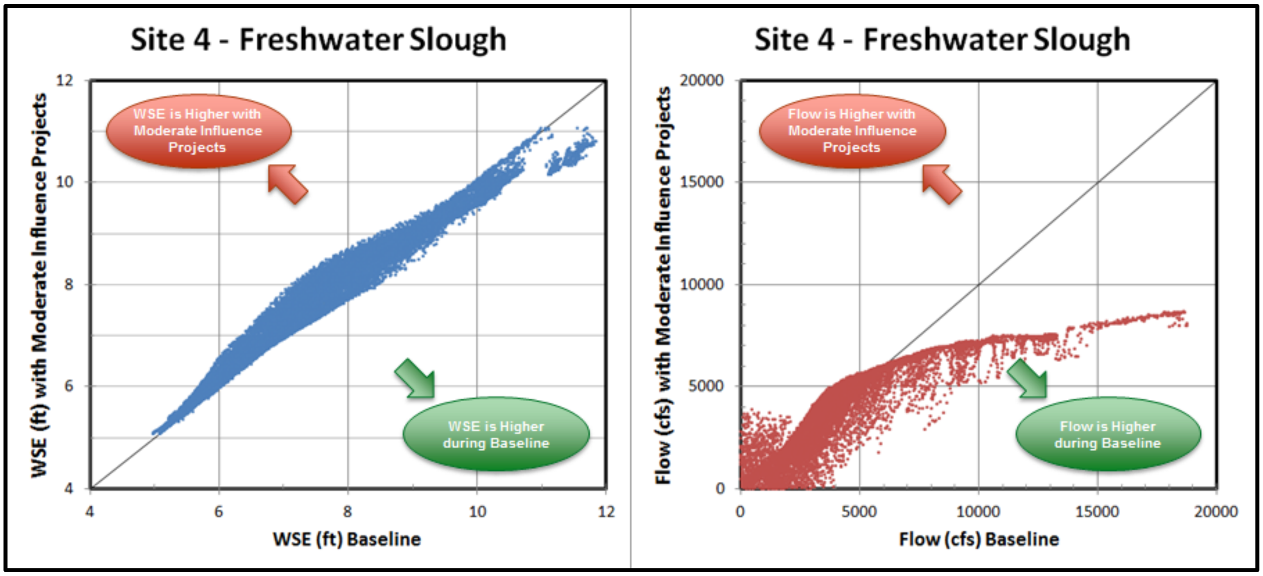


Figure H.31. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Moderate Influence Projects simulation at the Freshwater Slough gauge location compared with the same information under baseline conditions.

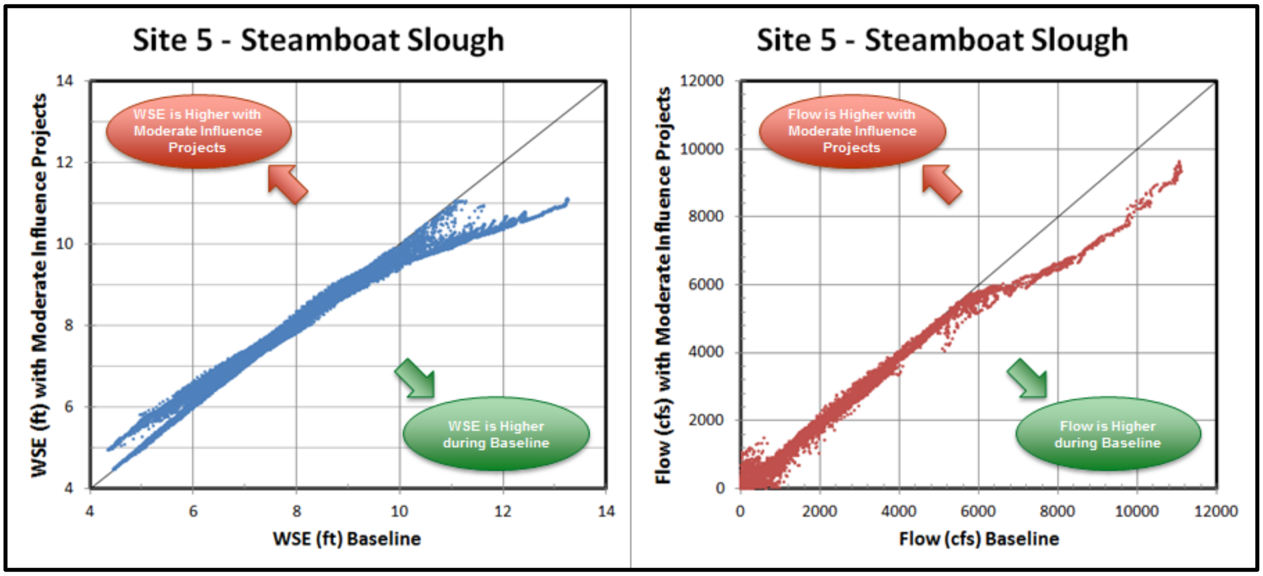


Figure H.32. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Moderate Influence Projects simulation at the Steamboat Slough gauge location compared with the same information under baseline conditions.

Appendix I

Simulation 8: Selected Projects Deliverables

Appendix I

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.

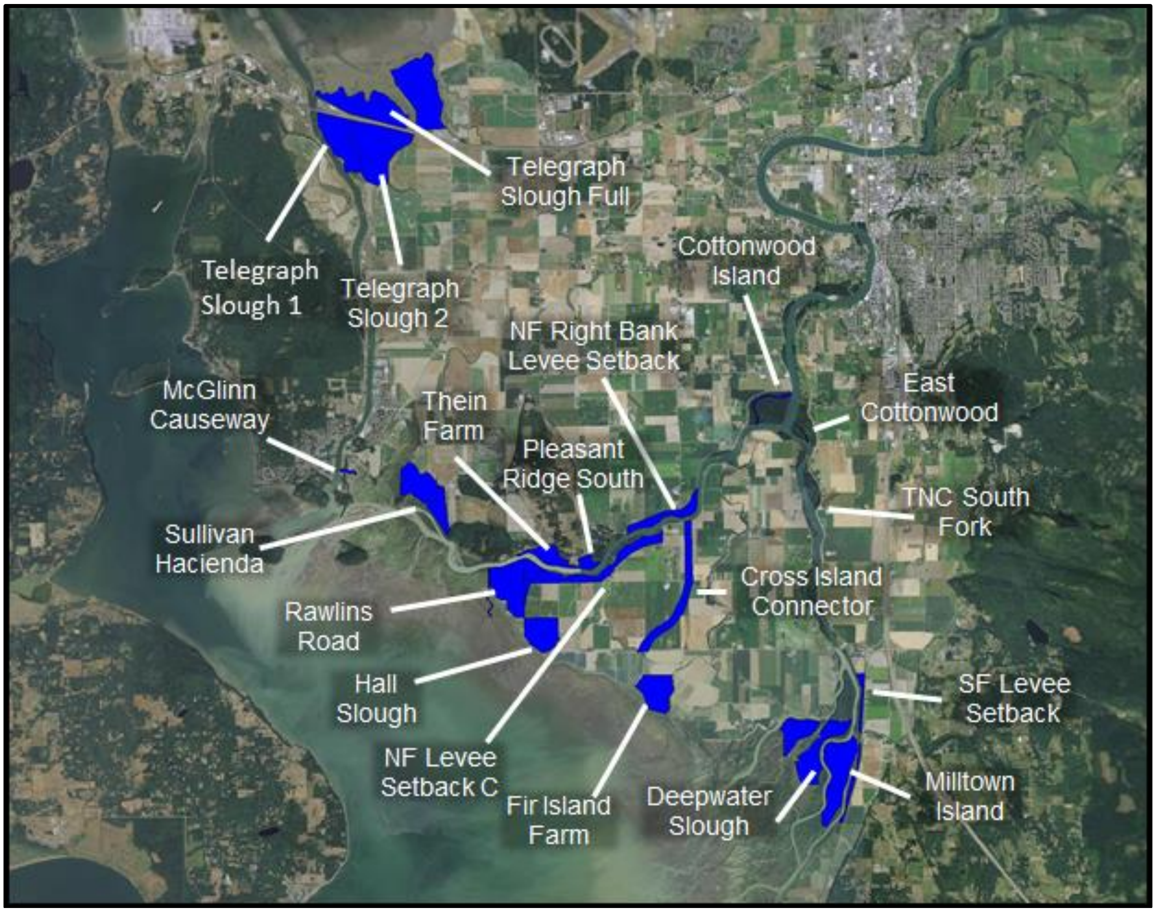


Figure I.1. A map of project area in the Selected Projects simulation.

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.

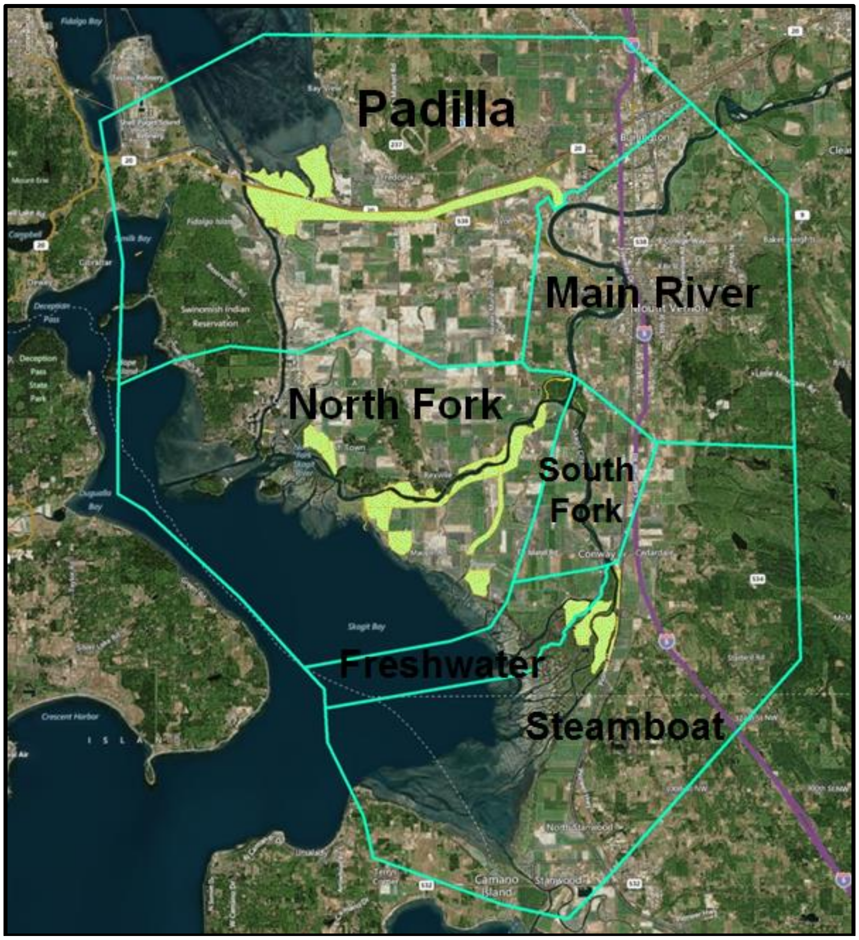


Figure I.2. Sub-basins within the Skagit region used for area calculations.

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.

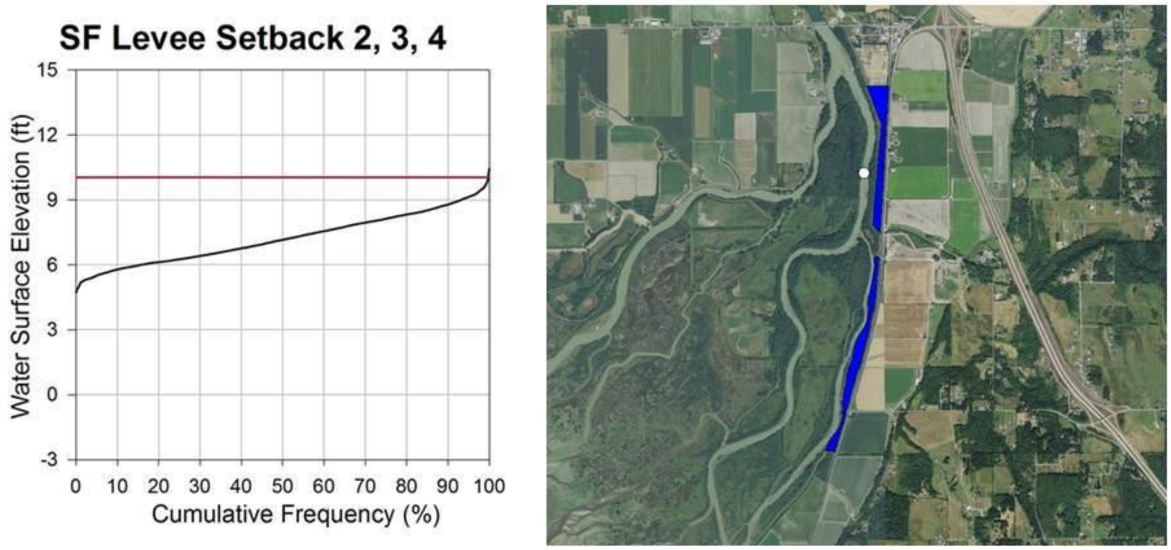


Figure I.3. Cumulative frequency plot and corresponding map for SF Levee Setbacks 2, 3, and 4 during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

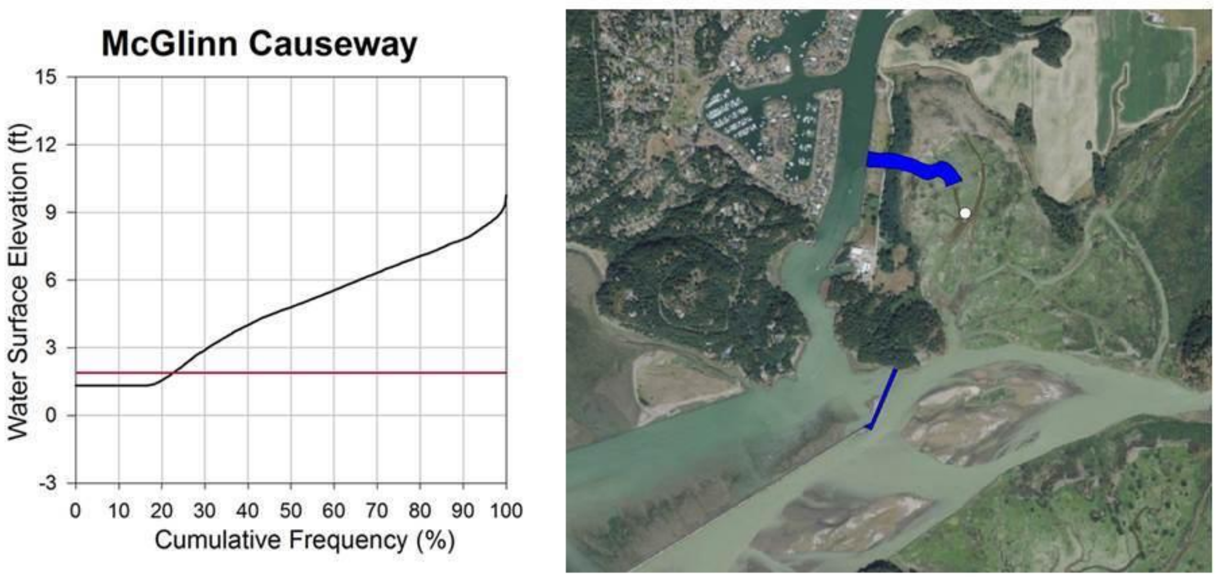


Figure I.4. Cumulative frequency plot and corresponding map for McGlinn Causeway during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

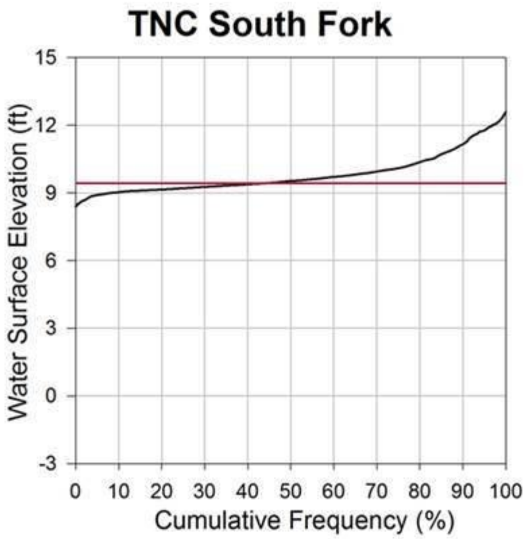


Figure I.5. Cumulative frequency plot and corresponding map for TNC South Fork during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

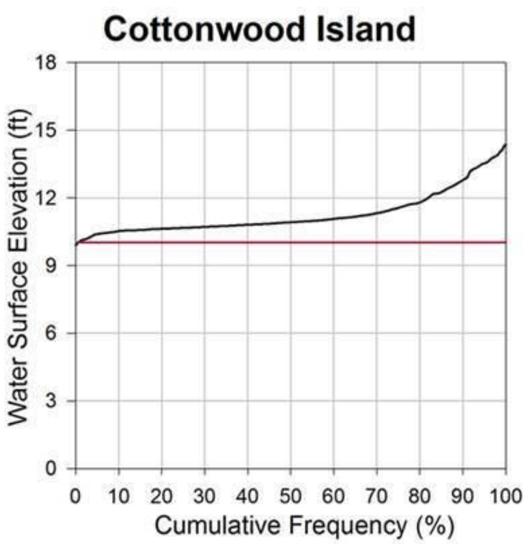


Figure I.6. Cumulative frequency plot and corresponding map for Cottonwood Island during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

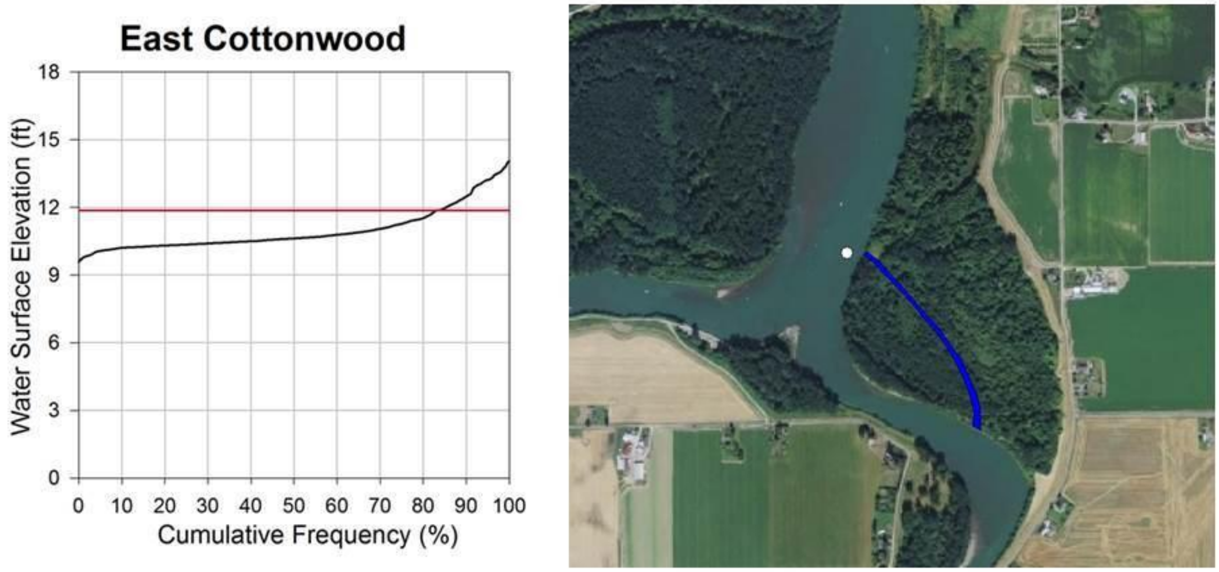


Figure I.7. Cumulative frequency plot and corresponding map for East Cottonwood during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

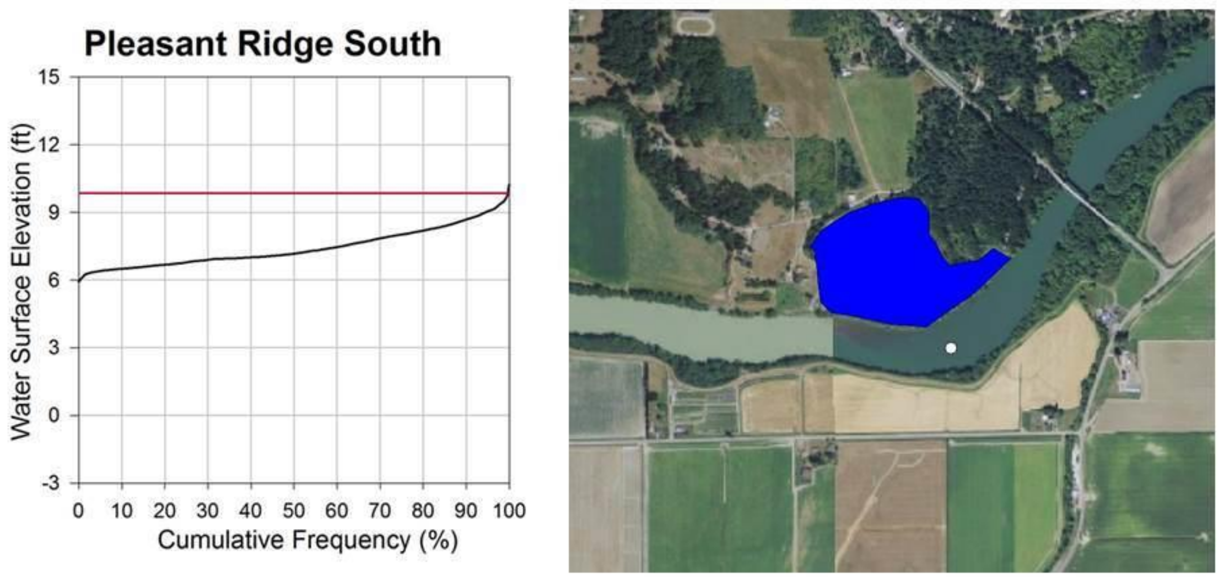


Figure I.8. Cumulative frequency plot and corresponding map for Pleasant Ridge South during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

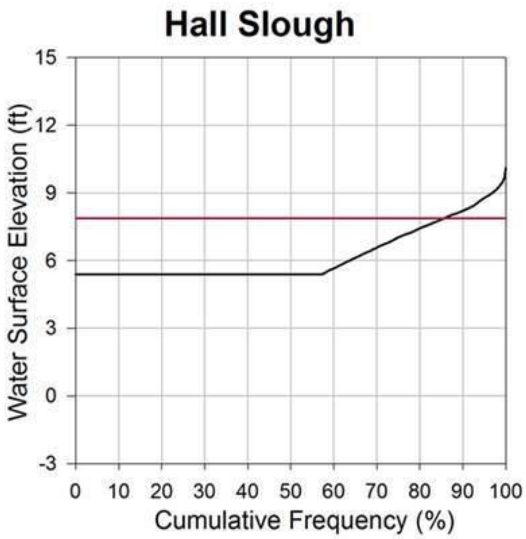


Figure I.9. Cumulative frequency plot and corresponding map for Hall Slough during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

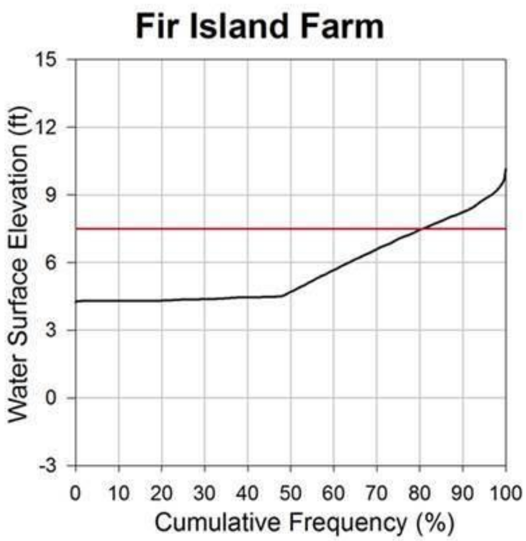


Figure I.10. Cumulative frequency plot and corresponding map for Fir Island Farm during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

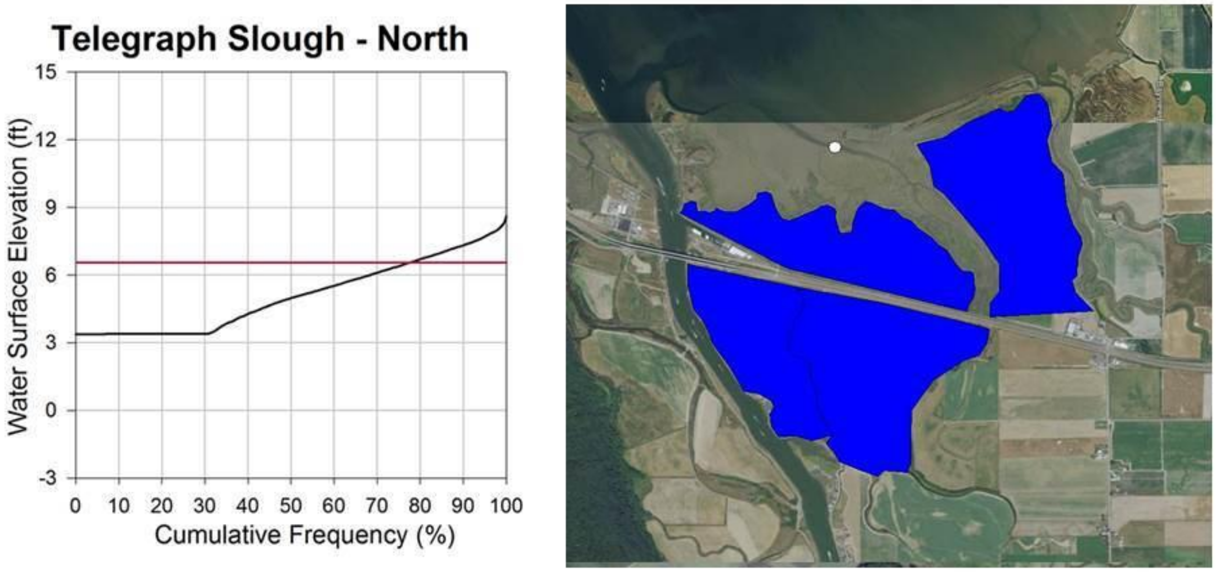


Figure I.11. Cumulative frequency plot and corresponding map for Telegraph Slough (North) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

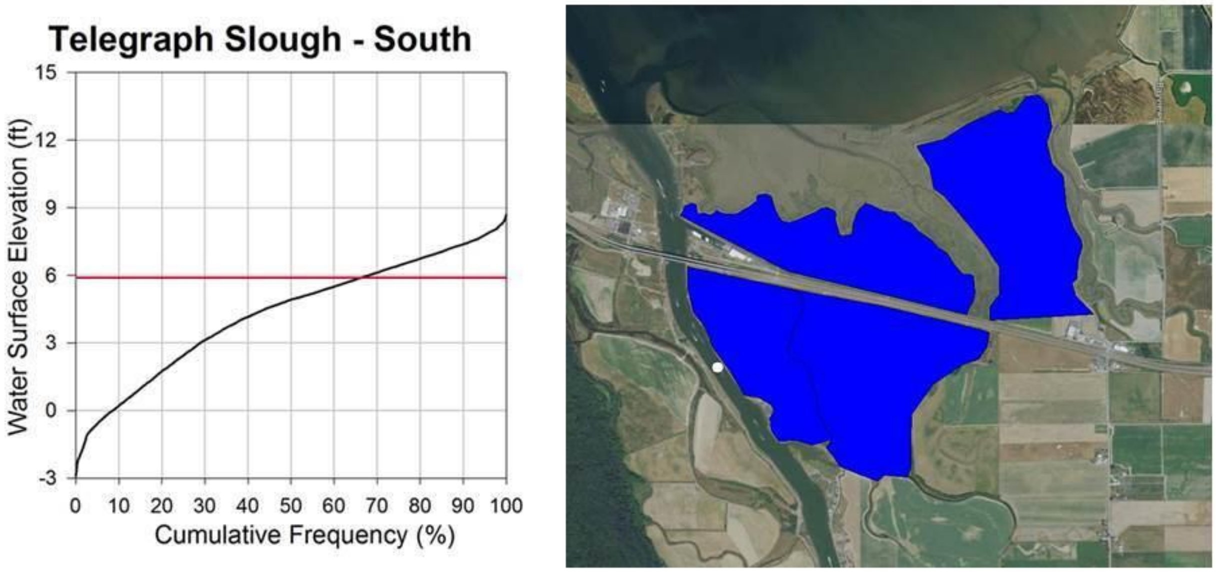


Figure I.12. Cumulative frequency plot and corresponding map for Telegraph Slough (South) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

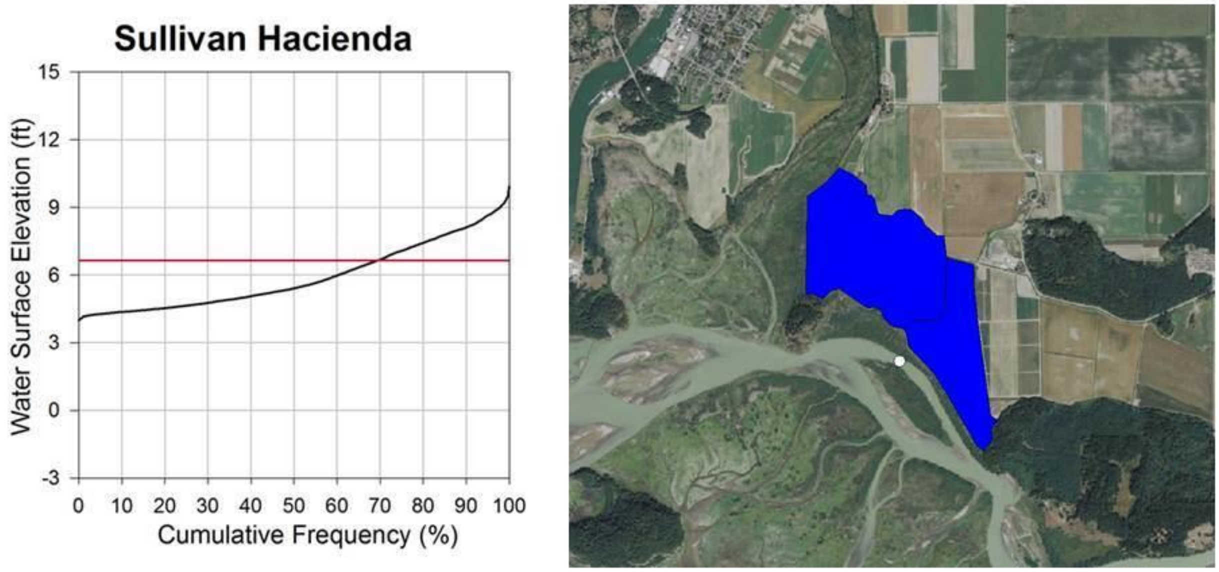


Figure I.13. Cumulative frequency plot and corresponding map for Sullivan Hacienda during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

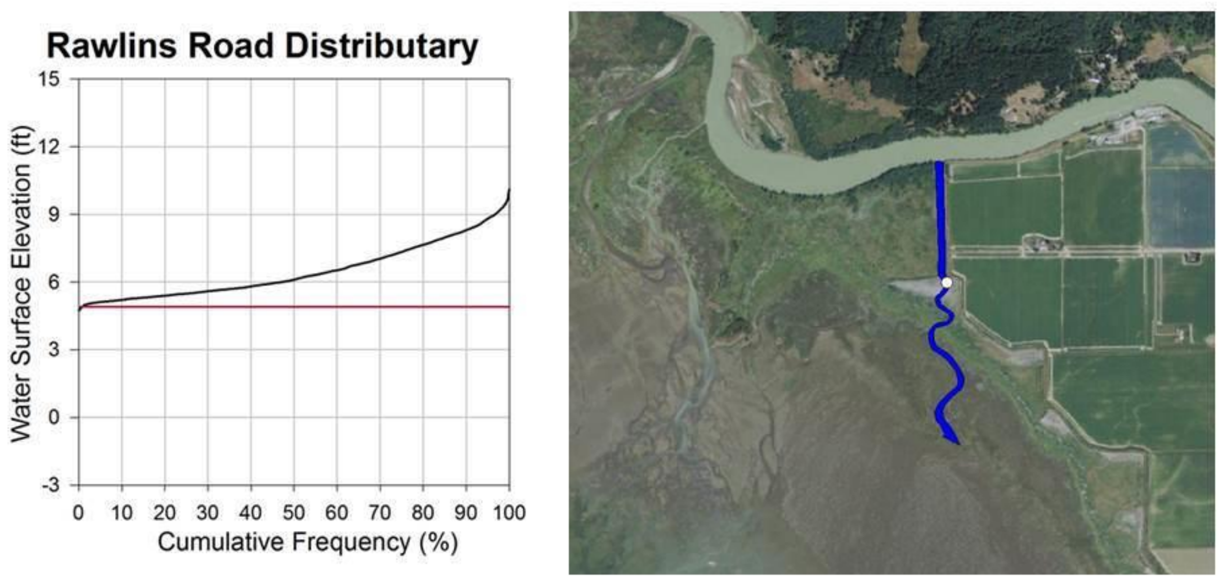


Figure I.14. Cumulative frequency plot and corresponding map for Rawlins Road Distributary during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

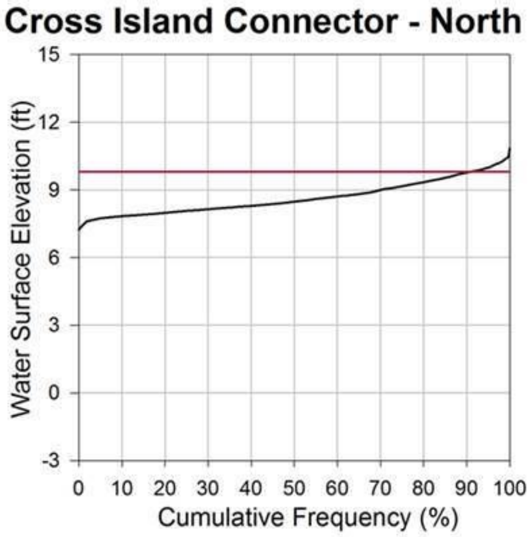


Figure I.15. Cumulative frequency plot and corresponding map for Cross Island Connector (north) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

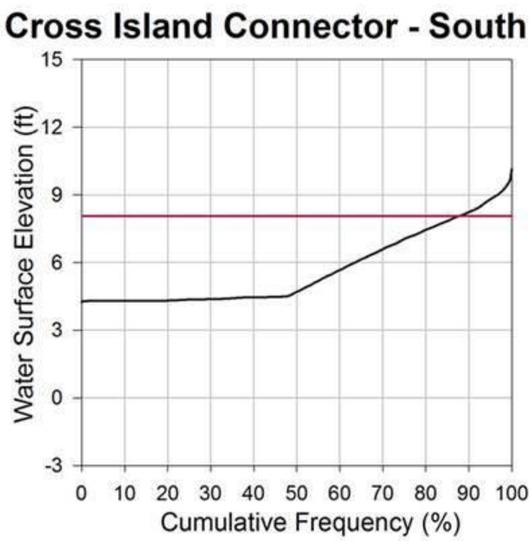


Figure I.16. Cumulative frequency plot and corresponding map for Cross Island Connector (south) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

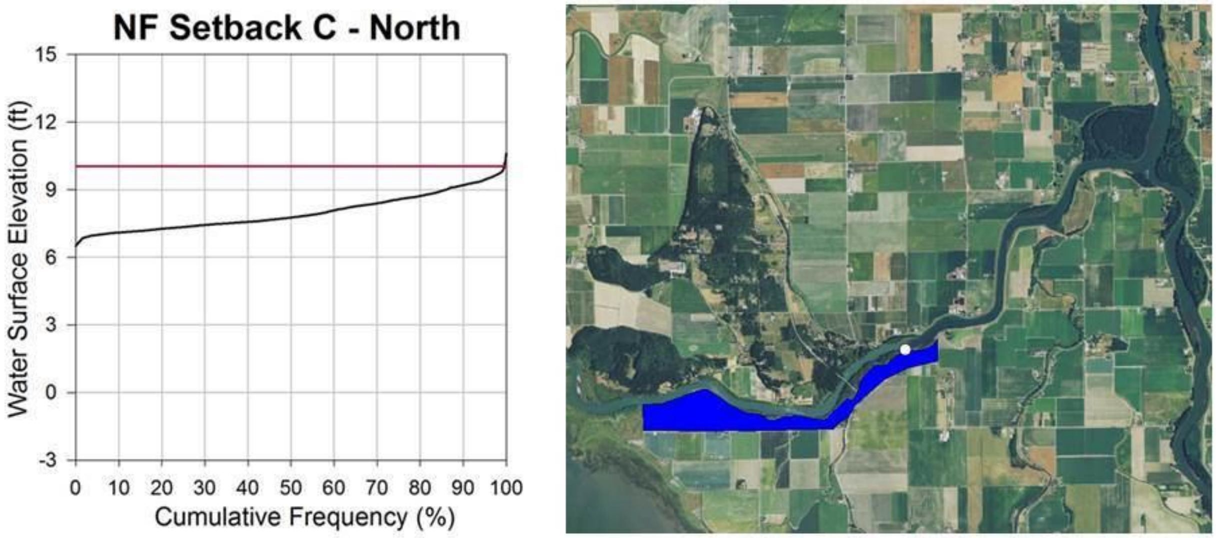


Figure I.17. Cumulative frequency plot and corresponding map for NF Levee Setback C (north) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

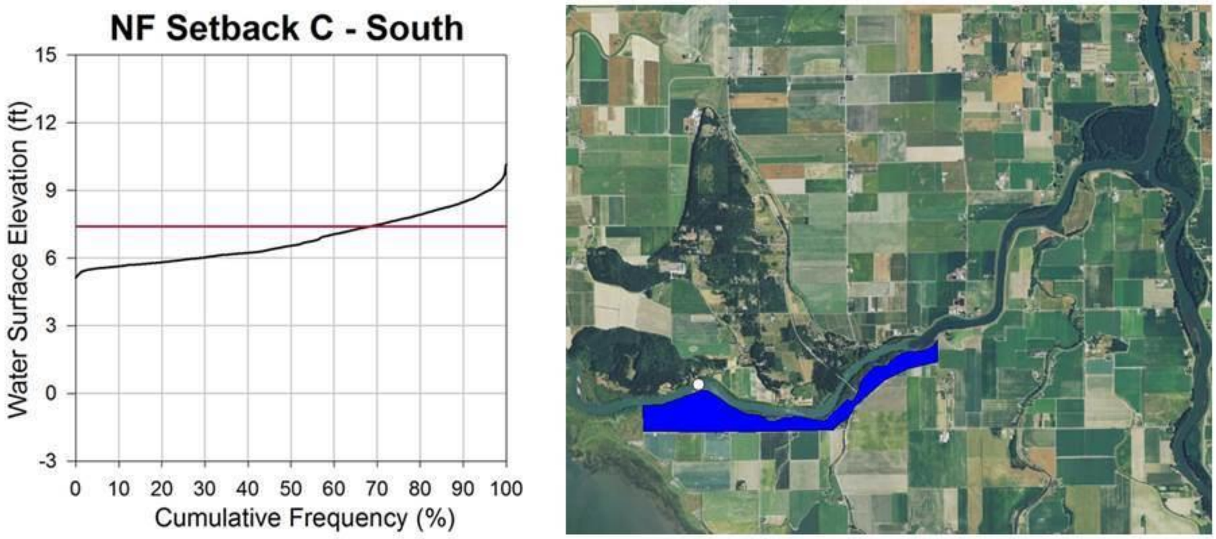


Figure I.18. Cumulative frequency plot and corresponding map for NF Levee Setback C (south) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

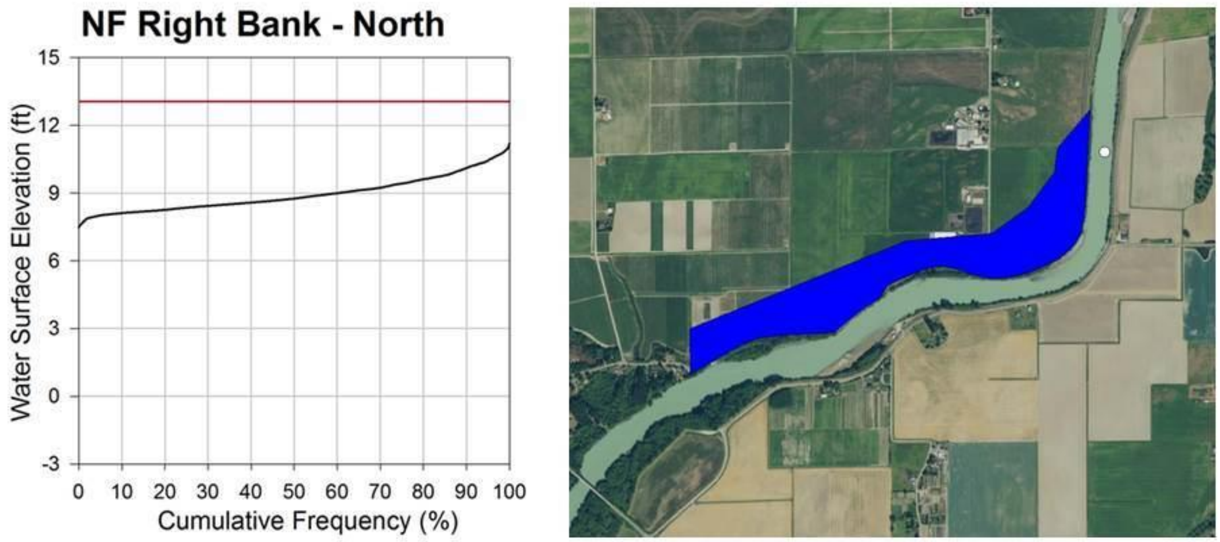


Figure I.19. Cumulative frequency plot and corresponding map for NF Right Bank (north) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

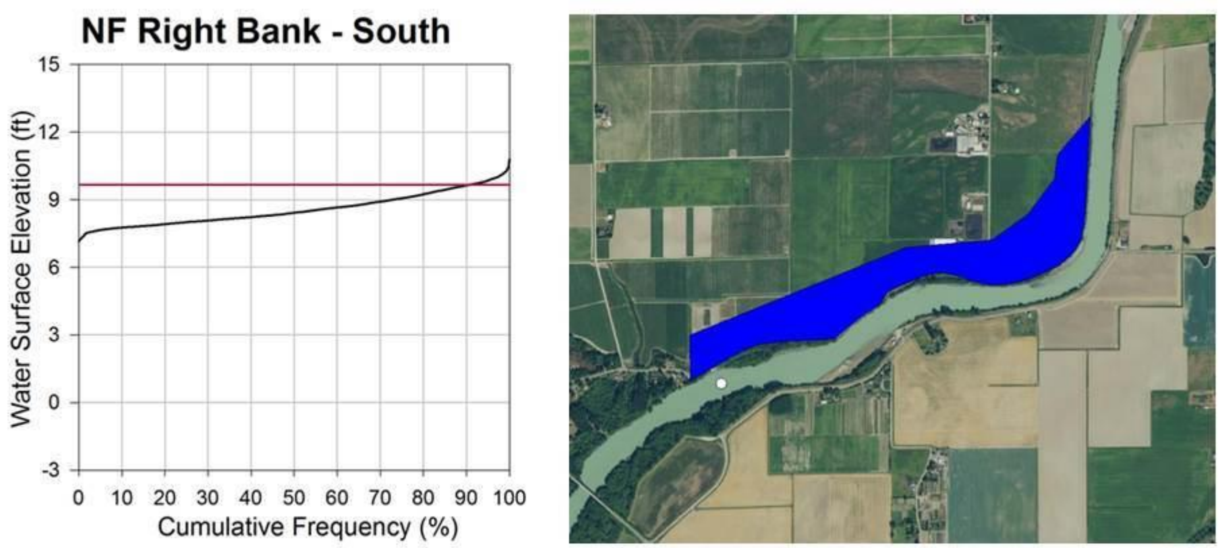


Figure I.20. Cumulative frequency plot and corresponding map for NF Right Bank (south) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

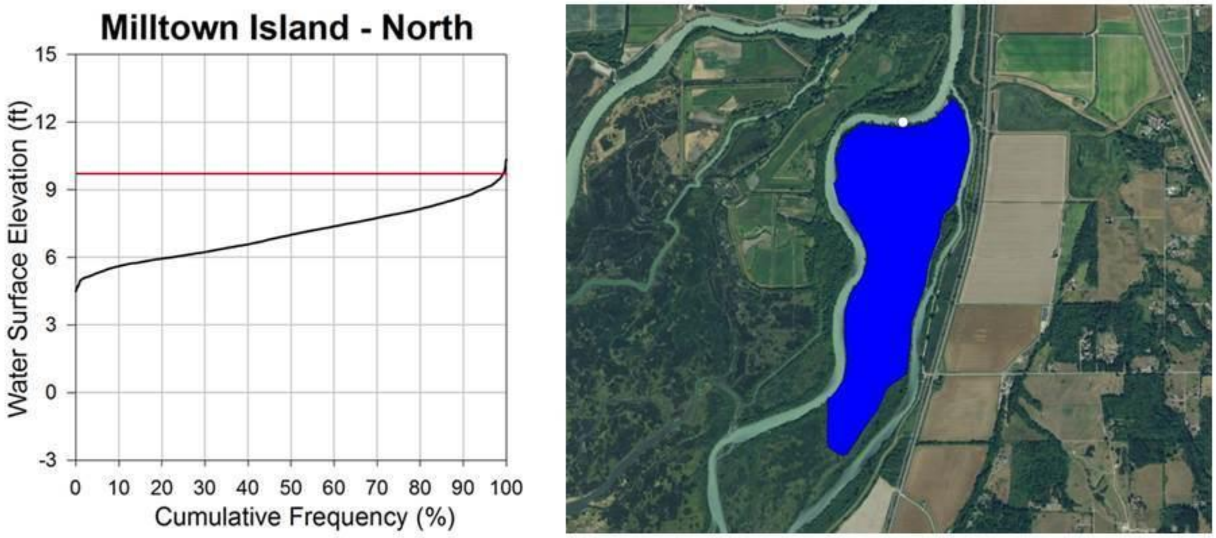


Figure I.21. Cumulative frequency plot and corresponding map for Milltown Island (north) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

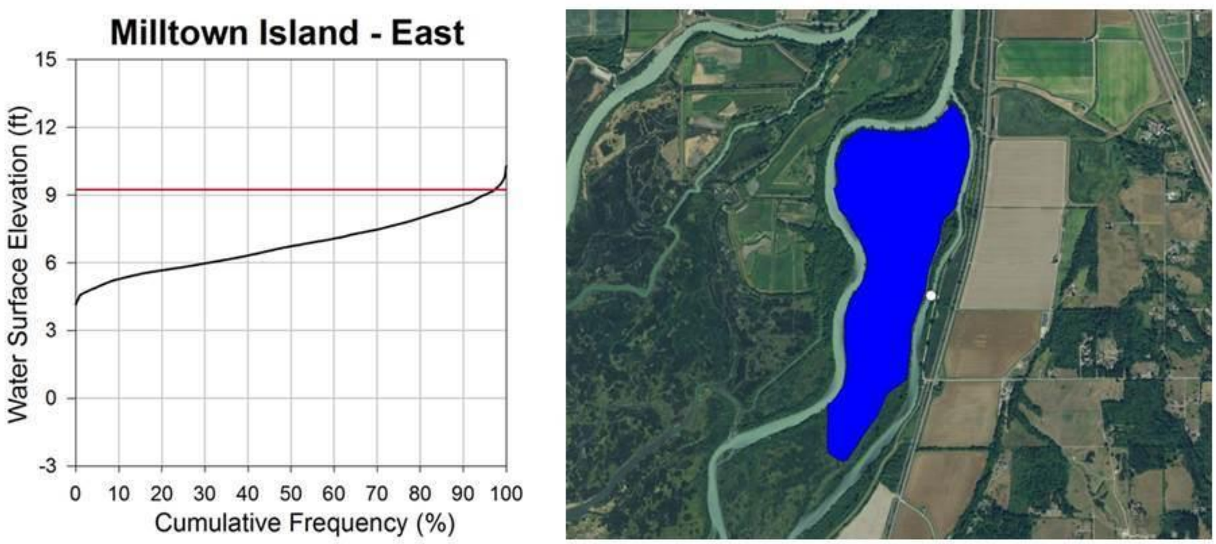


Figure I.22. Cumulative frequency plot and corresponding map for Milltown Island (east) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

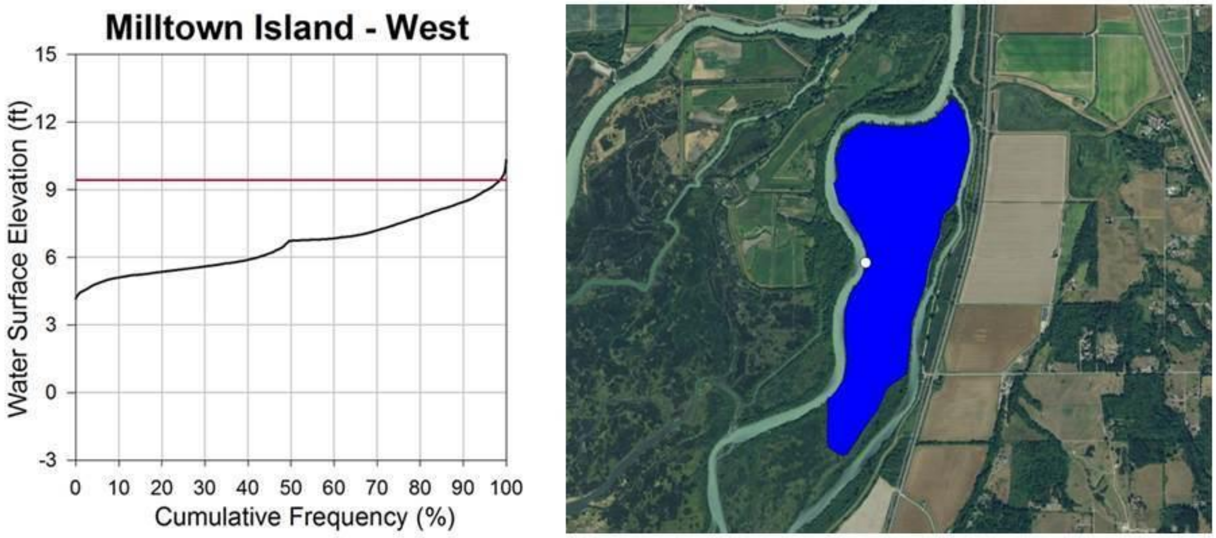


Figure I.23. Cumulative frequency plot and corresponding map for Milltown Island (west) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

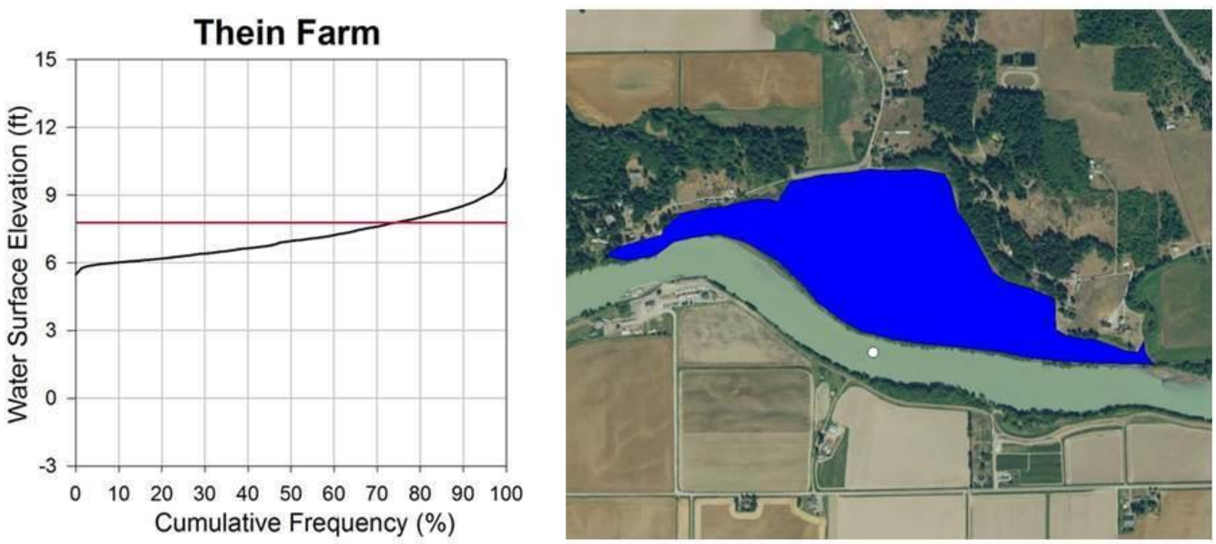


Figure I.24. Cumulative frequency plot and corresponding map for Thein Farm during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

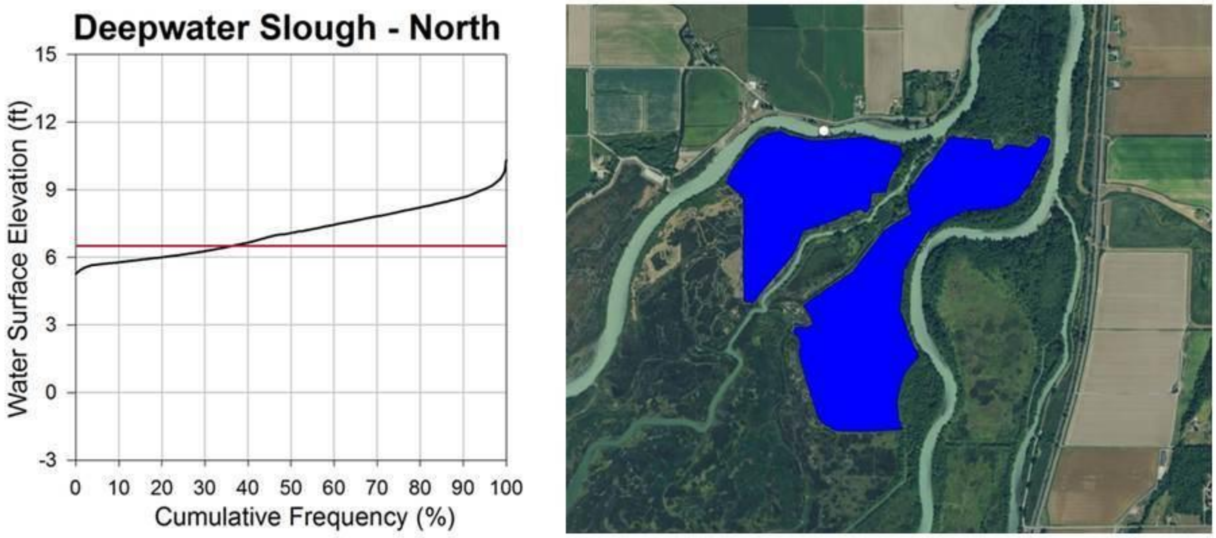


Figure I.25. Cumulative frequency plot and corresponding map for Deepwater Slough (north) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

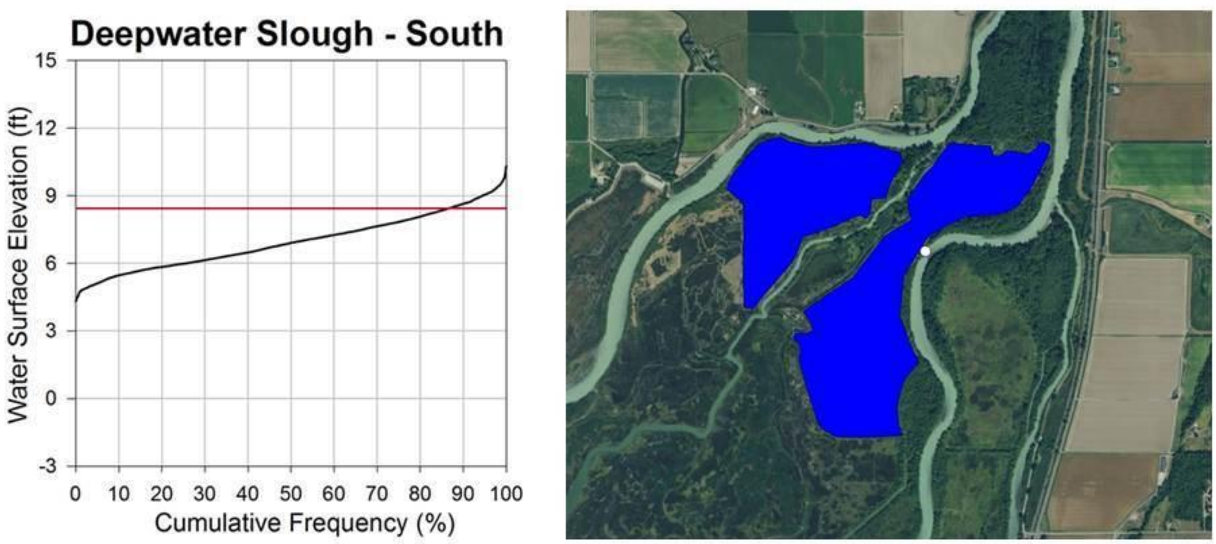


Figure I.26. Cumulative frequency plot and corresponding map for Deepwater Slough (south) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

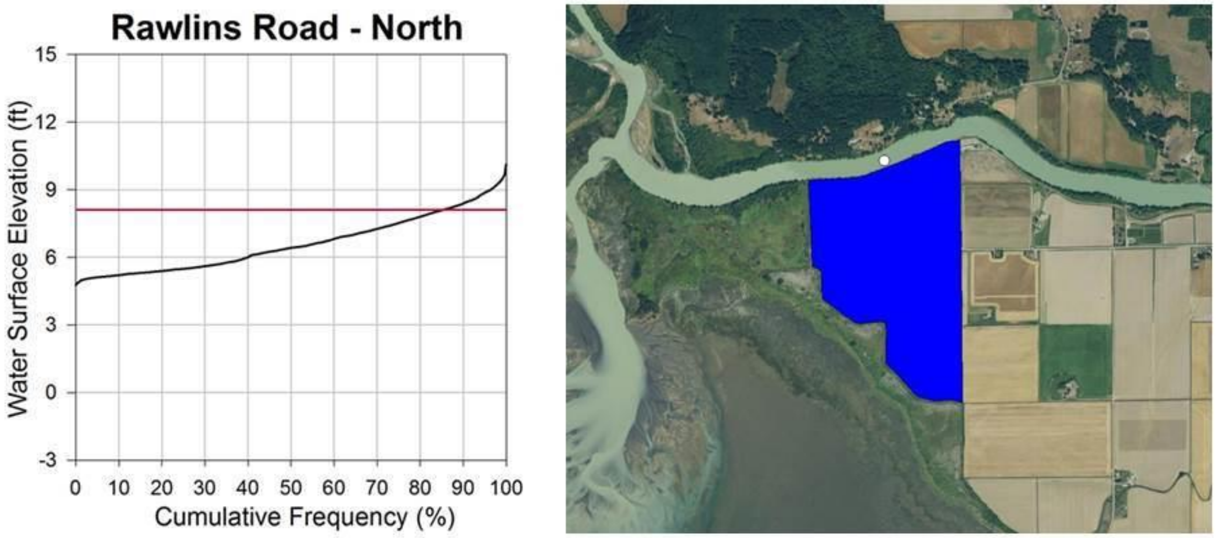


Figure I.27. Cumulative frequency plot and corresponding map for Rawlins Road (north) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

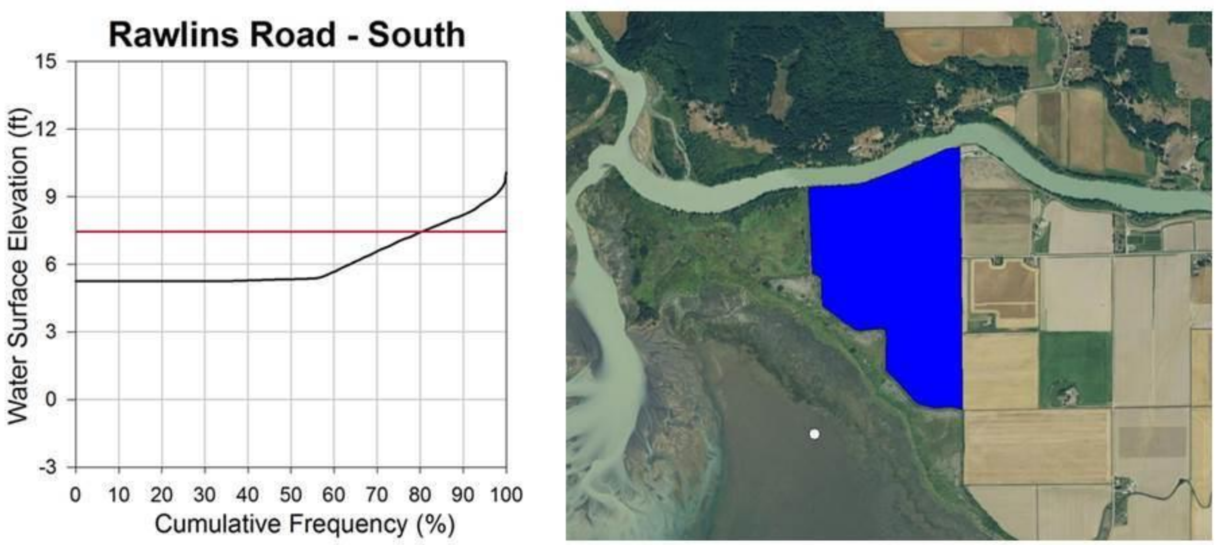


Figure I.28. Cumulative frequency plot and corresponding map for Rawlins Road (south) during the Selected Projects simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

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.

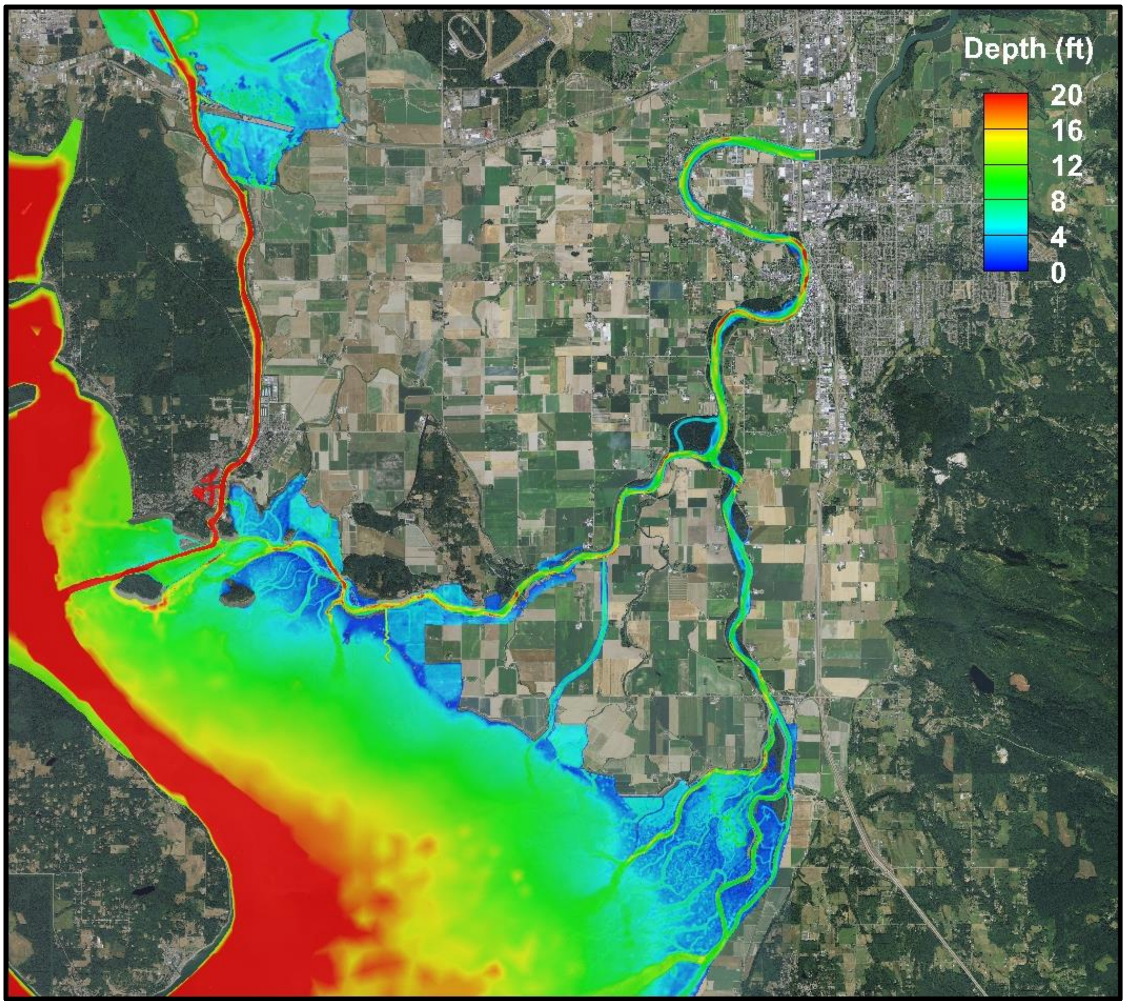


Figure I.29. Contour map of depths for the full domain during the Selected Projects simulation with May flow and high spring tide.

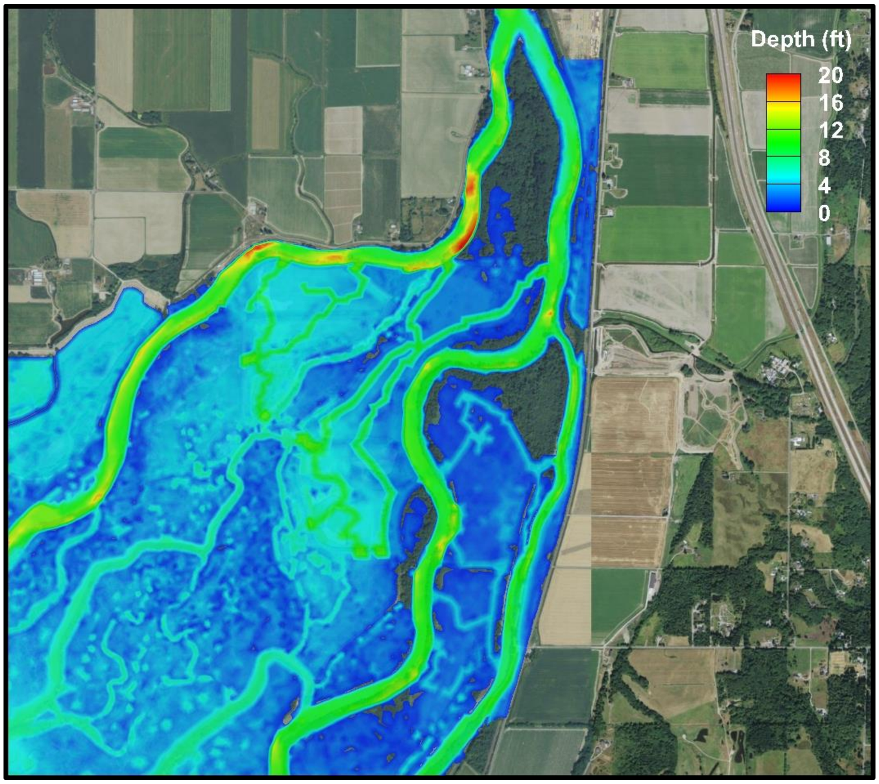


Figure I.30. Contour map of depths for SF Levee Setbacks 2, 3, and 4 during the Selected Projects simulation.

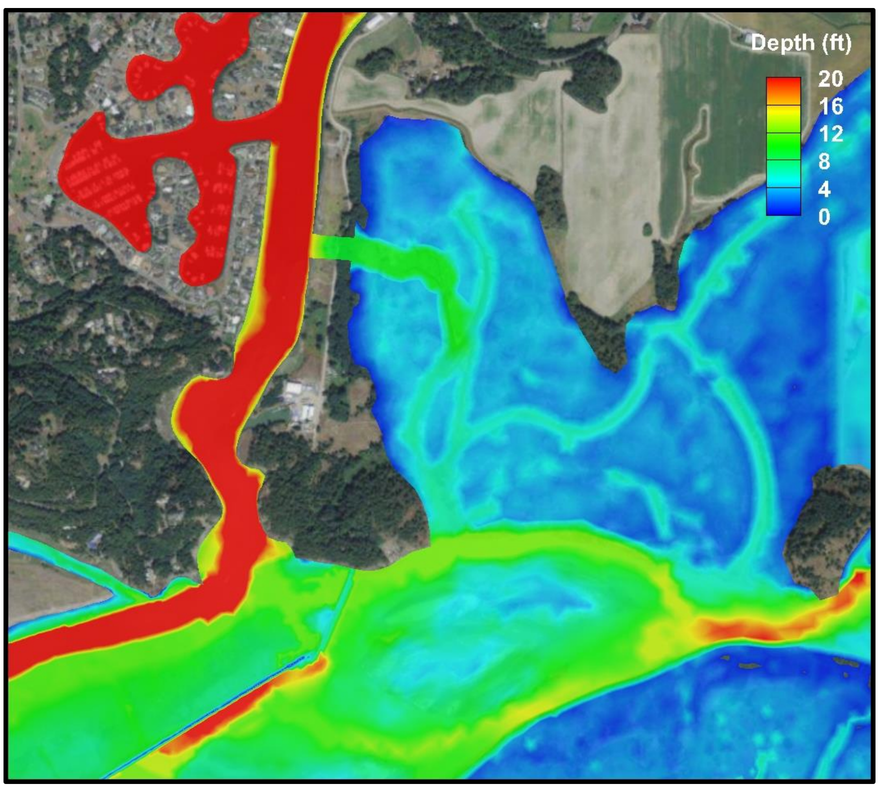


Figure I.31. Contour map of depths for McGlinn Causeway during the Selected Projects simulation.

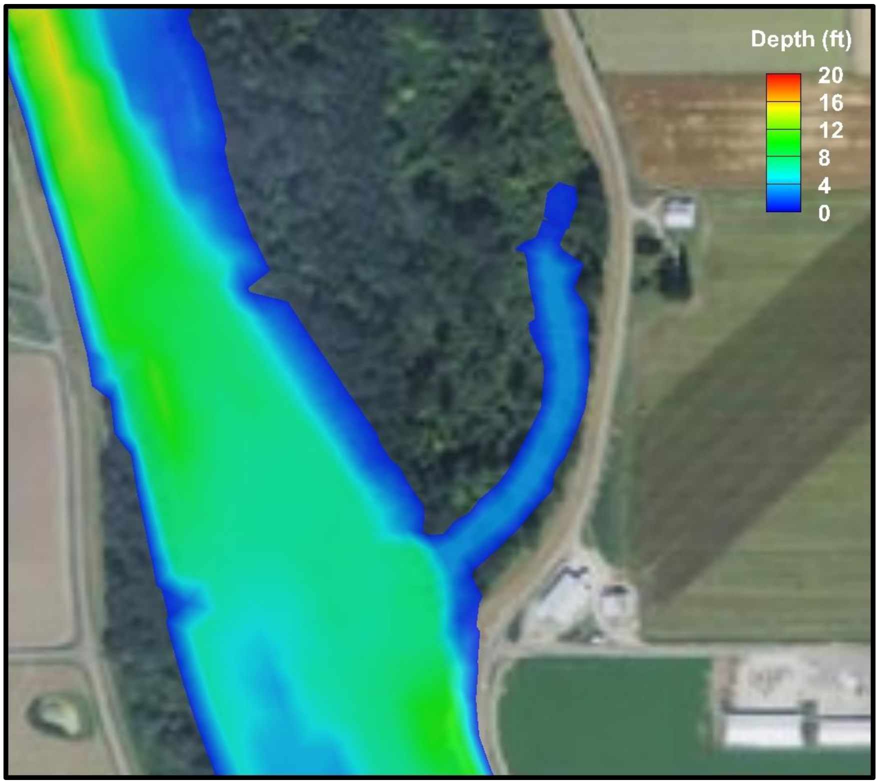


Figure I.32. Contour map of depths for TNC South Fork during the Selected Projects simulation.

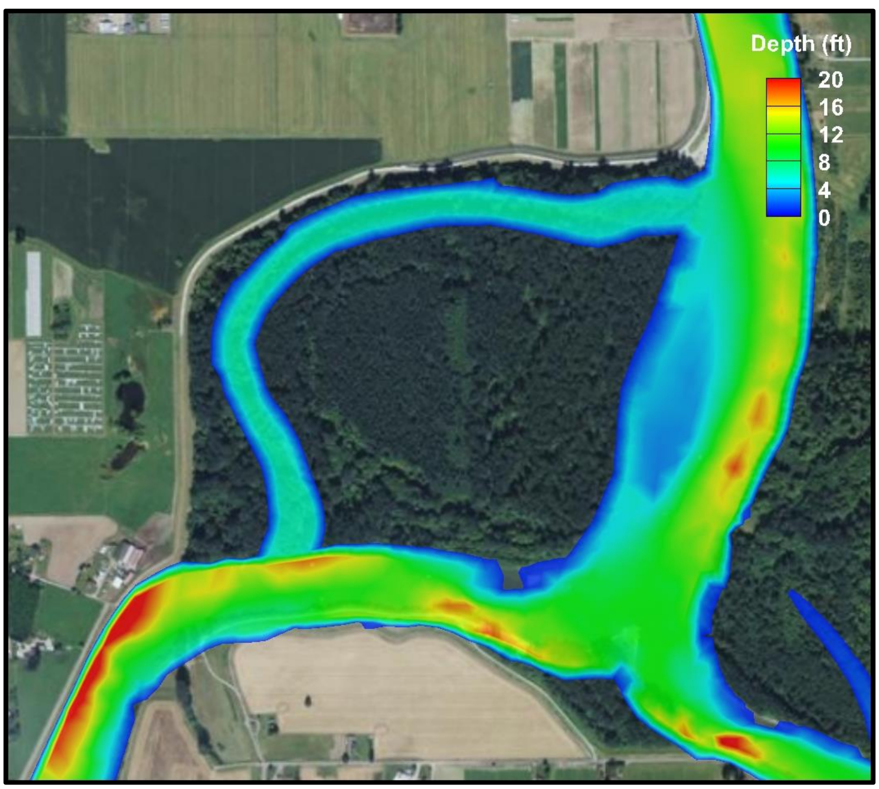


Figure I.33. Contour map of depths for Cottonwood Island during the Selected Projects simulation.

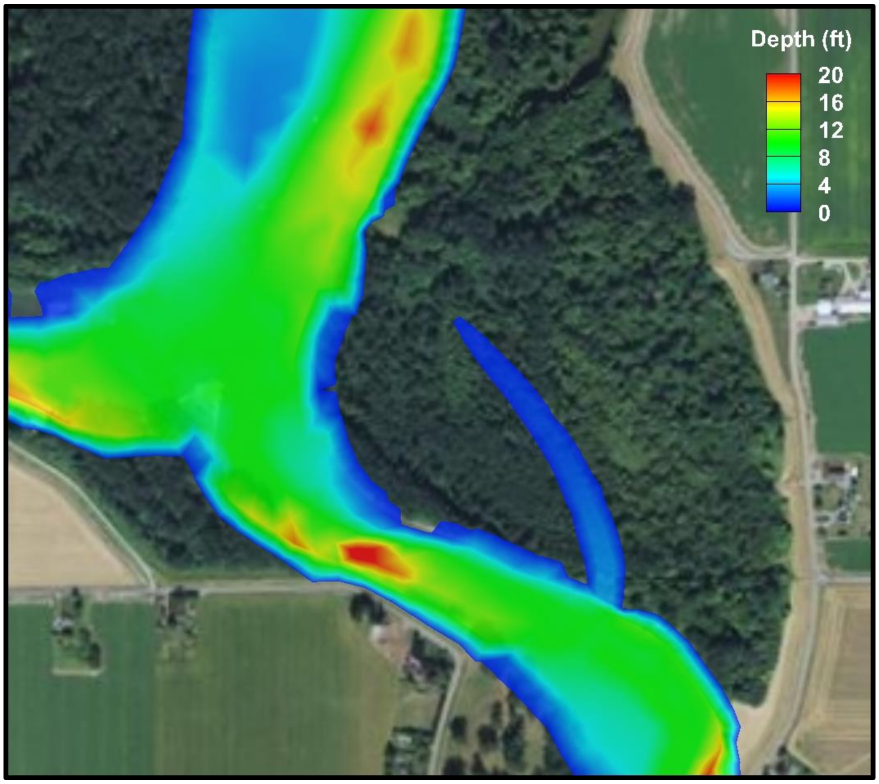


Figure I.34. Contour map of depths for East Cottonwood during the Selected Projects simulation.

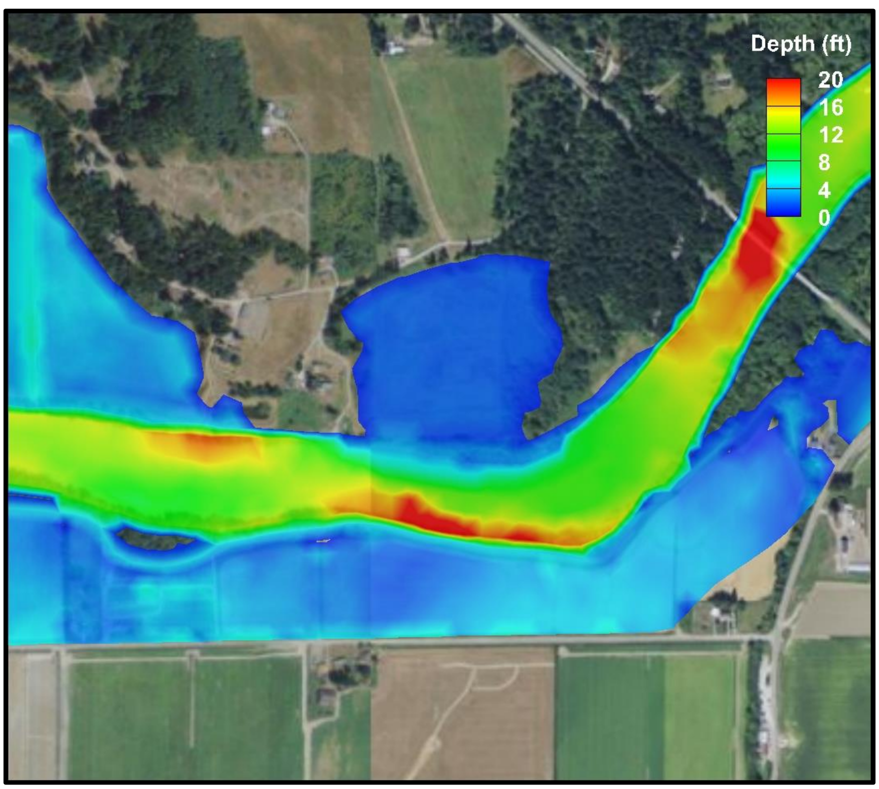


Figure I.35 Contour map of depths for Pleasant Ridge South during the Selected Projects simulation.

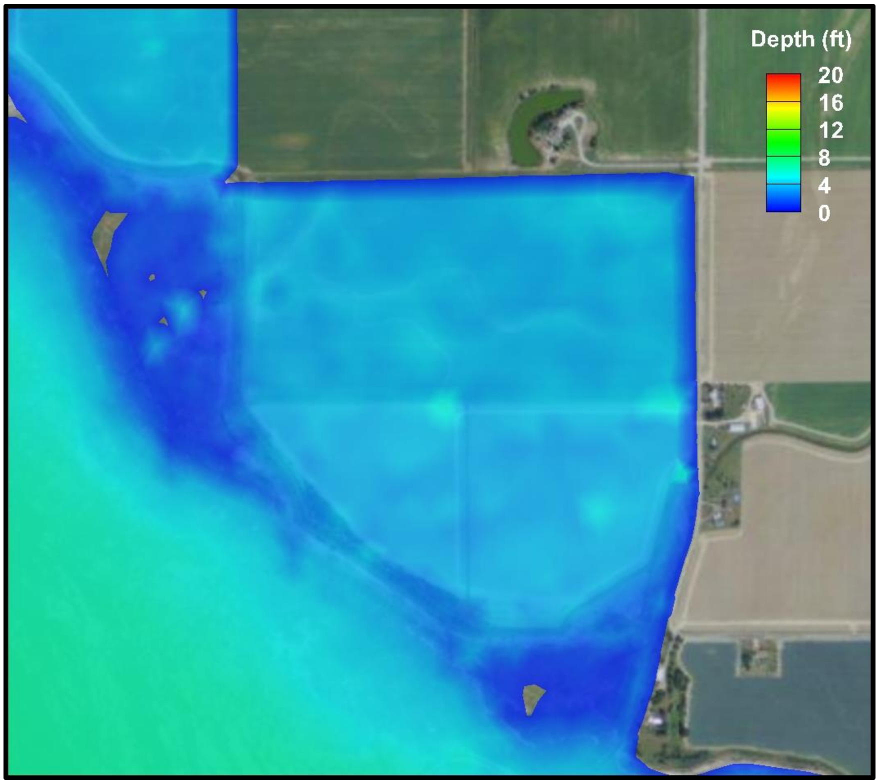


Figure I.36. Contour map of depths for Hall Slough during the Selected Projects simulation.

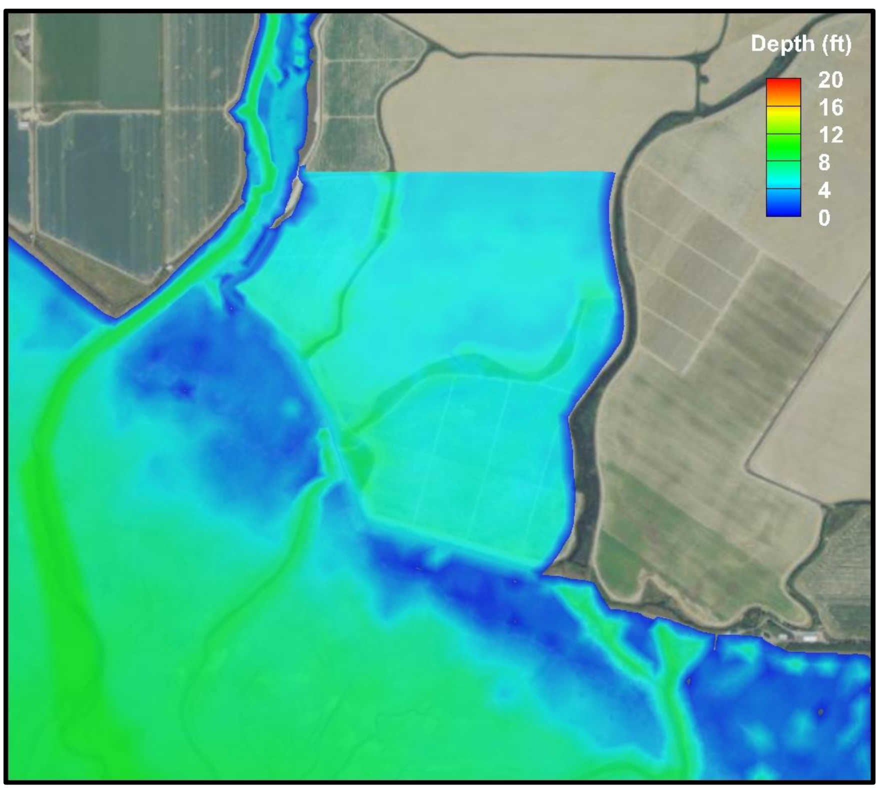


Figure I.37. Contour map of depths for Fir Island Farm during the Selected Projects simulation.

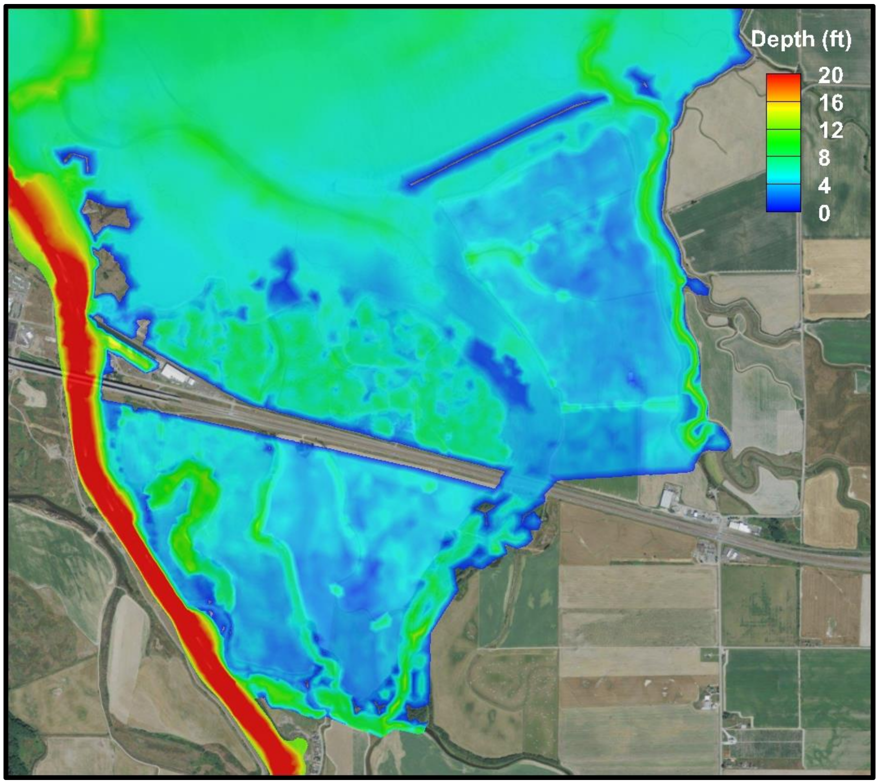


Figure I.38. Contour map of depths for Telegraph Slough Full during the Selected Projects simulation.

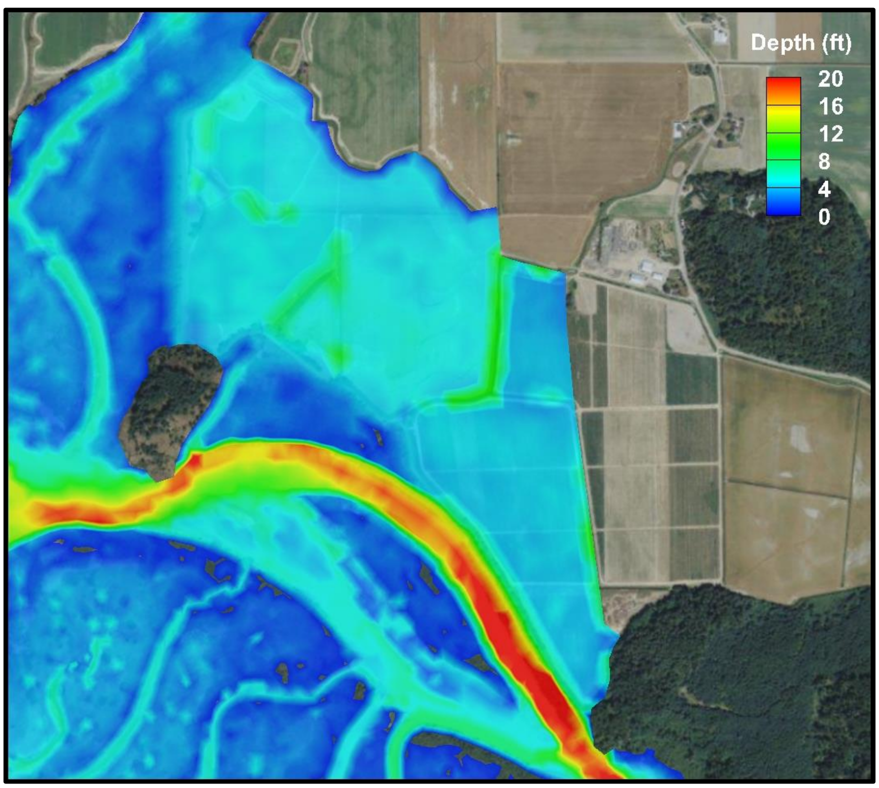


Figure I.39. Contour map of depths for Sullivan Hacienda during the Selected Projects simulation.

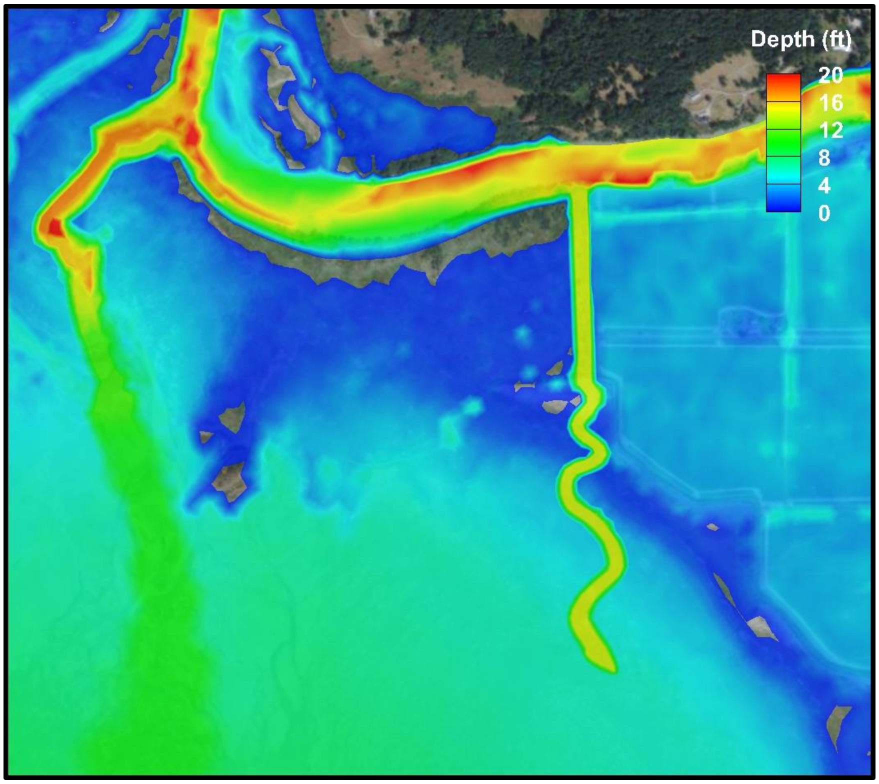


Figure I.40. Contour map of depths for Rawlins Road Distributary during the Selected Projects simulation.

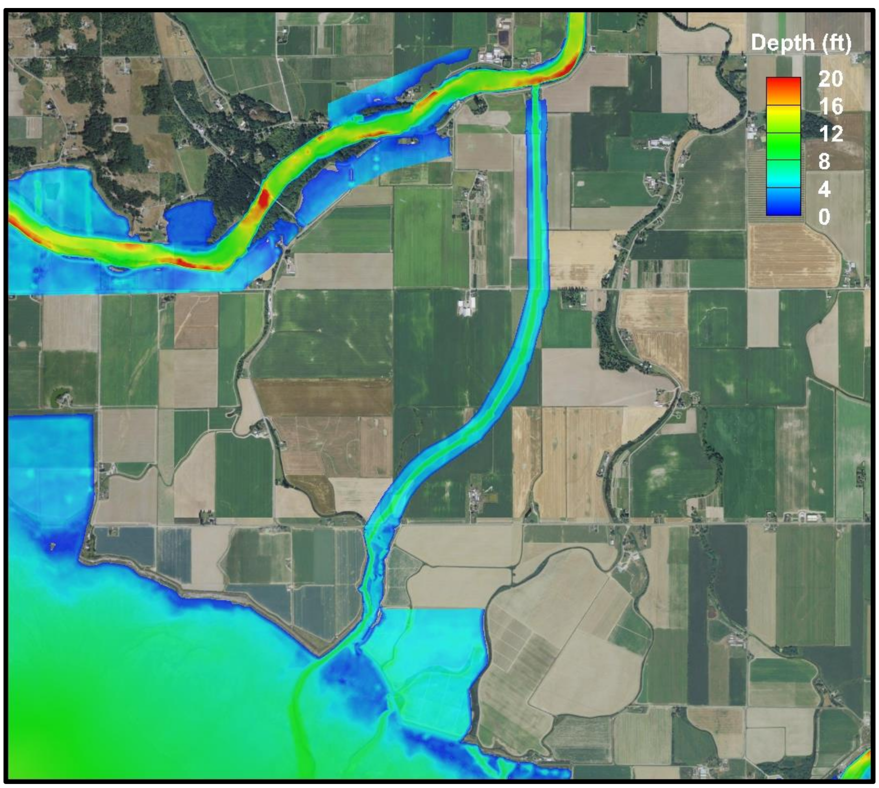


Figure I.41. Contour map of depths for Cross Island Connector during the Selected Projects simulation.

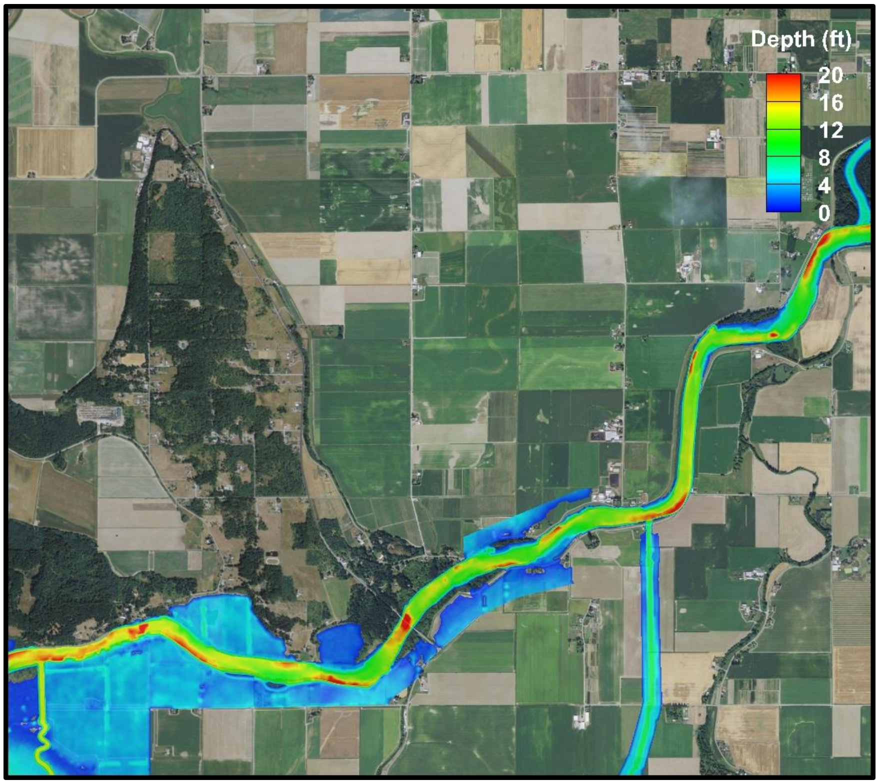


Figure I.42. Contour map of depths for NF Levee Setback C during the Selected Projects simulation.

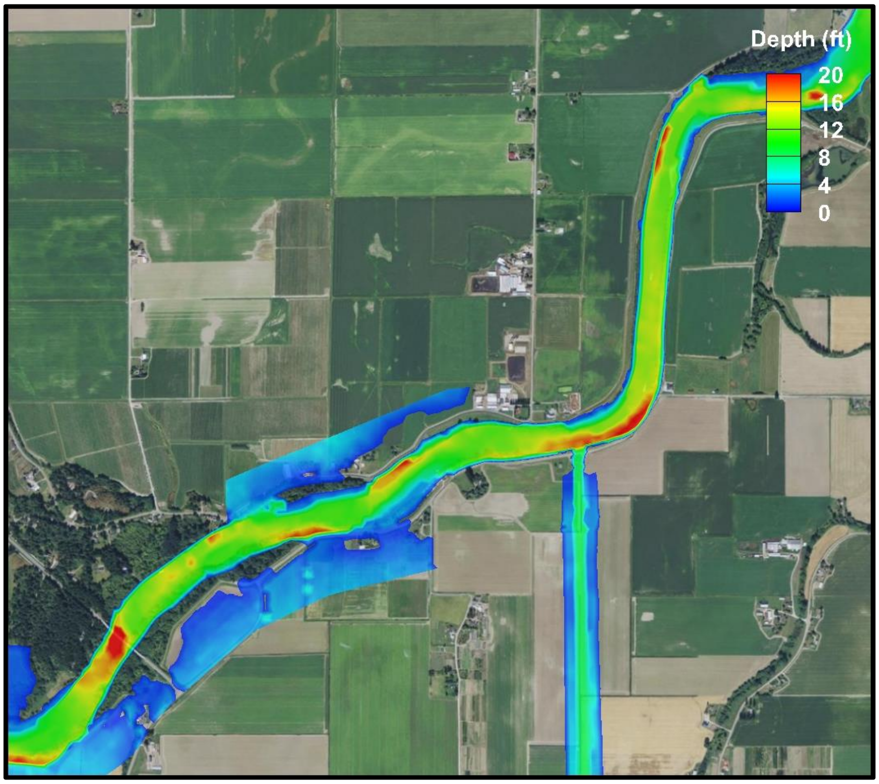


Figure I.43. Contour map of depths for NF Right Bank Levee Setback during the Selected Projects simulation.

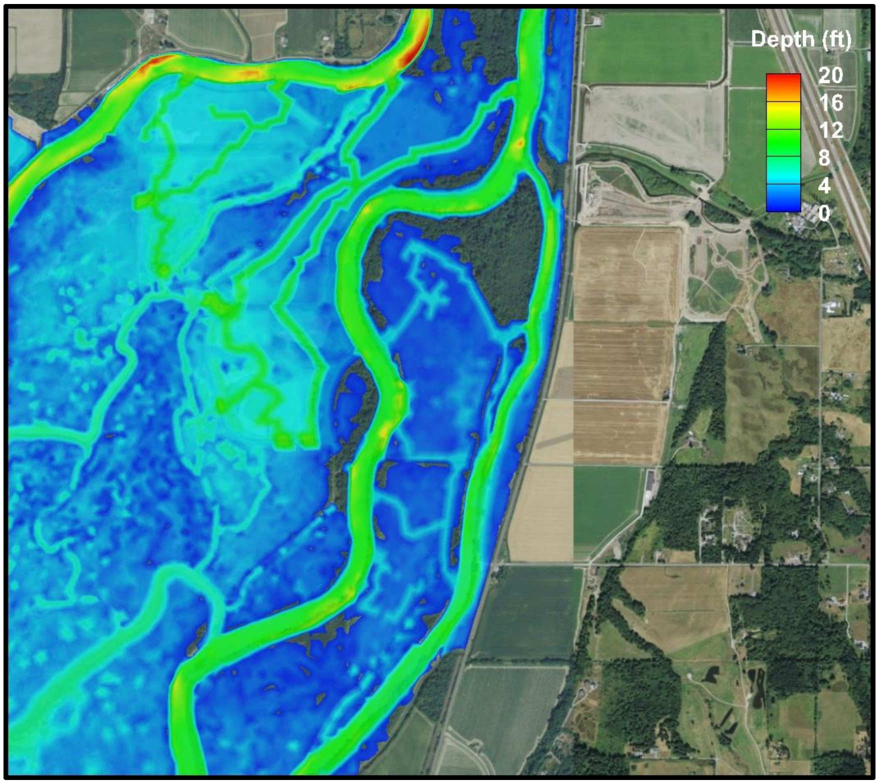


Figure I.44. Contour map of depths for Milltown Island during the Selected Projects simulation.

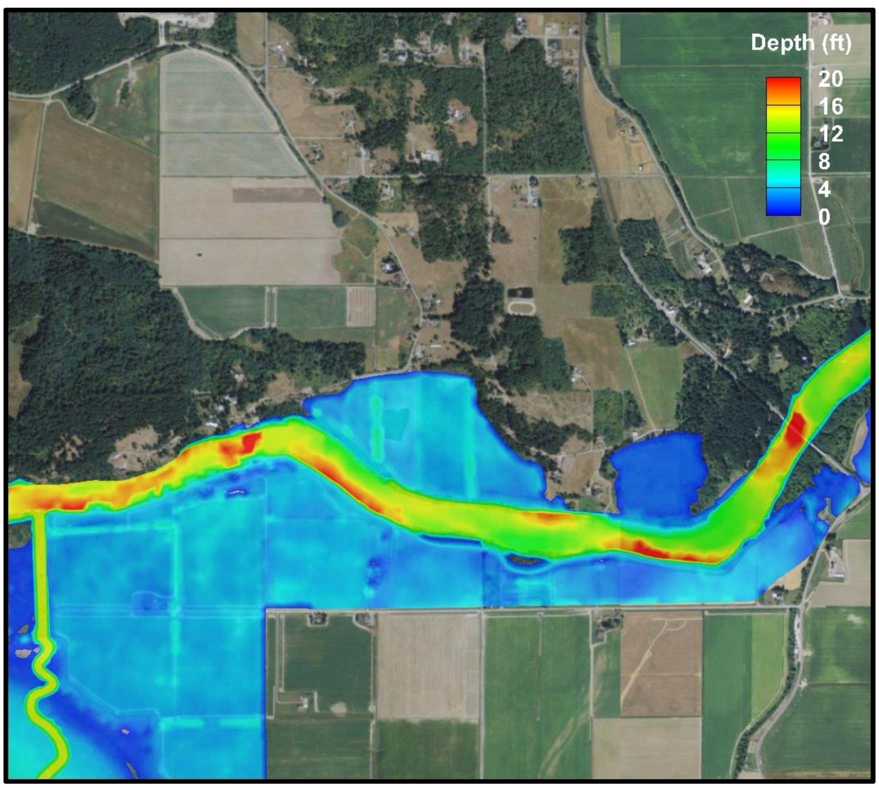


Figure I.45. Contour map of depths for Thein Farm during the Selected Projects simulation.

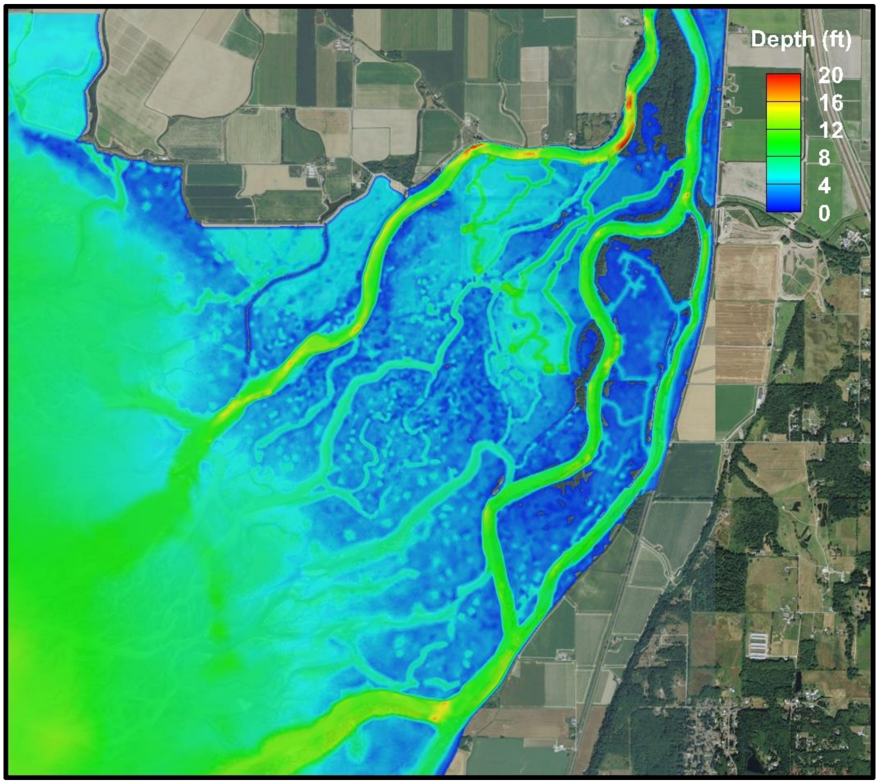


Figure I.46. Contour map of depths for Deepwater Slough Phase 2 during the Selected Projects simulation.

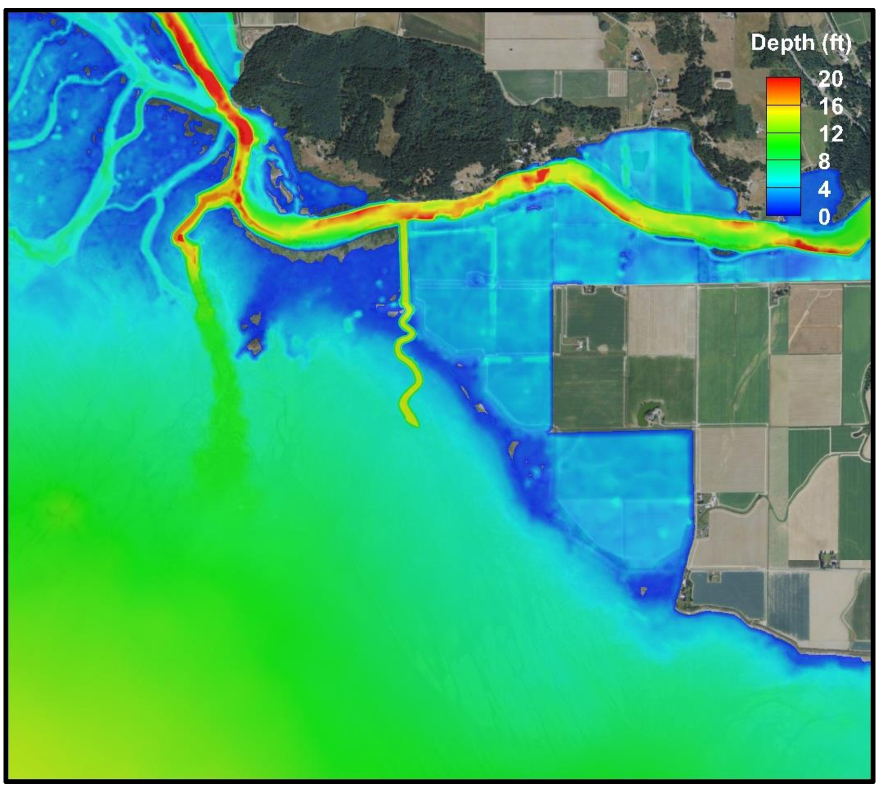


Figure I.47. Contour map of depths for Rawlins Road during the Selected Projects simulation.

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.

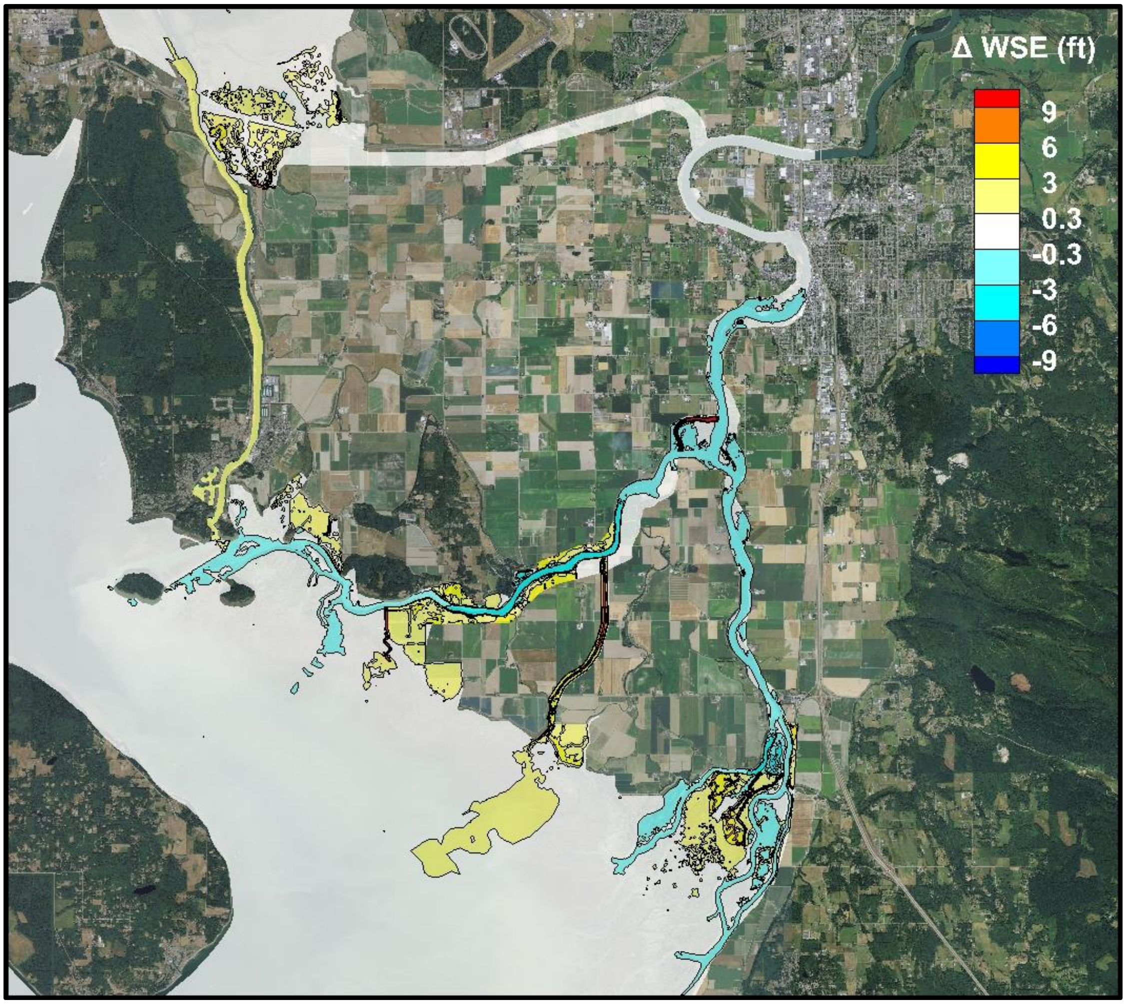


Figure I.48. Contour map of change in WSE from the Baseline to Selected Projects simulation with Q2 flow and low tide.

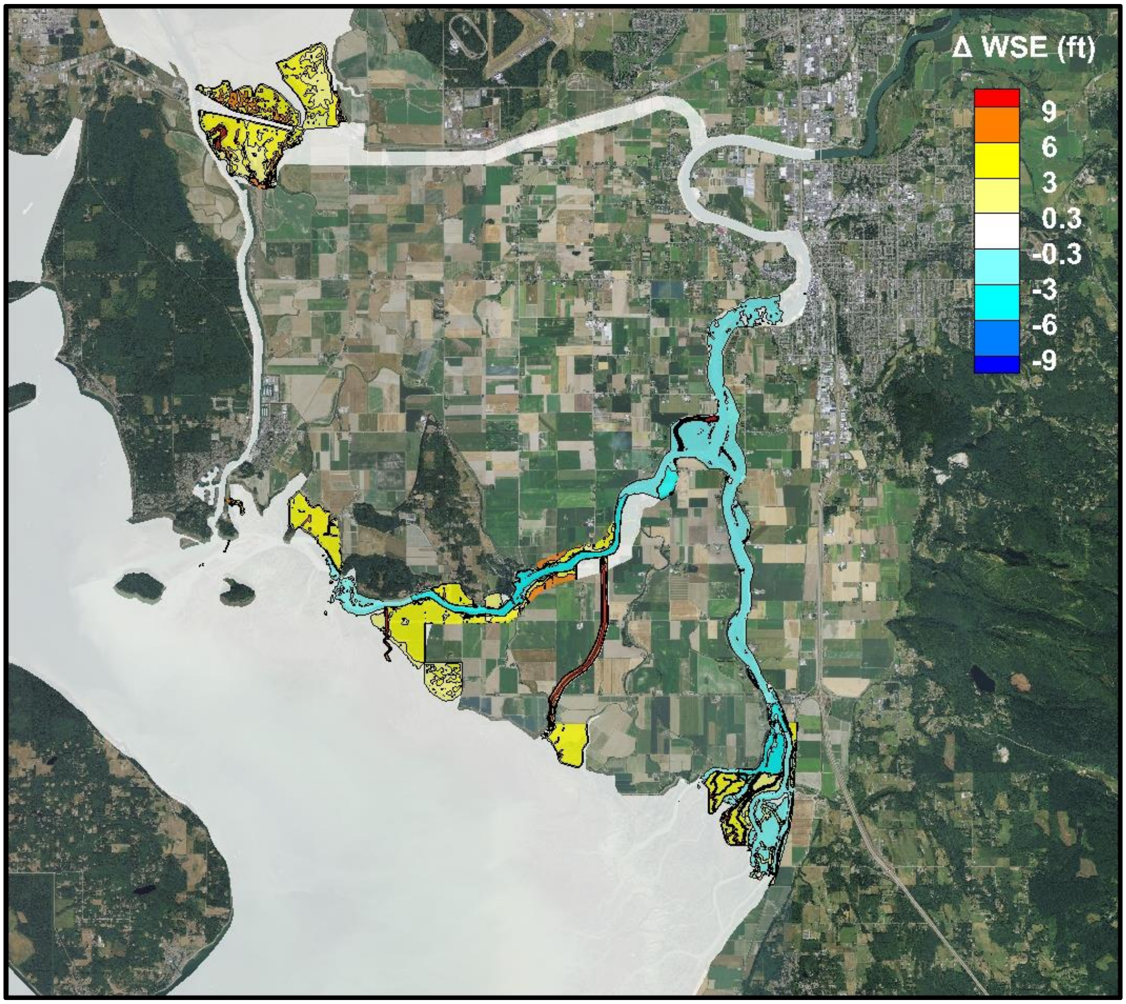


Figure I.49. Contour map of change in WSE from the Baseline to Selected Projects simulation with flood flow and high tide.

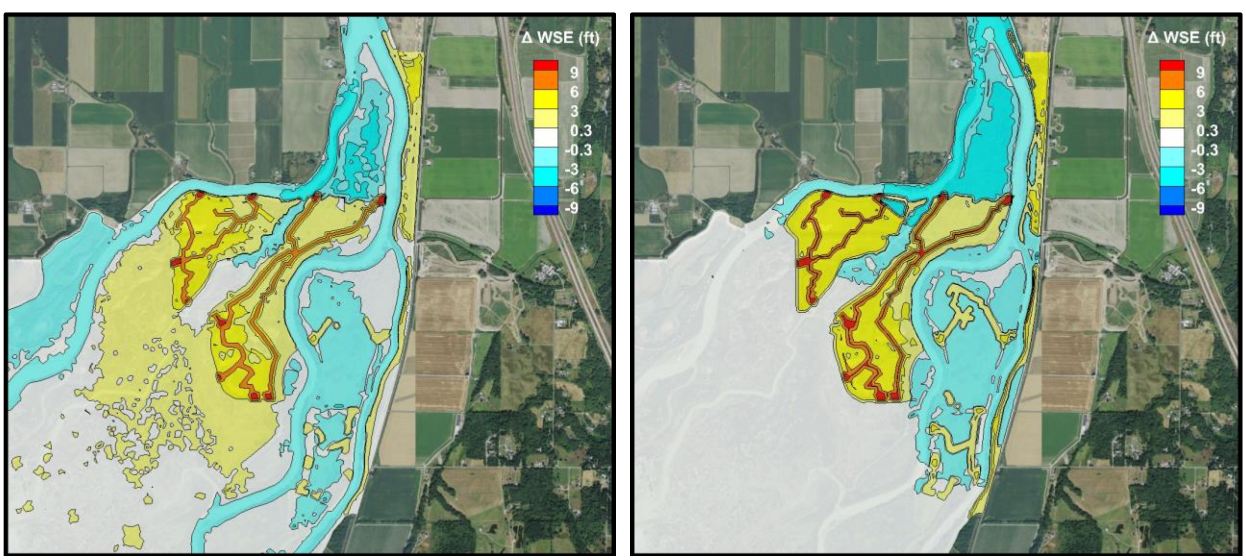


Figure I.50. Contour map of change in WSE from the Baseline simulation for SF Levee Setbacks 2, 3, and 4 with Q2 flow and low tide (left) and flood flow and high tide (right).

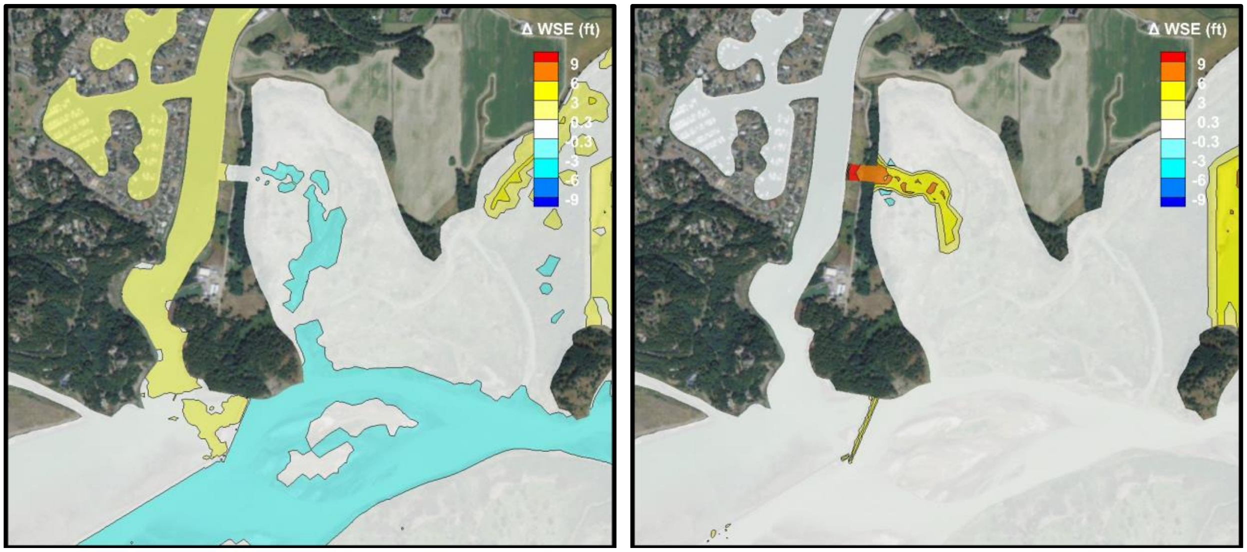


Figure I.51. Contour map of change in WSE from the Baseline simulation for McGlinn Causeway with Q2 flow and low tide (left) and flood flow and high tide (right).

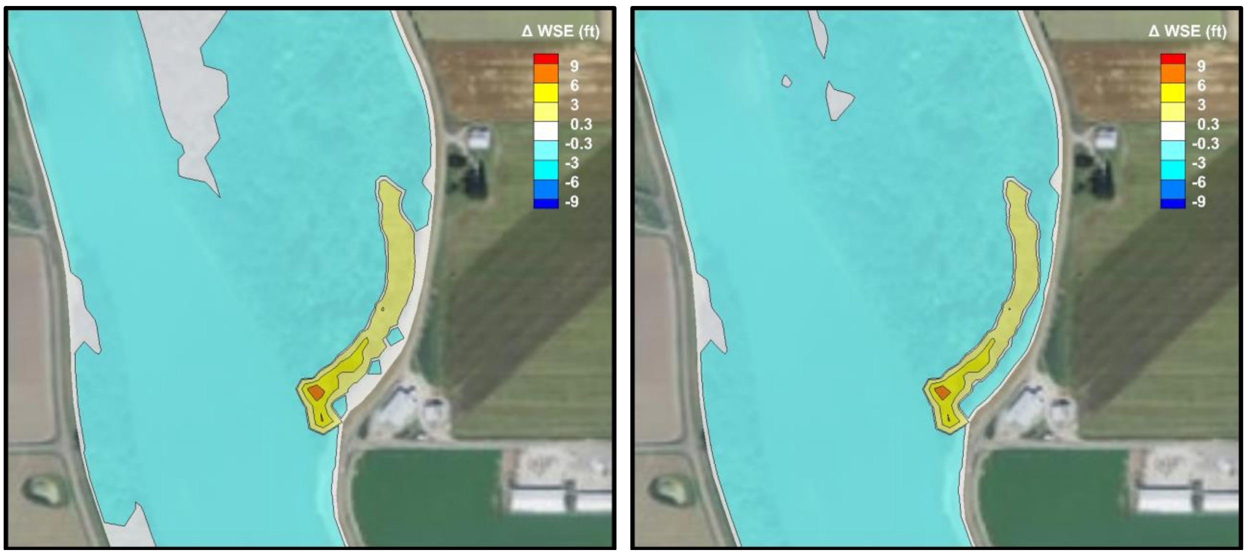


Figure I.52. Contour map of change in WSE from the Baseline simulation for TNC South Fork with Q2 flow and low tide (left) and flood flow and high tide (right).

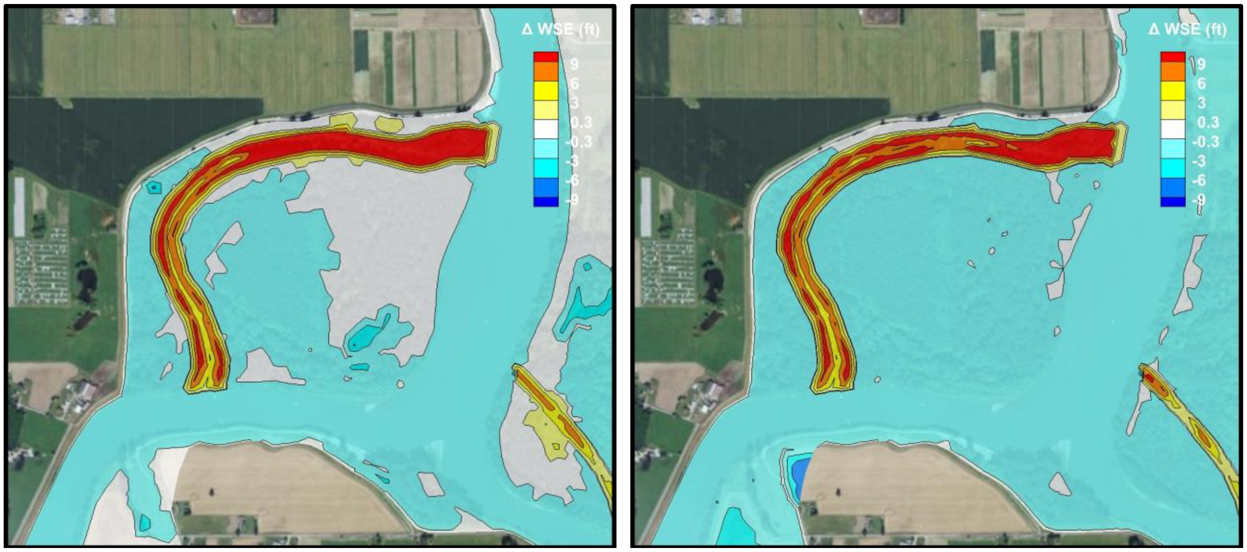


Figure I.53. Contour map of change in WSE from the Baseline simulation for Cottonwood Island with Q2 flow and low tide (left) and flood flow and high tide (right).

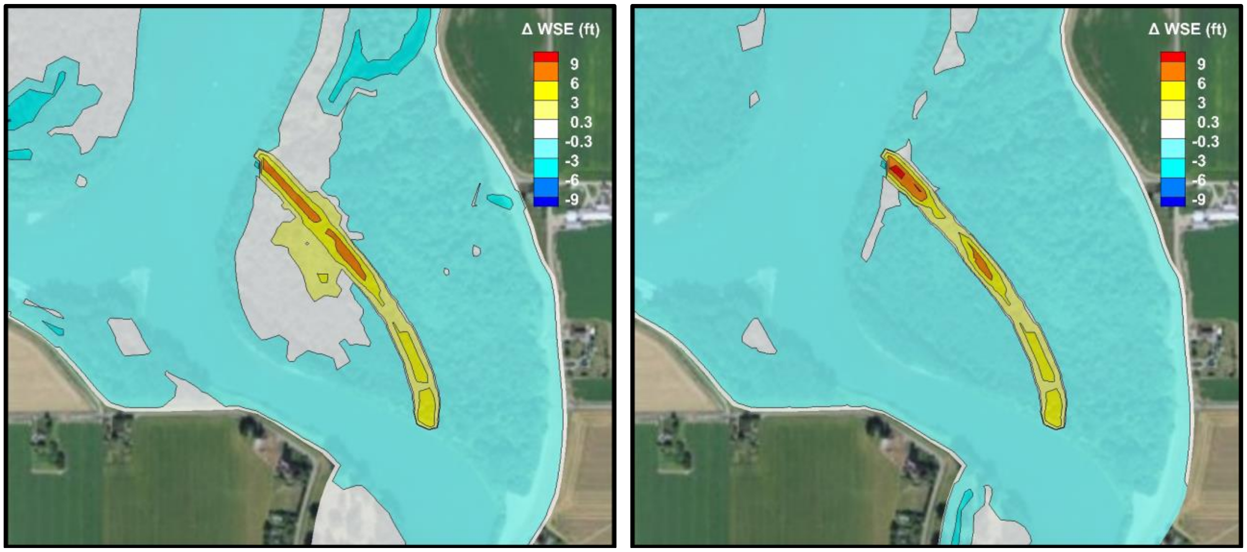


Figure I.54. Contour map of change in WSE from the Baseline simulation for East Cottonwood with Q2 flow and low tide (left) and flood flow and high tide (right).

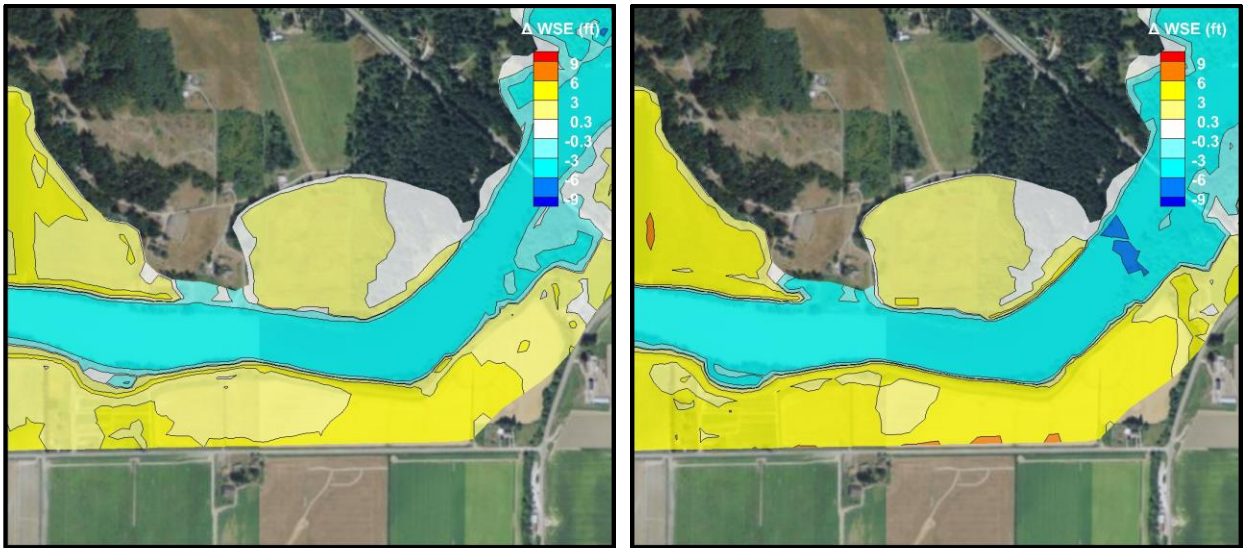


Figure I.55. Contour map of change in WSE from the Baseline simulation for Pleasant Ridge South with Q2 flow and low tide (left) and flood flow and high tide (right).

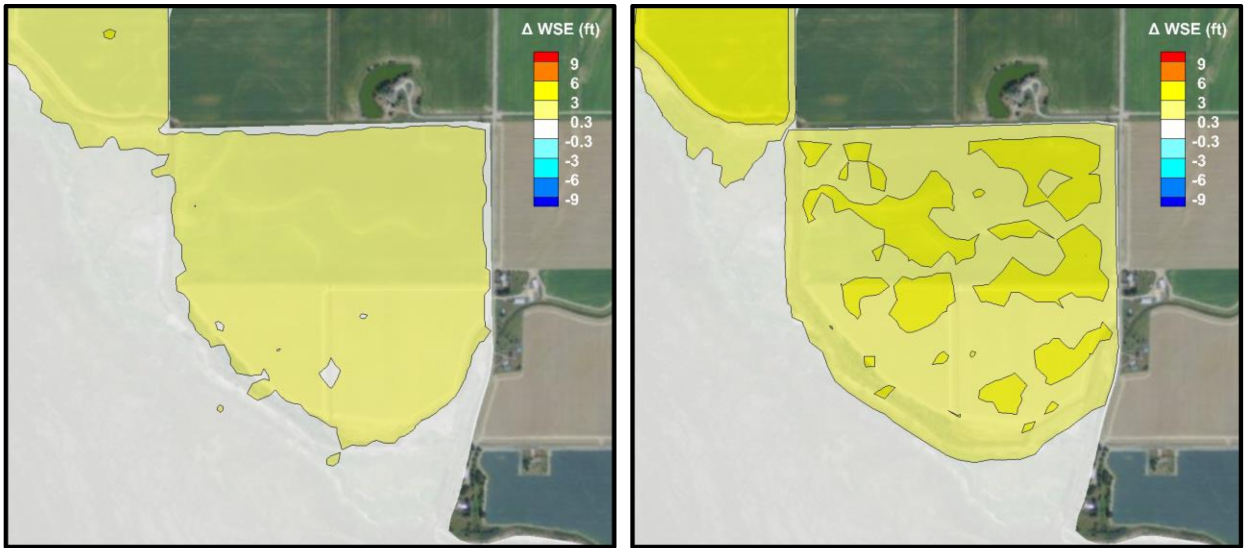


Figure I.56. Contour map of change in WSE from the Baseline simulation for Hall Slough with Q2 flow and low tide (left) and flood flow and high tide (right).

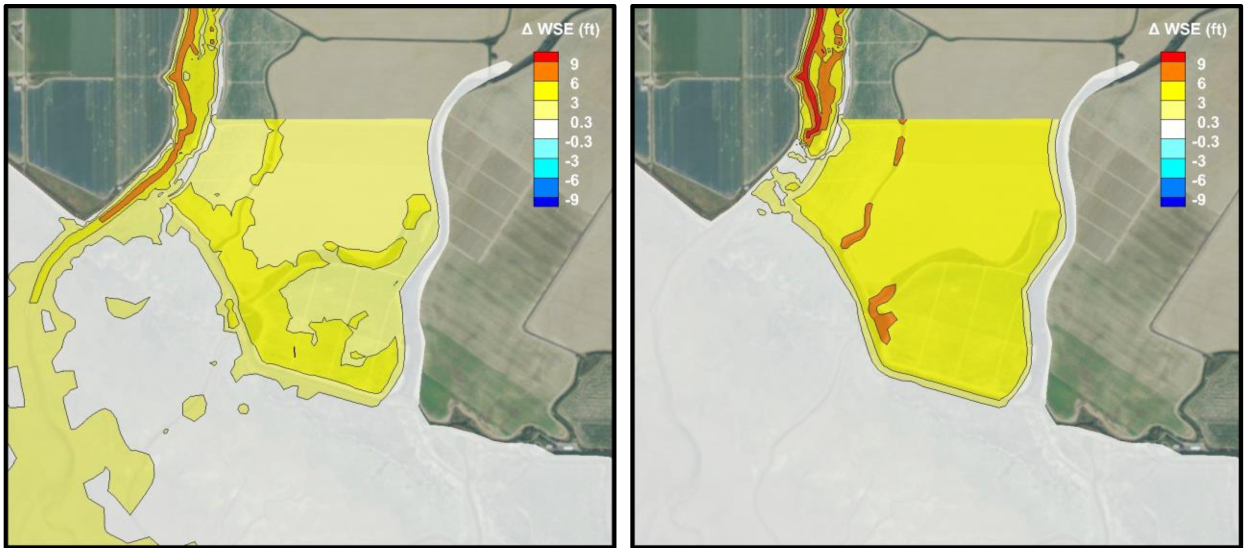


Figure I.57. Contour map of change in WSE from the Baseline simulation for Fir Island Farm with Q2 flow and low tide (left) and flood flow and high tide (right).

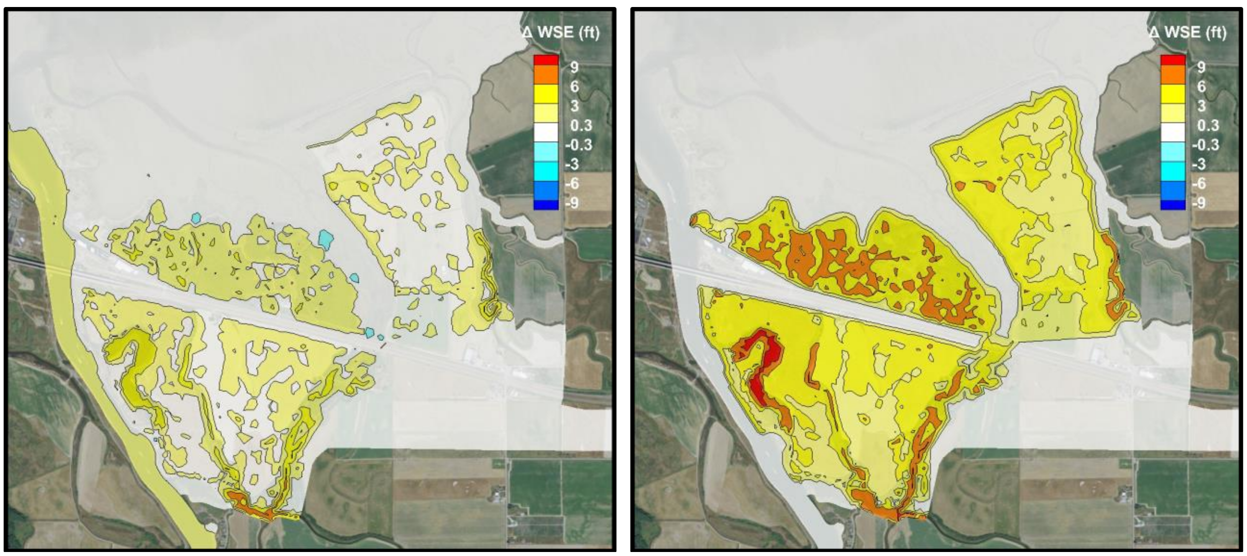


Figure I.58. Contour map of change in WSE from the Baseline simulation for Telegraph Slough Full with Q2 flow and low tide (left) and flood flow and high tide (right).

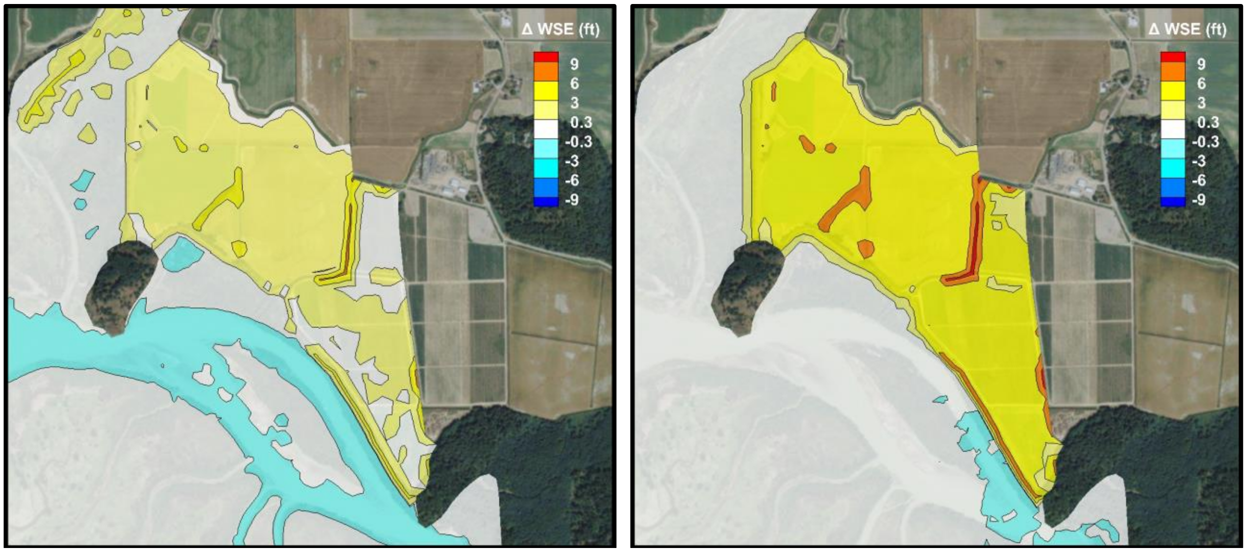


Figure I.59. Contour map of change in WSE from the Baseline simulation for Sullivan Hacienda with Q2 flow and low tide (left) and flood flow and high tide (right).

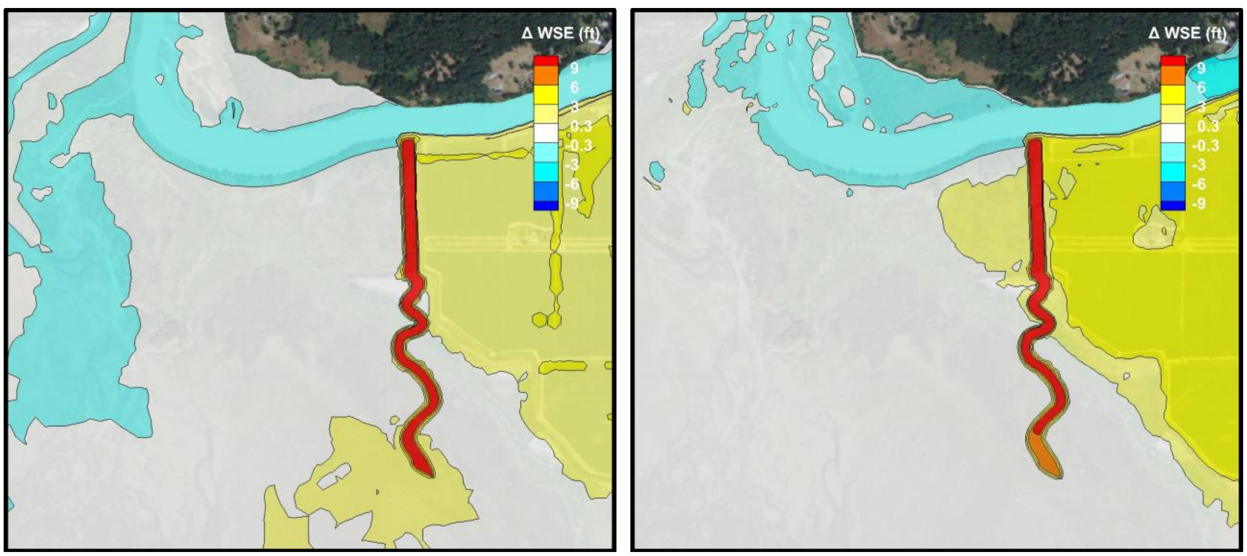


Figure I.60. Contour map of change in WSE from the Baseline simulation for Rawlins Road Distributary with Q2 flow and low tide (left) and flood flow and high tide (right).

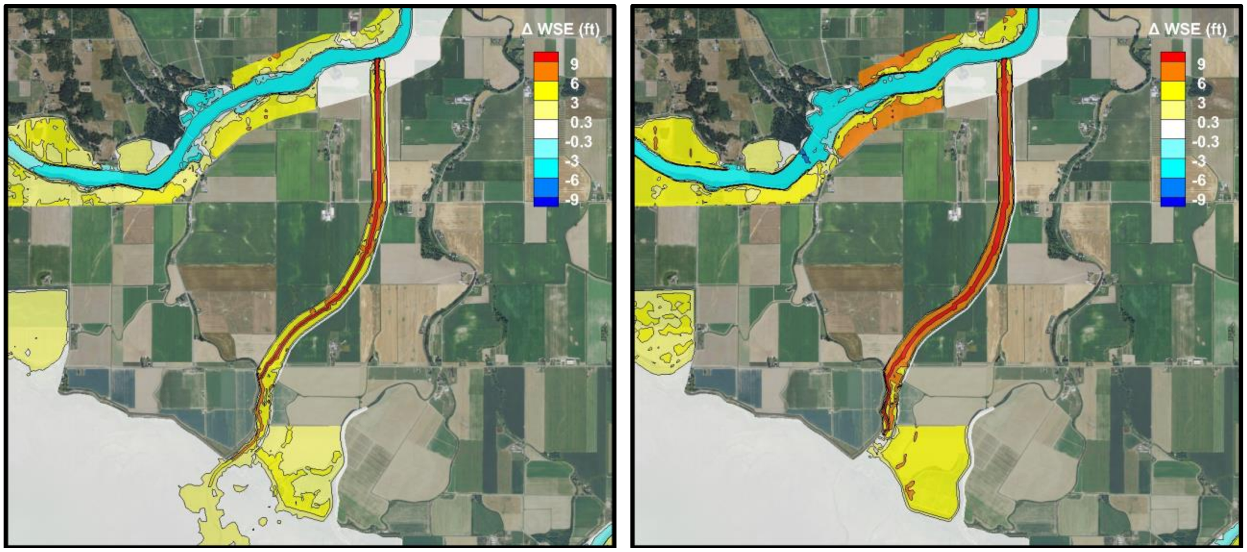


Figure I.61. Contour map of change in WSE from the Baseline simulation for Cross Island Connector with Q2 flow and low tide (left) and flood flow and high tide (right).

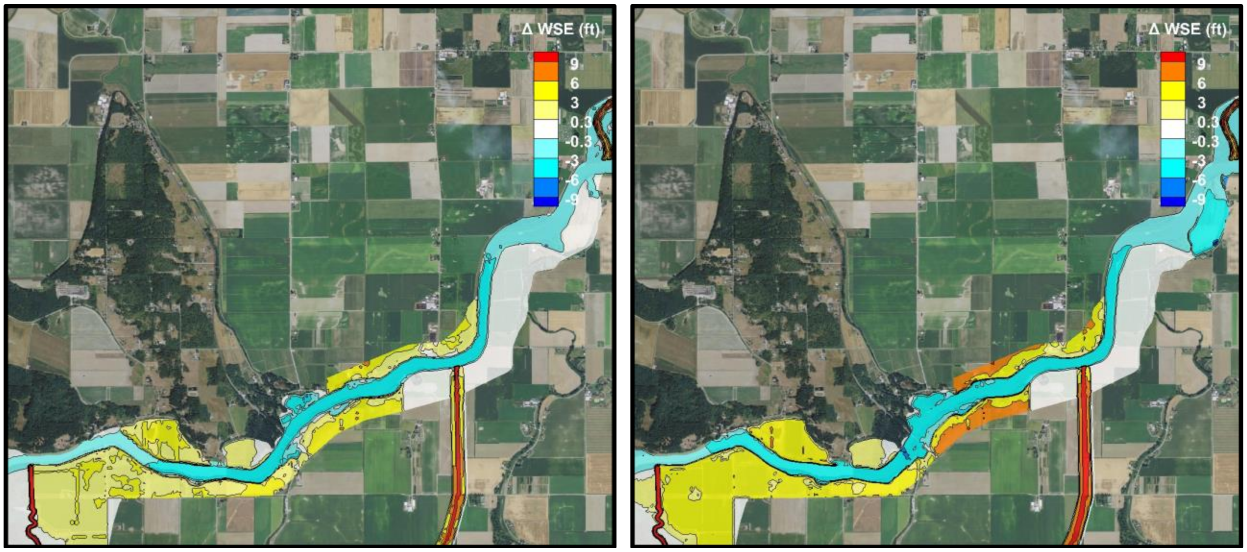


Figure I.62. Contour map of change in WSE from the Baseline simulation for NF Levee Setback C with Q2 flow and low tide (left) and flood flow and high tide (right).

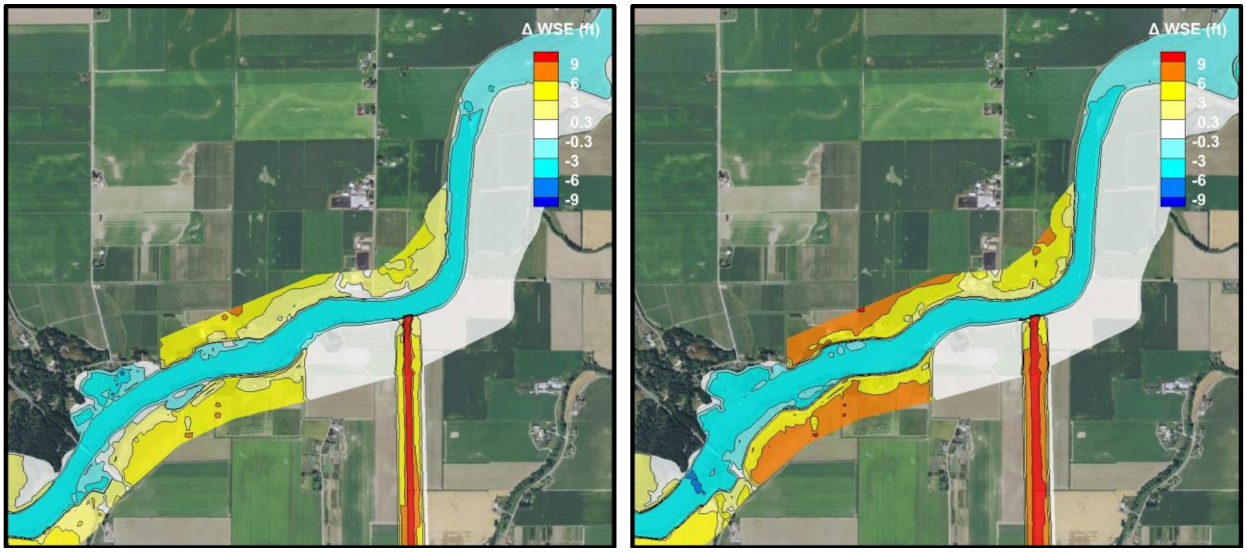


Figure I.63. Contour map of change in WSE from the Baseline simulation for NF Right Bank Levee Setback with Q2 flow and low tide (left) and flood flow and high tide (right).

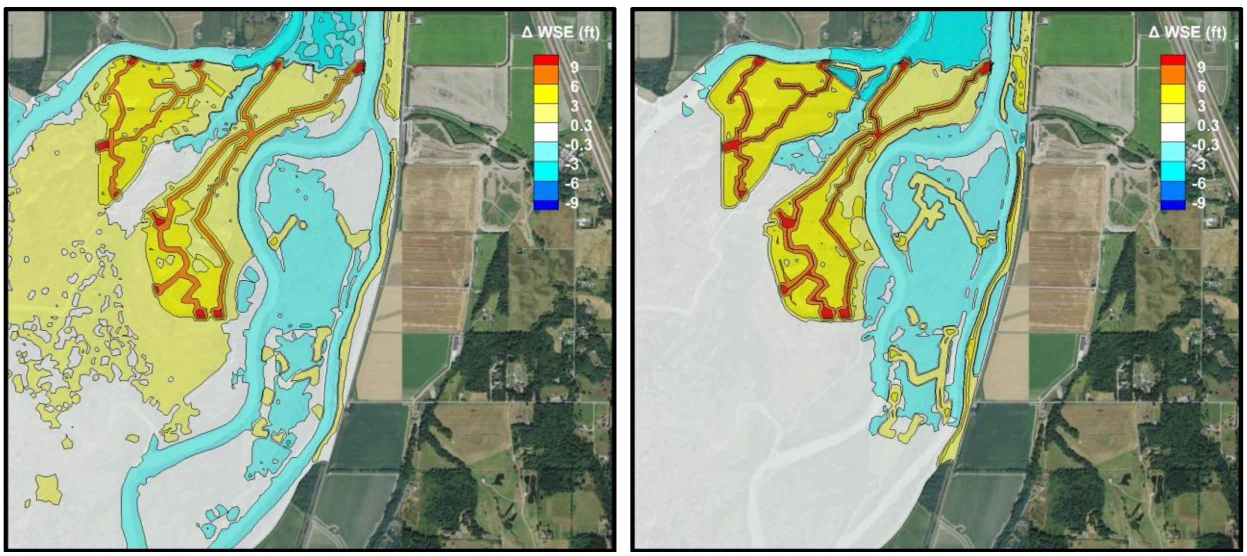


Figure I.64. Contour map of change in WSE from the Baseline simulation for Milltown Island with Q2 flow and low tide (left) and flood flow and high tide (right).

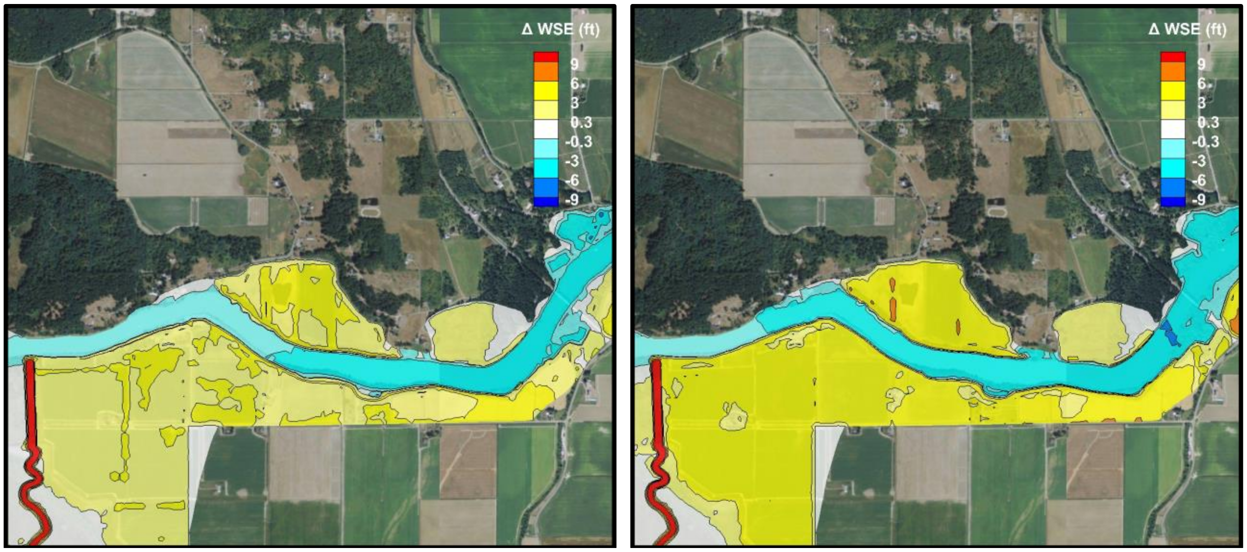


Figure I.65. Contour map of change in WSE from the Baseline simulation for Thein Farm with Q2 flow and low tide (left) and flood flow and high tide (right).

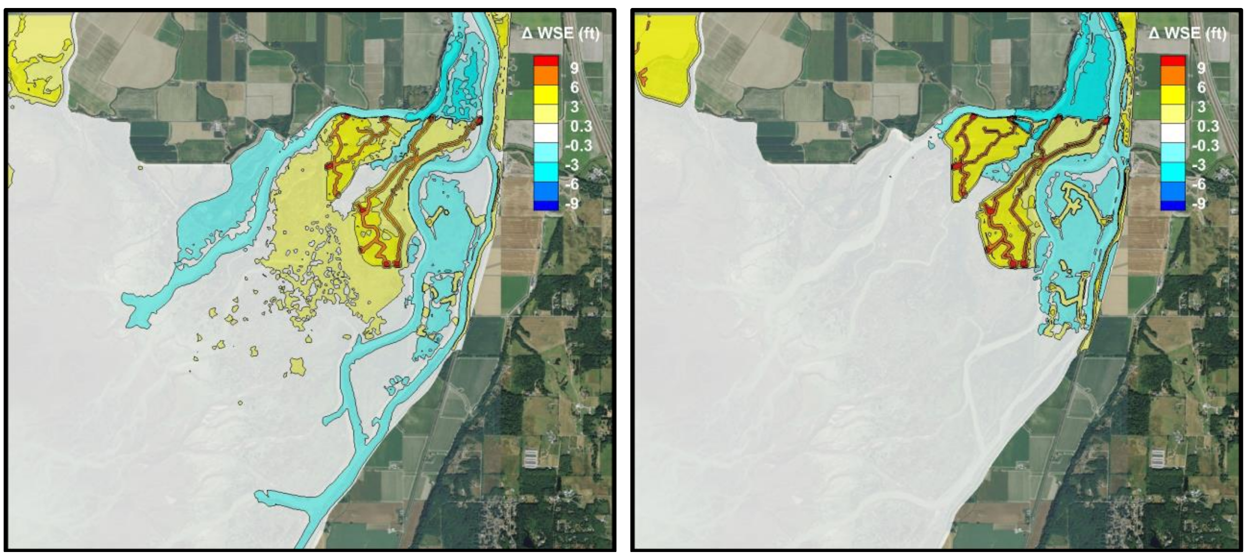


Figure I.66. Contour map of change in WSE from the Baseline simulation for Deepwater Slough Phase 2 with Q2 flow and low tide (left) and flood flow and high tide (right).

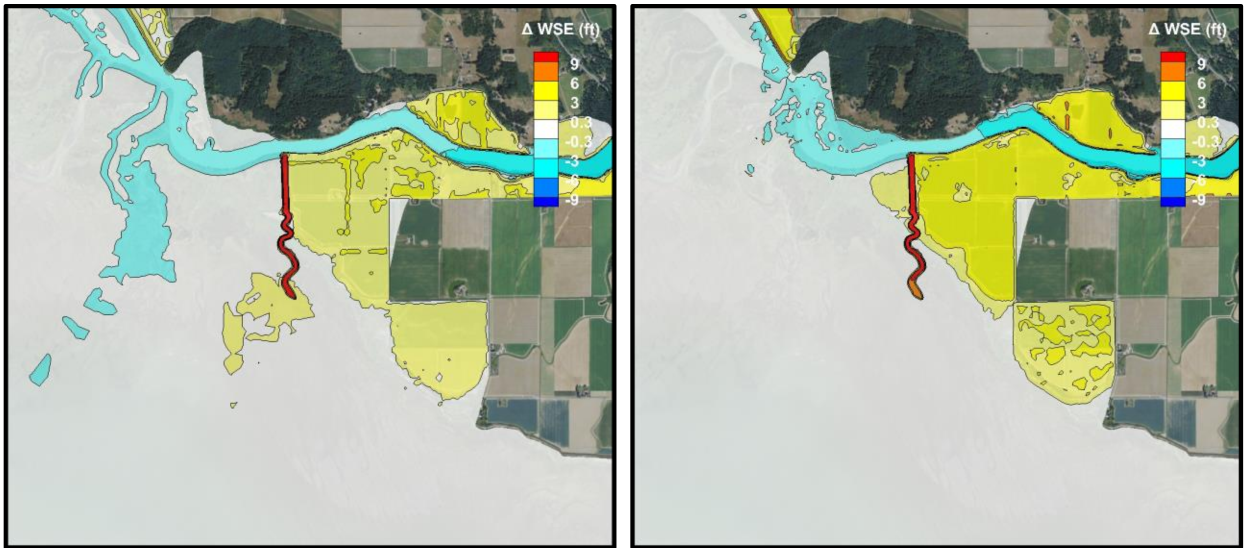


Figure I.67. Contour map of change in WSE from the Baseline simulation for Rawlins Road with Q2 flow and low tide (left) and flood flow and high tide (right).

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.

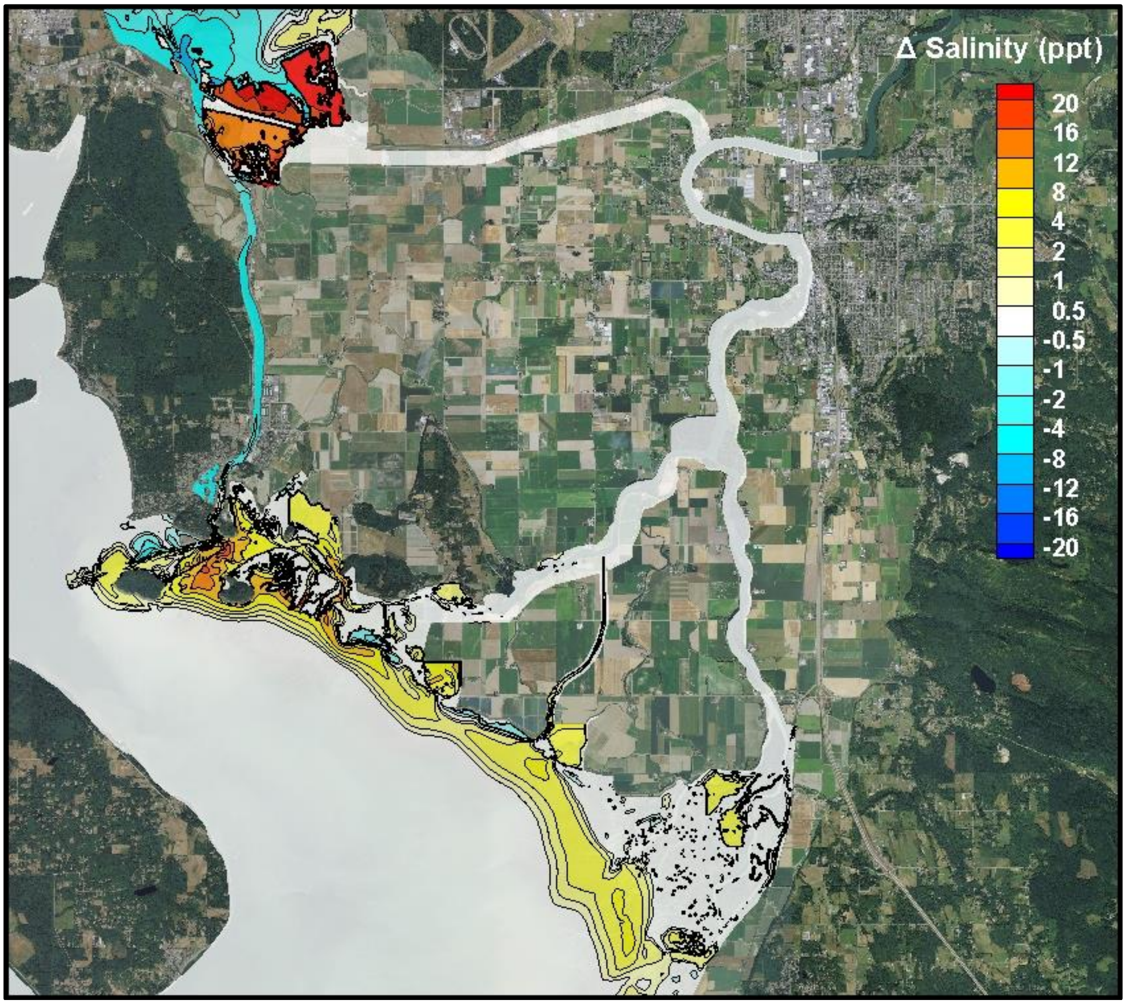


Figure I.68. Contour map of change in salinity from the Baseline to Selected Projects simulation with low flow and high tide.

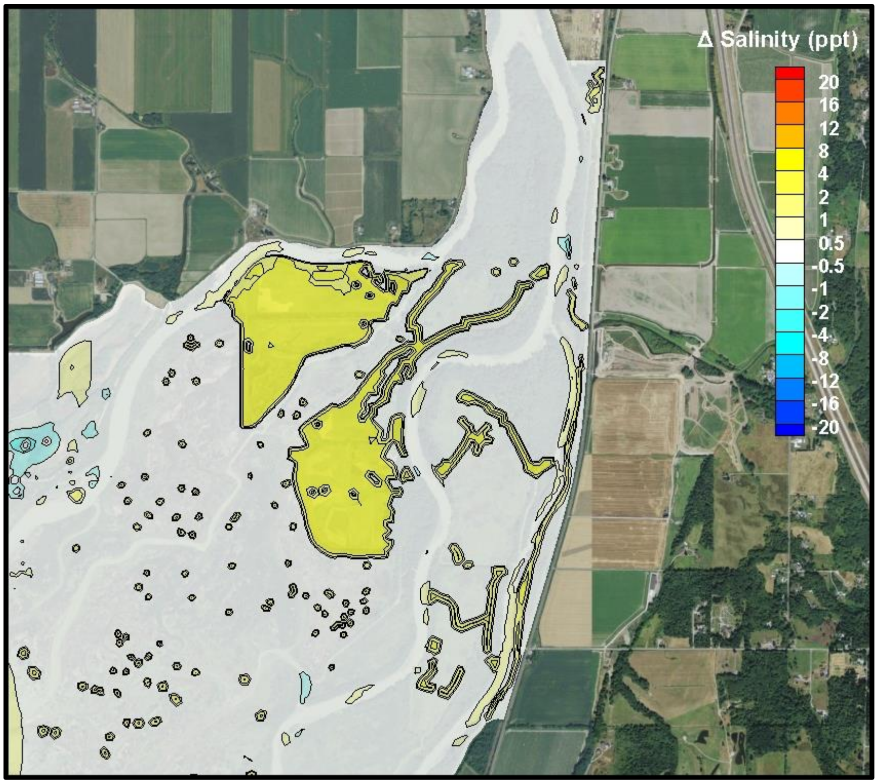


Figure I.69. Contour map of change in salinity from the Baseline simulation for SF Levee Setback 2, 3, 4 with low flow and high tide.

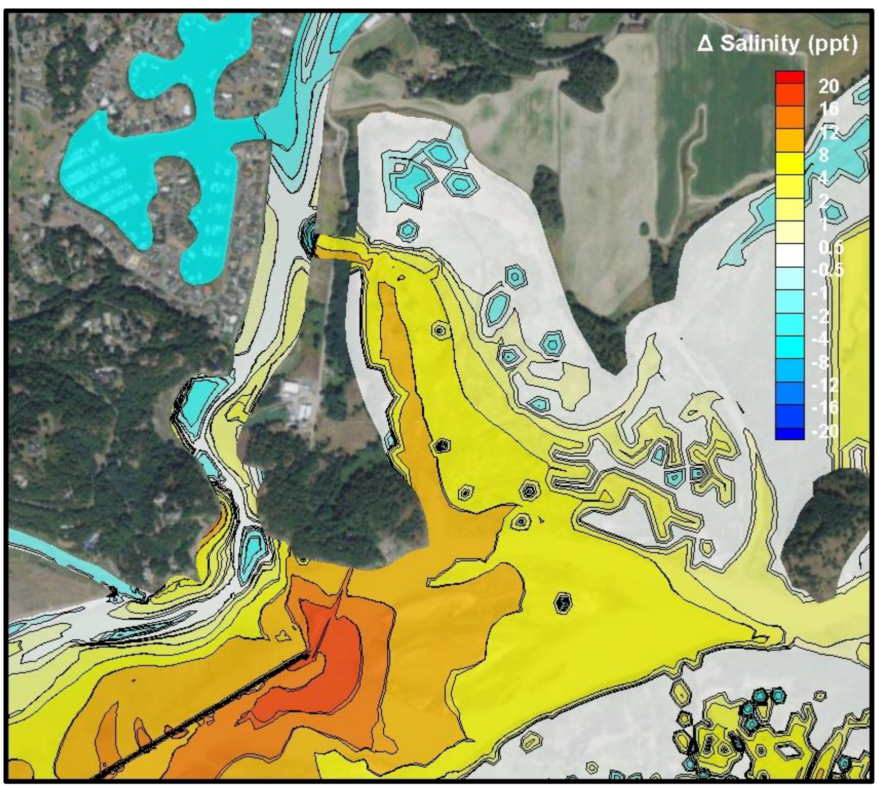


Figure I.70. Contour map of change in salinity from the Baseline simulation for McGlinn Causeway with low flow and high tide.

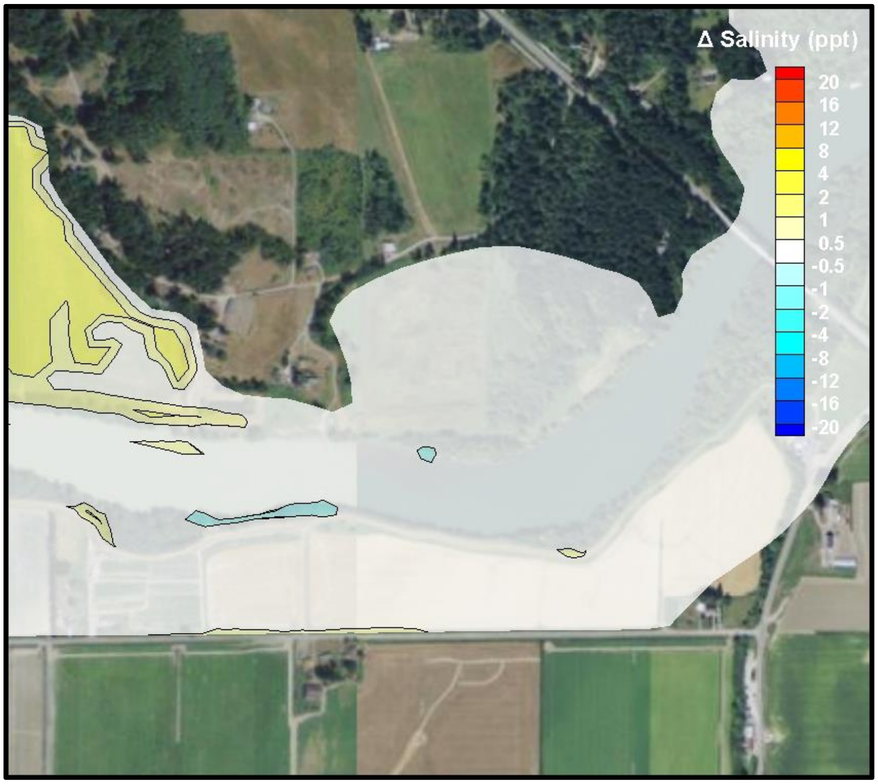


Figure I.71. Contour map of change in salinity from the Baseline simulation for Pleasant Ridge South with low flow and high tide.

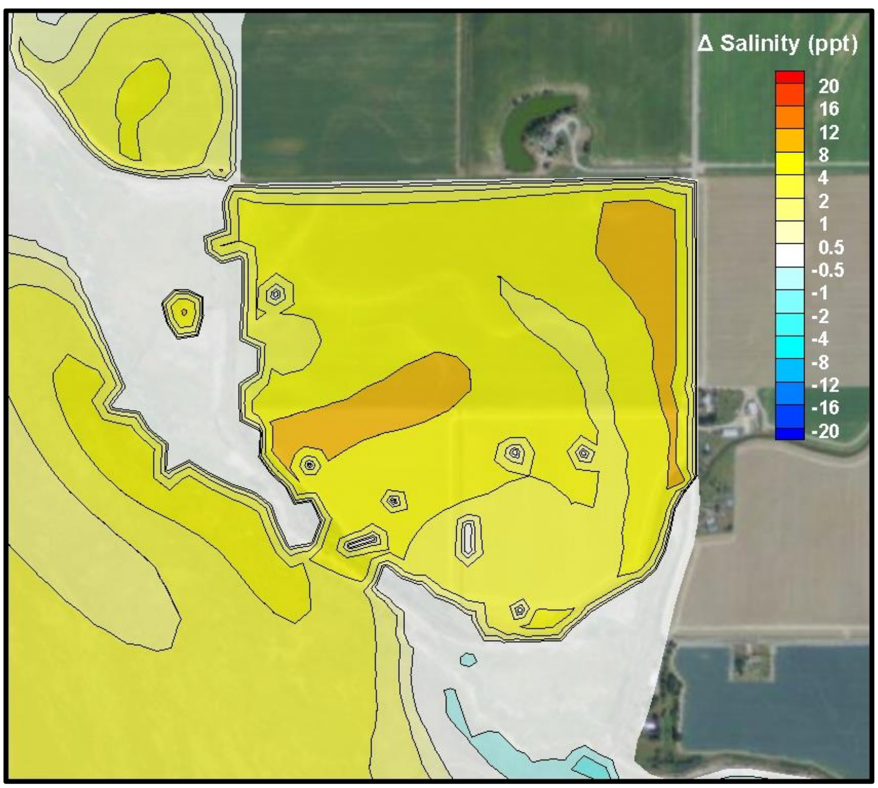


Figure I.72. Contour map of change in salinity from the Baseline simulation for Hall Slough with low flow and high tide.

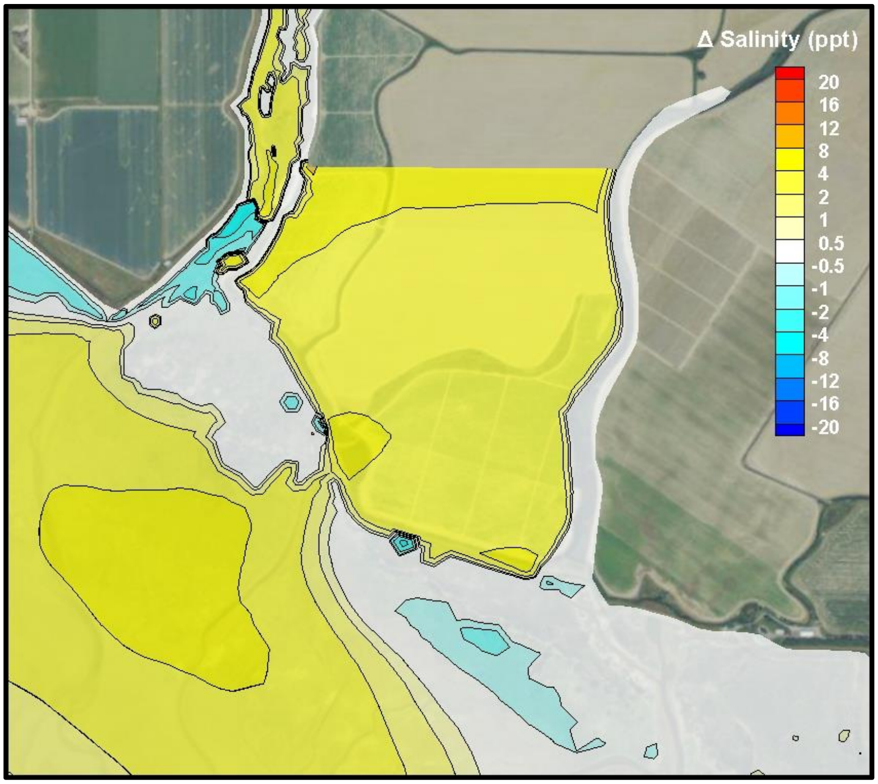


Figure I.73. Contour map of change in salinity from the Baseline simulation for Fir Island Farm with low flow and high tide.

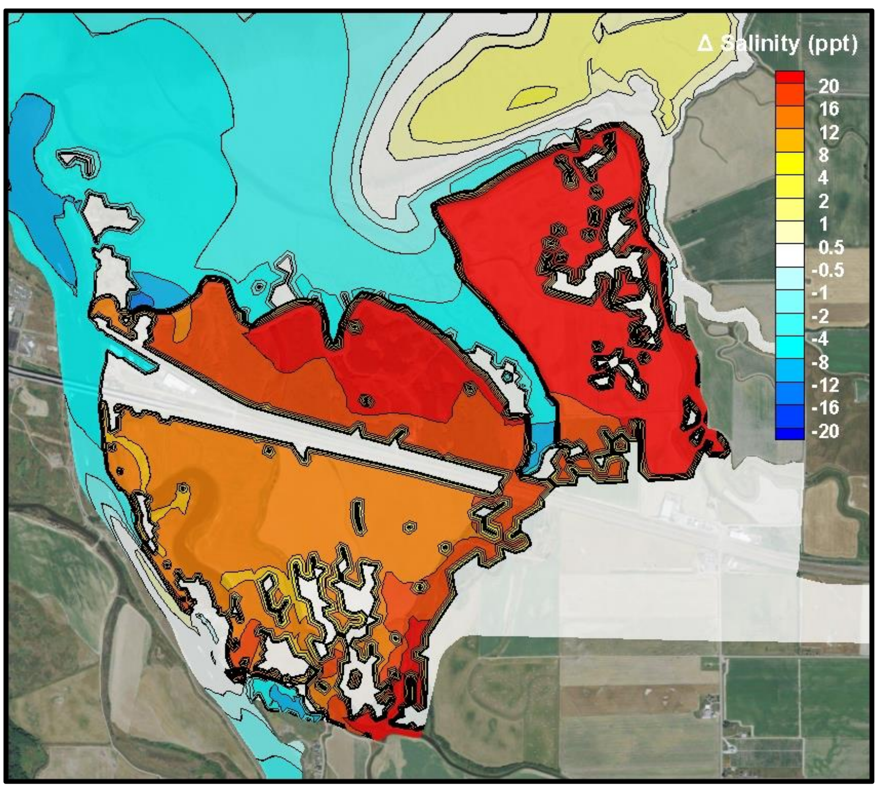


Figure I.74. Contour map of change in salinity from the Baseline simulation for Telegraph Slough Full with low flow and high tide.

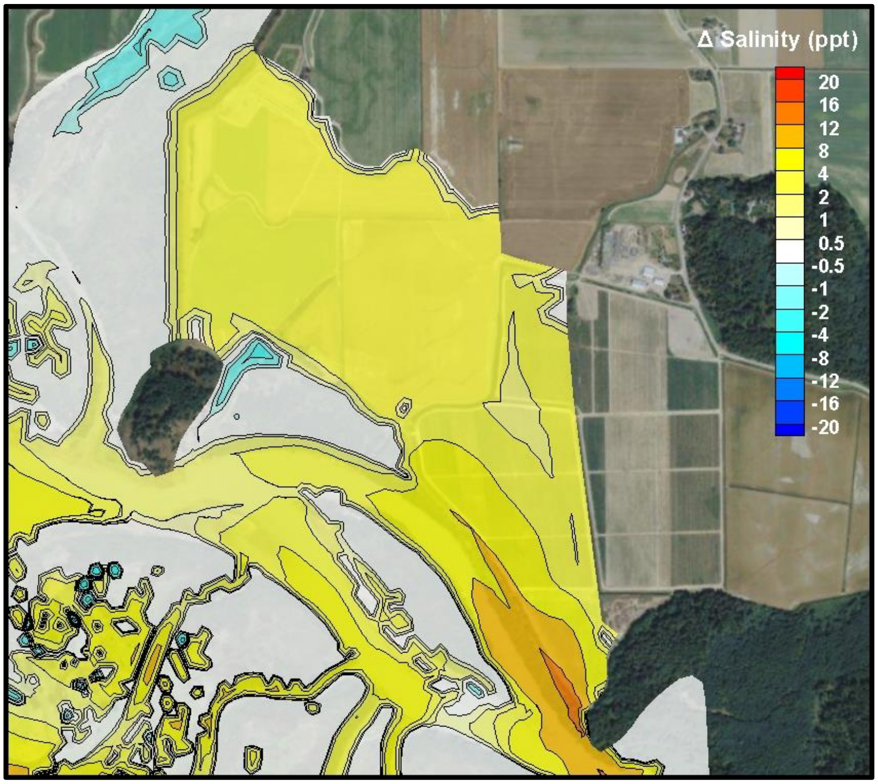


Figure I.75. Contour map of change in salinity from the Baseline simulation for Sullivan Hacienda with low flow and high tide.

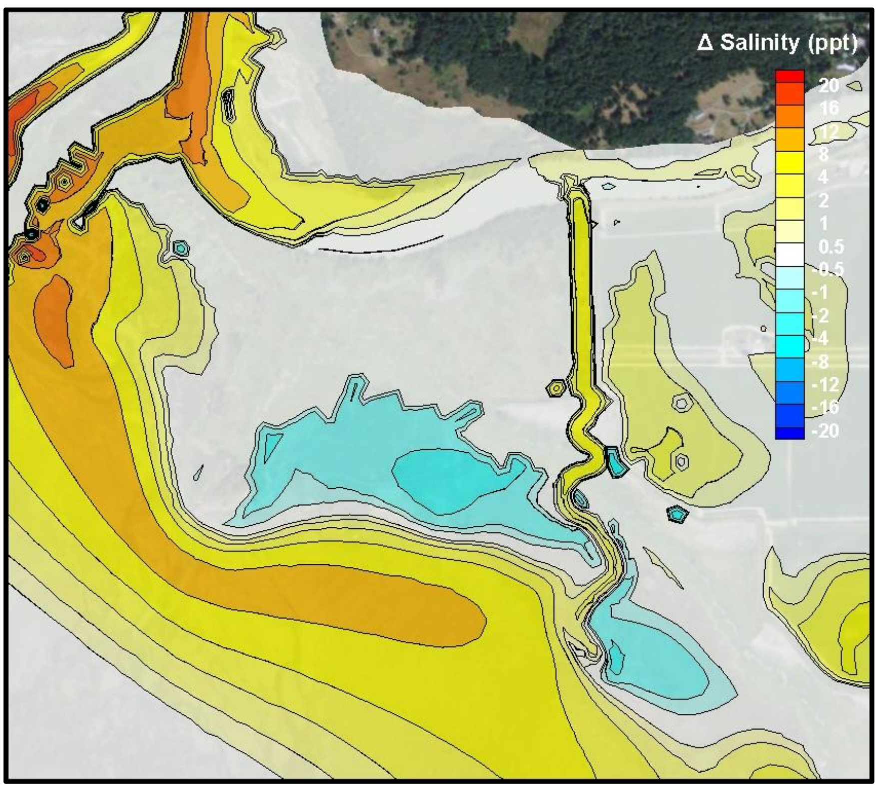


Figure I.76. Contour map of change in salinity from the Baseline simulation for Rawlins Distributary with low flow and high tide.

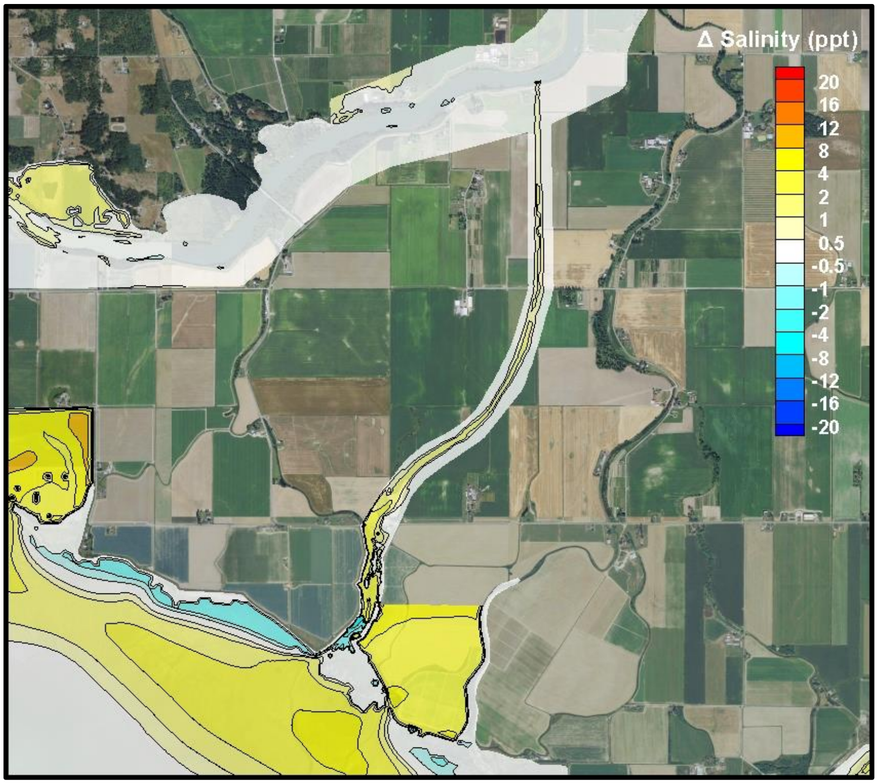


Figure I.77. Contour map of change in salinity from the Baseline simulation for Cross Island Connector with low flow and high tide.

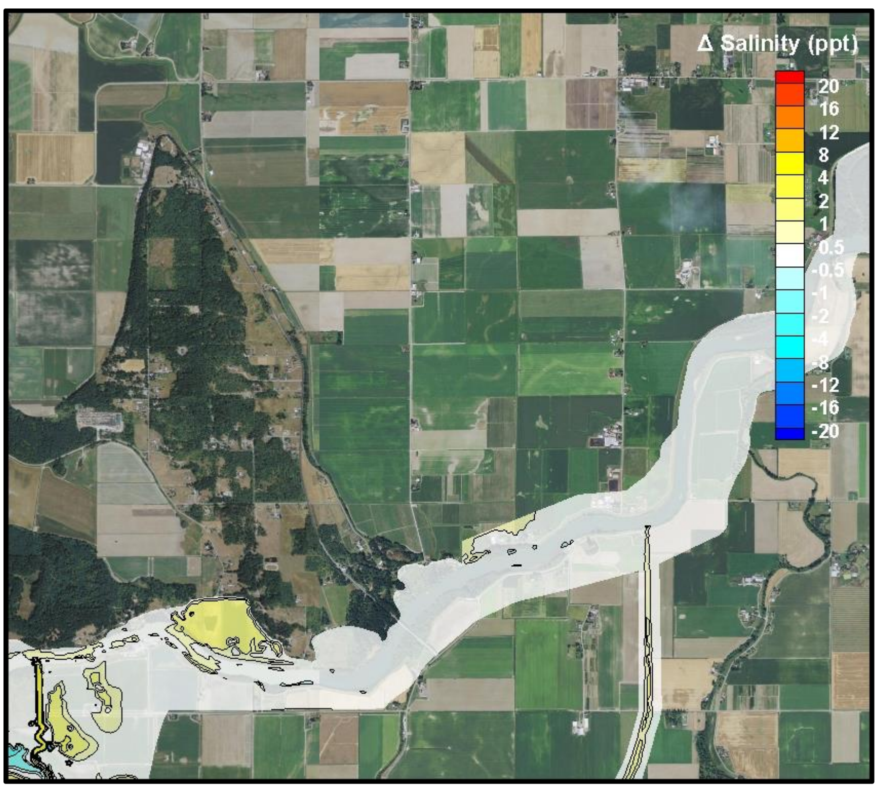


Figure I.78. Contour map of change in salinity from the Baseline simulation for NF Levee Setback C with low flow and high tide.

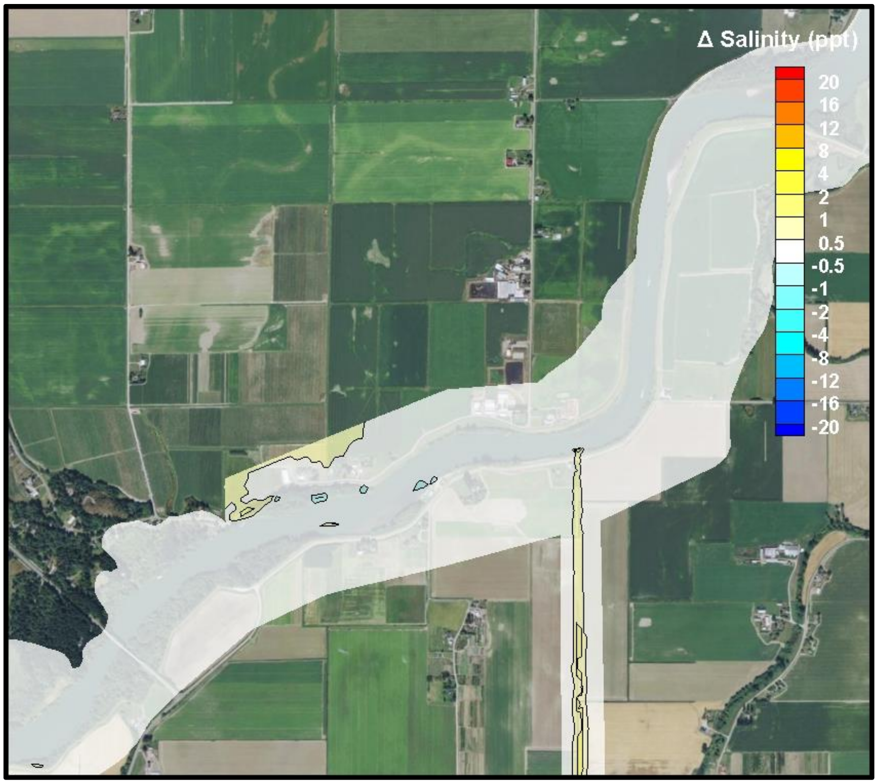


Figure I.79. Contour map of change in salinity from the Baseline simulation for NF Right Bank Levee Setback with low flow and high tide.

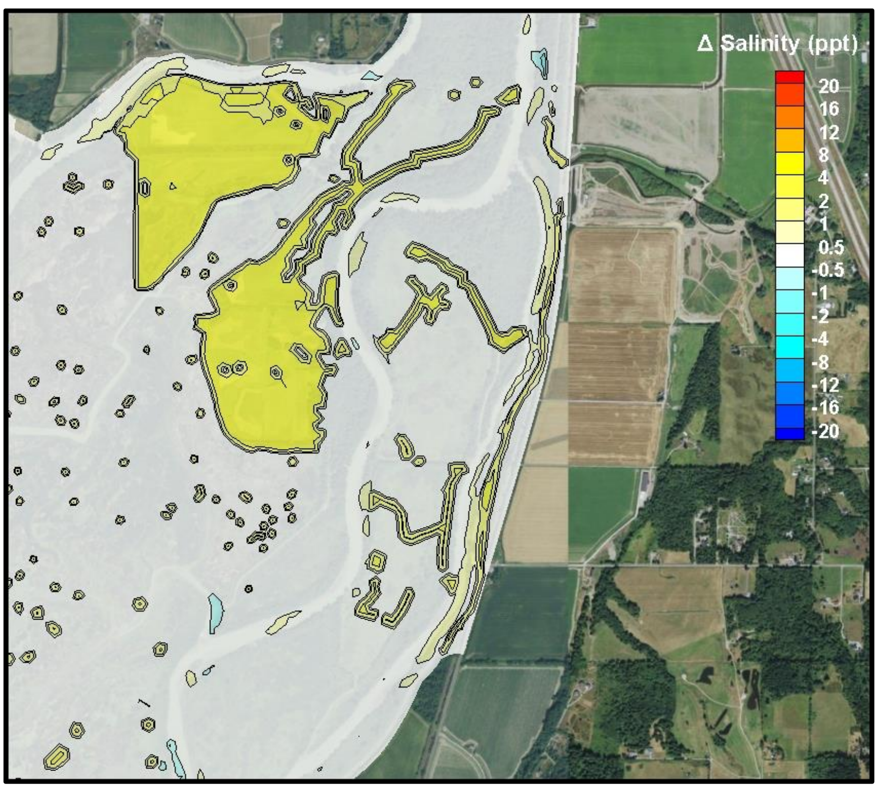


Figure I.80. Contour map of change in salinity from the Baseline simulation for Milltown Island with low flow and high tide.

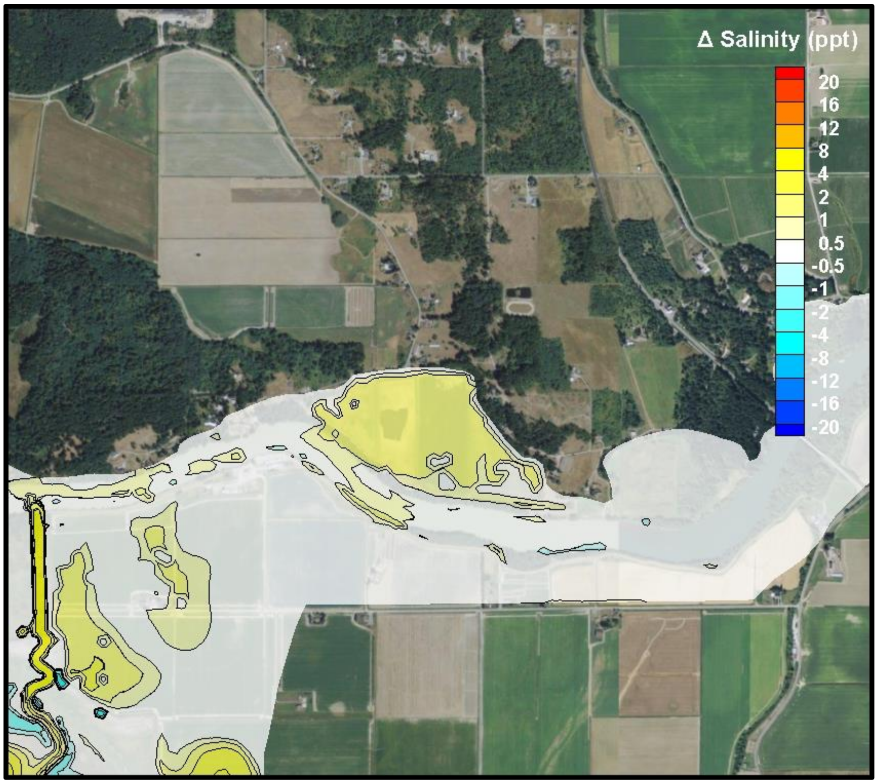


Figure I.81. Contour map of change in salinity from the Baseline simulation for Thein Farm with low flow and high tide.

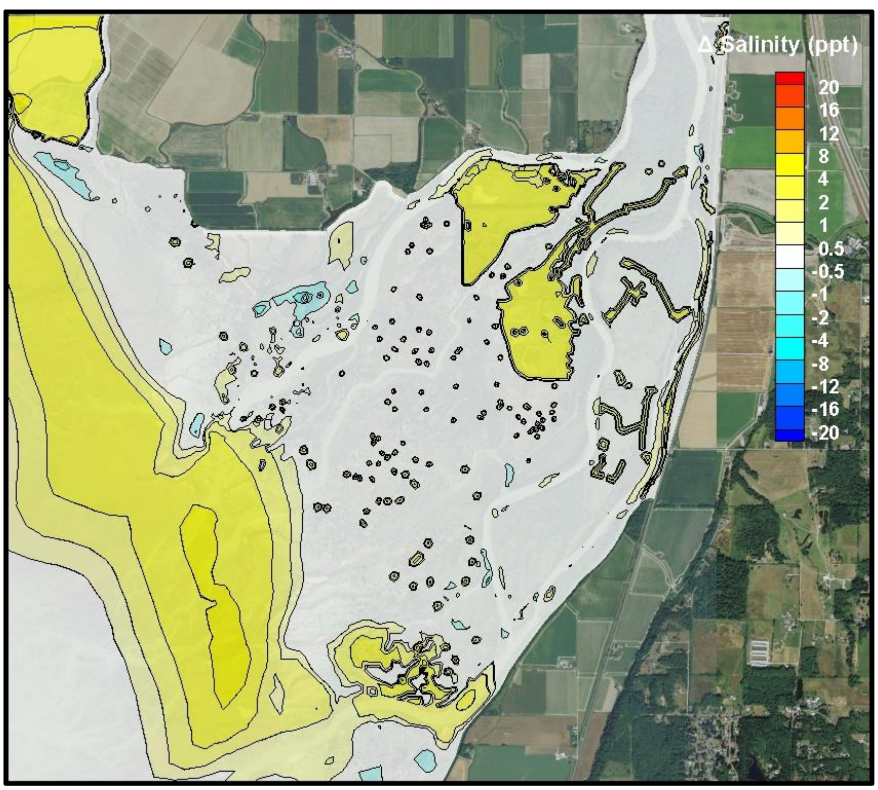


Figure I.82. Contour map of change in salinity from the Baseline simulation for Deepwater Slough Phase 2 with low flow and high tide.

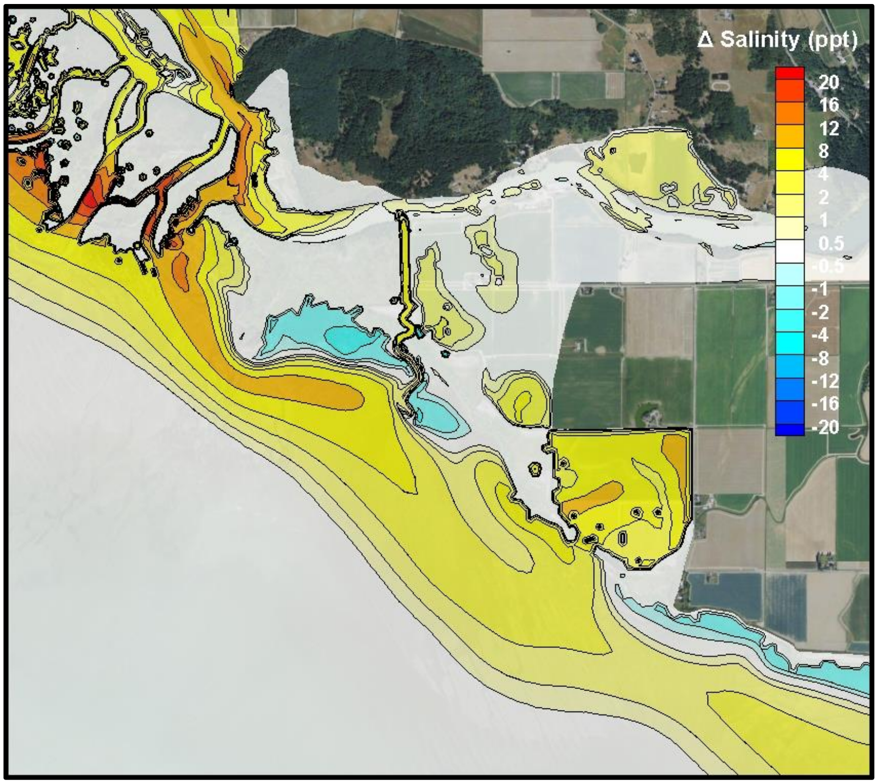


Figure I.83. Contour map of change in salinity from the Baseline simulation for Rawlins Road with low flow and high tide.

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.

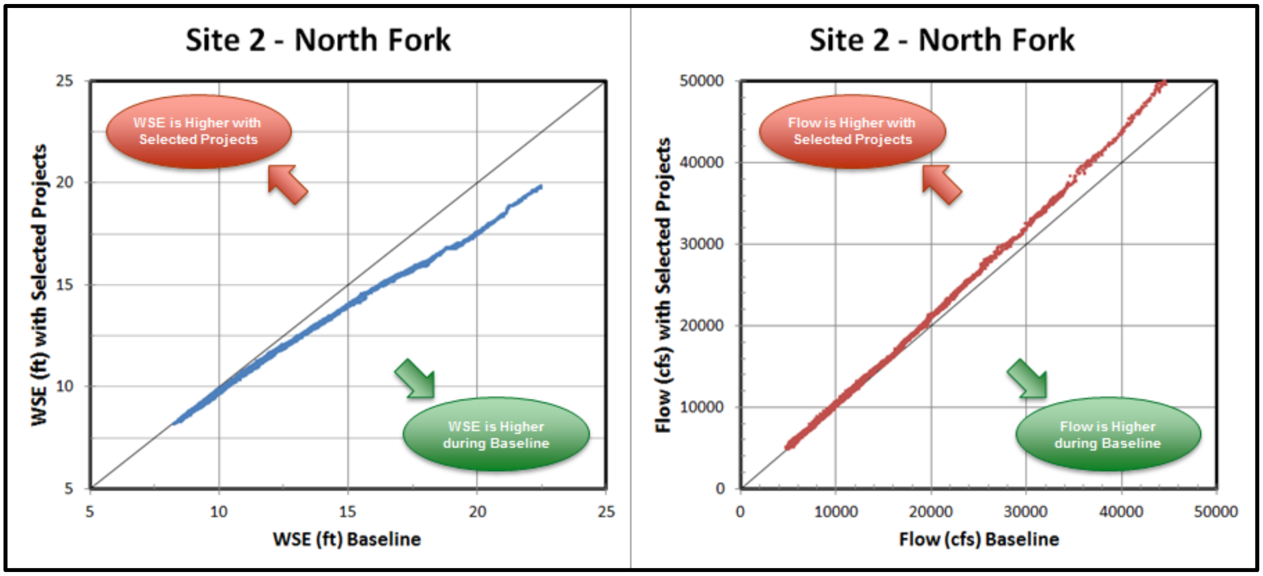


Figure I.84. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Selected Projects simulation at the North Fork gauge location compared with the same information under baseline conditions.

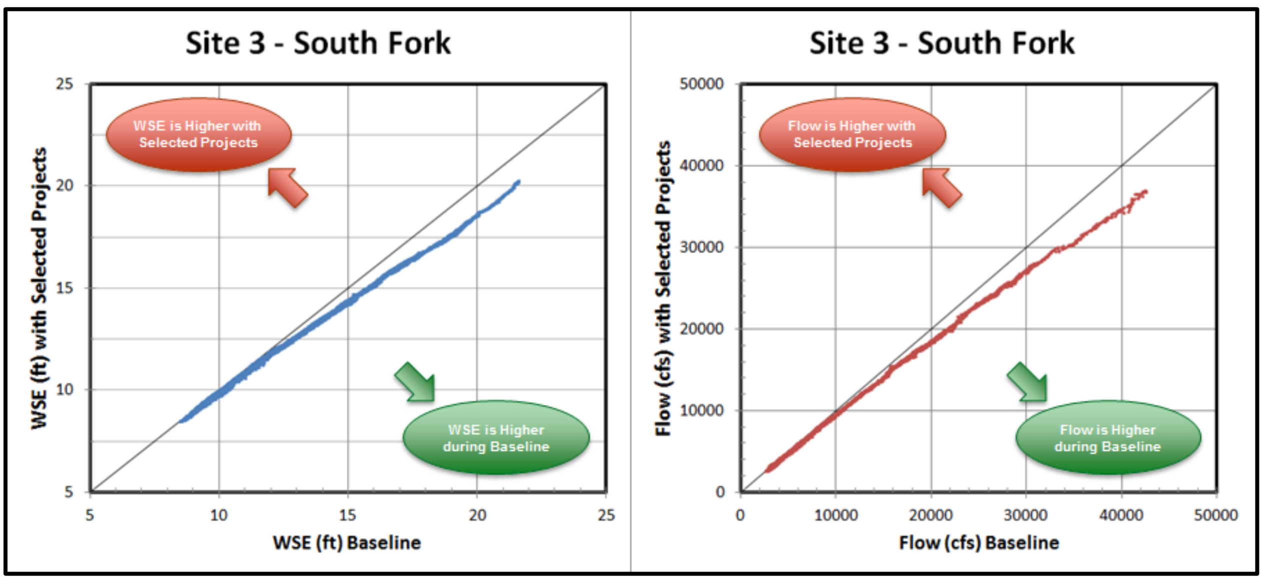


Figure I.85. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Selected Projects simulation at the South Fork gauge location compared with the same information under baseline conditions.

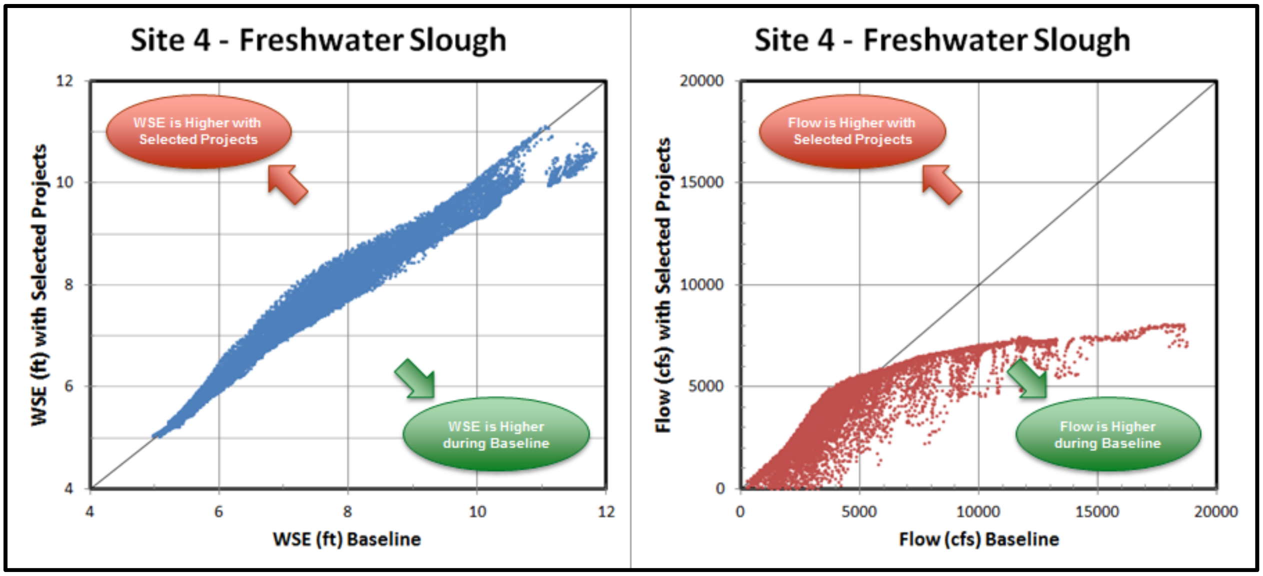


Figure I.86. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Selected Projects simulation at the Freshwater Slough gauge location compared with the same information under baseline conditions.

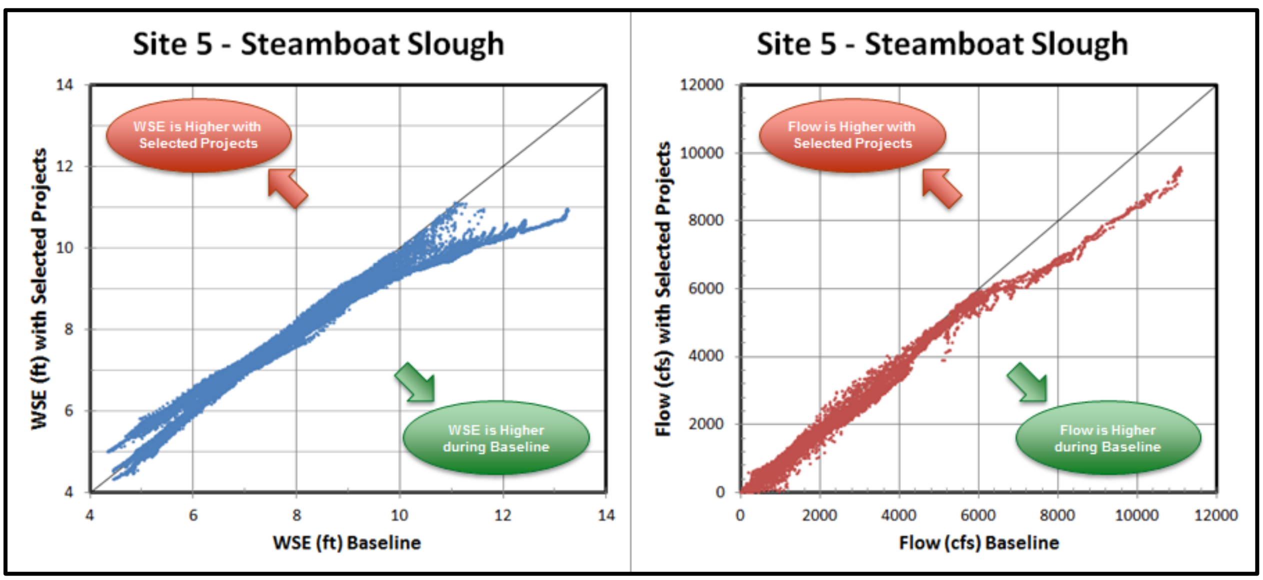


Figure I.87. Plots comparing WSE (left) and flow (right) at every time step across the 7-month Selected Projects simulation at the Steamboat Slough gauge location compared with the same information under baseline conditions.

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.

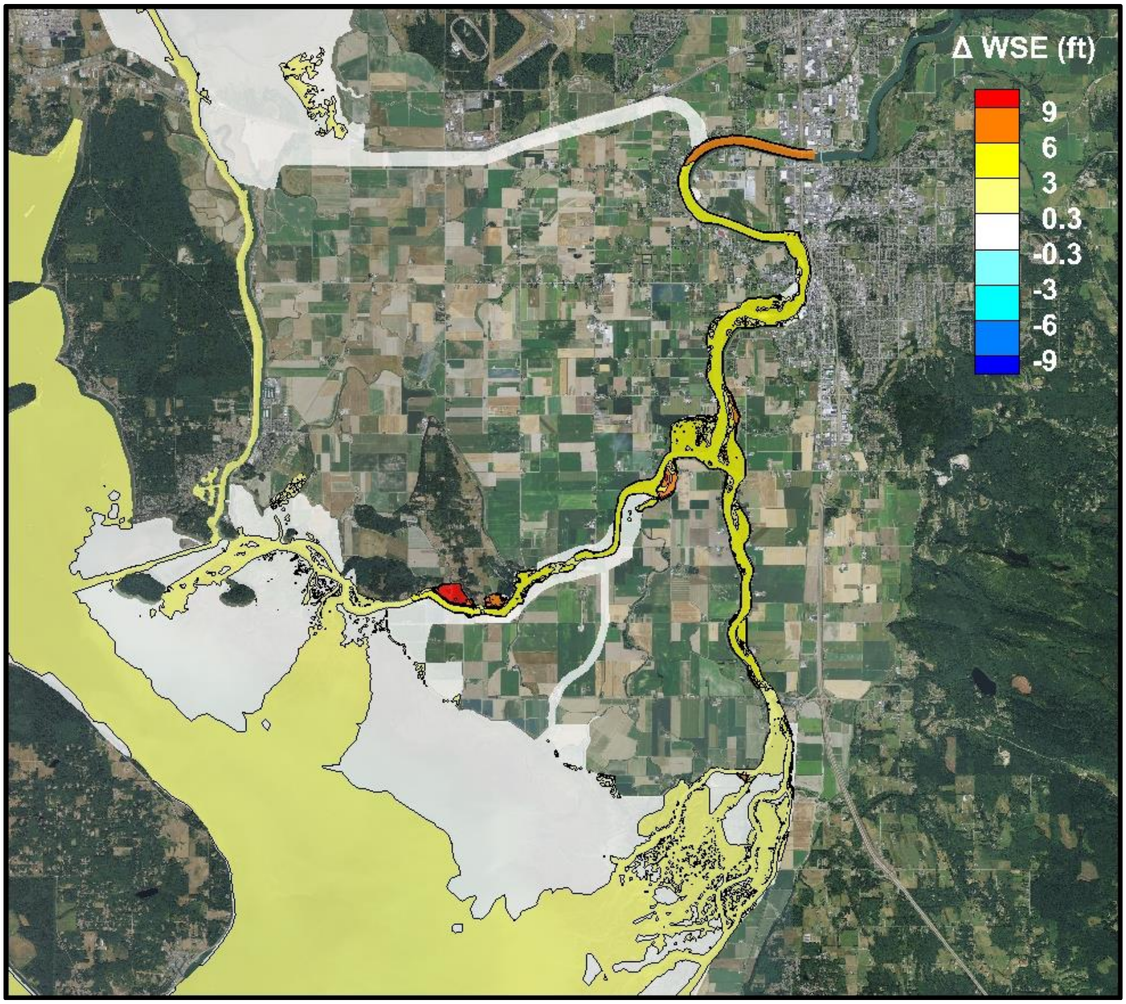


Figure J.1. Contour map of change in WSE for Q2 and low tide for the full basin, comparing Baseline and Climate Change Baseline simulations.

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.

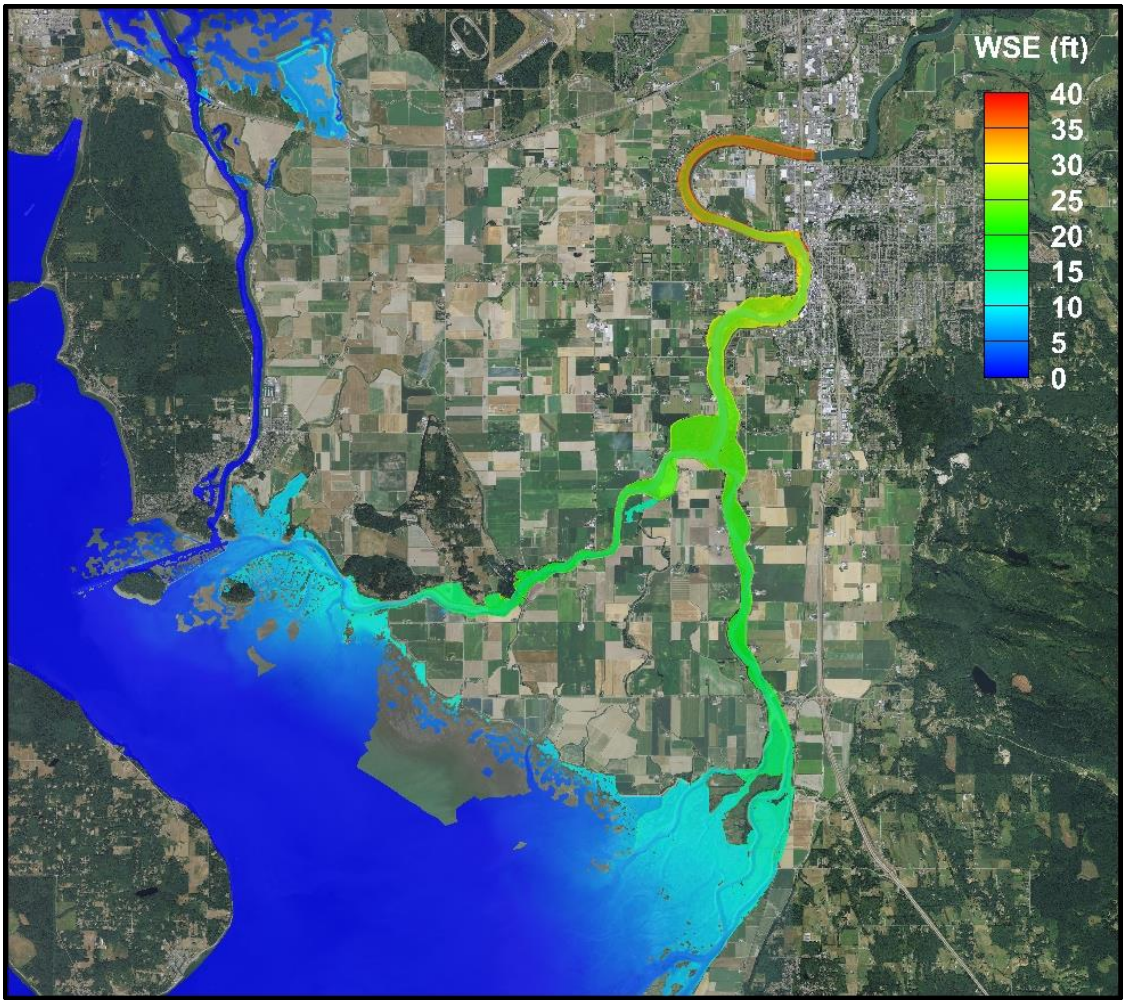


Figure J.2. Contour map of water surface elevation for the full domain during the 2080 Climate Change Baseline Simulation with future Q2 flow and future low spring tide.

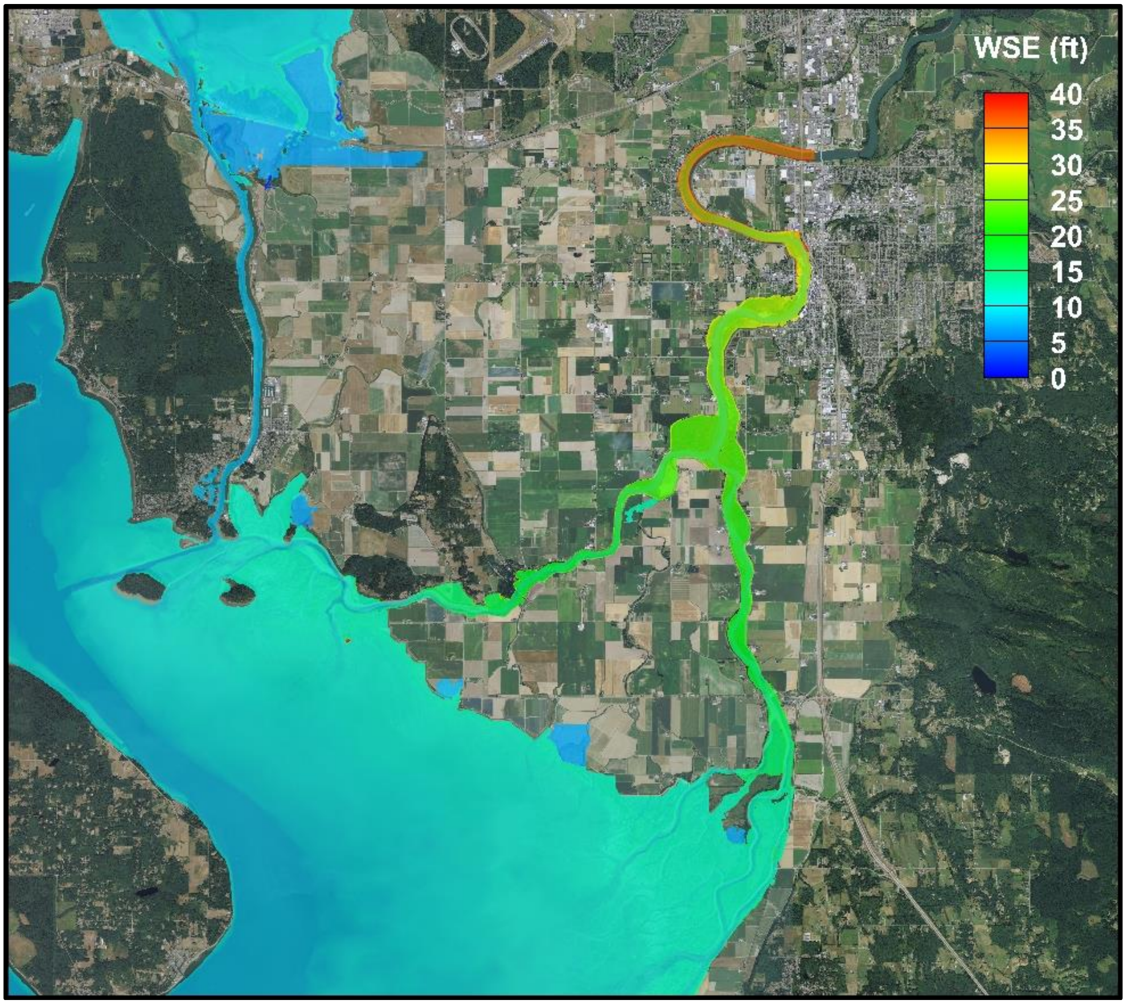


Figure J.3. Contour map of water surface elevation for the full domain during the 2080 Climate Change Baseline Simulation with future Q2 flow and future high spring tide.

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.

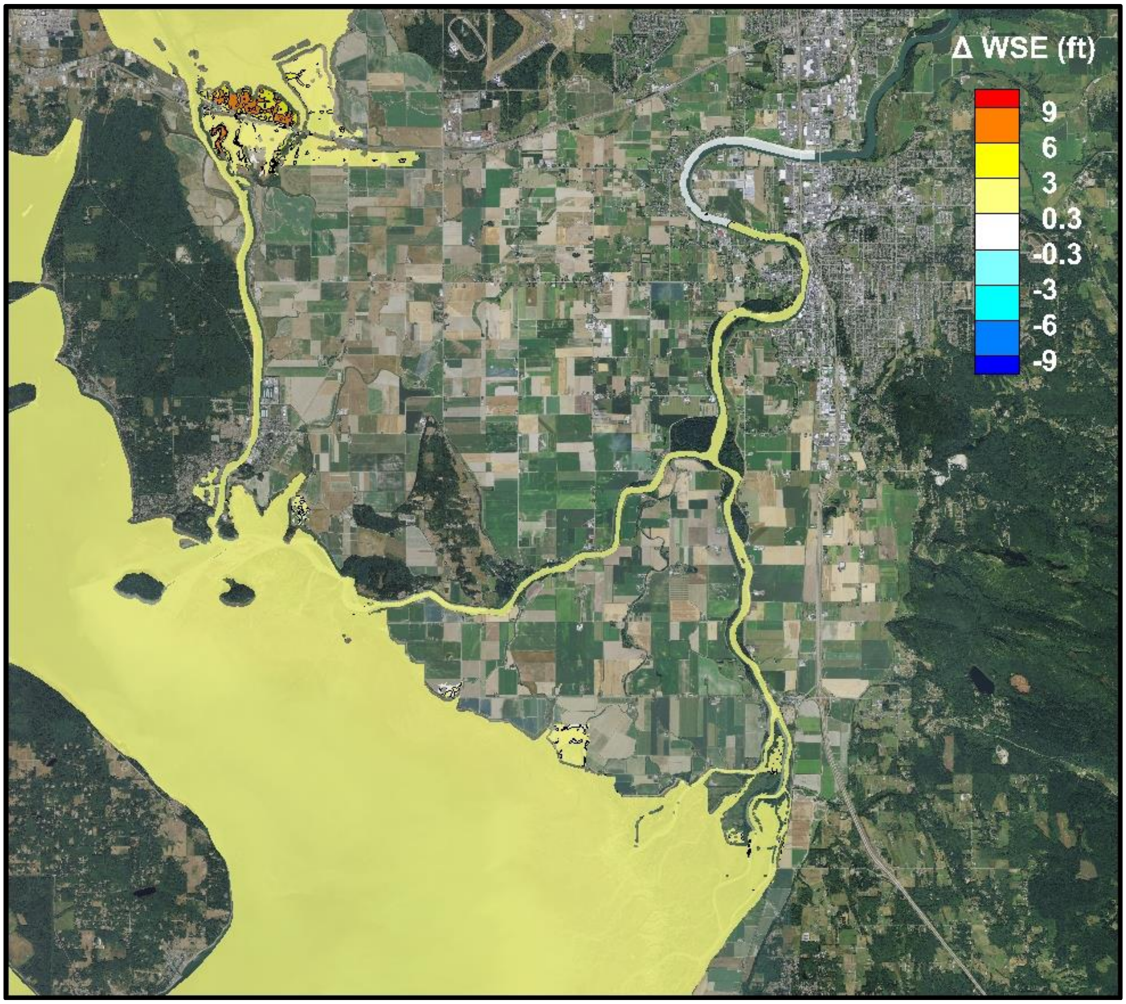


Figure J.4. Contour map of change in WSE for low flow and high tide for the full basin, comparing Baseline and Climate Change Baseline simulations.

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.

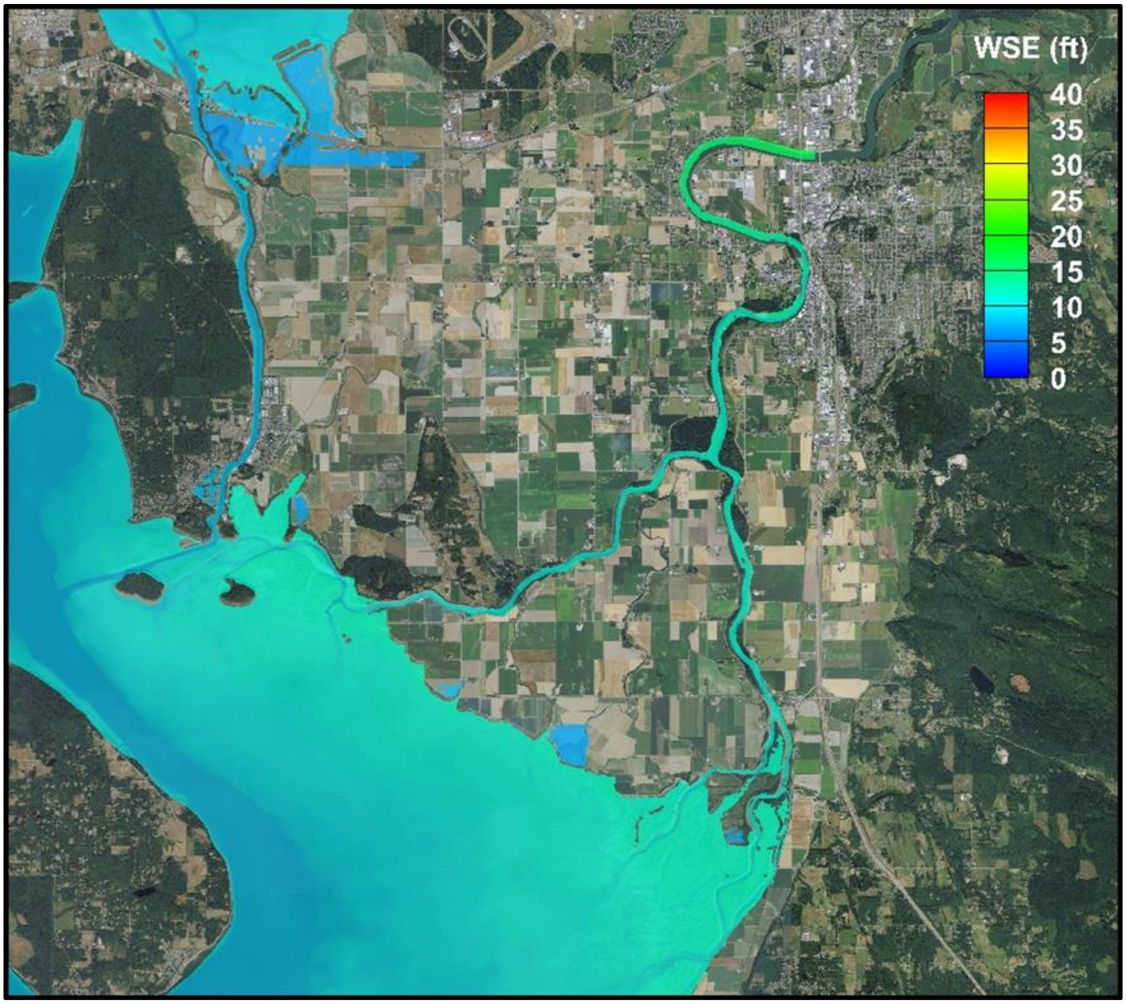


Figure J.5. Contour map of water surface elevation for the full domain during the 2080 Climate Change Baseline Simulation with low flow and future high spring tide.

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.

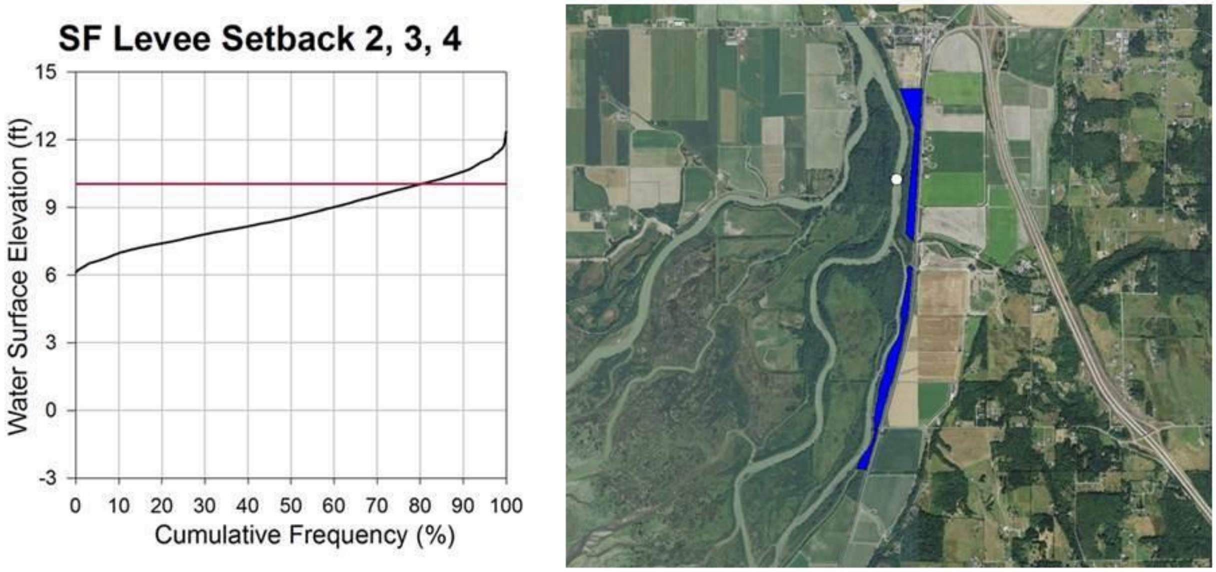


Figure J.6. Cumulative frequency plot and corresponding map for SF Levee Setbacks 2, 3, and 4 during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

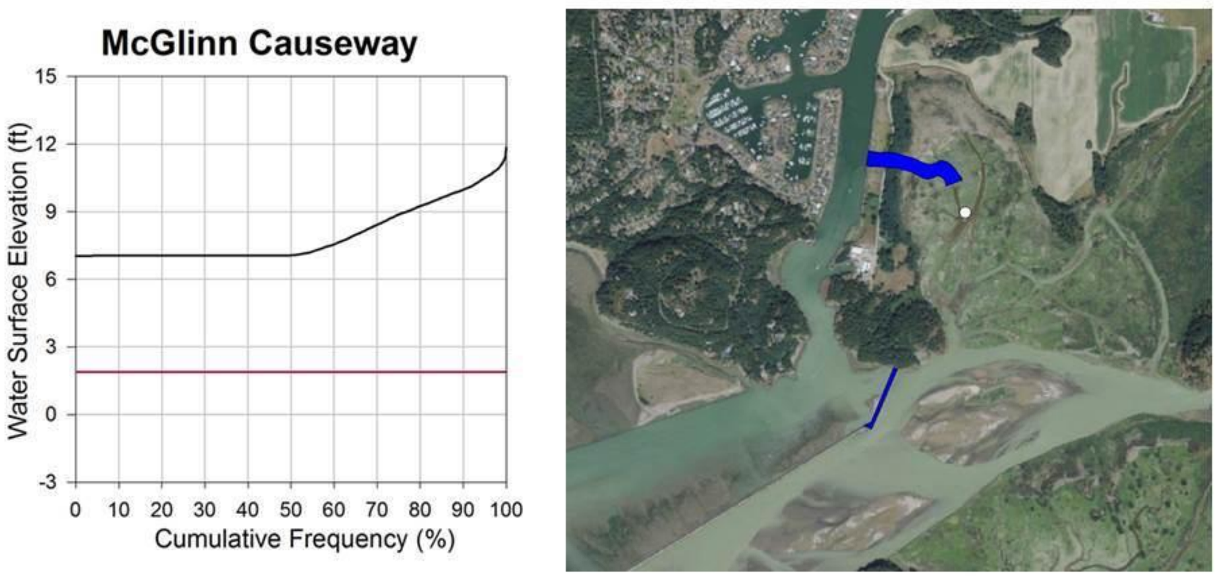


Figure J.7. Cumulative frequency plot and corresponding map for McGlinn Causeway during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

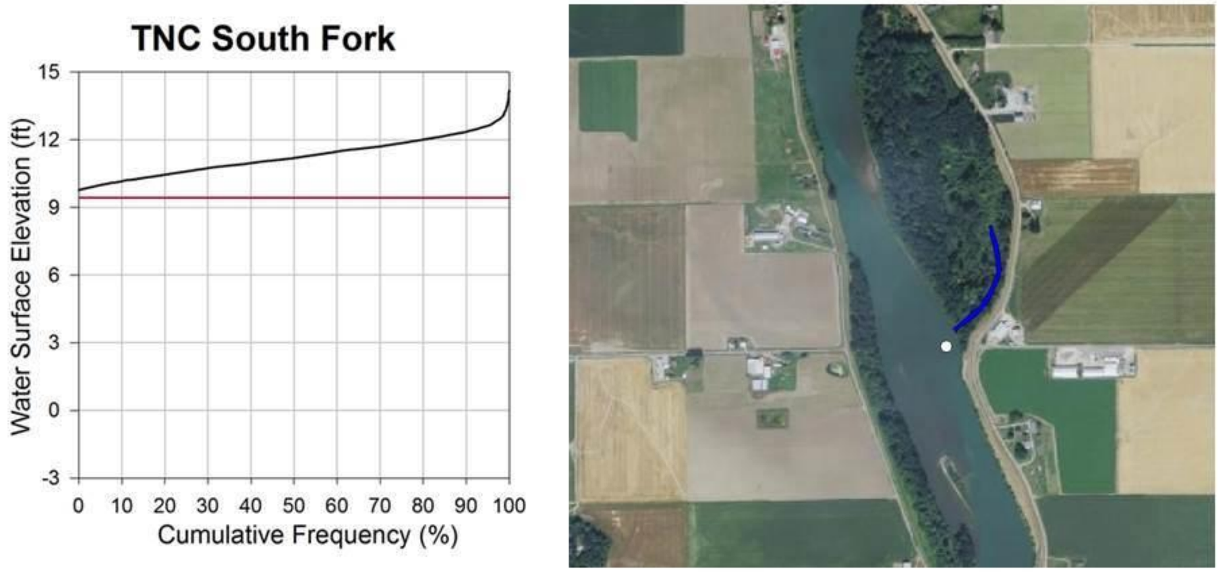


Figure J.8. Cumulative frequency plot and corresponding map for TNC South Fork during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

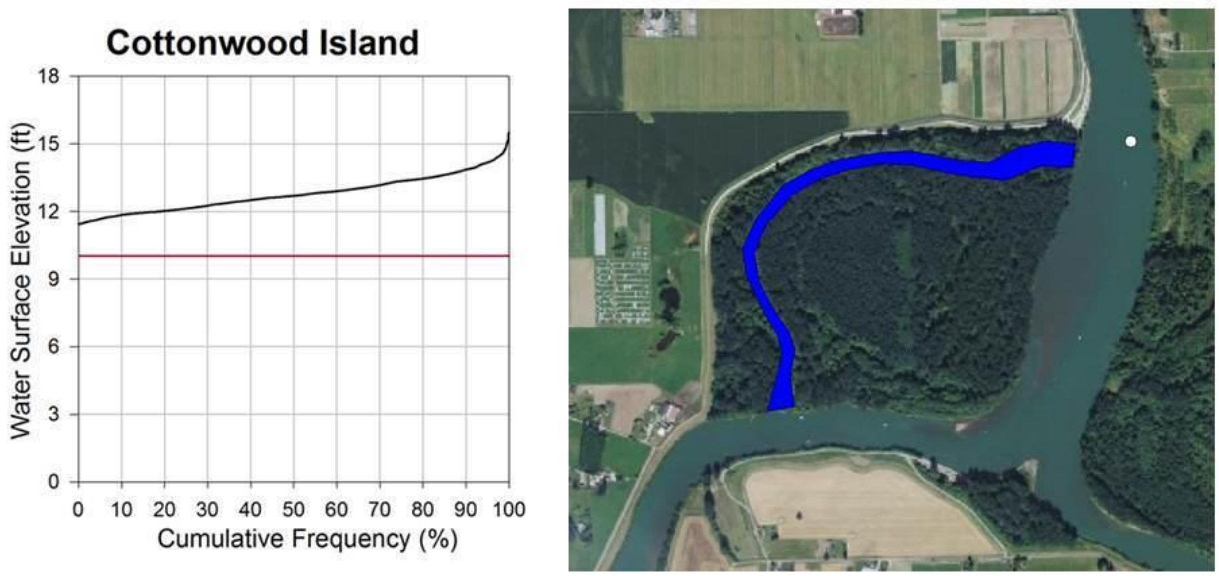


Figure J.9. Cumulative frequency plot and corresponding map for Cottonwood Island during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

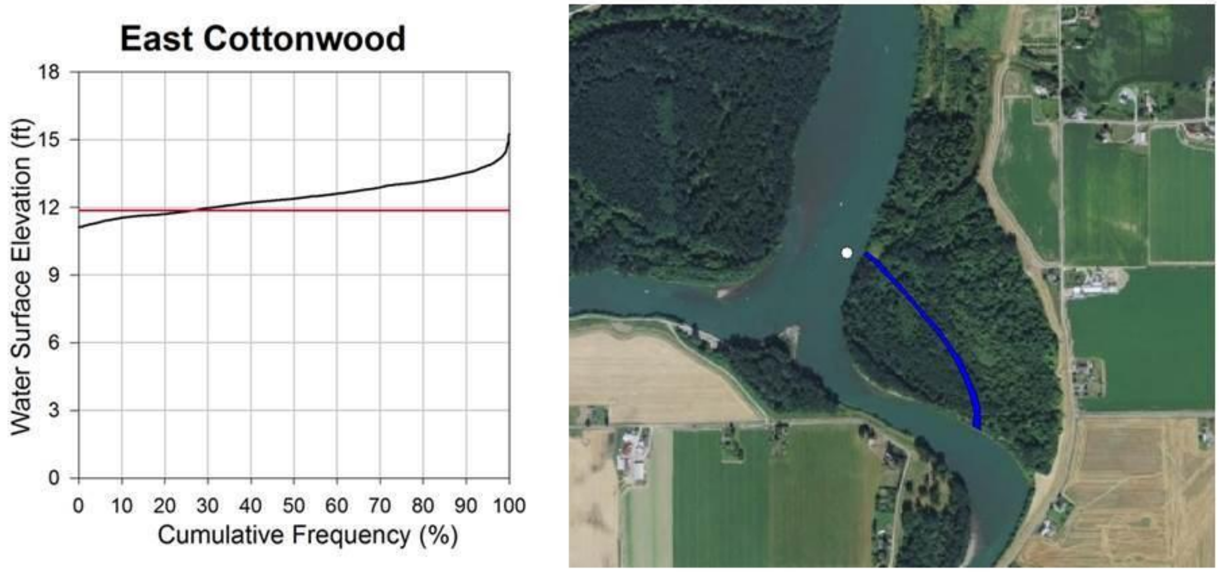


Figure J.10. Cumulative frequency plot and corresponding map for East Cottonwood during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

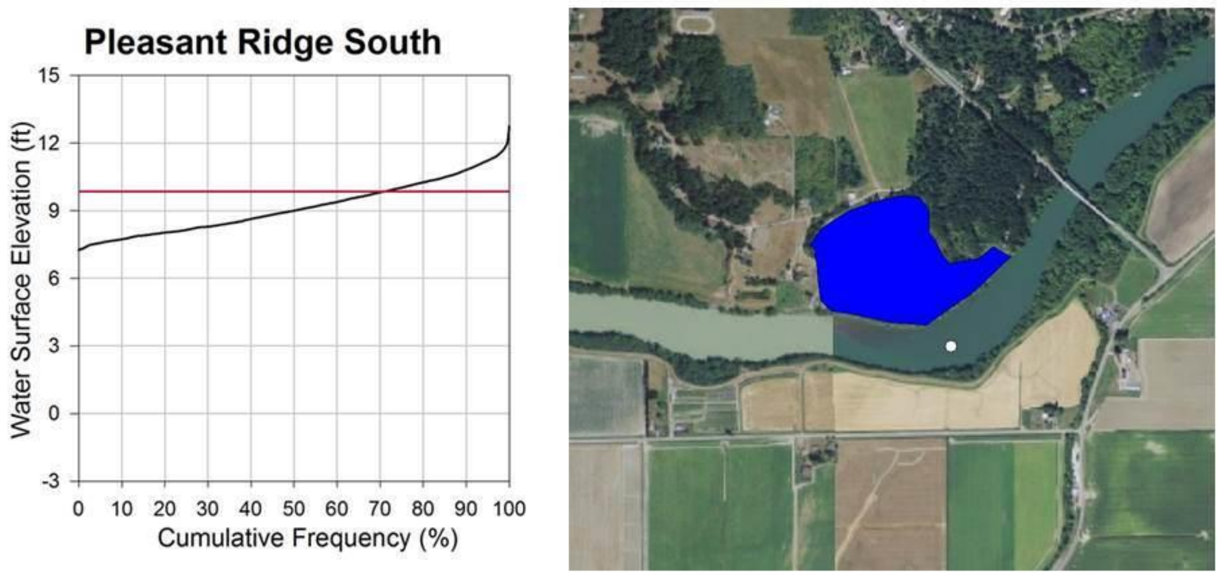


Figure J.11. Cumulative frequency plot and corresponding map for Pleasant Ridge South during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

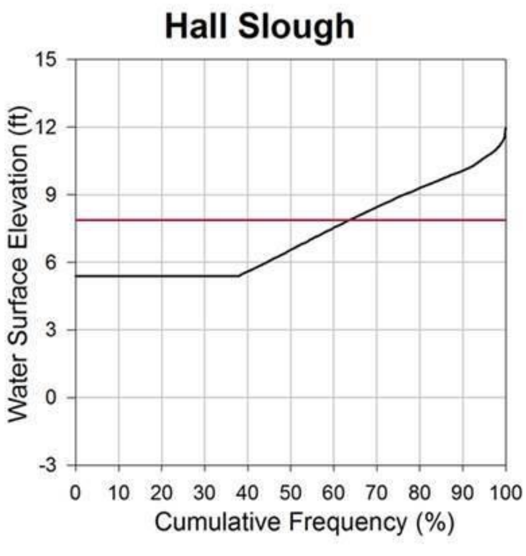


Figure J.12. Cumulative frequency plot and corresponding map for Hall Slough during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

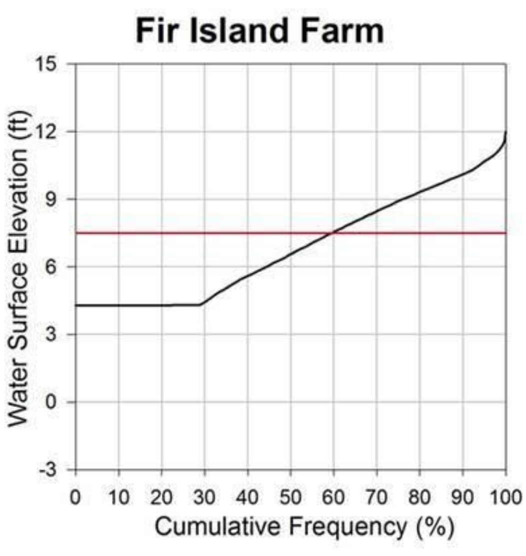


Figure J.13. Cumulative frequency plot and corresponding map for Fir Island Farm during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

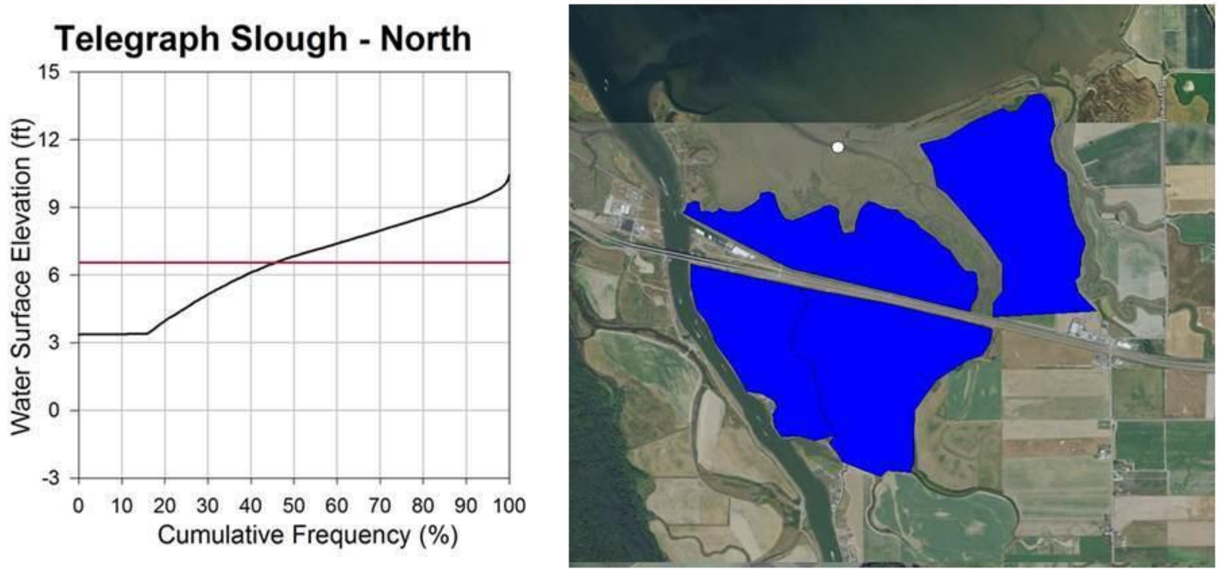


Figure J.14. Cumulative frequency plot and corresponding map for Telegraph Slough (north) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

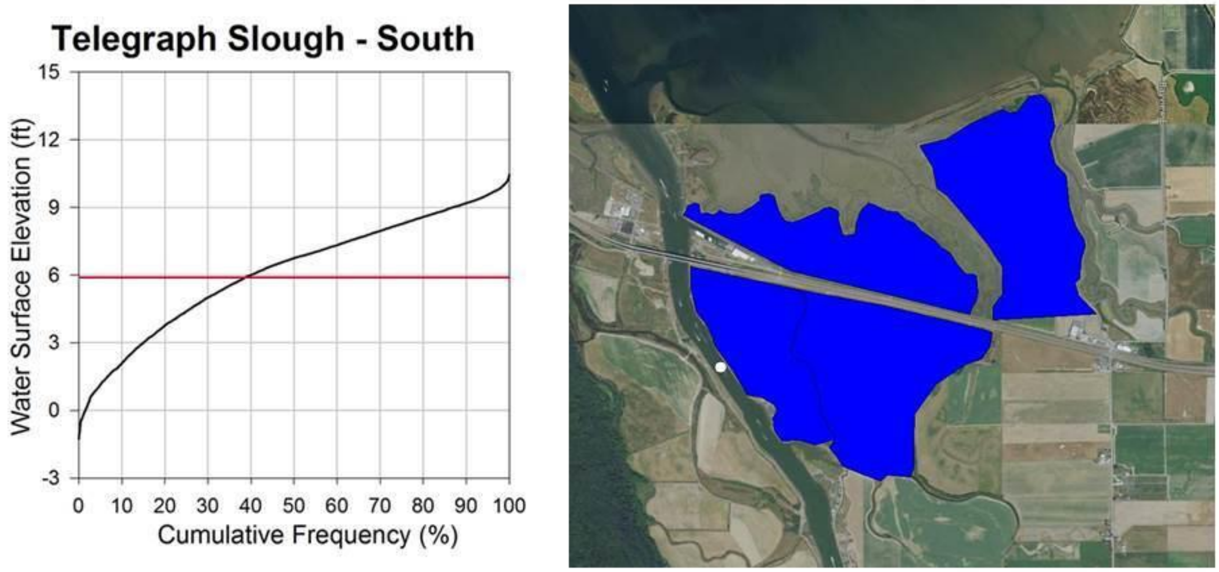


Figure J.15. Cumulative frequency plot and corresponding map for Telegraph Slough (south) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

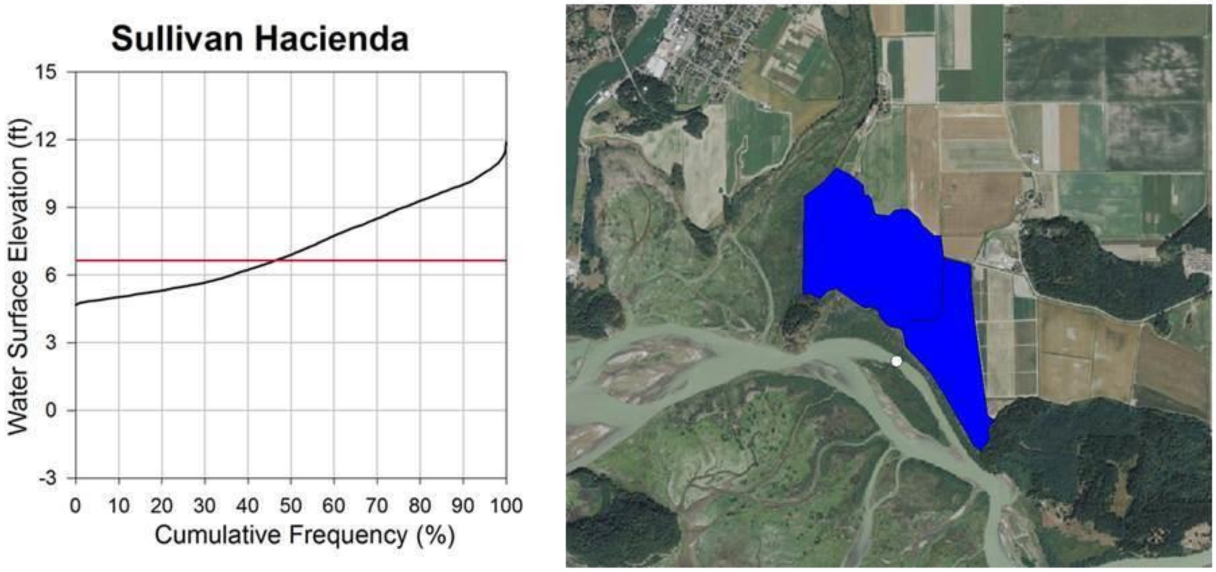


Figure J.16. Cumulative frequency plot and corresponding map for Sullivan Hacienda during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

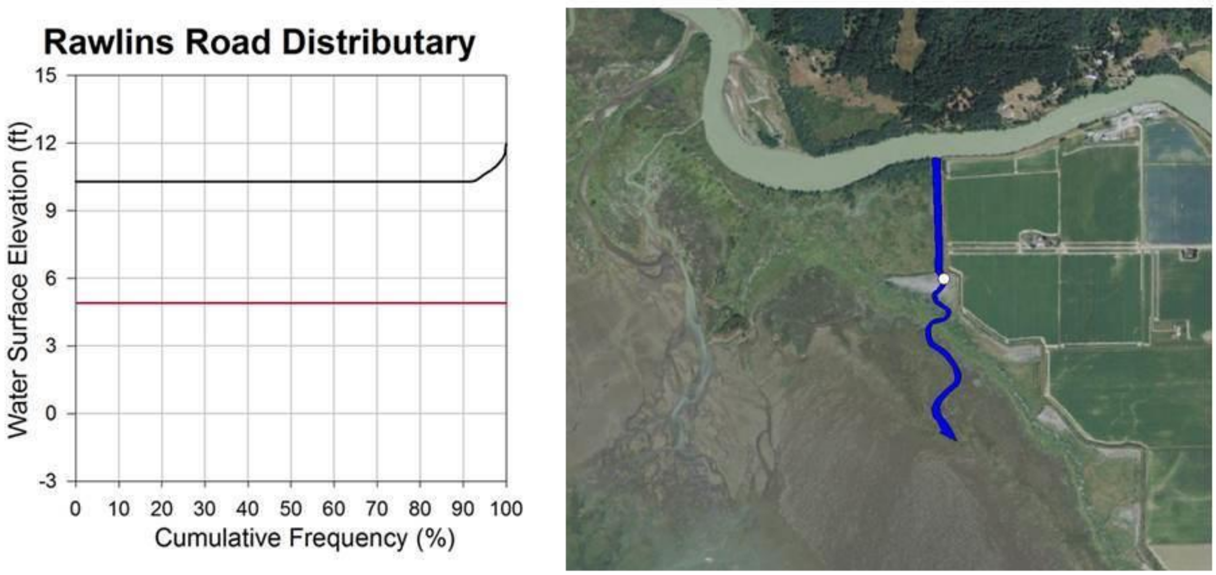


Figure J.17. Cumulative frequency plot and corresponding map for Rawlins Road Distributary during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

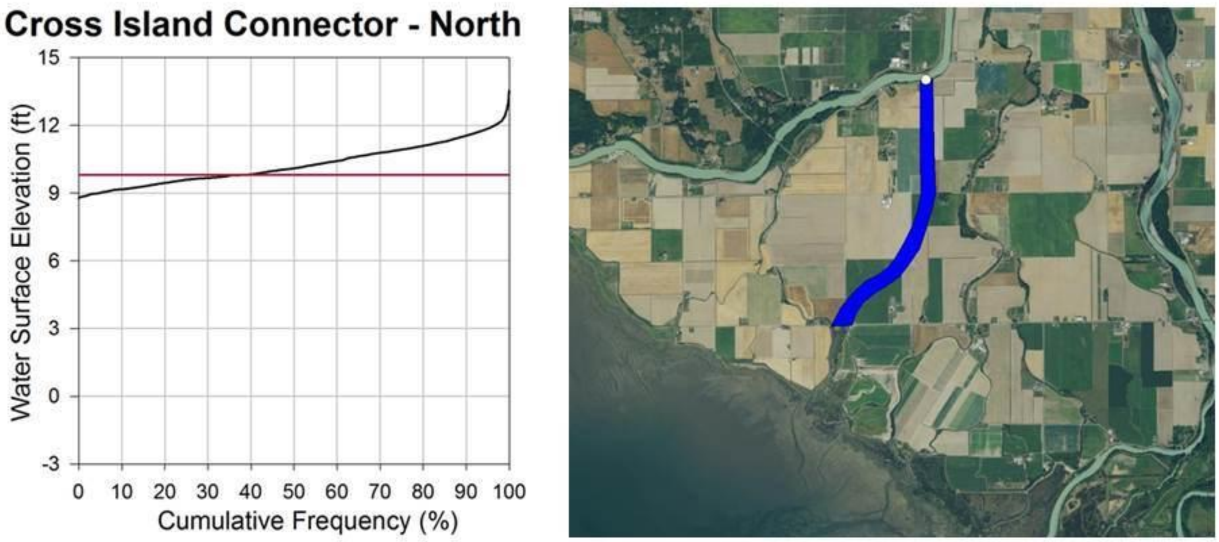


Figure J.18. Cumulative frequency plot and corresponding map for Cross Island Connector (north) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

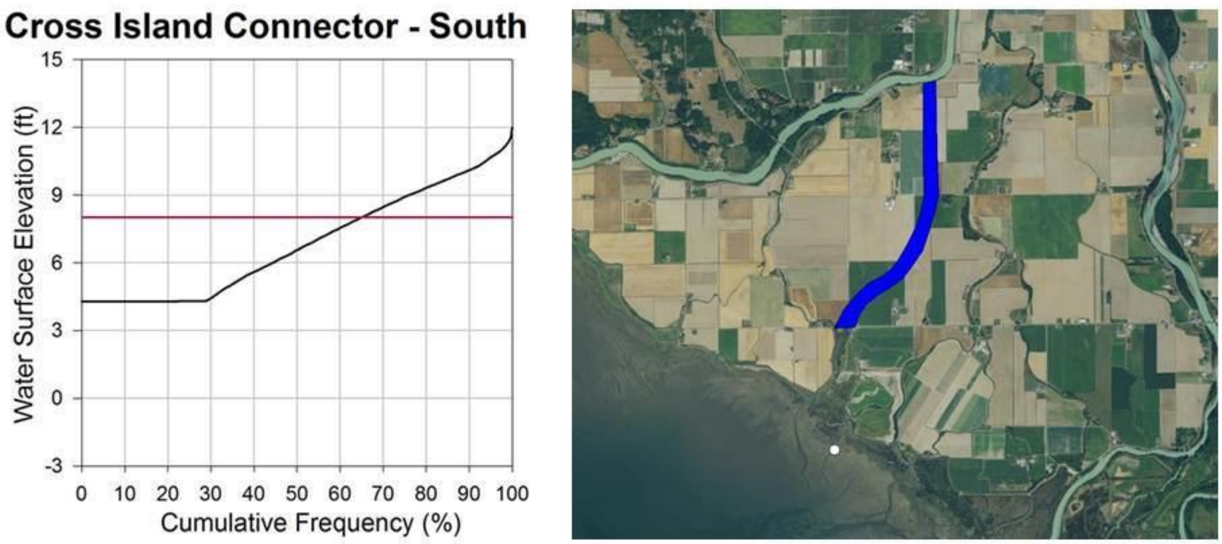


Figure J.19. Cumulative frequency plot and corresponding map for Cross Island Connector (south) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

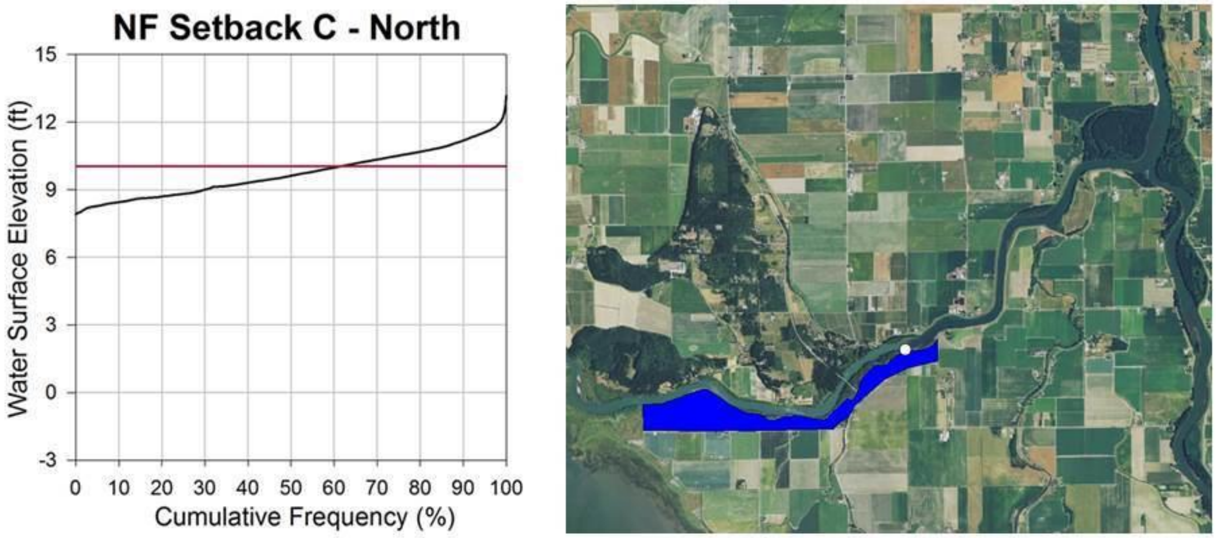


Figure J.20. Cumulative frequency plot and corresponding map for NF Levee Setback C (north) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

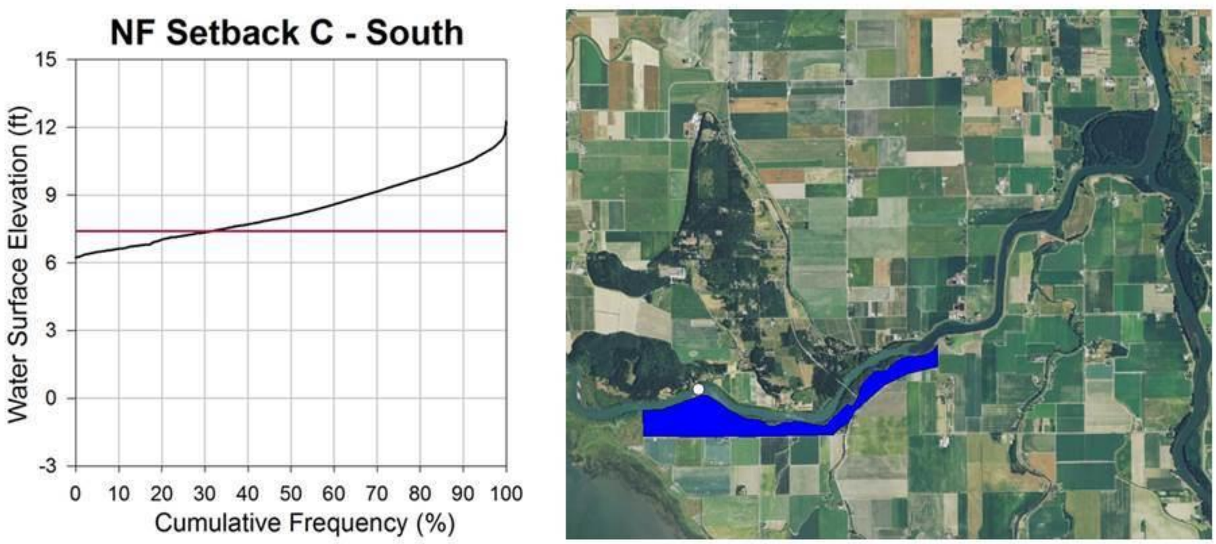


Figure J.21. Cumulative frequency plot and corresponding map for NF Levee Setback C (south) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

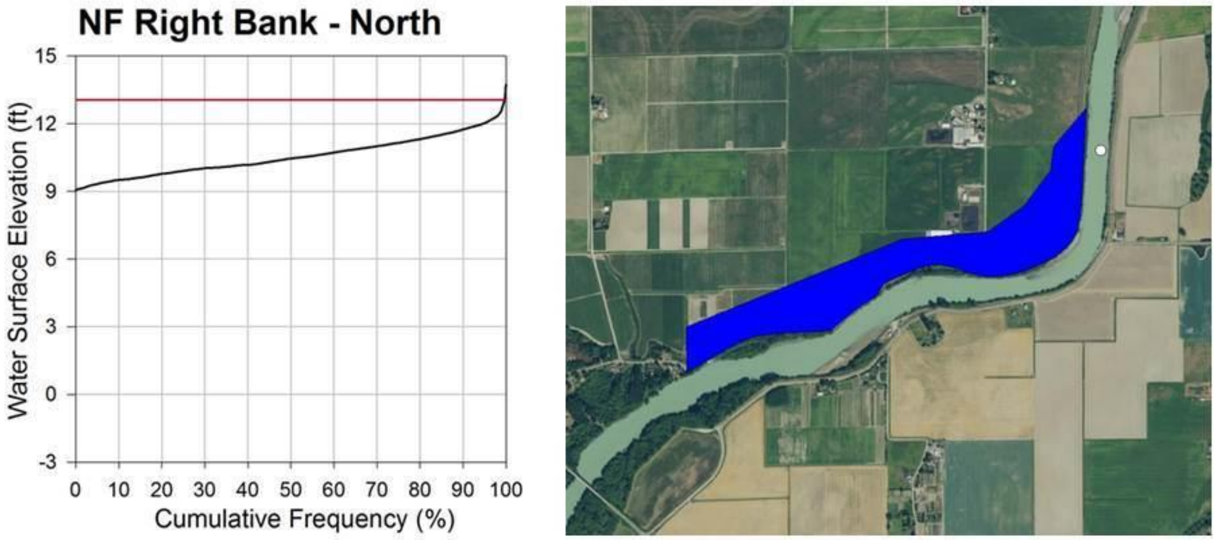


Figure J.22. Cumulative frequency plot and corresponding map for NF Right Bank Levee Setback (north) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

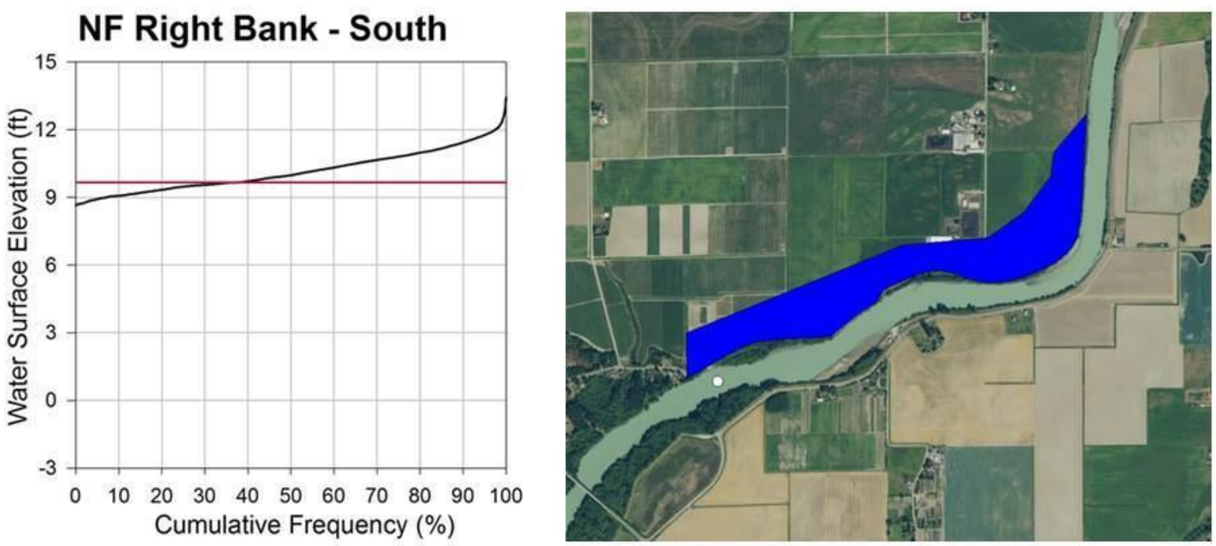


Figure J.23. Cumulative frequency plot and corresponding map for NF Right Bank Levee Setback (south) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

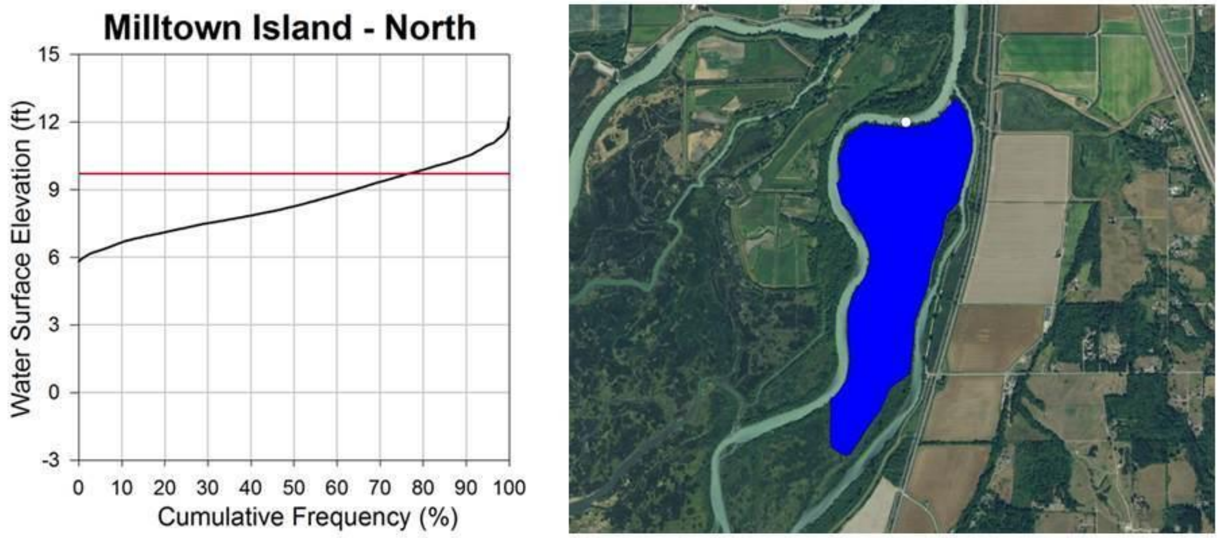


Figure J.24. Cumulative frequency plot and corresponding map for Milltown Island (north) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

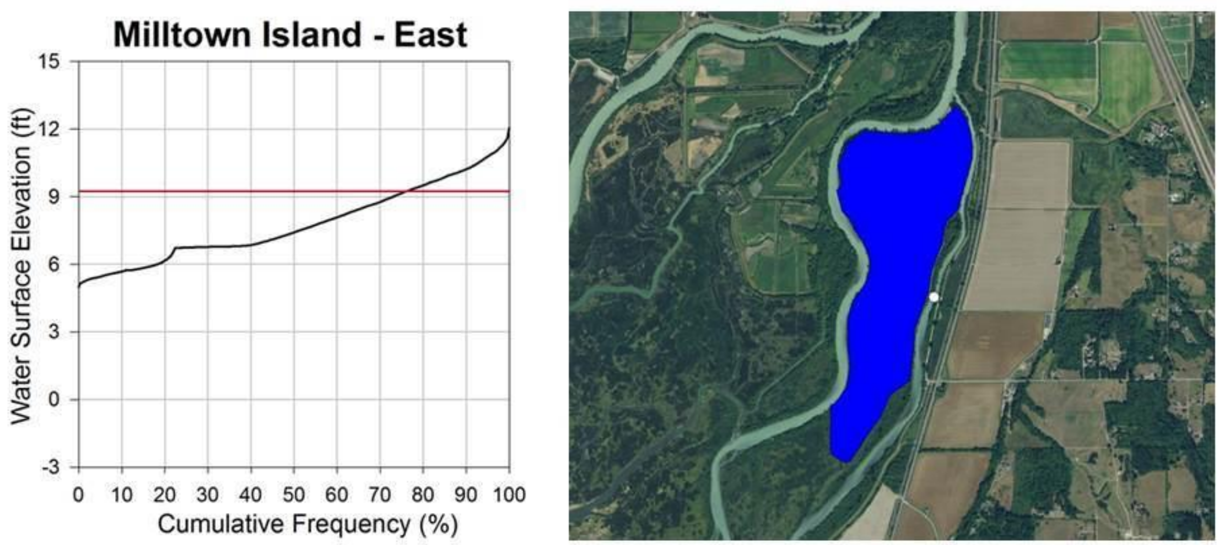


Figure J.25. Cumulative frequency plot and corresponding map for Milltown Island (east) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

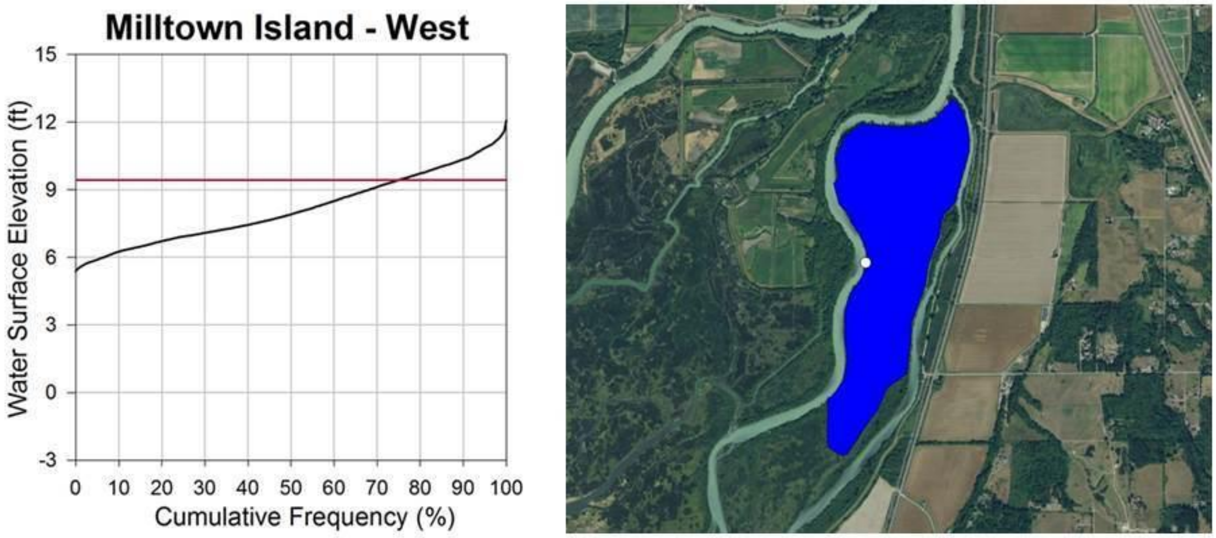


Figure J.26. Cumulative frequency plot and corresponding map for Milltown Island (west) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

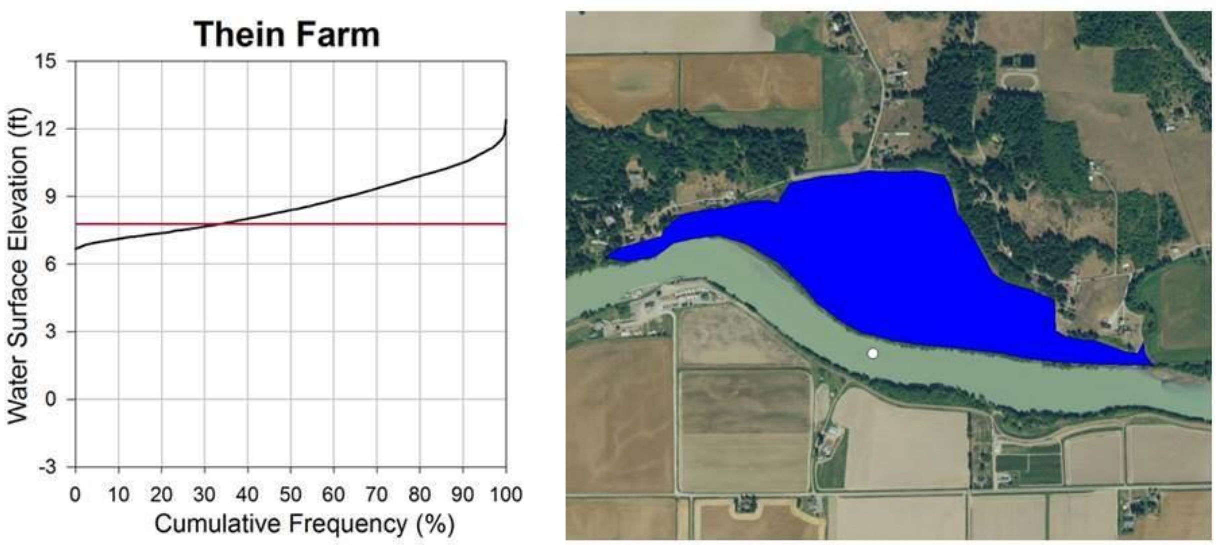


Figure J.27. Cumulative frequency plot and corresponding map for Thein Farm during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

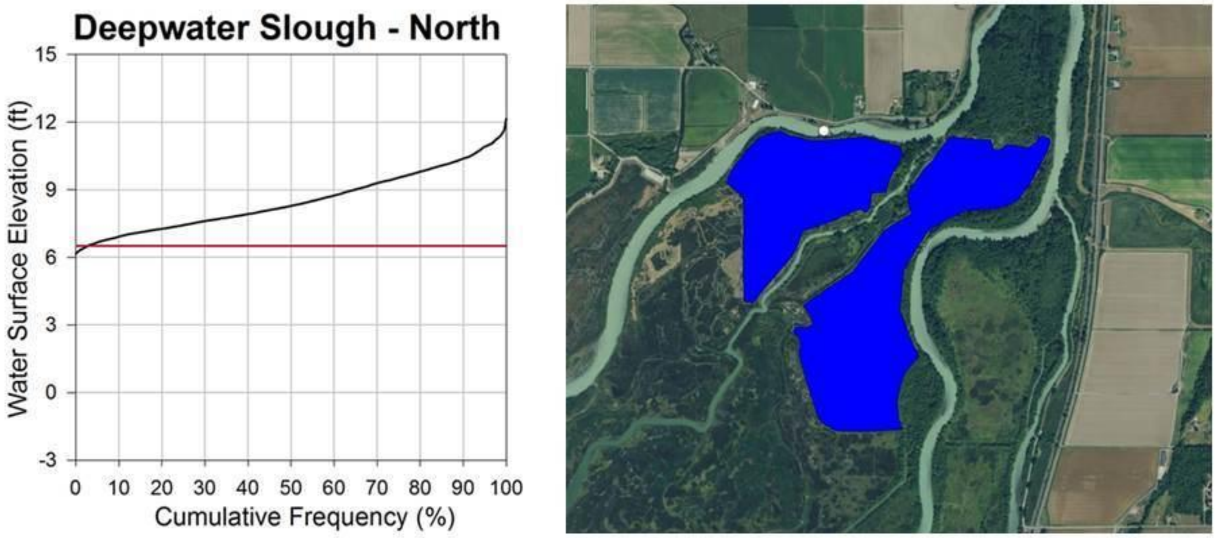


Figure J.28. Cumulative frequency plot and corresponding map for Deepwater Slough (north) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

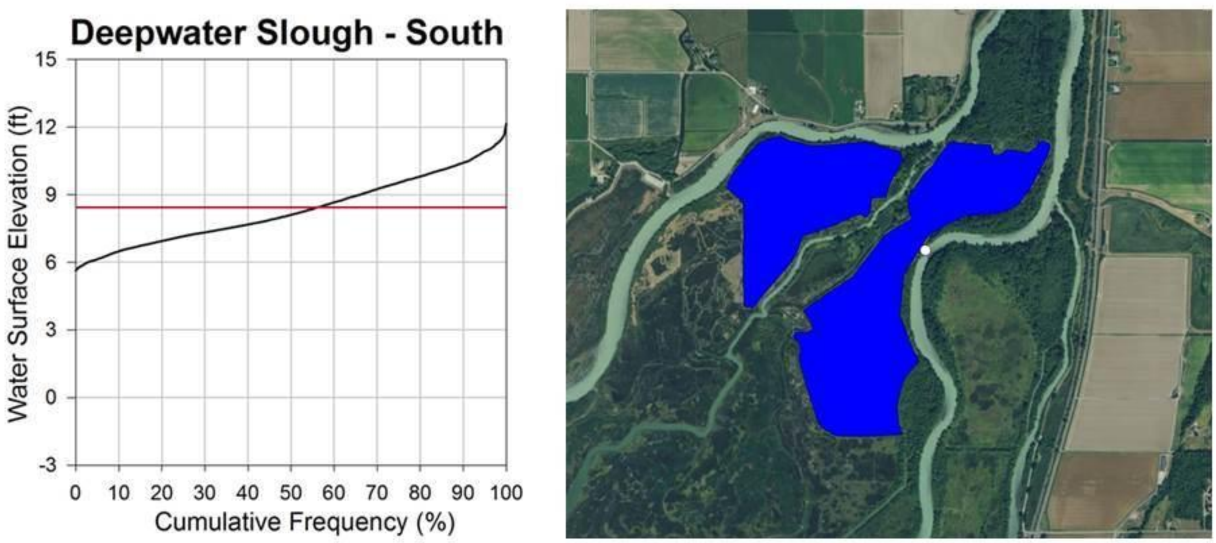


Figure J.29. Cumulative frequency plot and corresponding map for Deepwater Slough (south) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

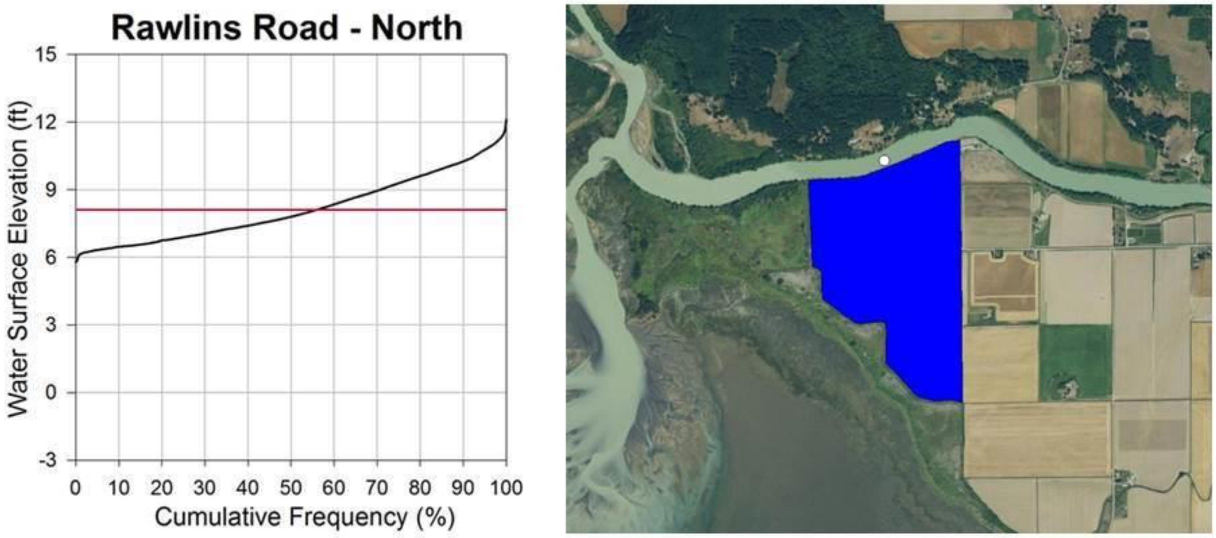


Figure J.30. Cumulative frequency plot and corresponding map for Rawlins Road (north) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

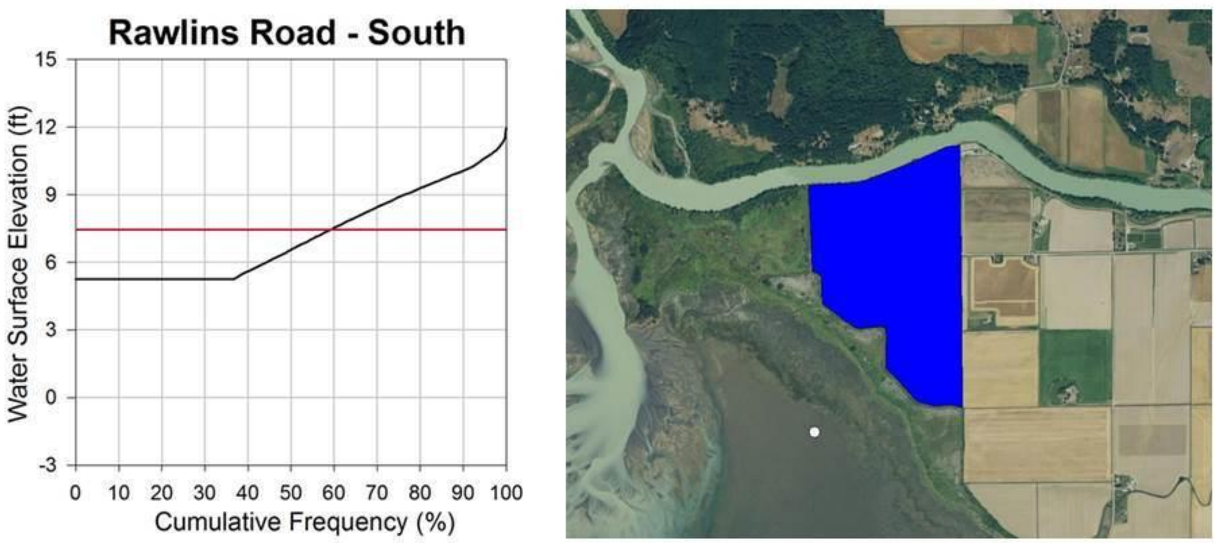


Figure J.31. Cumulative frequency plot and corresponding map for Rawlins Road (south) during the 2080 Climate Change Baseline Simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

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.

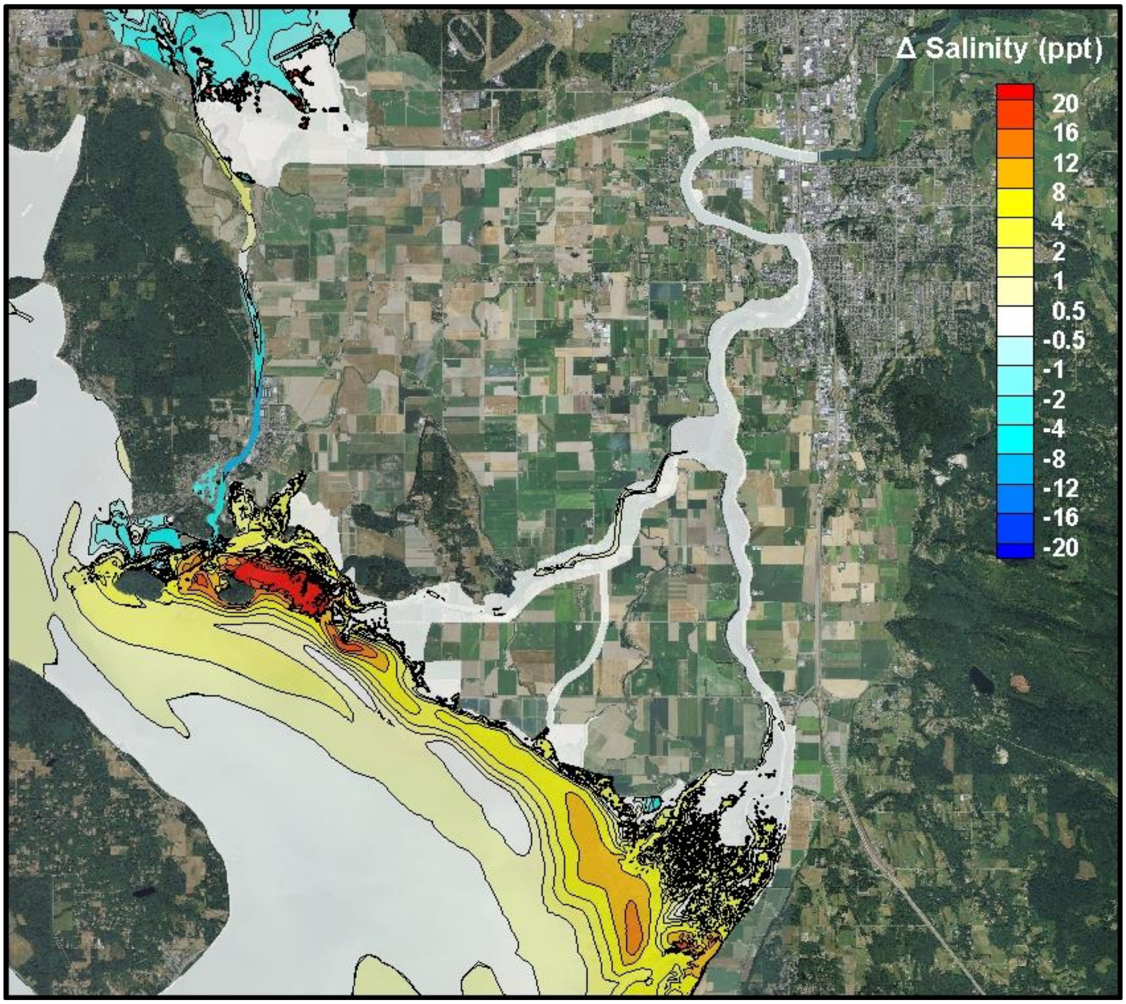


Figure J.32. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation with low flow and high tide.

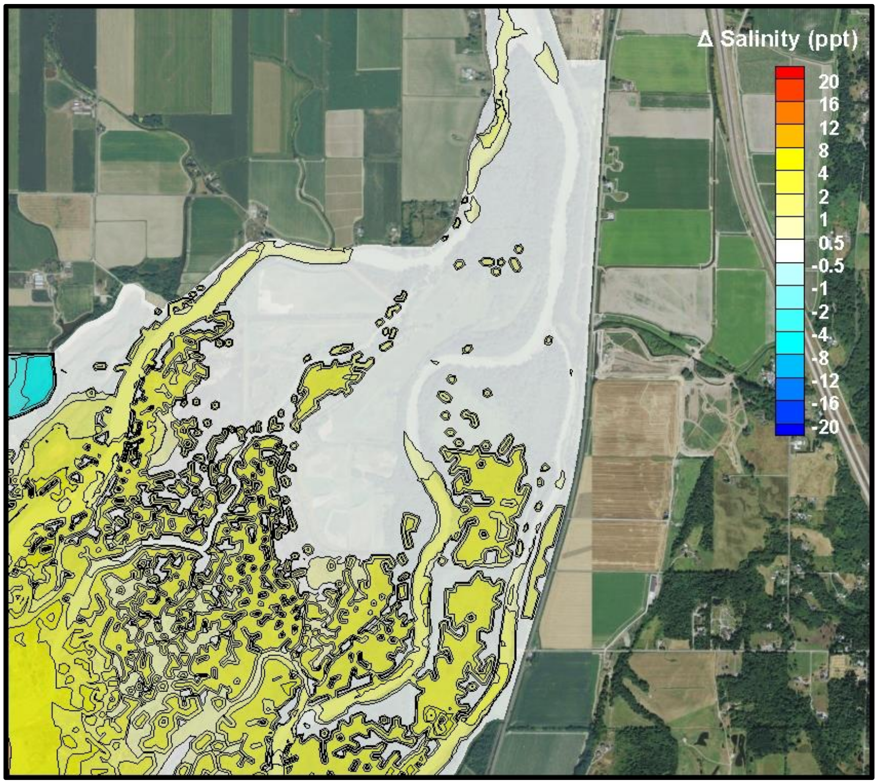


Figure J.33. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for SF Levee Setback 2, 3, 4 with low flow and high tide.

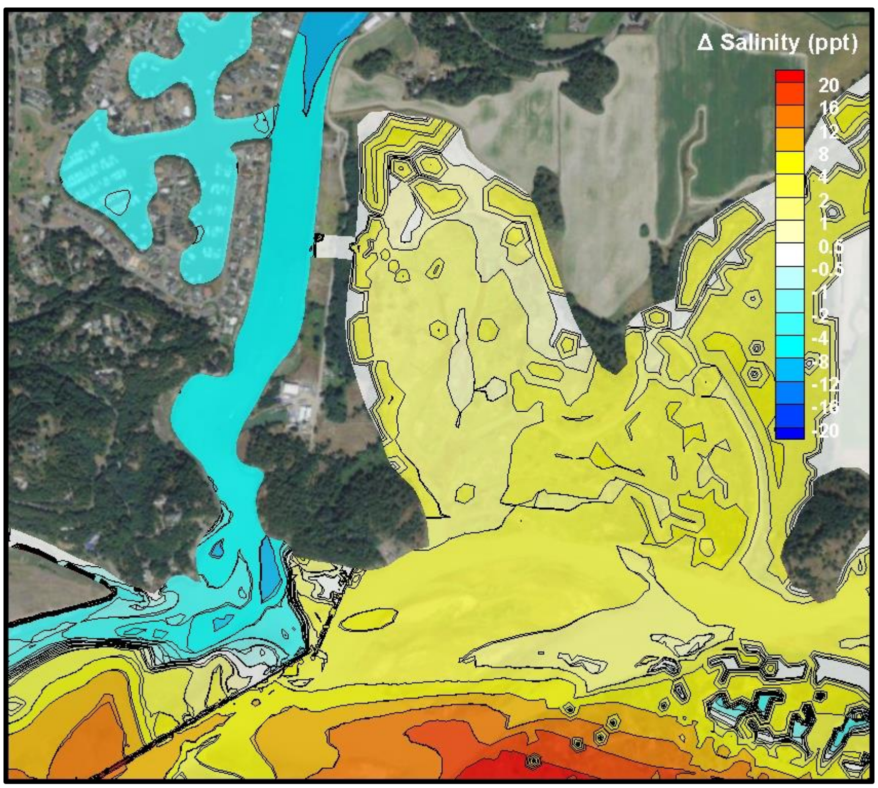


Figure J.34. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for McGlinn Causeway with low flow and high tide.

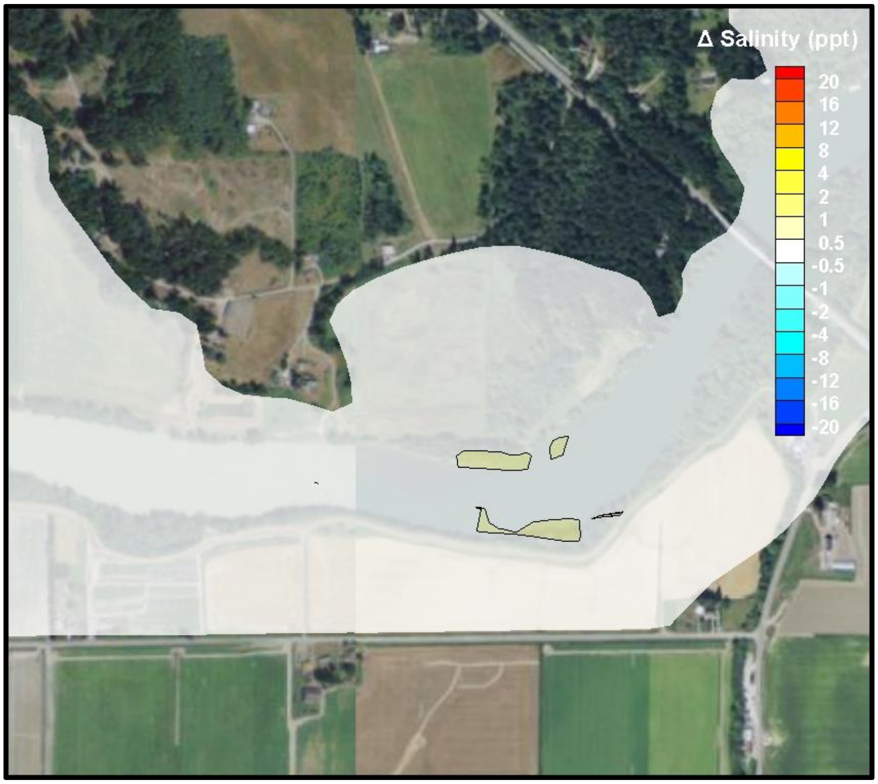


Figure J.35. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Pleasant Ridge South with low flow and high tide.

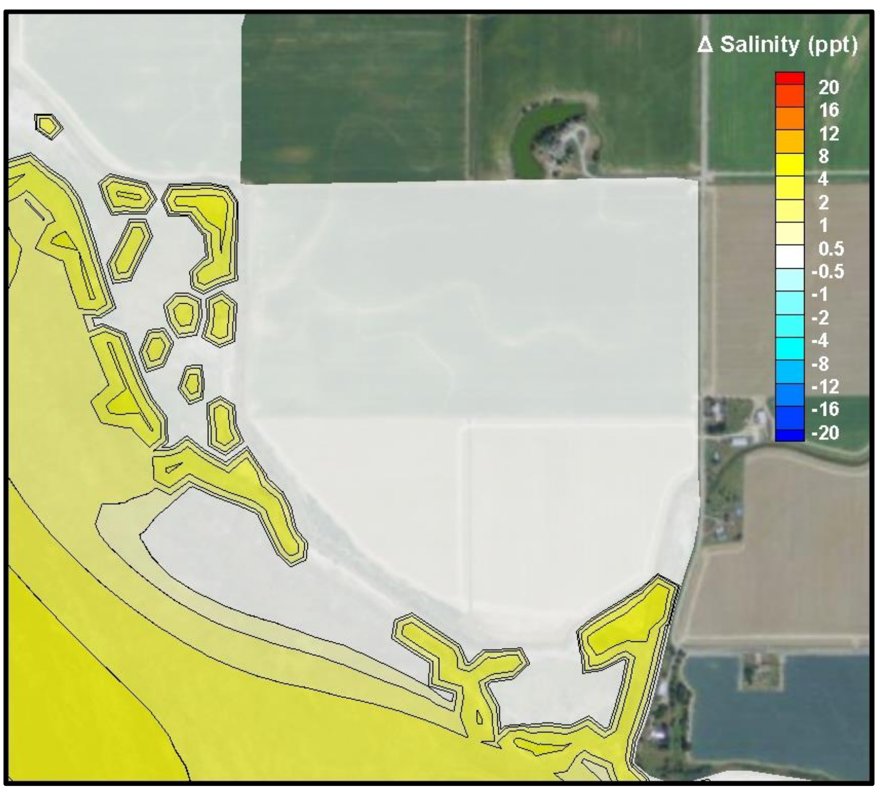


Figure J.36. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Hall Slough with low flow and high tide.

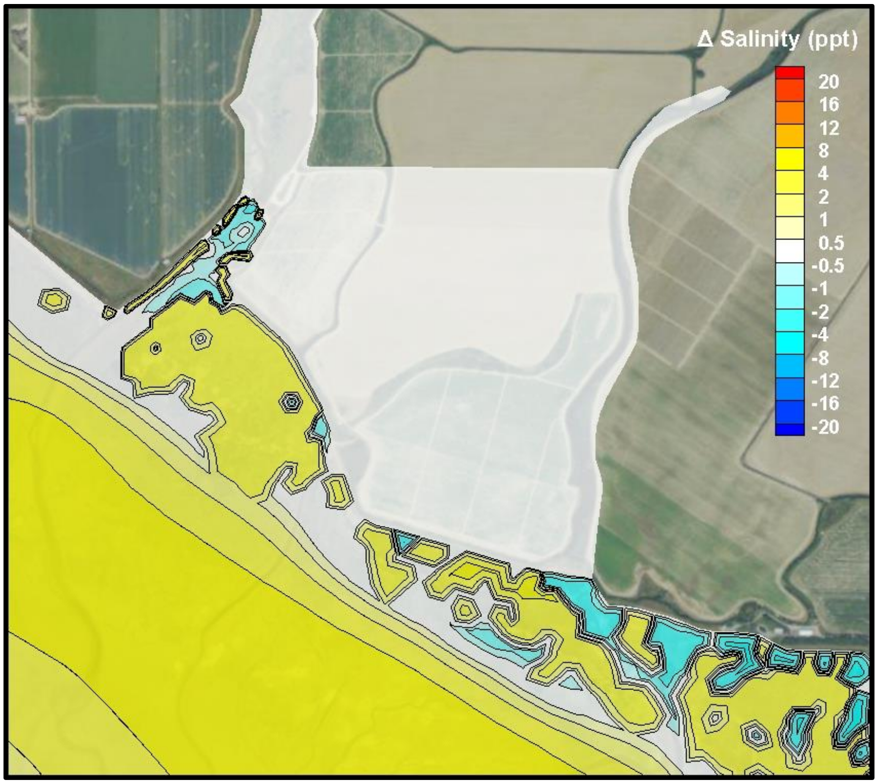


Figure J.37. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Fir Island Farm with low flow and high tide.

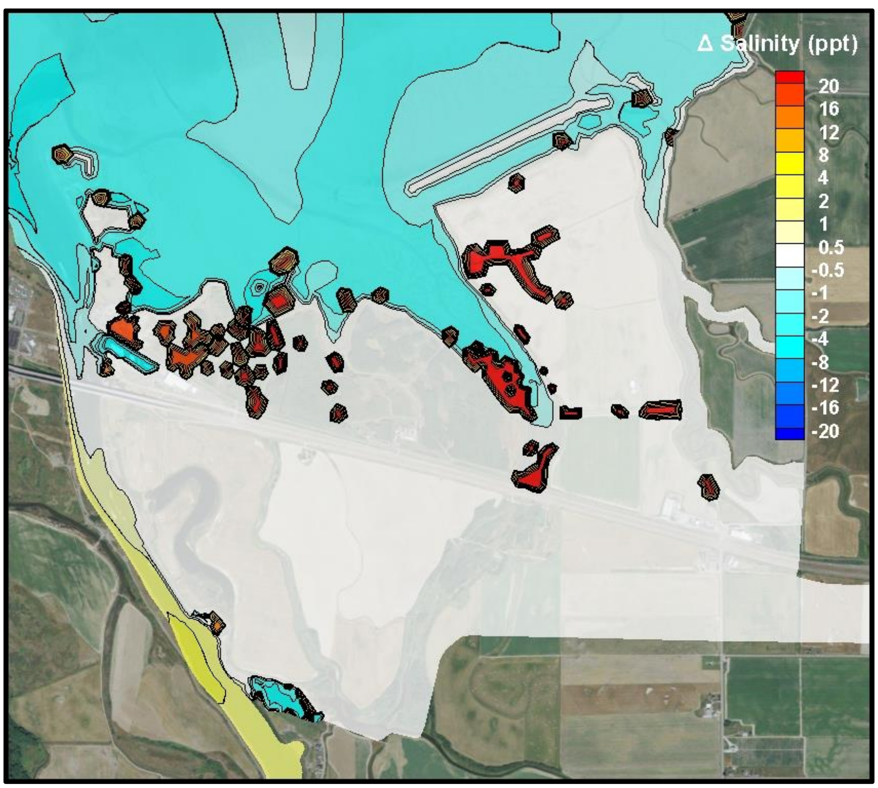


Figure J.38. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Telegraph Slough Full with low flow and high tide.

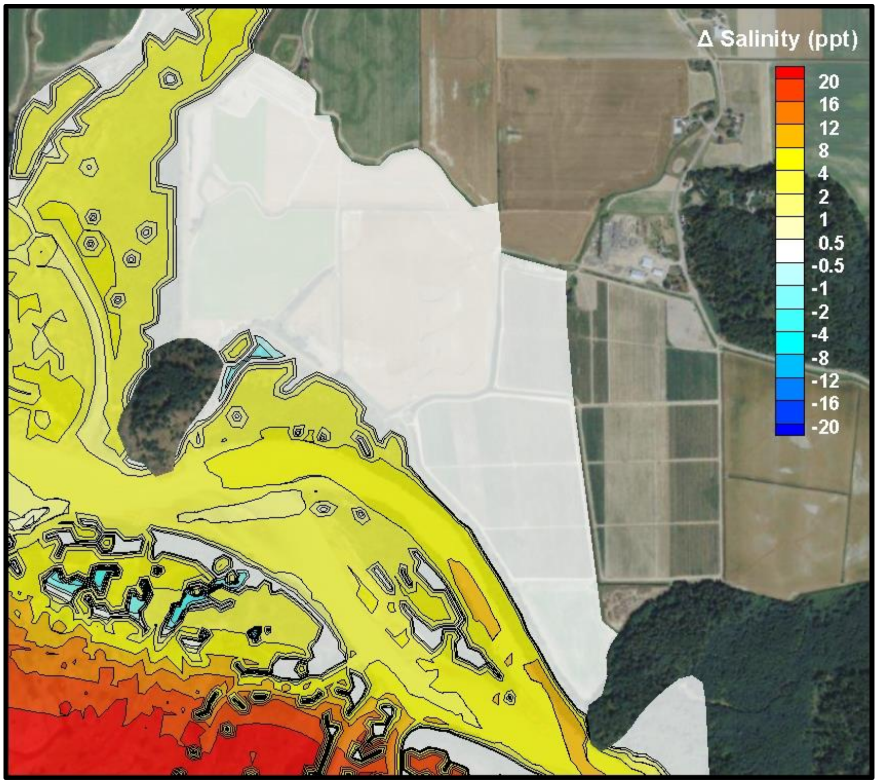


Figure J.39. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Sullivan Hacienda with low flow and high tide.

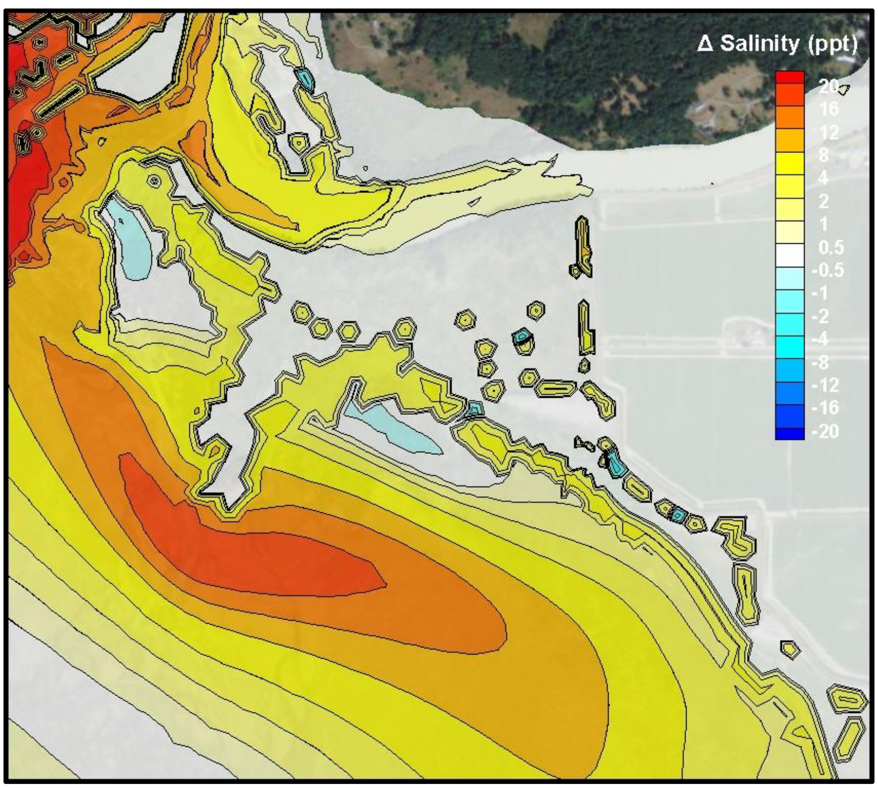


Figure J.40. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Rawlins Distributary with low flow and high tide.

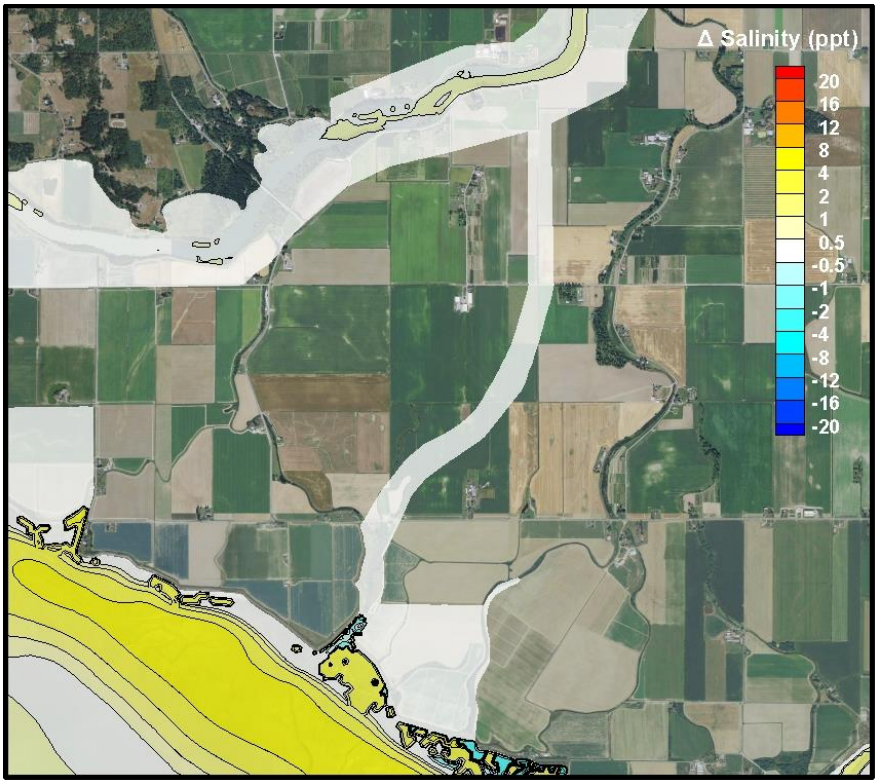


Figure J.41. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Cross Island Connector with low flow and high tide.

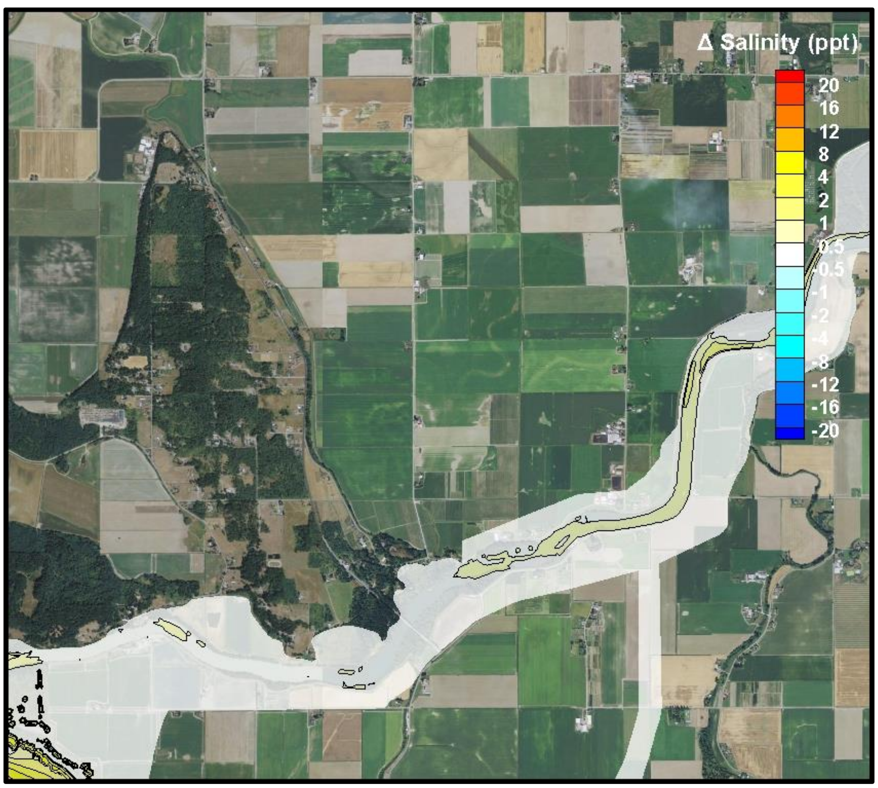


Figure J.42. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for NF Levee Setback C with low flow and high tide.

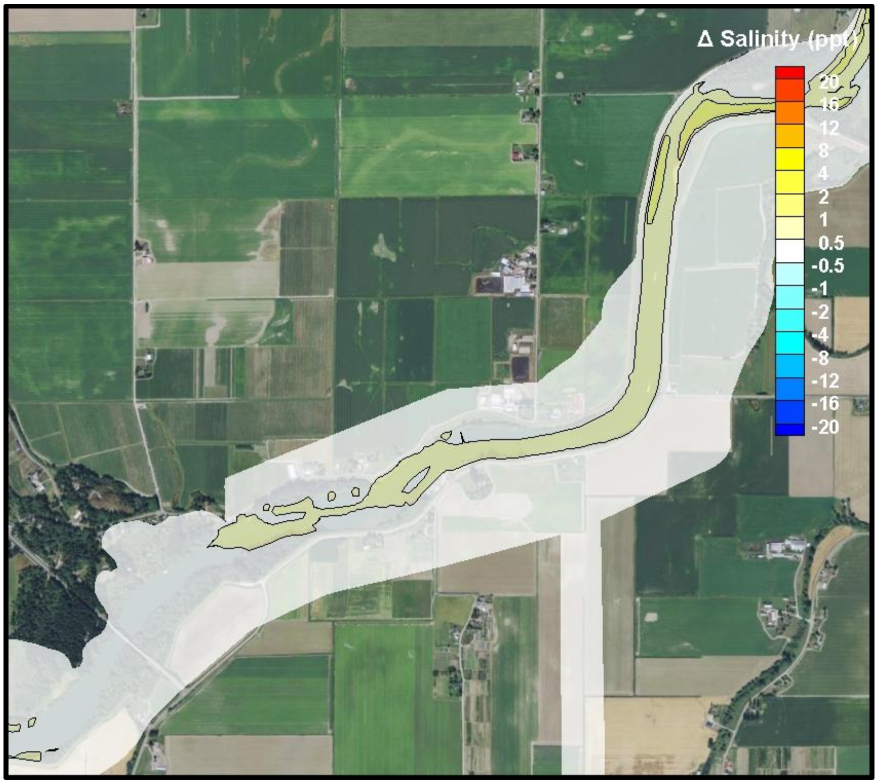


Figure J.43. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for NF Right Bank Levee Setback with low flow and high tide.

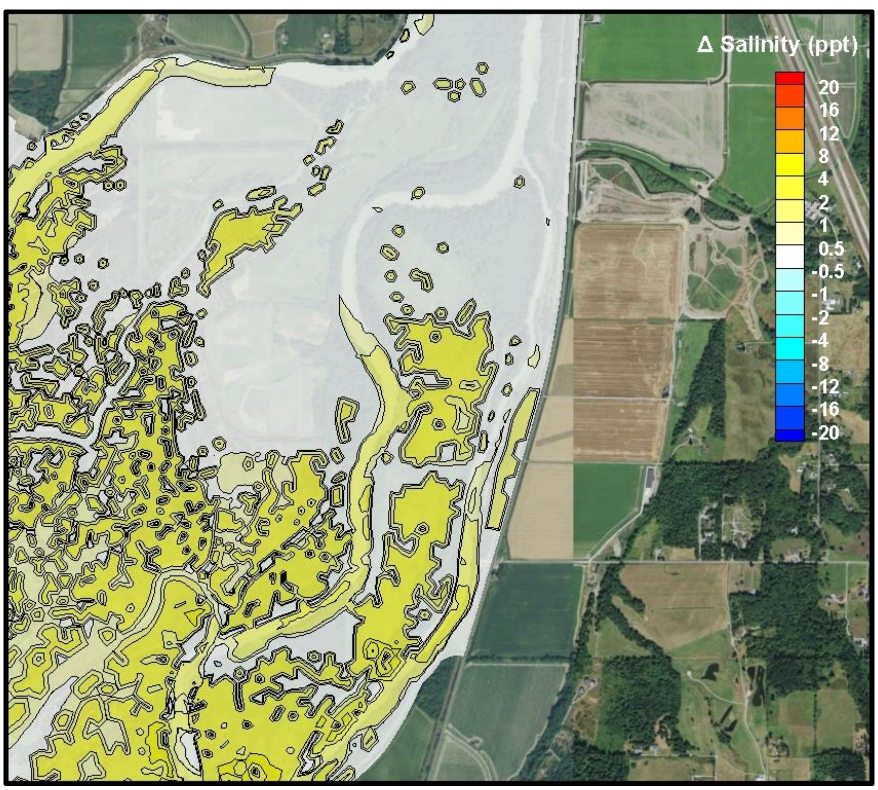


Figure J.44. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Milltown Island with low flow and high tide.

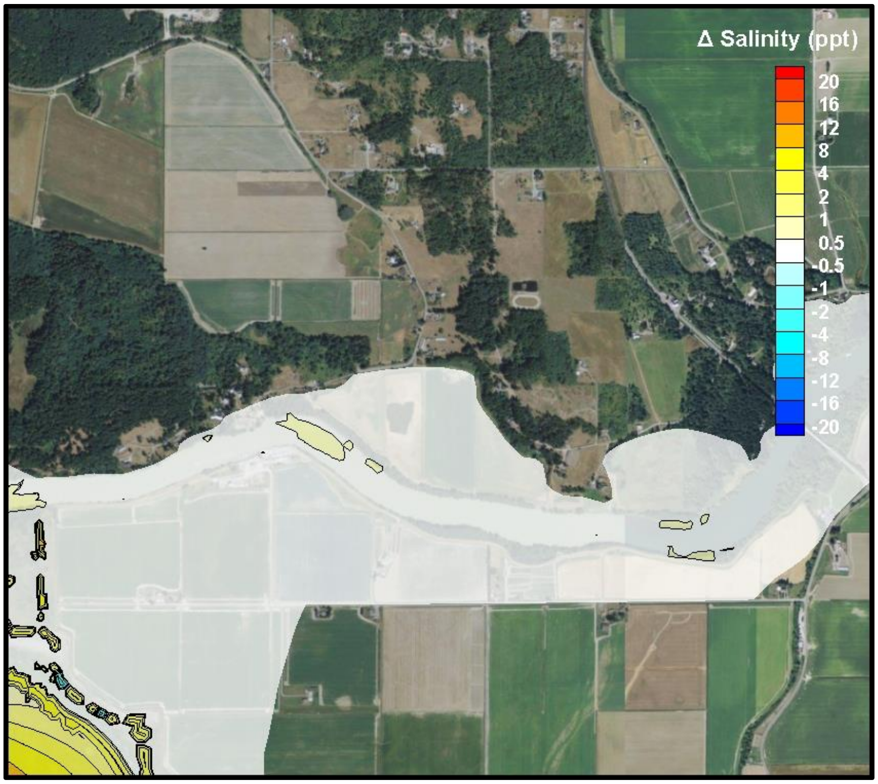


Figure J.45. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Thein Farm with low flow and high tide.

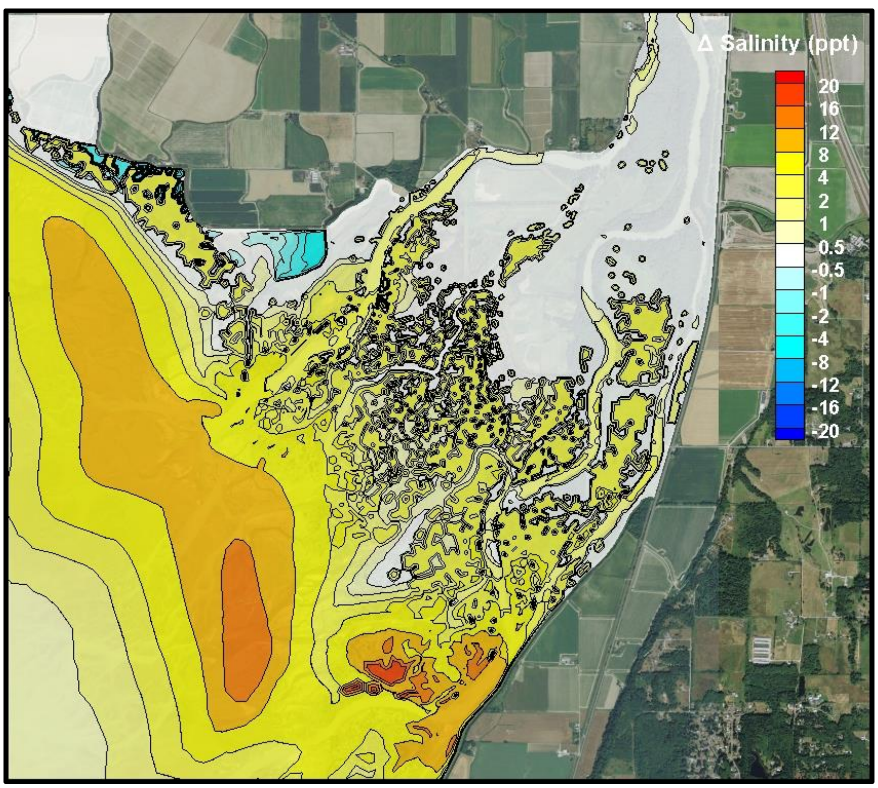


Figure J.46. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Deepwater Slough Phase 2 with low flow and high tide.

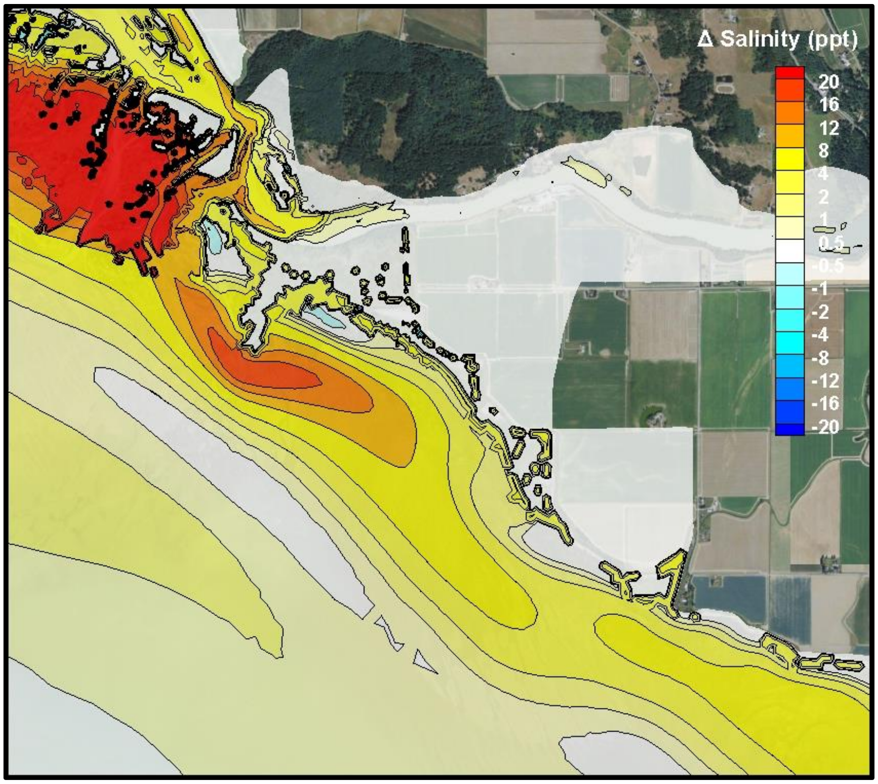


Figure J.47. Contour map of change in salinity from the Baseline to Climate Change Baseline simulation for Rawlins Road with low flow and high tide.

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).

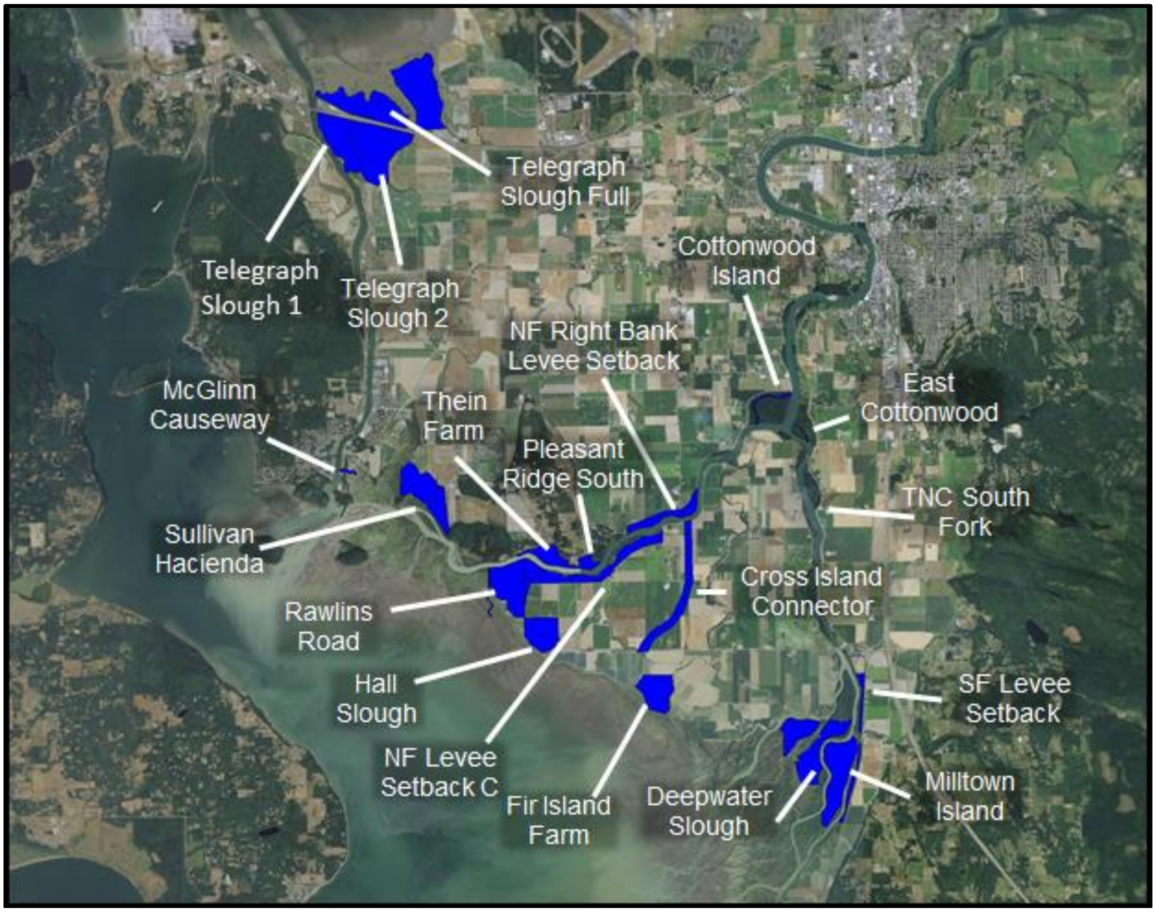


Figure K.1. A map of project area in the Climate Change with Projects simulation.

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.

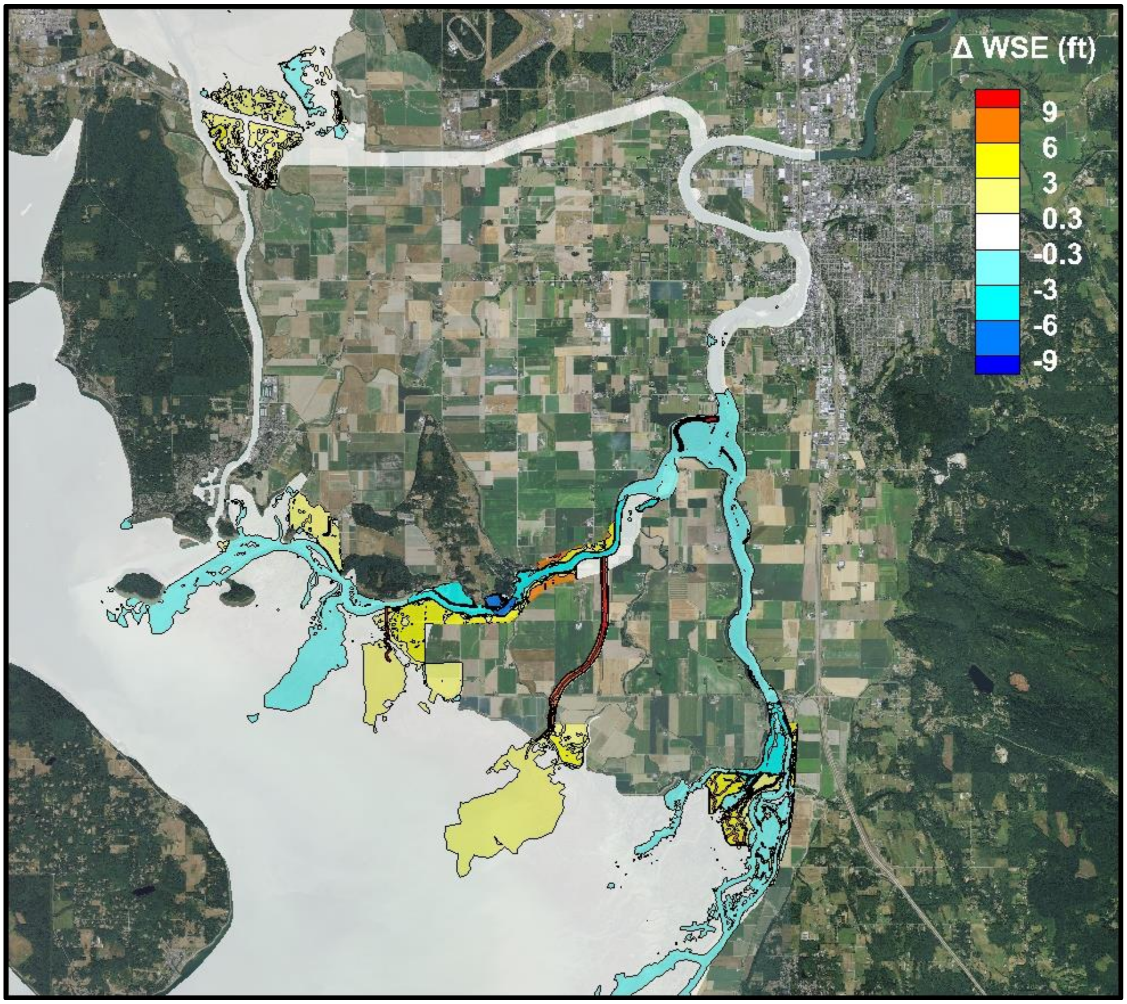


Figure K.2. Contour map of change in WSE for future Q2 and future low tide for the full basin, comparing Climate Change Baseline and Climate Change Projects simulations.

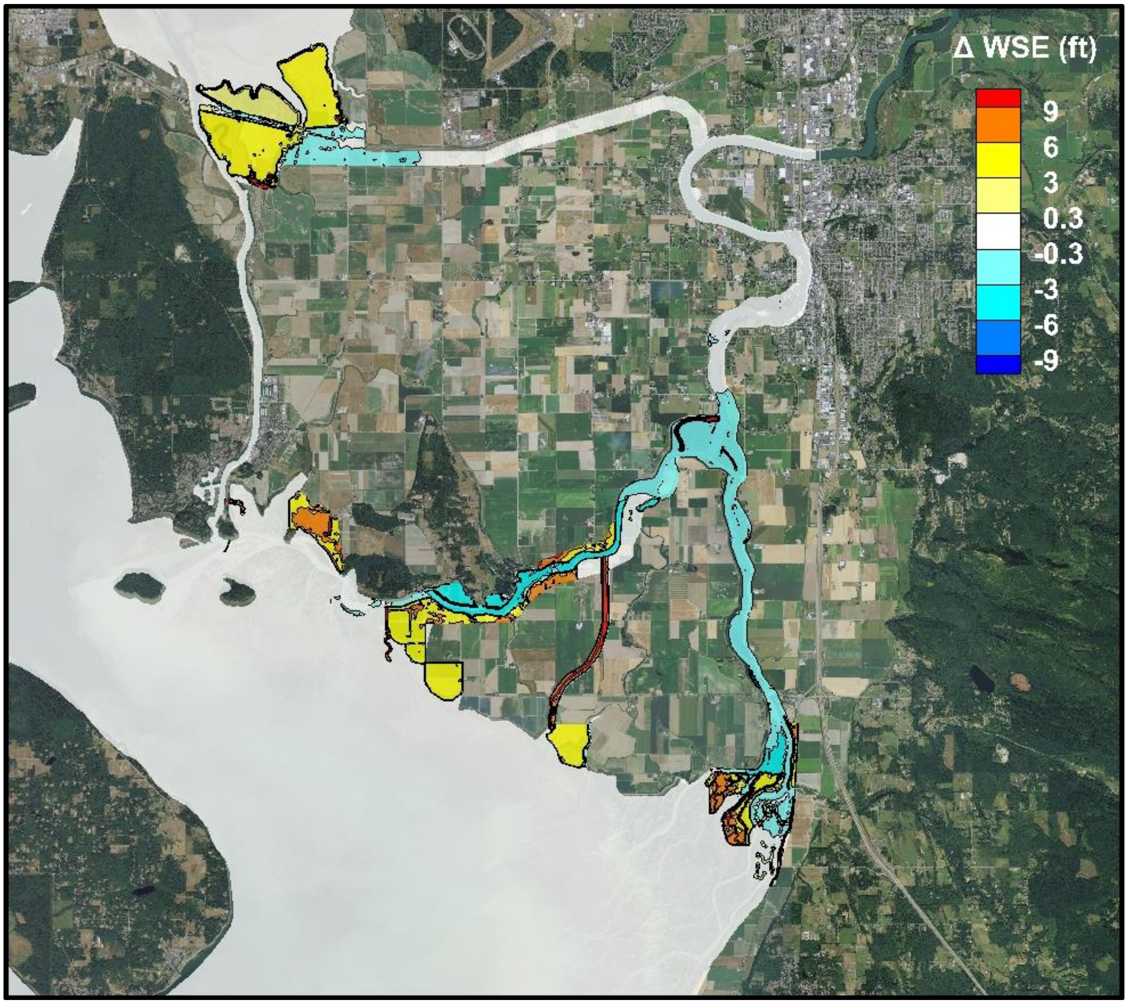


Figure K.3. Contour map of change in WSE for a future Q2 and future high tide for the full basin, comparing Climate Change Baseline and Climate Change Projects simulations.

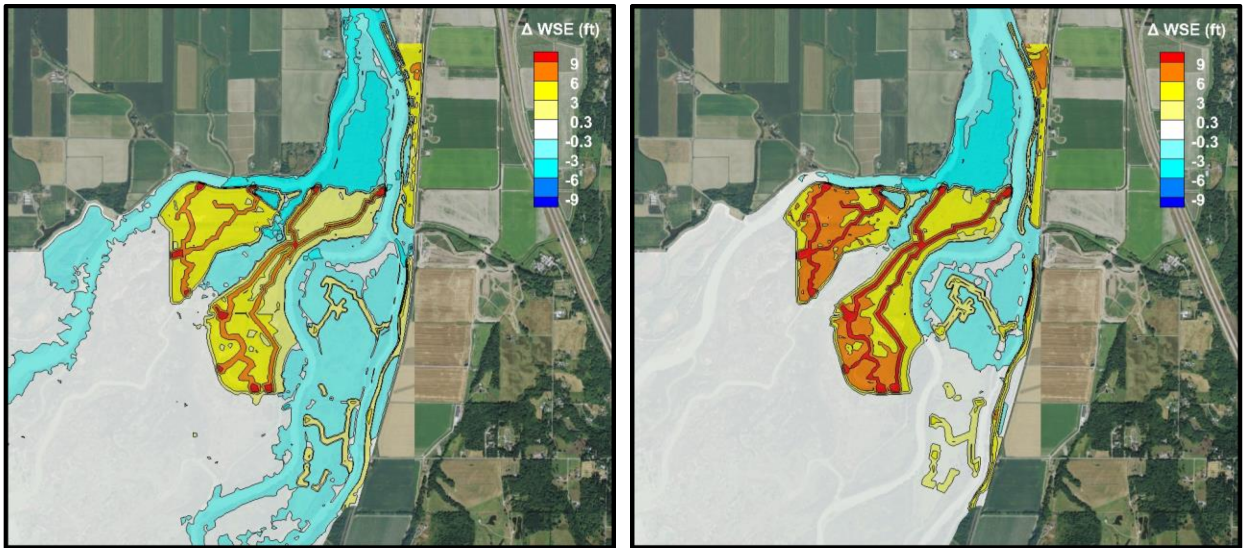


Figure K.4. Contour maps showing the change in WSE for SF Levee Setbacks 2, 3, and 4 with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

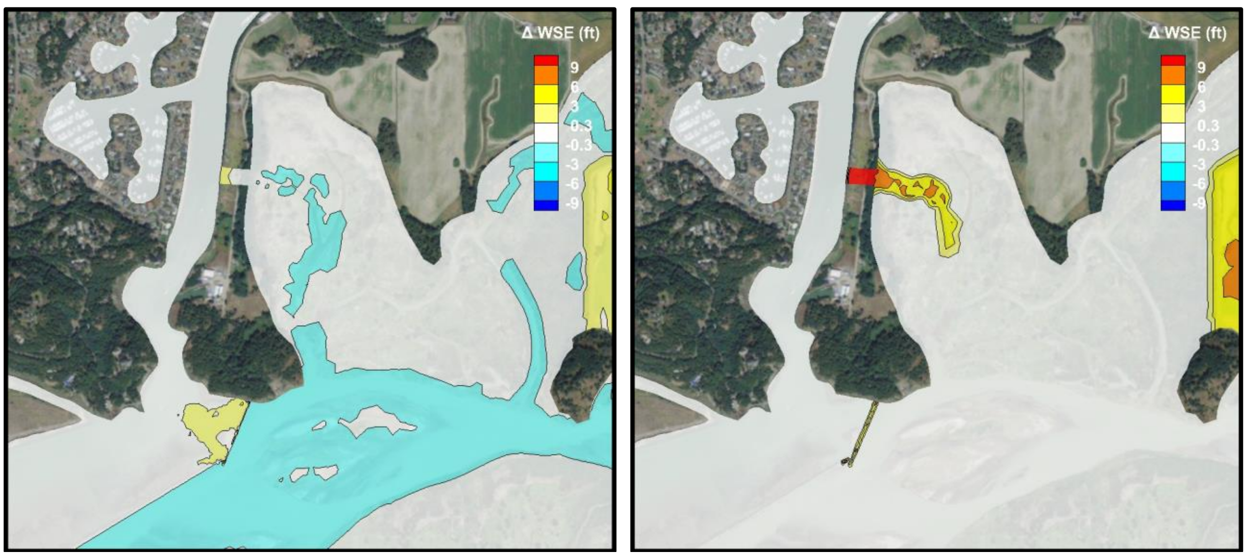


Figure K.5. Contour maps showing the change in WSE for McGlinn Causeway with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

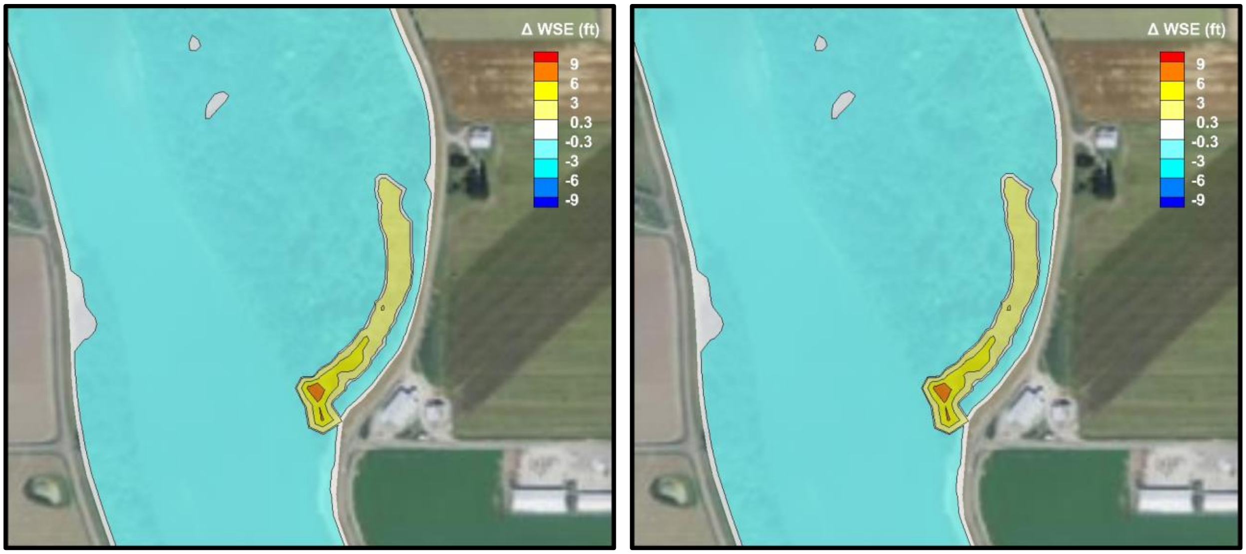


Figure K.6. Contour maps showing the change in WSE for TNC South Fork with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

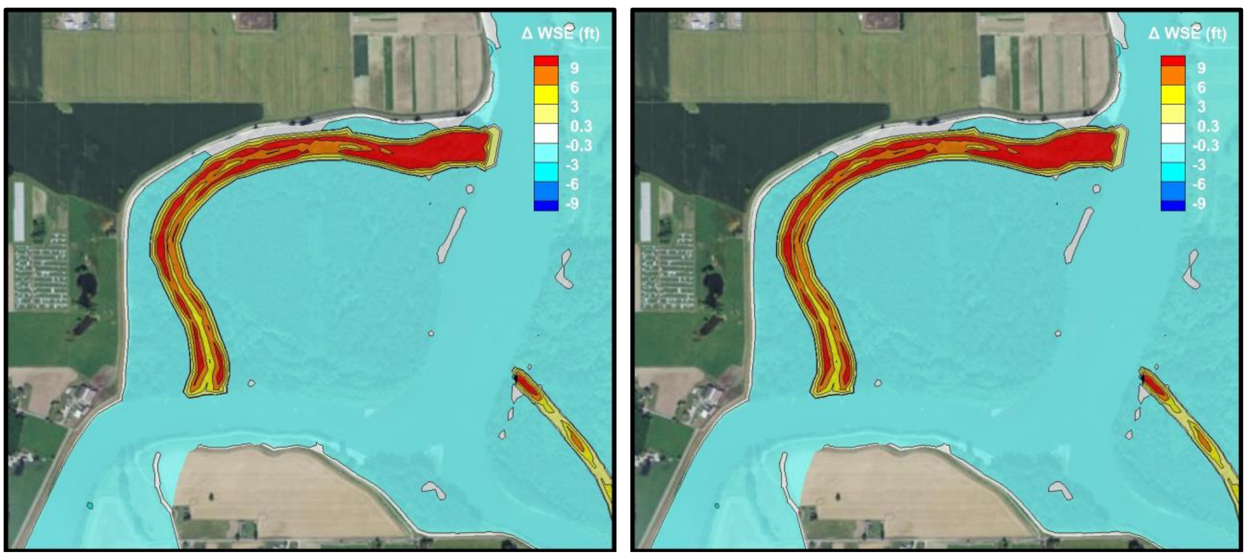


Figure K.7. Contour maps showing the change in WSE for Cottonwood Island with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

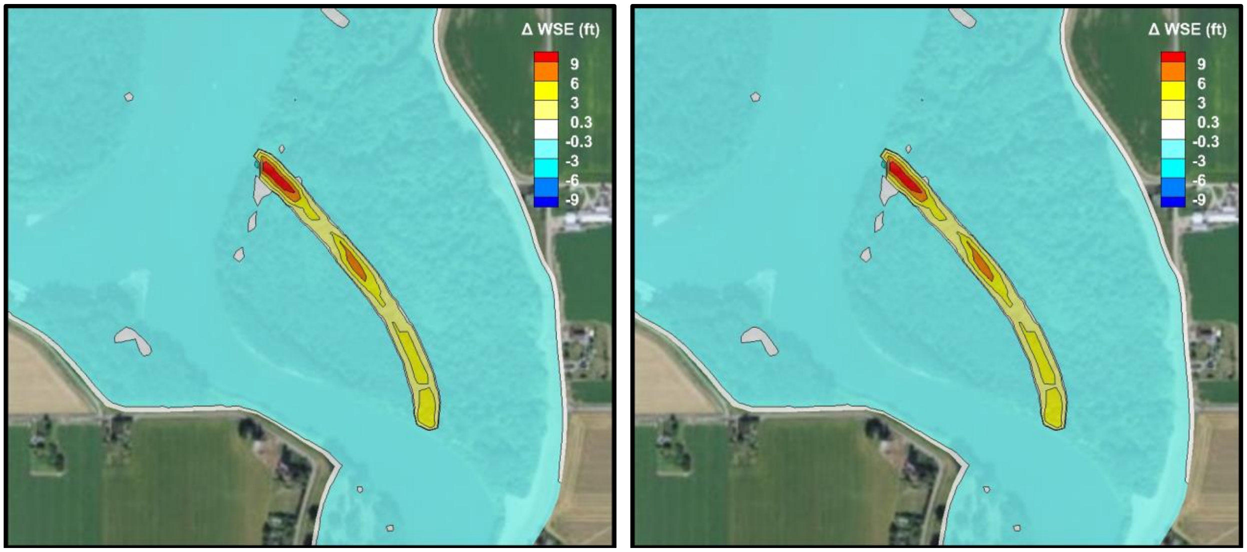


Figure K.8. Contour maps showing the change in WSE for East Cottonwood with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

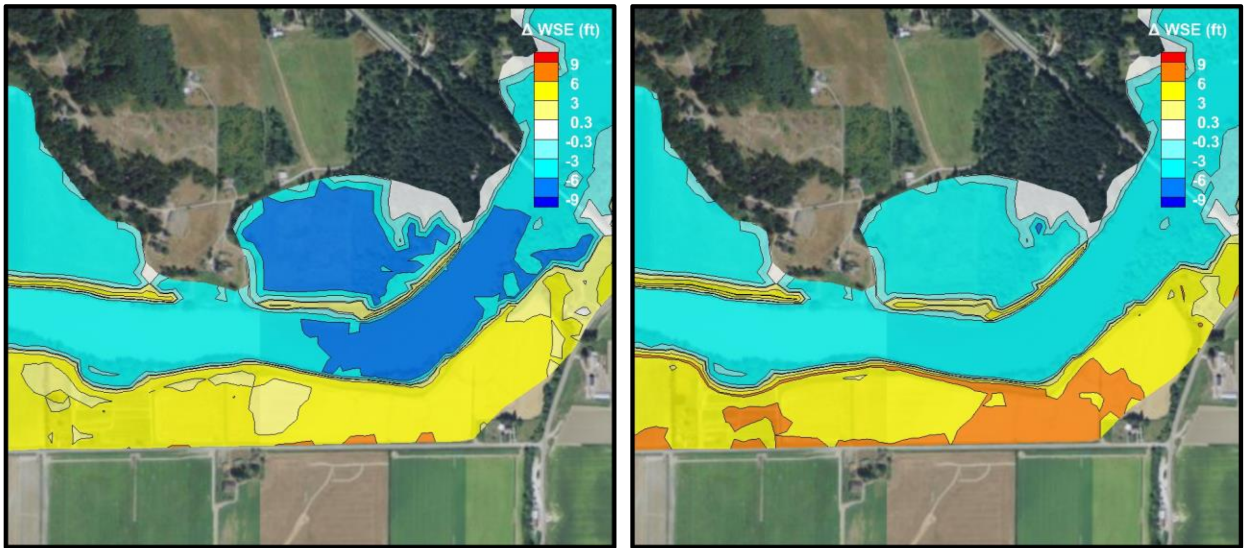


Figure K.9. Contour maps showing the change in WSE for Pleasant Ridge South with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations. A decrease in WSE is caused by water overtopping the dikes during future baseline and flowing through the upstream Cross Island Connector project during restored conditions.

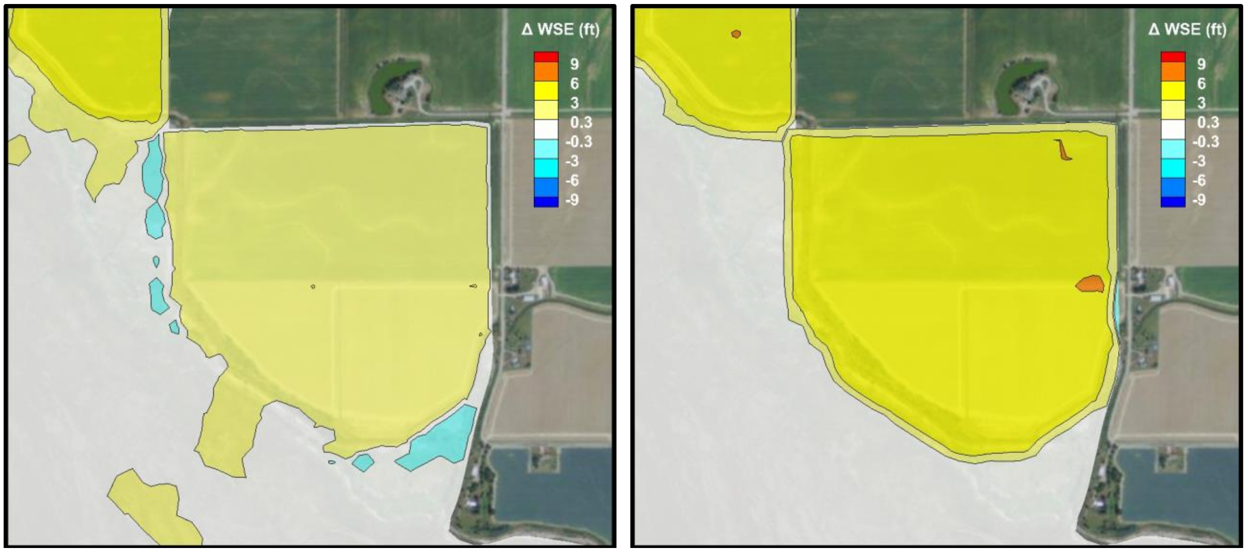


Figure K.10. Contour maps showing the change in WSE for Hall Slough with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations. Small blue reduction areas are caused by the removal of the dike, because the removed dikes acted as ramps to create drainage before.

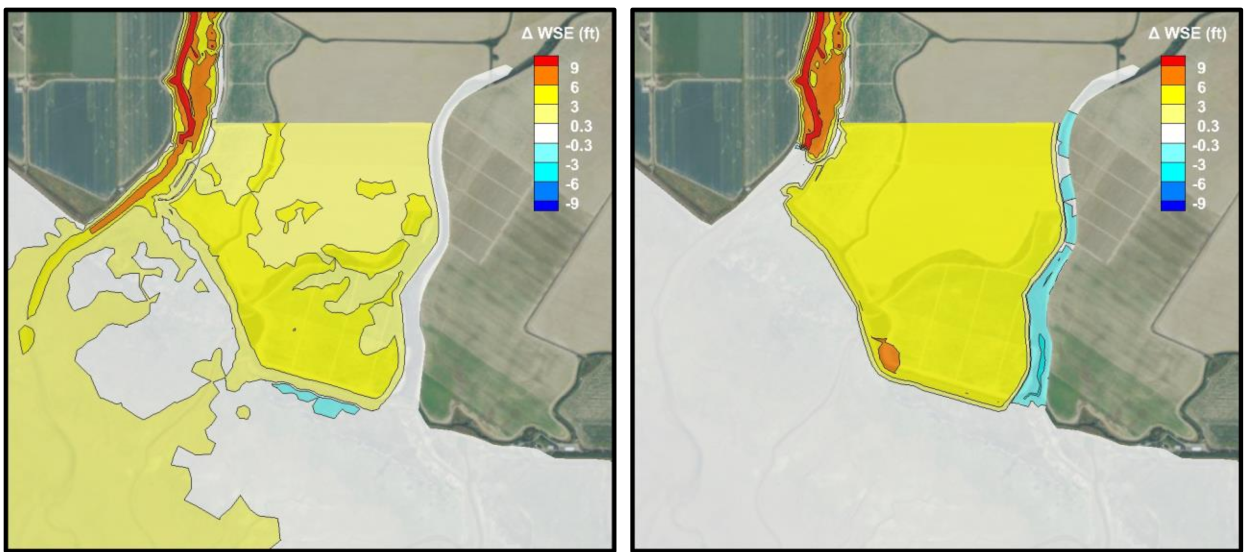


Figure K.11. Contour maps showing the change in WSE for Fir Island Farm with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

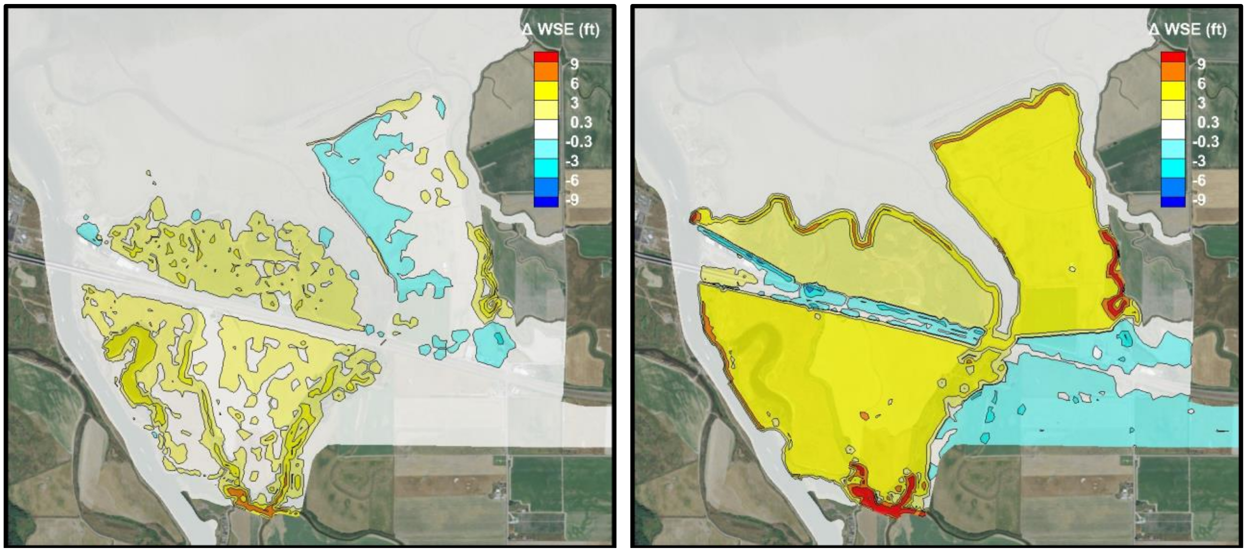


Figure K.12. Contour maps showing the change in WSE for Telegraph Slough Full with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations. Increases in WSE during low tide.

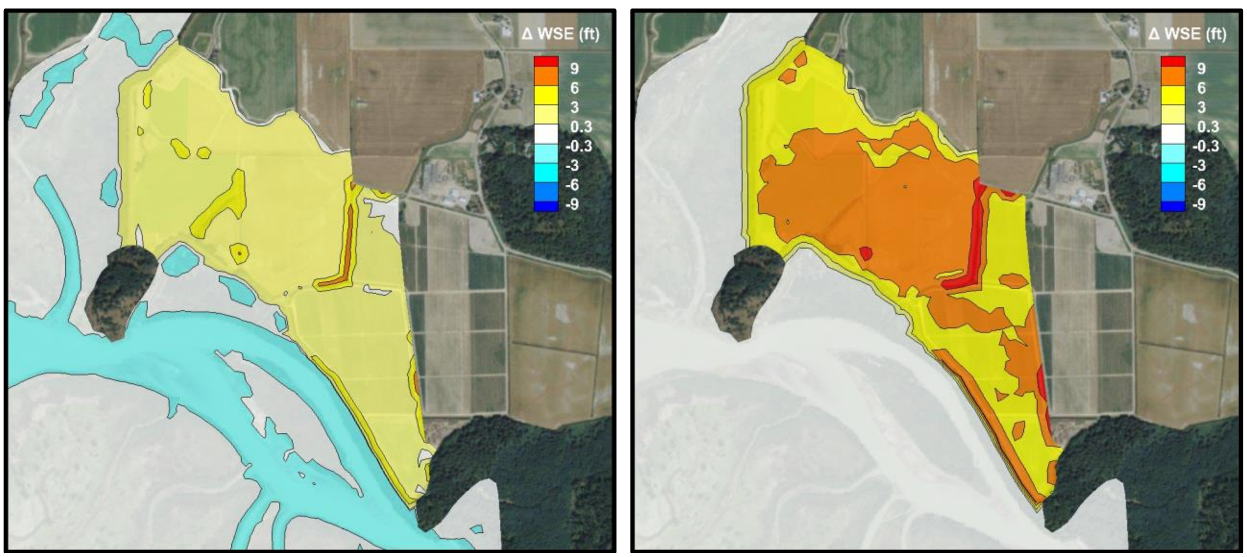


Figure K.13. Contour maps showing the change in WSE for Sullivan Hacienda with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

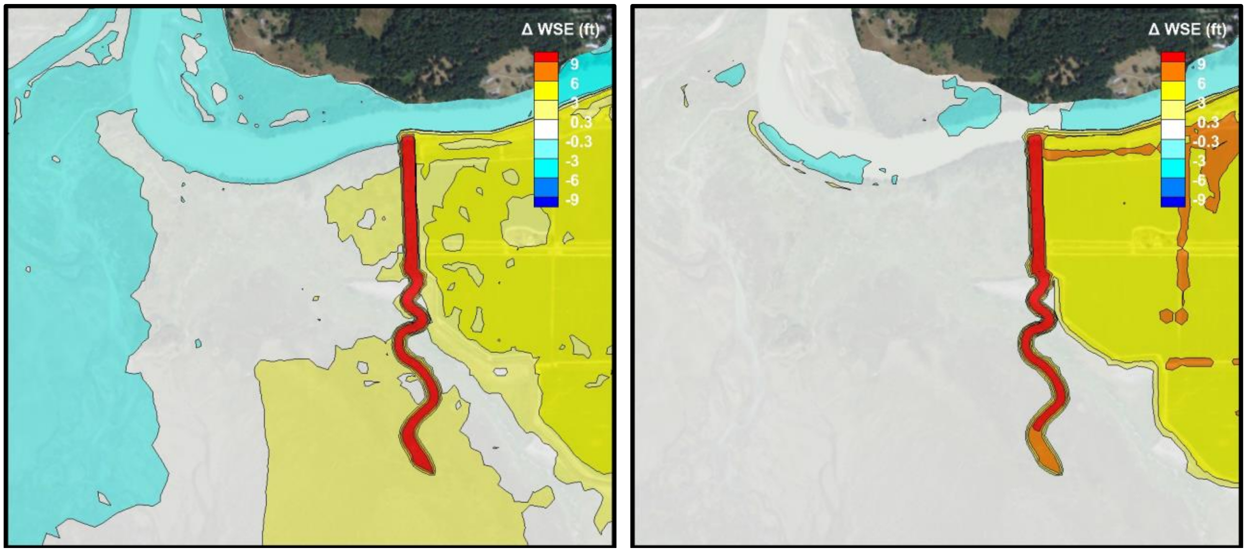


Figure K.14. Contour maps showing the change in WSE for Rawlins Road Distributary with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

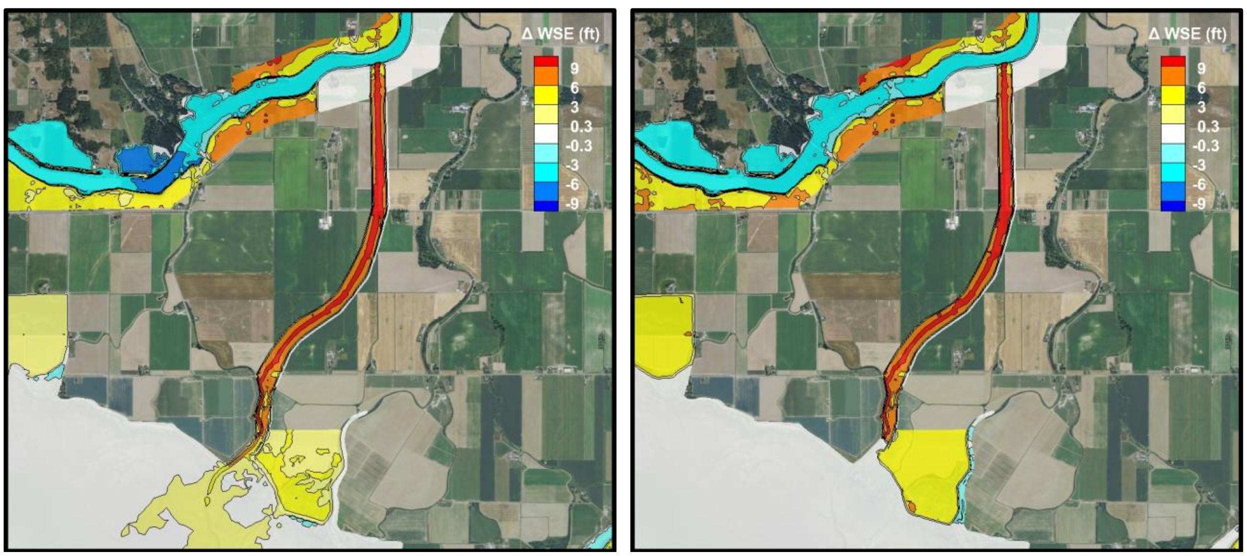


Figure K.15. Contour maps showing the change in WSE for Cross Island Connector with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

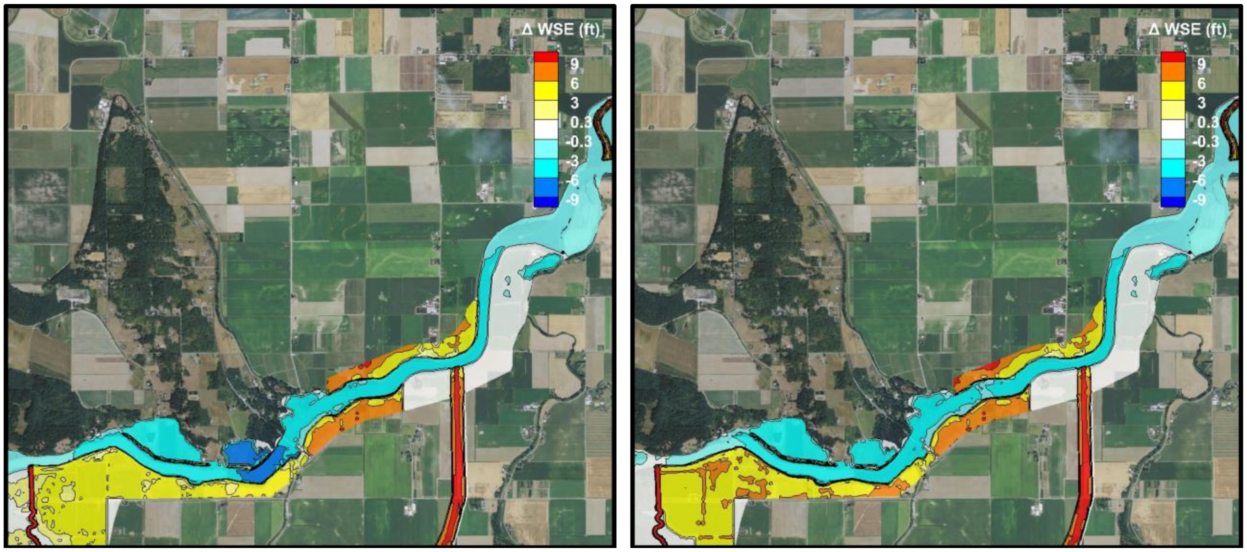


Figure K.16. Contour maps showing the change in WSE for NF Levee Setback C with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

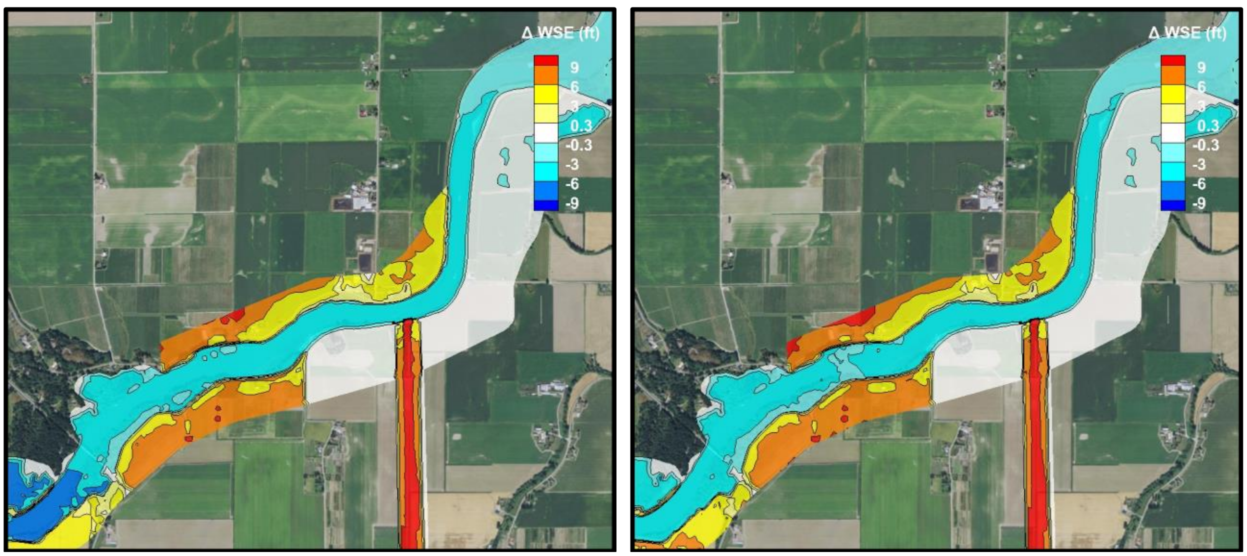


Figure K.17. Contour maps showing the change in WSE for NF Right Bank Levee Setback with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

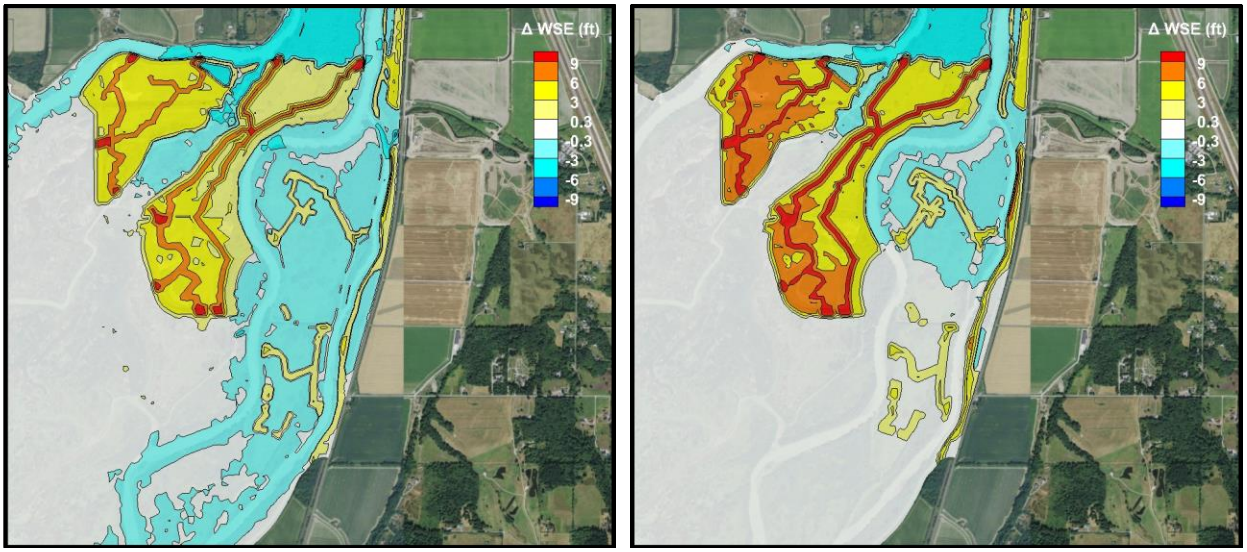


Figure K.18. Contour maps showing the change in WSE for Milltown Island with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

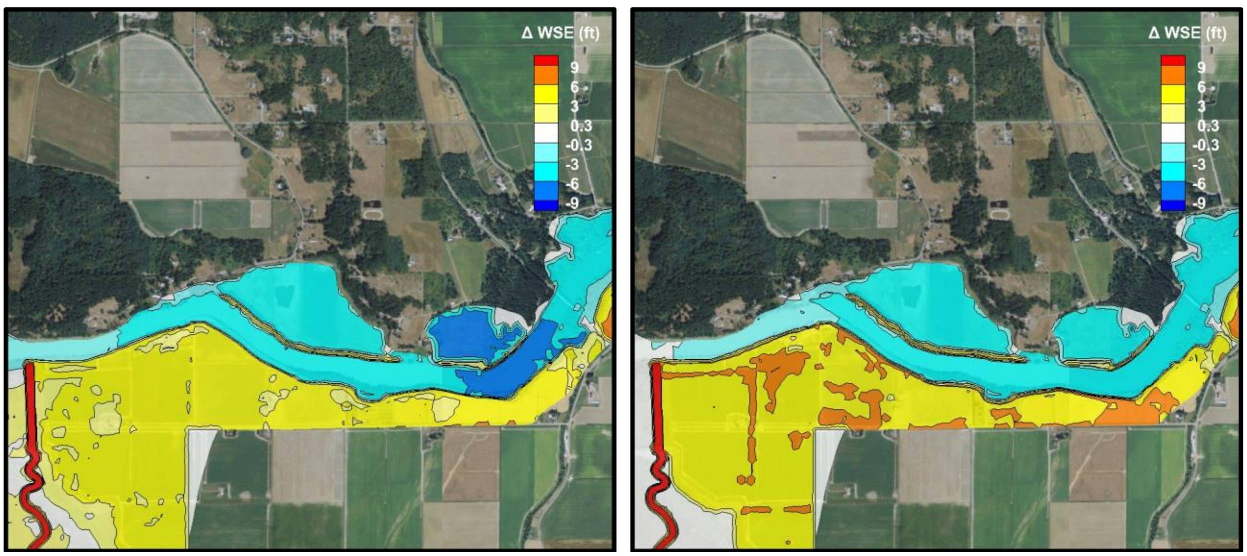


Figure K.19. Contour maps showing the change in WSE for Thein Farm with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations. A decrease in WSE is caused by water overtopping the dikes during future baseline and flowing through the upstream Cross Island Connector project during restored conditions.

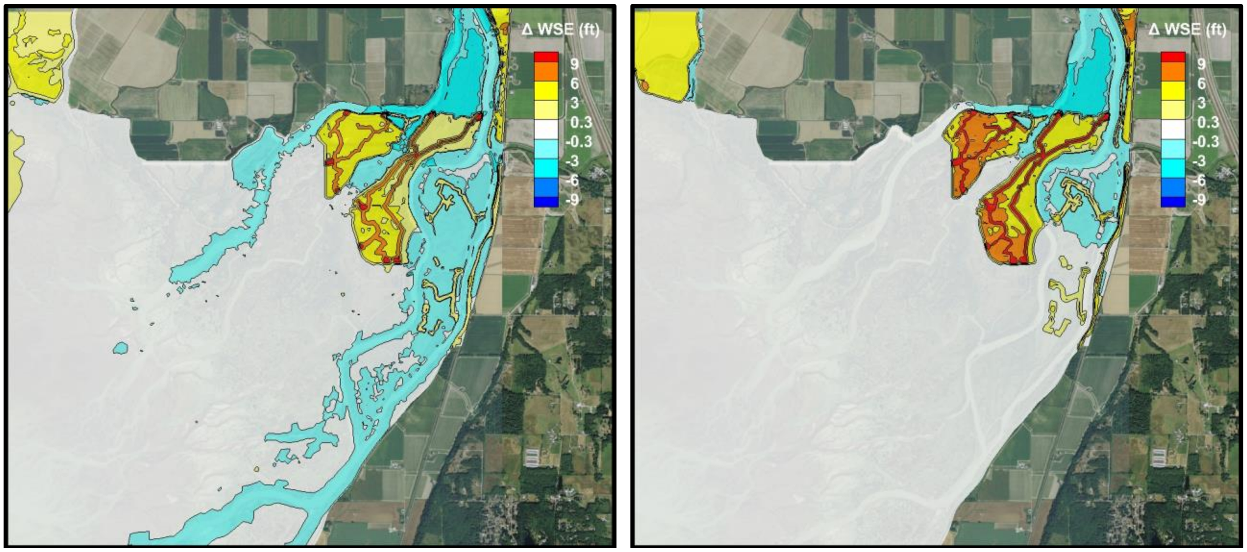


Figure K.20. Contour maps showing the change in WSE for Deepwater Slough Phase 2 with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

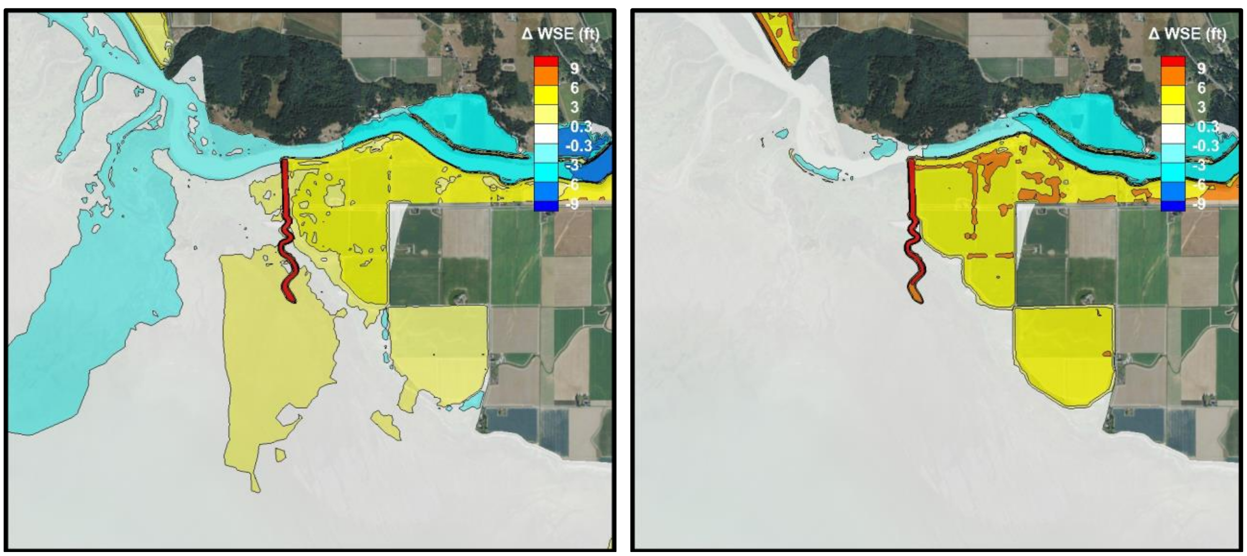


Figure K.21. Contour maps showing the change in WSE for Rawlins Road with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right), comparing Climate Change Baseline and Climate Change Projects simulations.

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.

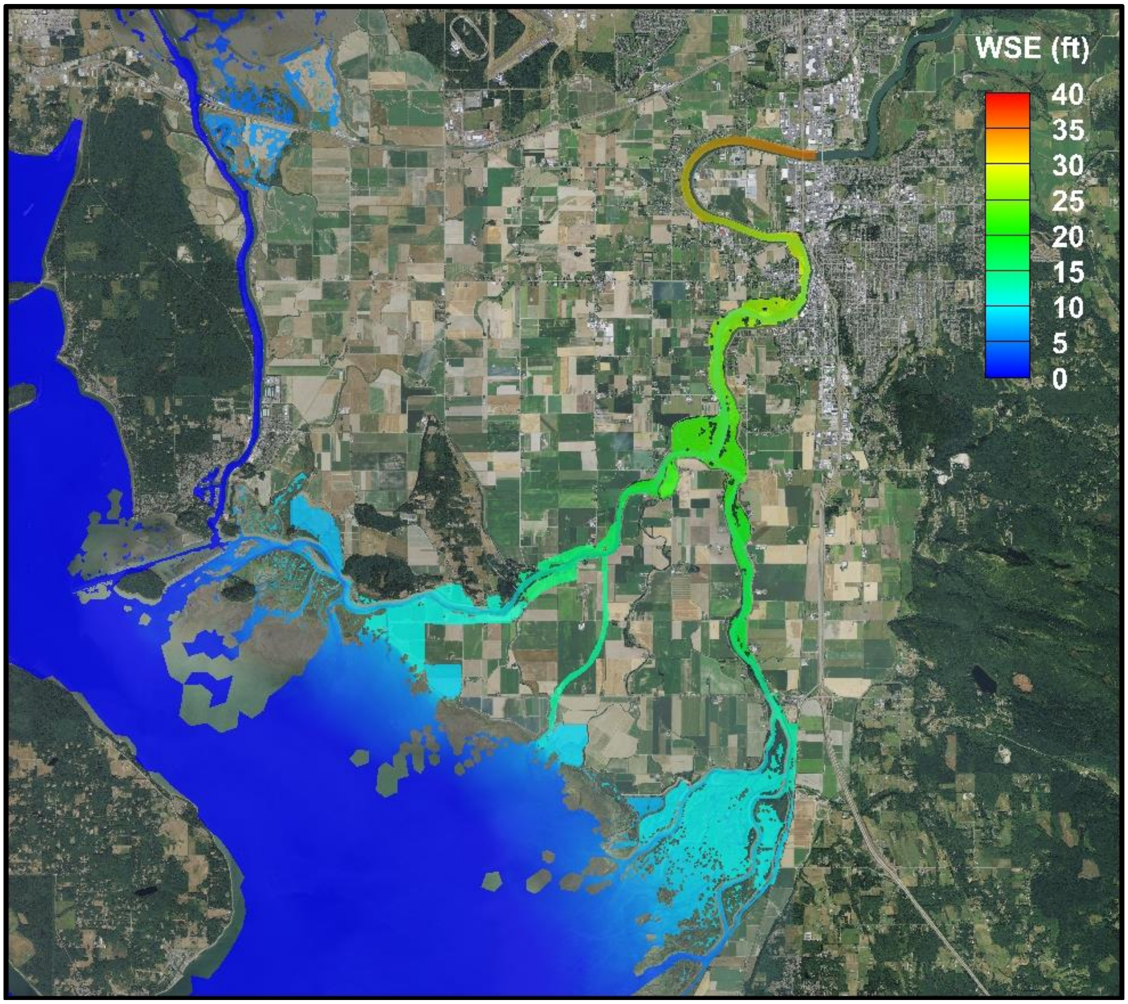


Figure K.22. Contour map of water surface elevation for the full domain during the 2080 Climate Change with Projects simulation with future Q2 flow and future low spring tide.

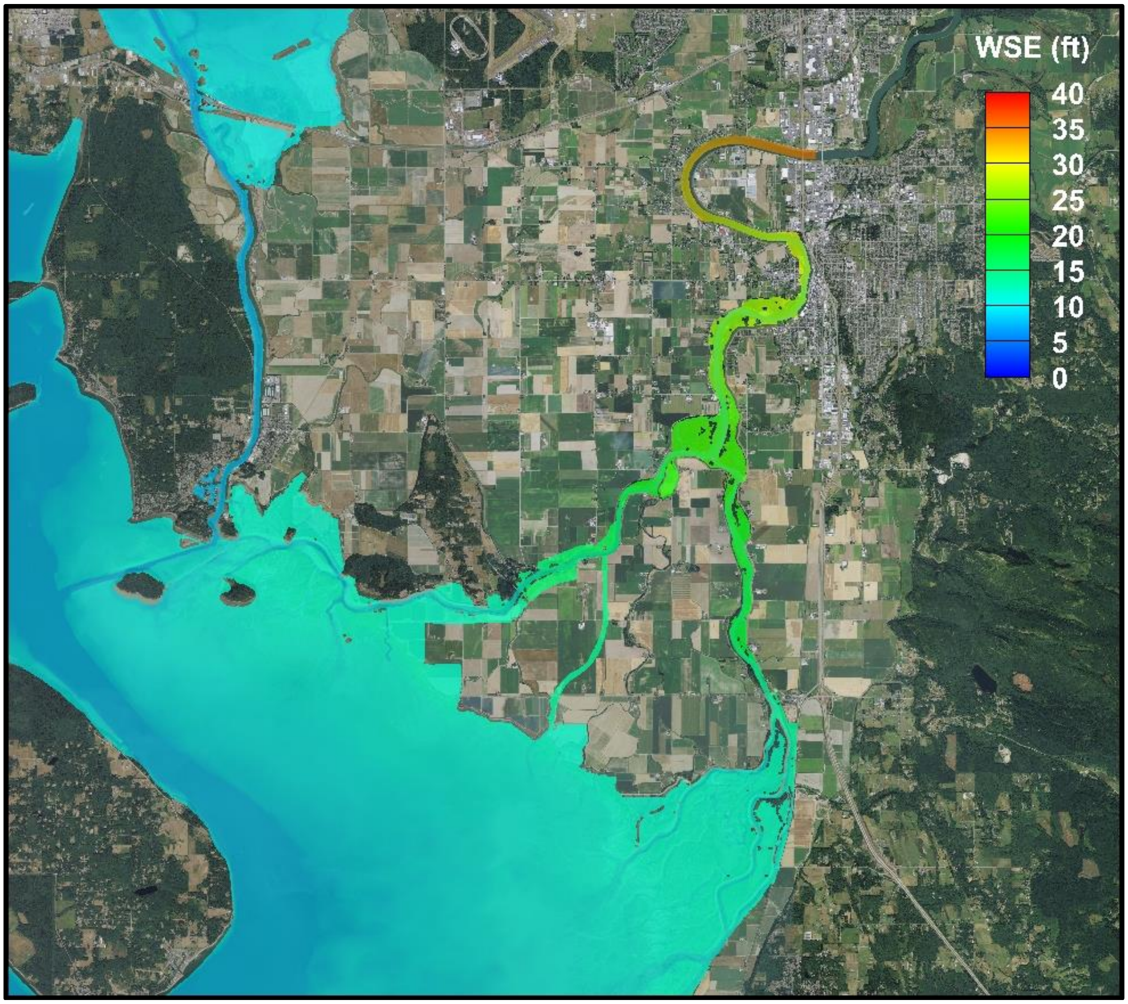


Figure K.23. Contour map of water surface elevation for the full domain during the 2080 Climate Change Baseline Simulation with future Q2 flow and future high spring tide.

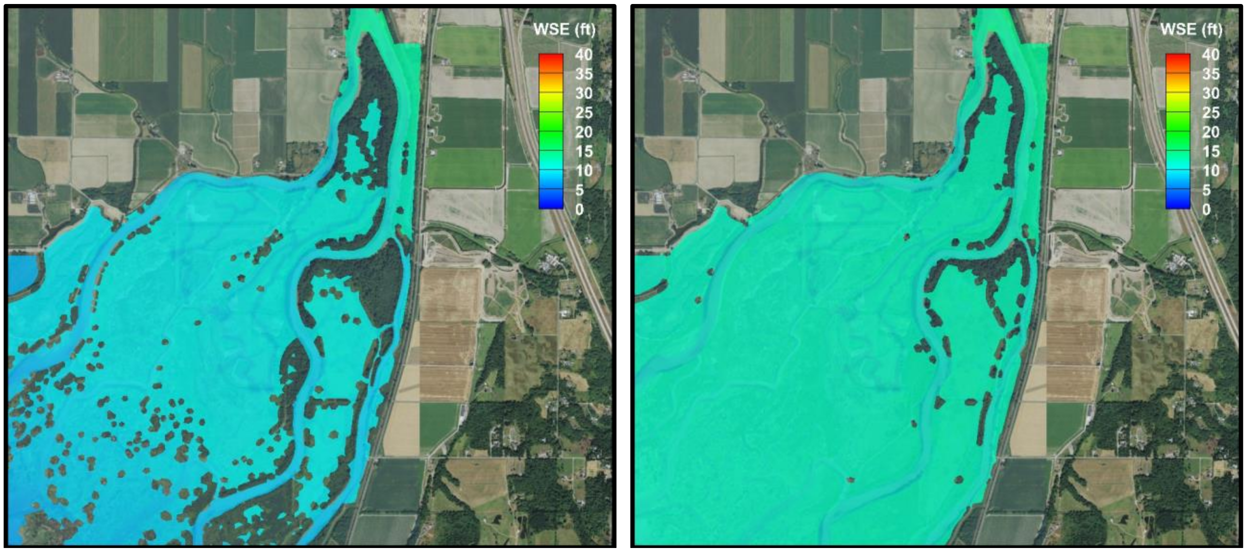


Figure K.24. Contour maps of water surface elevation for SF Levee Setbacks 2, 3, and 4 during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

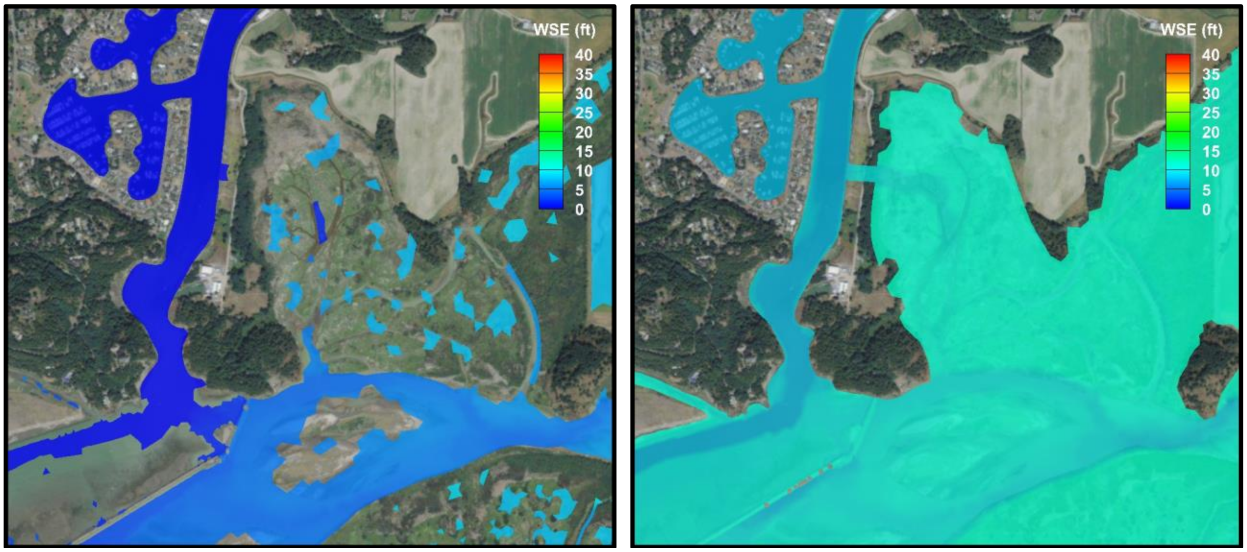


Figure K.25. Contour maps of water surface elevation for McGlinn Causeway during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

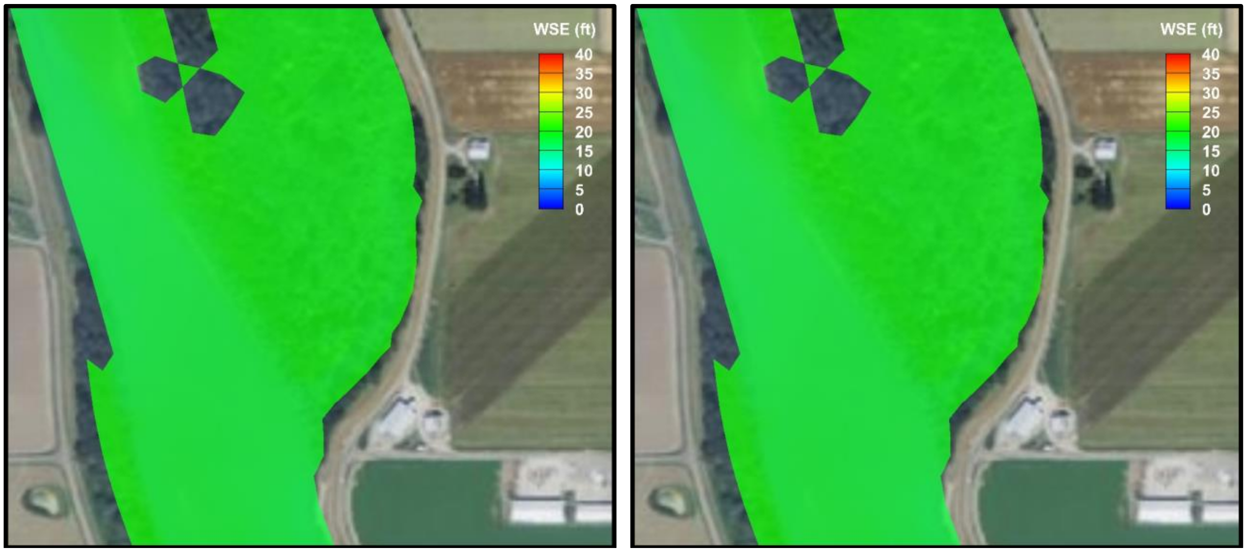


Figure K.26. Contour maps of water surface elevation for TNC South Fork during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

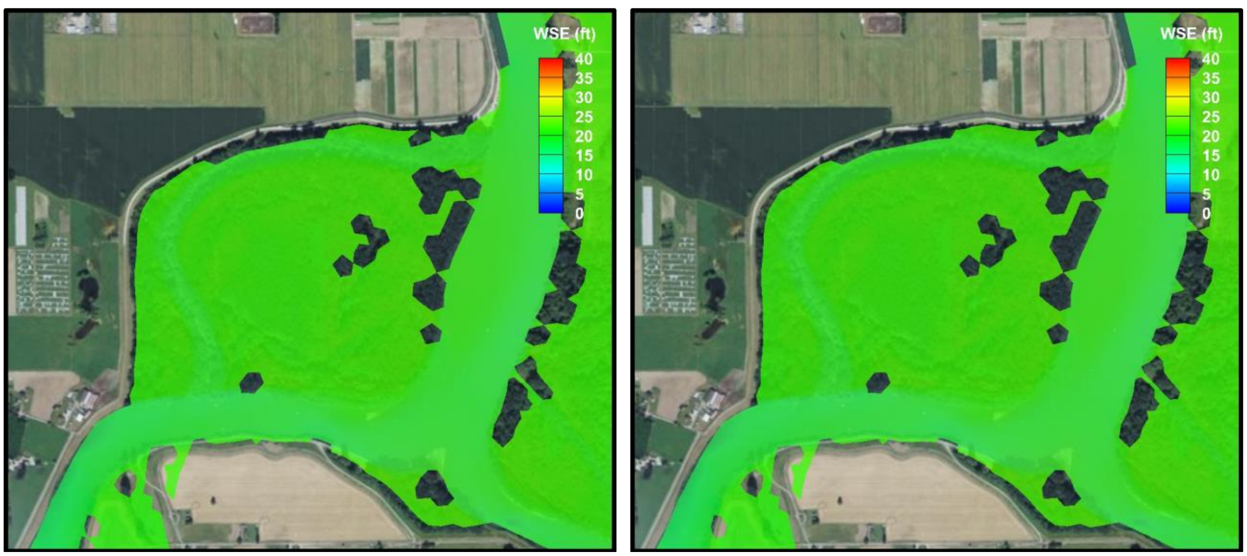


Figure K.27. Contour maps of water surface elevation for Cottonwood Island during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

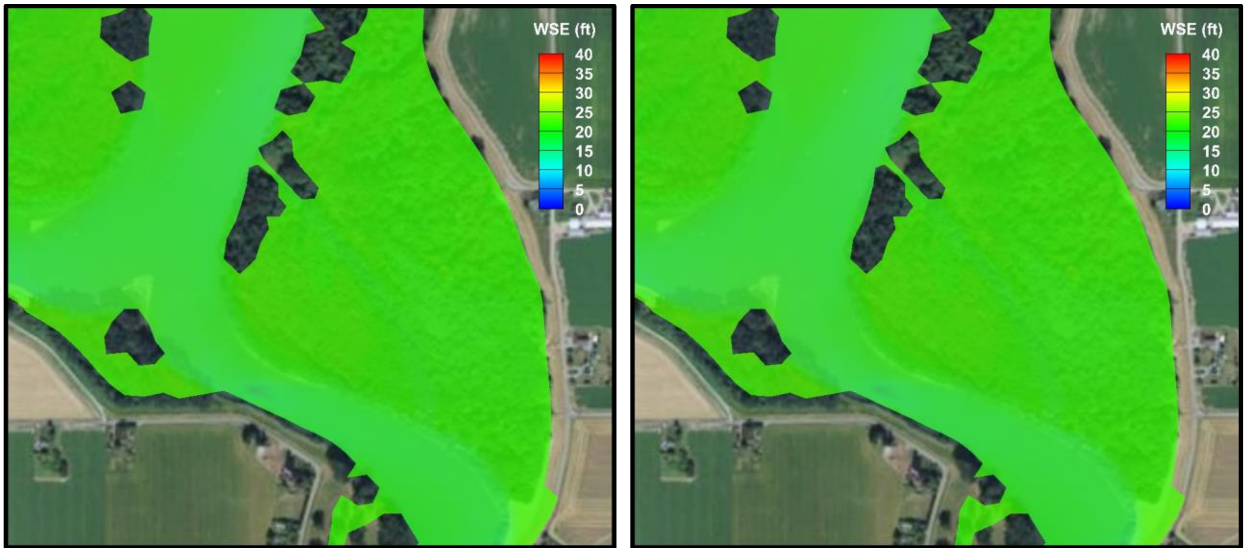


Figure K.28. Contour maps of water surface elevation for East Cottonwood during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

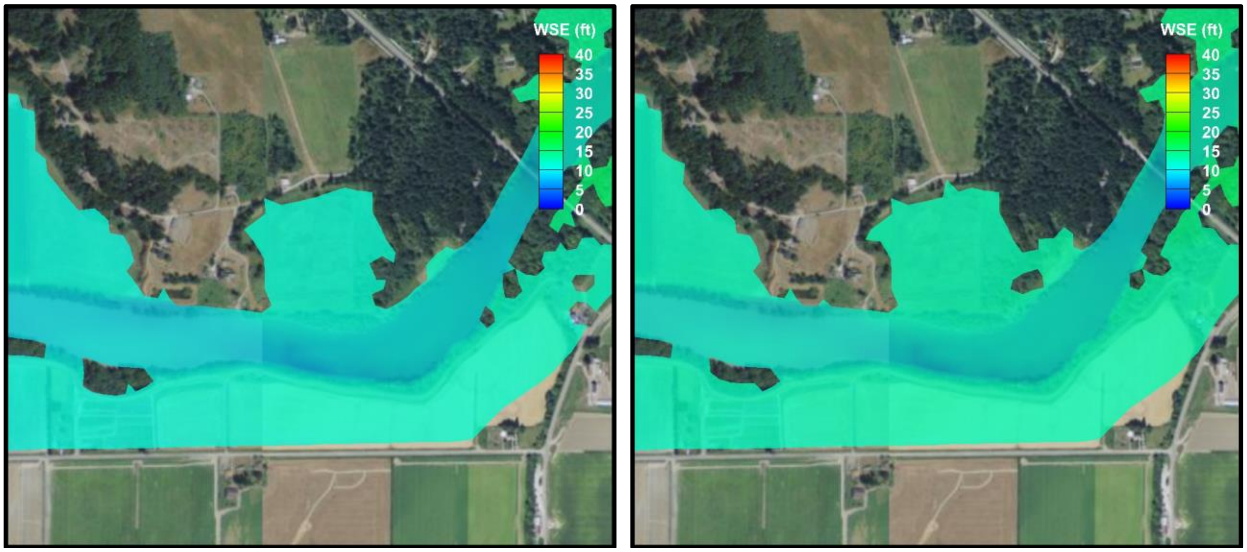


Figure K.29. Contour maps of water surface elevation for Pleasant Ridge South during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

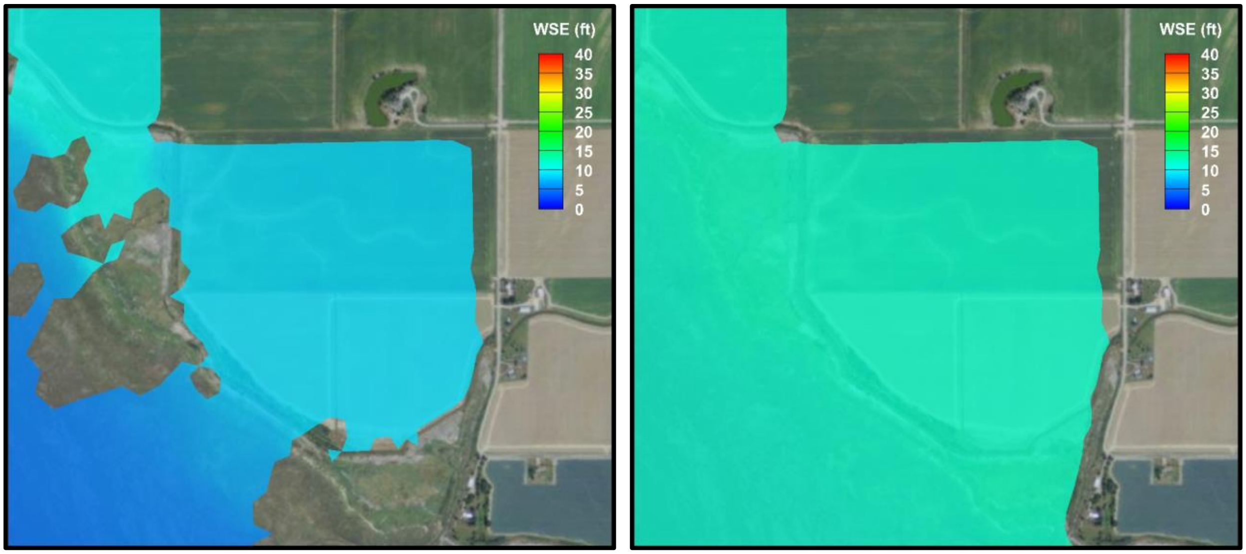


Figure K.30. Contour maps of water surface elevation for Hall Slough during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

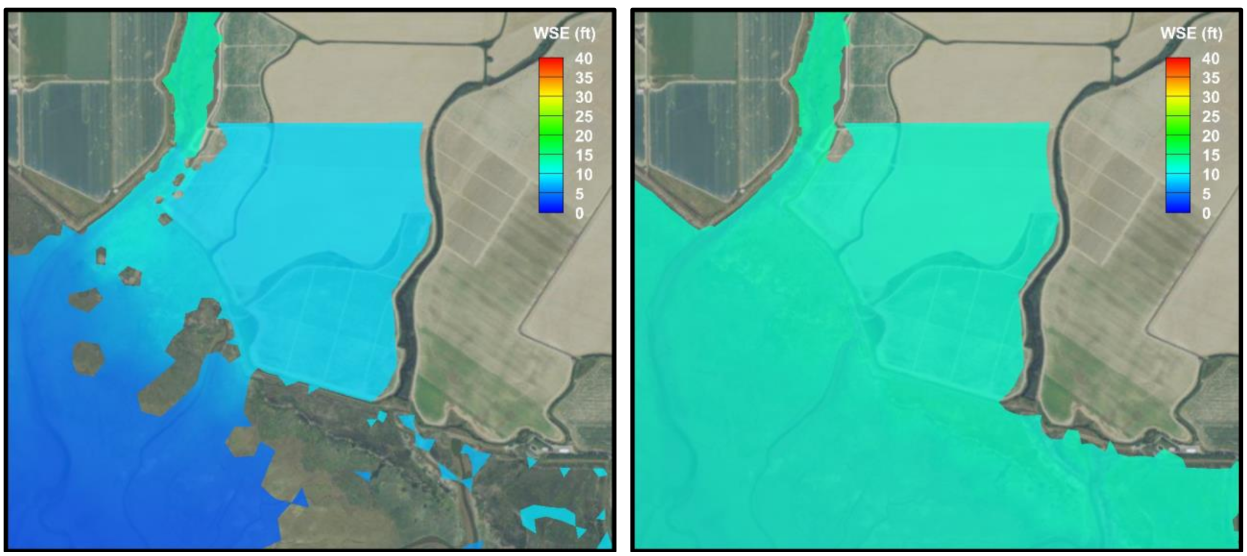


Figure K.31. Contour maps of water surface elevation for Fir Island Farm during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

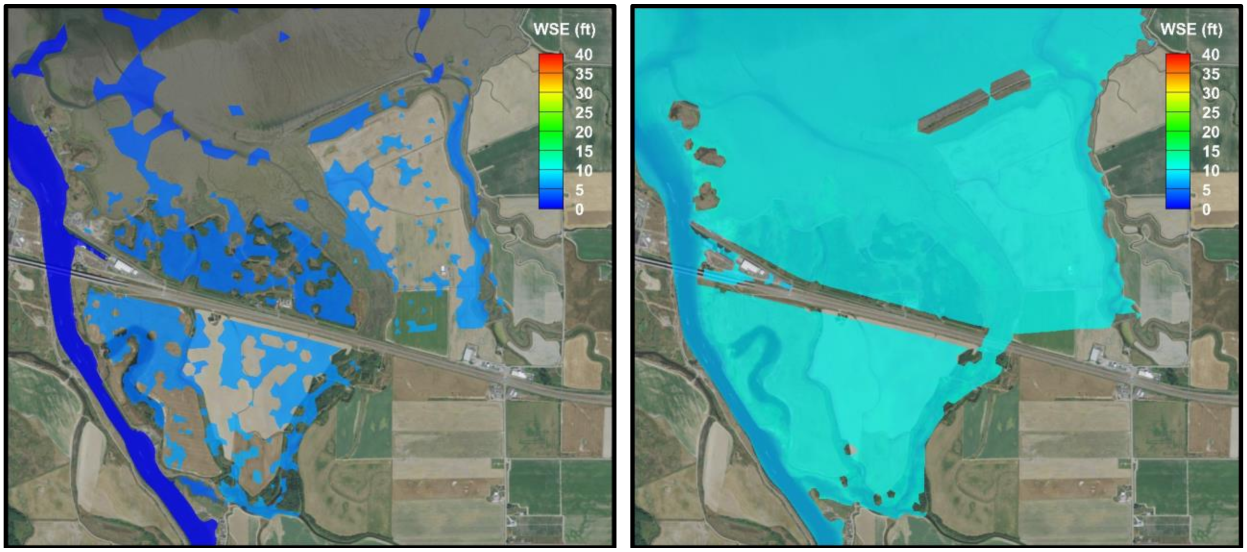


Figure K.32. Contour maps of water surface elevation for Telegraph Slough Full during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

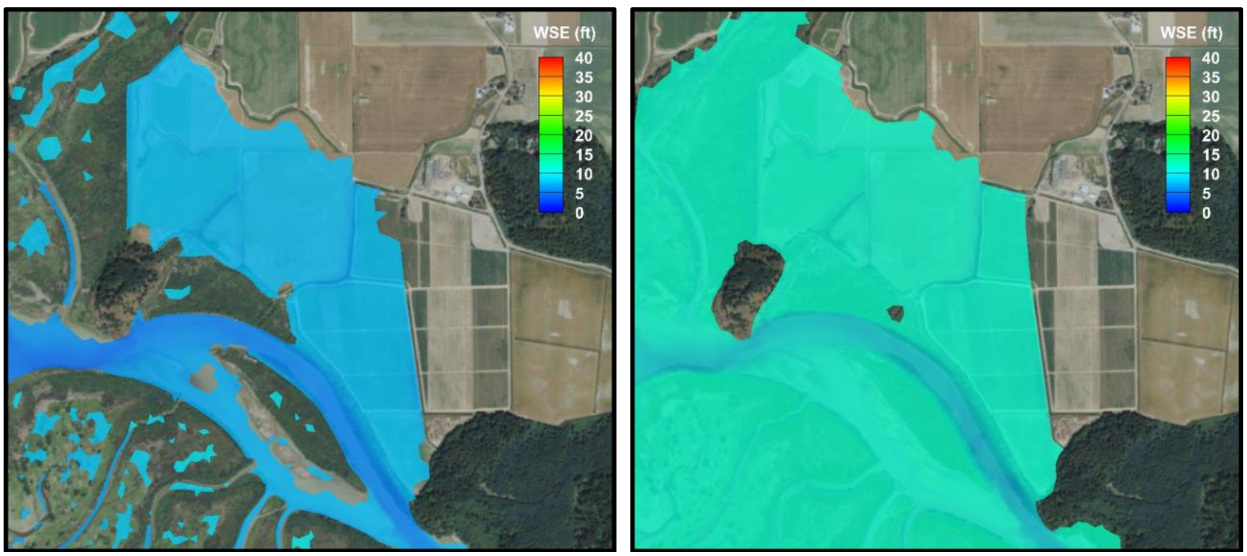


Figure K.33. Contour maps of water surface elevation for Sullivan Hacienda during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

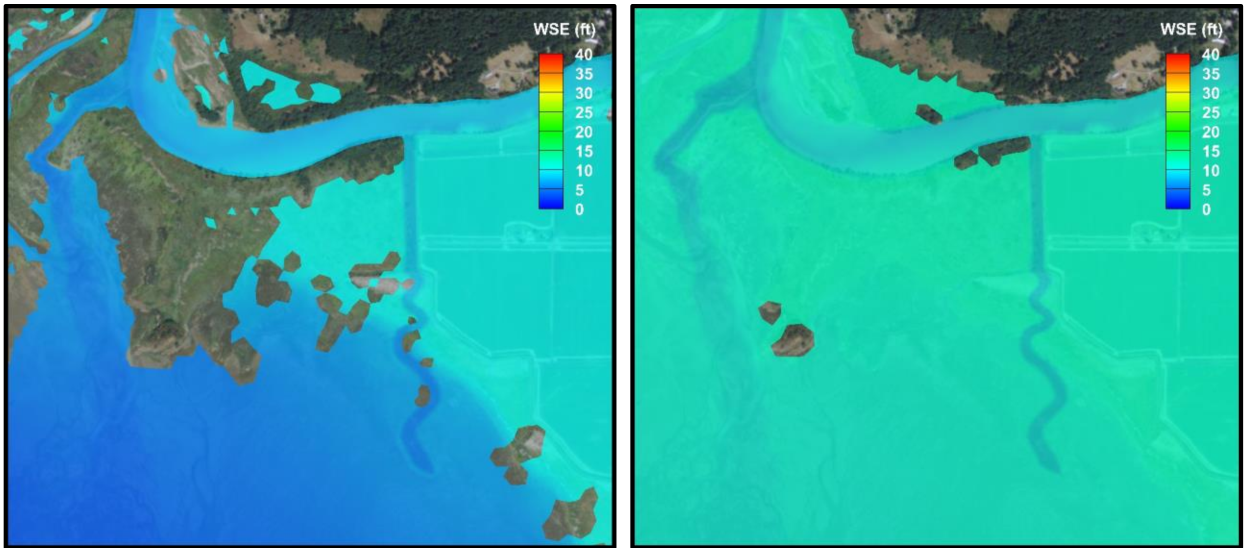


Figure K.34. Contour maps of water surface elevation for Rawlins Road Distributary during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

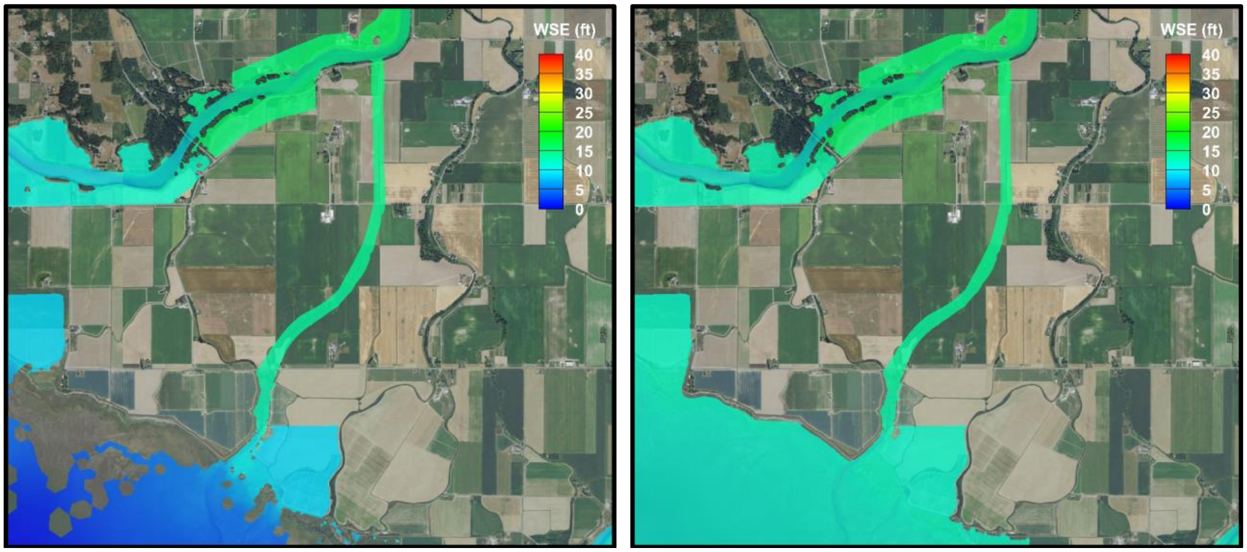


Figure K.35. Contour maps of water surface elevation for Cross Island Connector during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

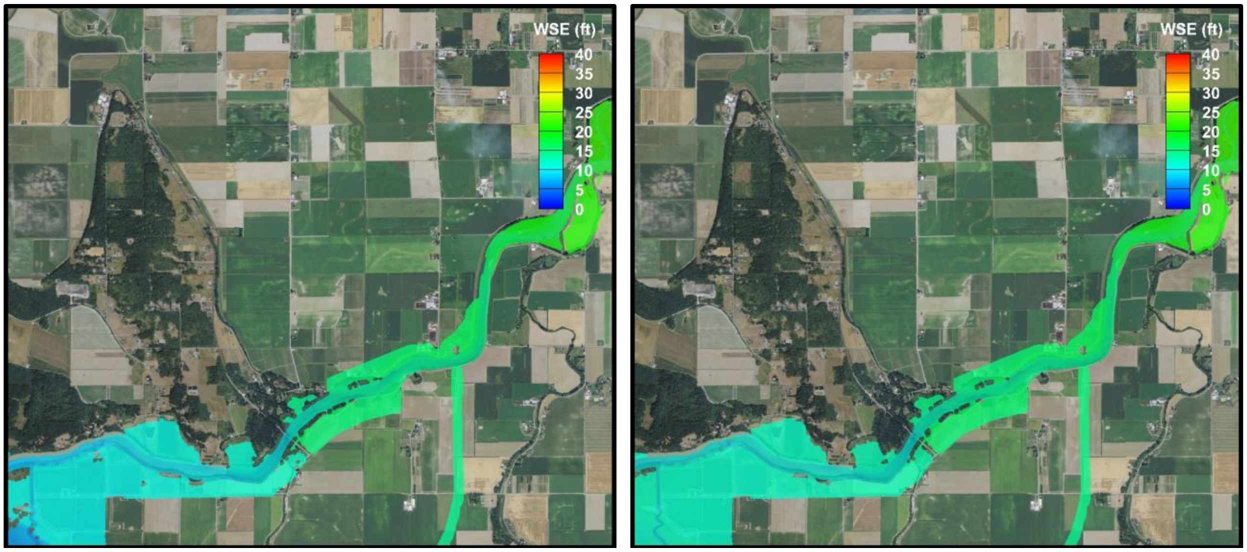


Figure K.36. Contour maps of water surface elevation for NF Levee Setback C during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

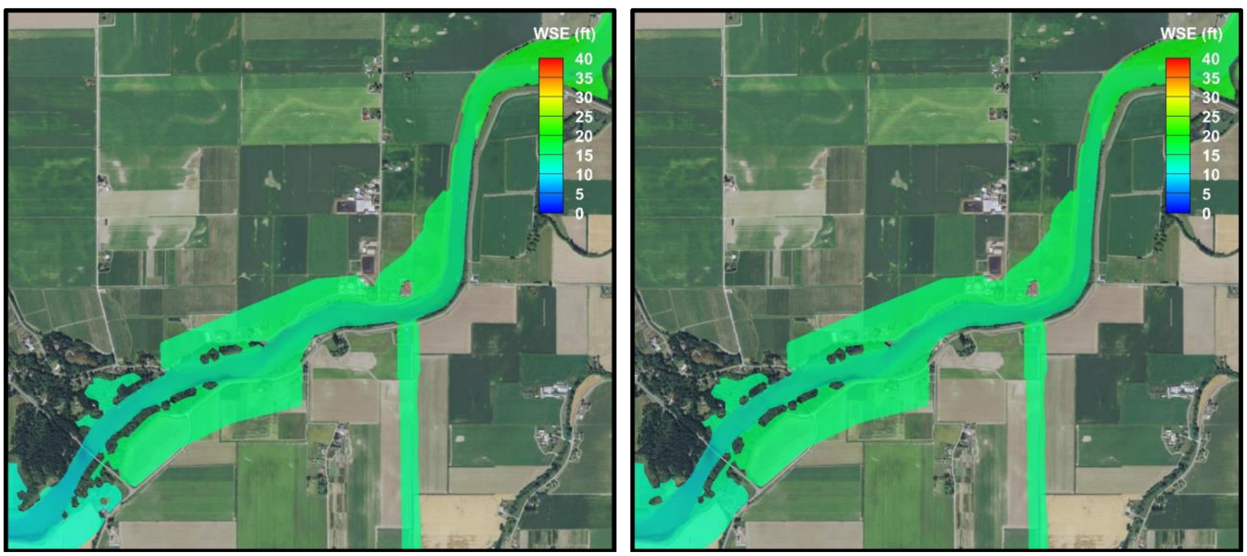


Figure K.37. Contour maps of water surface elevation for NF Right Bank Levee Setback during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

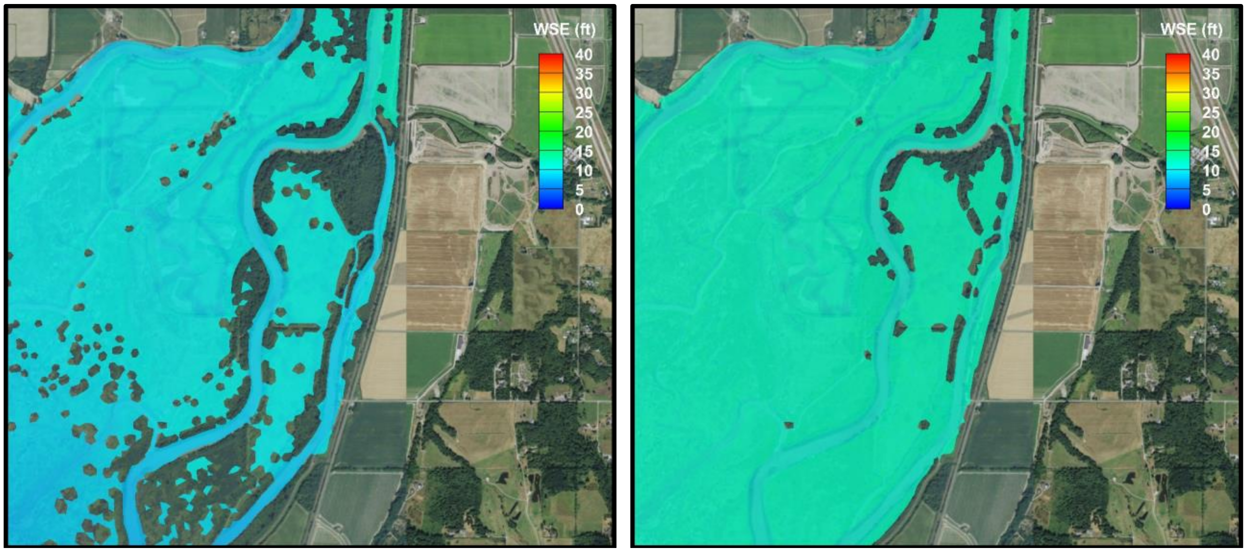


Figure K.38. Contour maps of water surface elevation for Milltown Island during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

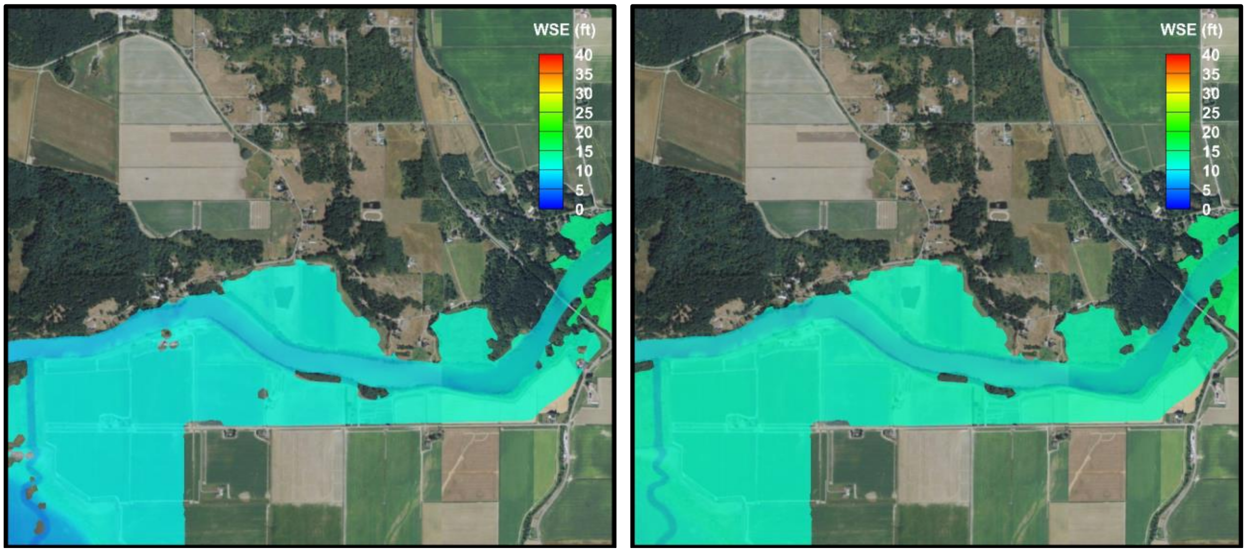


Figure K.39. Contour maps of water surface elevation for Thein Farm during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

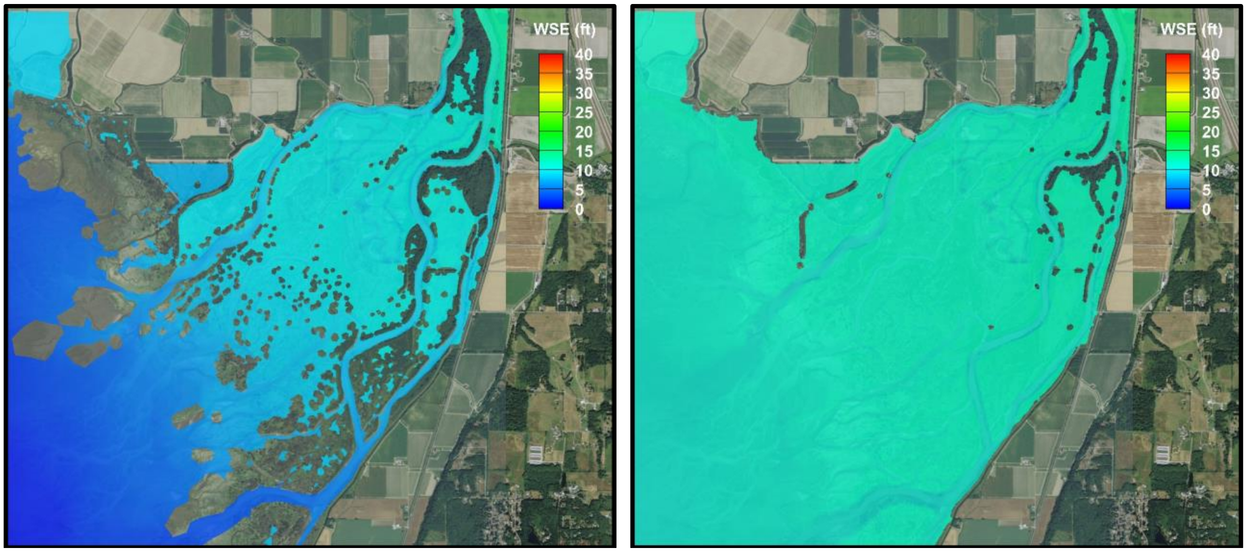


Figure K.40. Contour maps of water surface elevation for Deepwater Slough Phase 2 during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

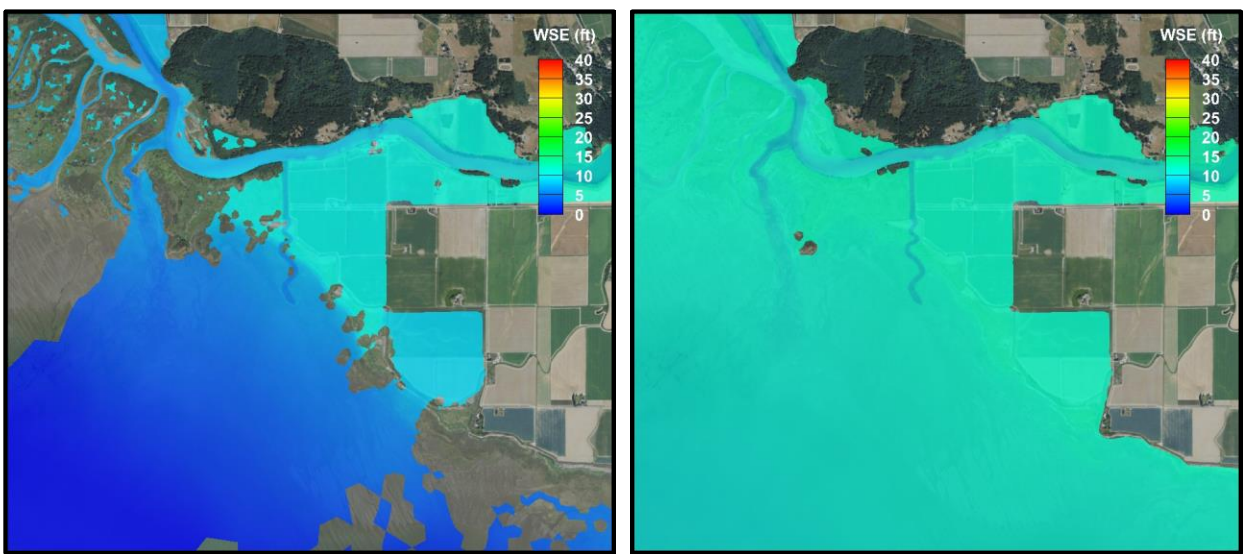


Figure K.41. Contour maps of water surface elevation for Rawlins Road during the 2080 Climate Change with Projects simulation with a future Q2 flow and future low tide (left) and a future Q2 flow and future high tide (right).

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.

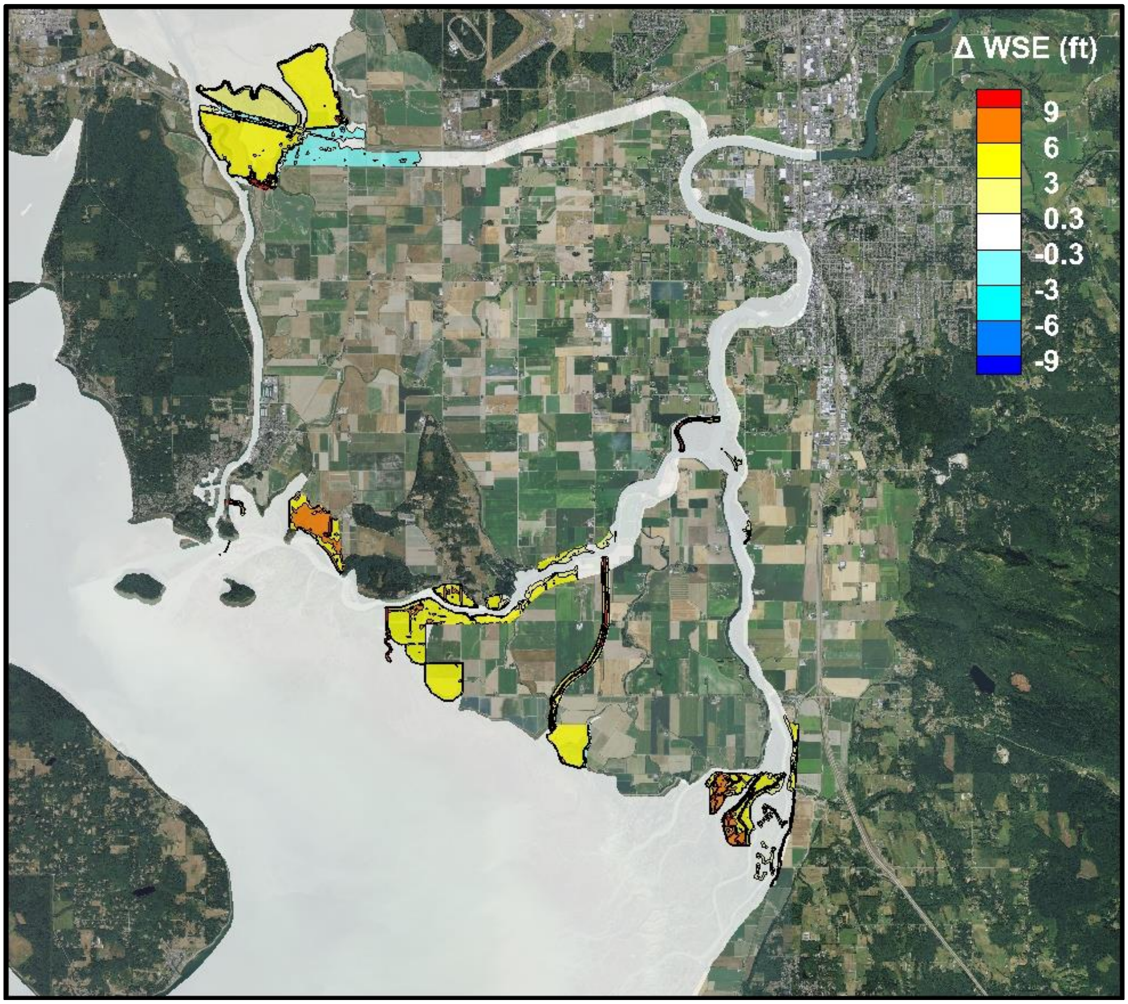


Figure K.42. Contour map of change in WSE for low flow and high tide for the full basin, comparing Climate Change Baseline and Climate Change Projects simulations.

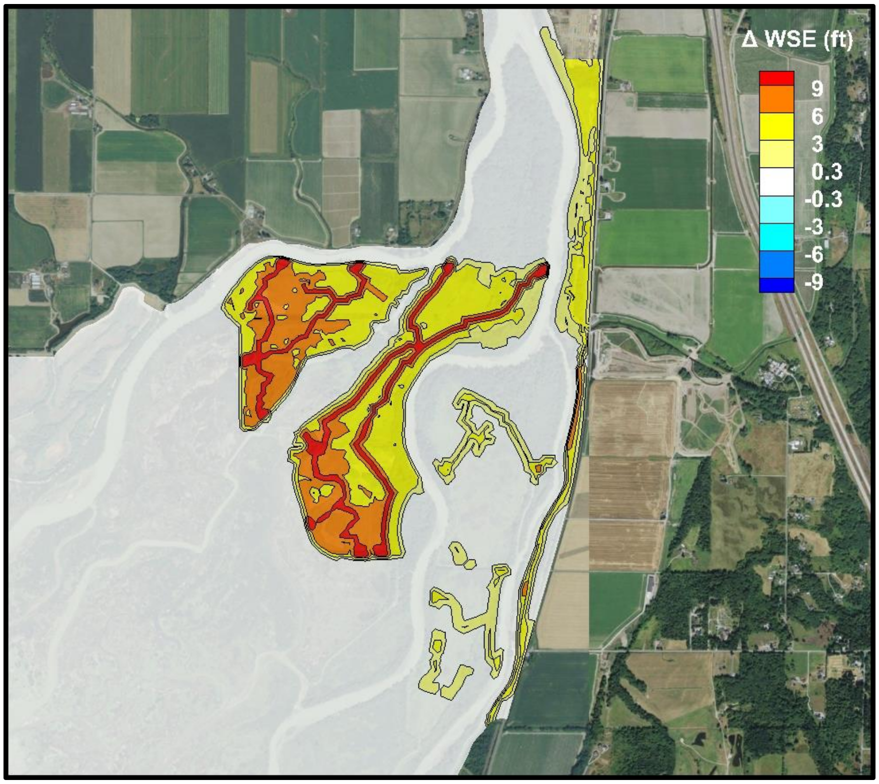


Figure K.43. Contour map of change in WSE for low flow and high tide for SF Levee Setbacks 2, 3, and 4, comparing Climate Change Baseline and Climate Change Projects simulations.

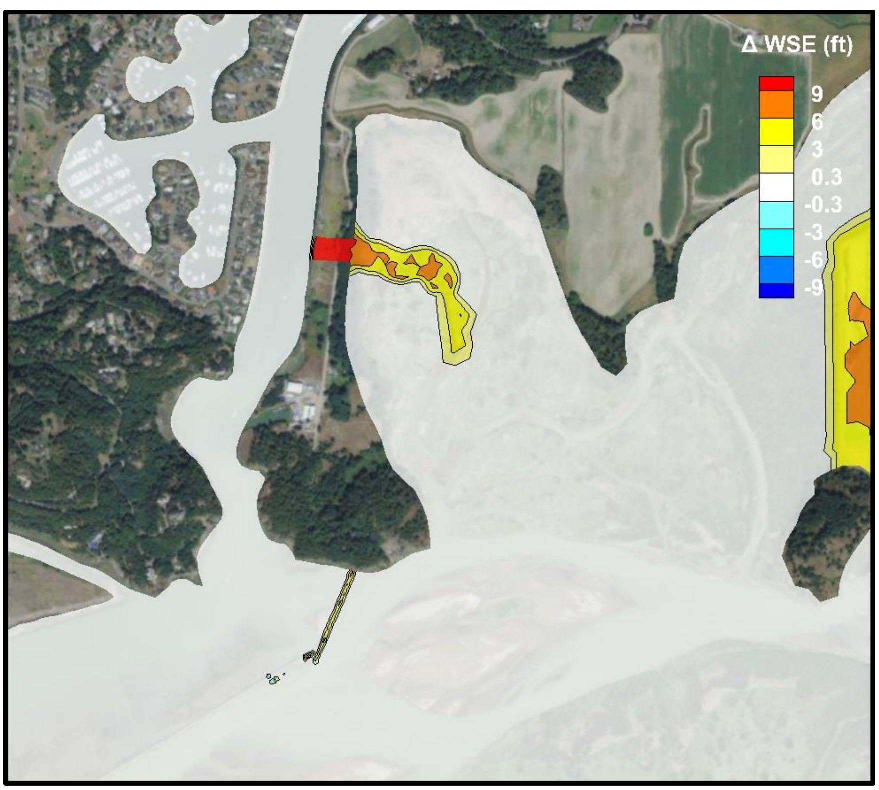


Figure K.44. Contour map of change in WSE for low flow and high tide for McGlinn Causeway, comparing Climate Change Baseline and Climate Change Projects simulations.

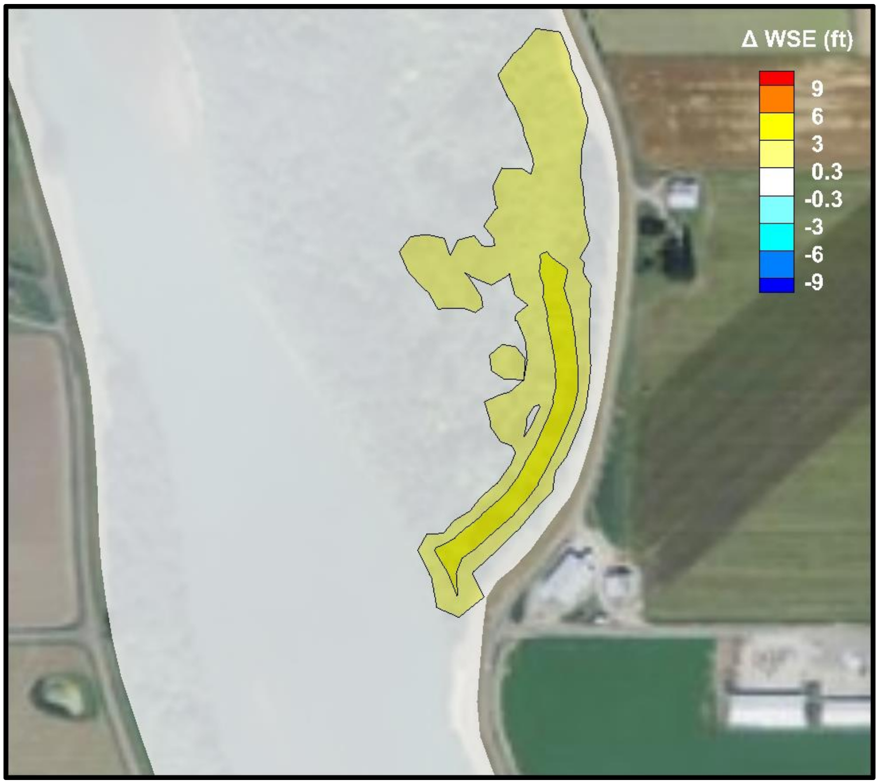


Figure K.45. Contour map of change in WSE for low flow and high tide for TNC South Fork, comparing Climate Change Baseline and Climate Change Projects simulations.

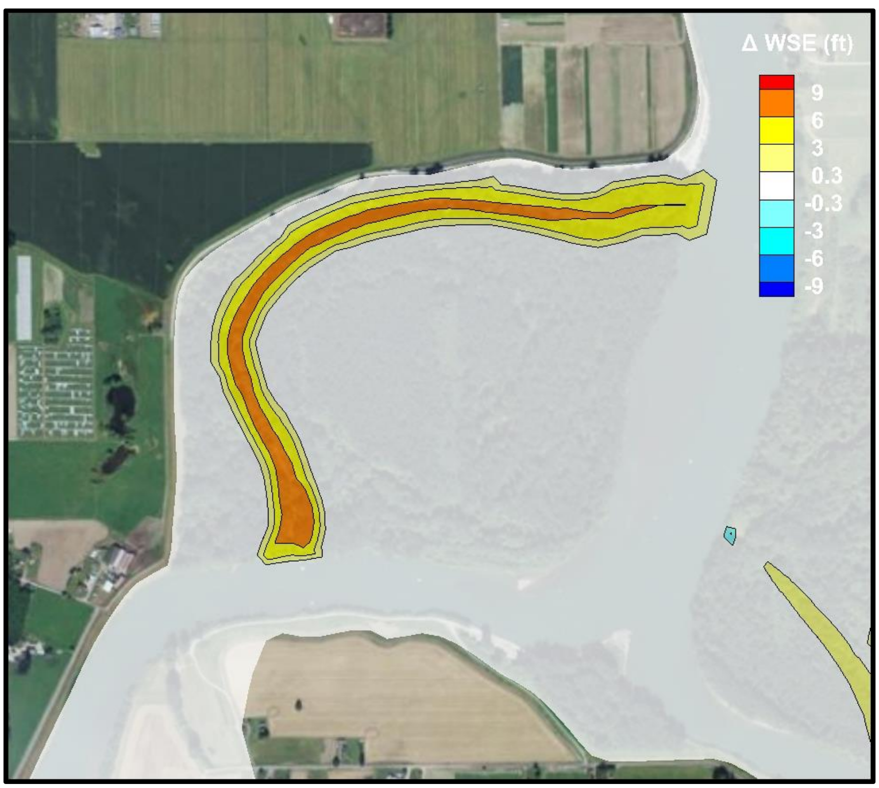


Figure K.46. Contour map of change in WSE for low flow and high tide for Cottonwood Island, comparing Climate Change Baseline and Climate Change Projects simulations.

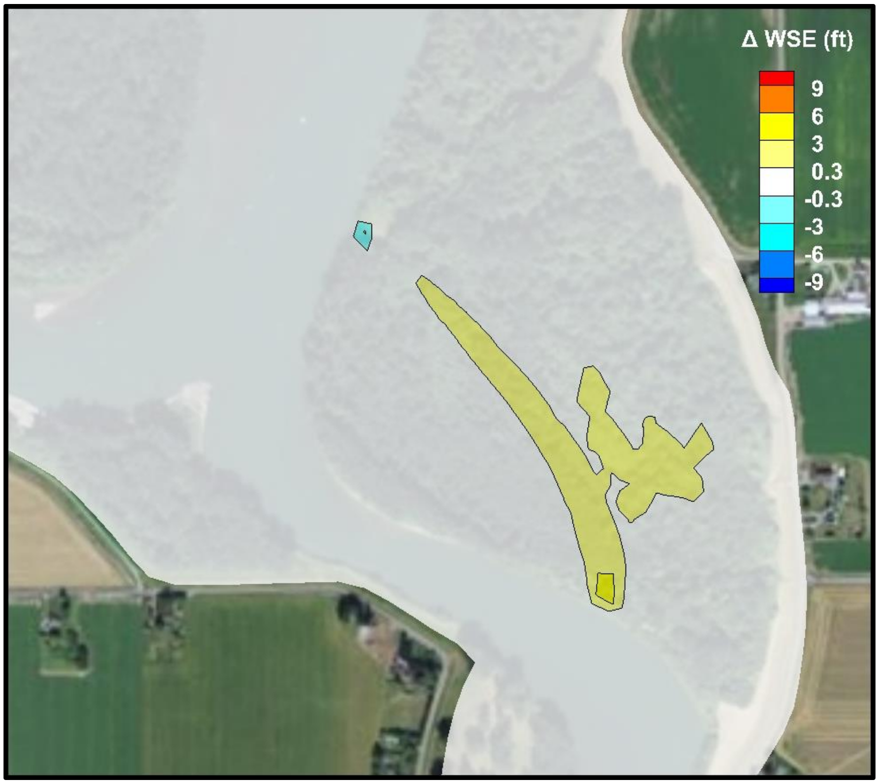


Figure K.47. Contour map of change in WSE for low flow and high tide for East Cottonwood, comparing Climate Change Baseline and Climate Change Projects simulations.

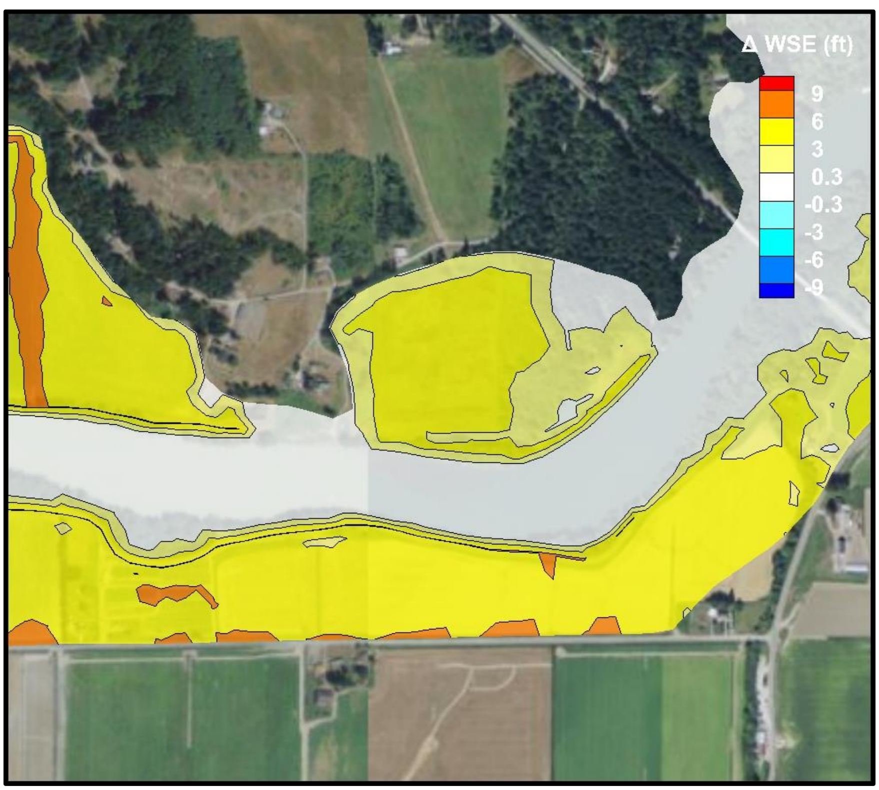


Figure K.48. Contour map of change in WSE for low flow and high tide for Pleasant Ridge South, comparing Climate Change Baseline and Climate Change Projects simulations.

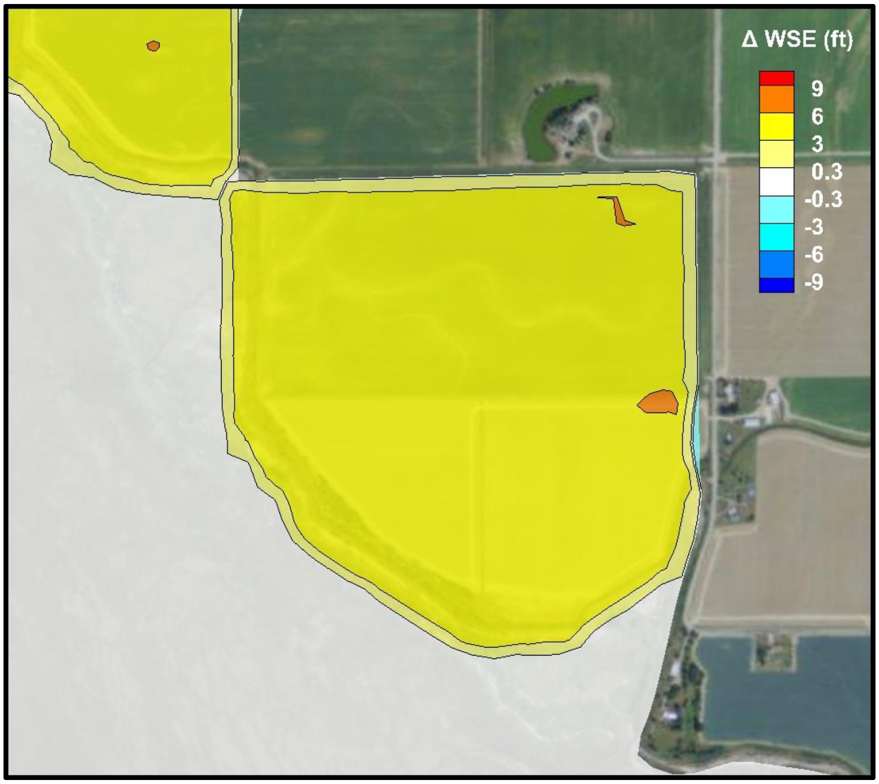


Figure K.49. Contour map of change in WSE for low flow and high tide for Hall Slough, comparing Climate Change Baseline and Climate Change Projects simulations.

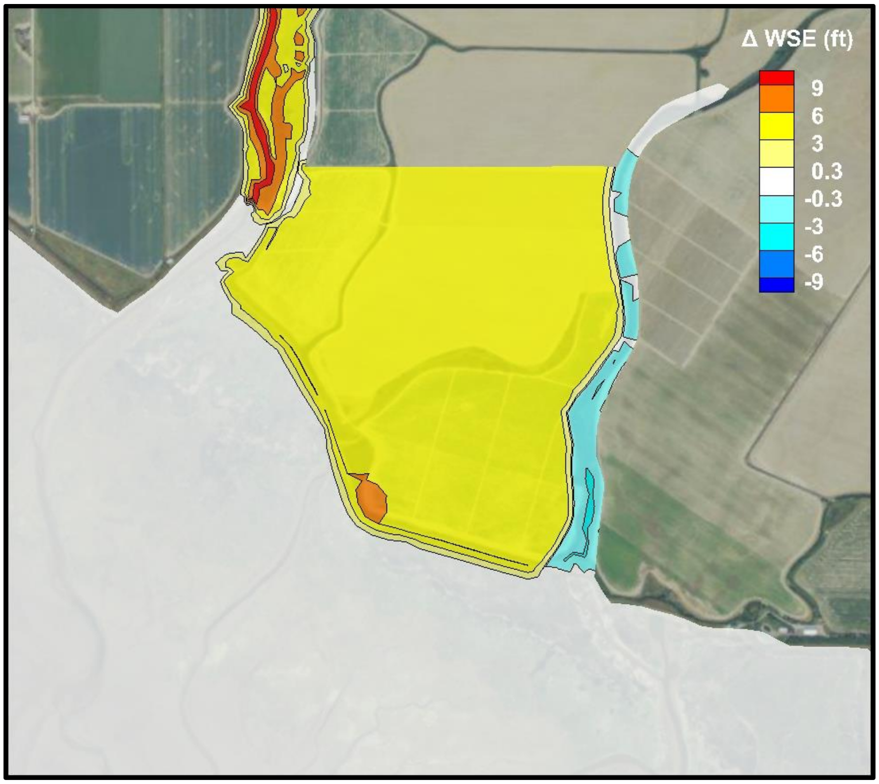


Figure K.50. Contour map of change in WSE for low flow and high tide for Fir Island Farm, comparing Climate Change Baseline and Climate Change Projects simulations.

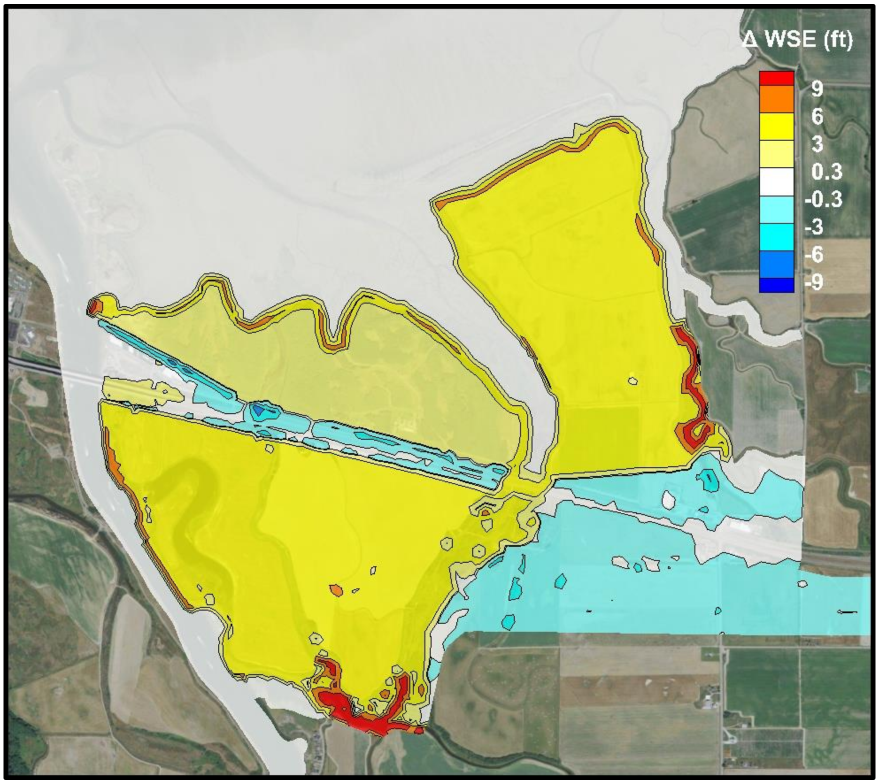


Figure K.51. Contour map of change in WSE for low flow and high tide for Telegraph Slough Full, comparing Climate Change Baseline and Climate Change Projects simulations.

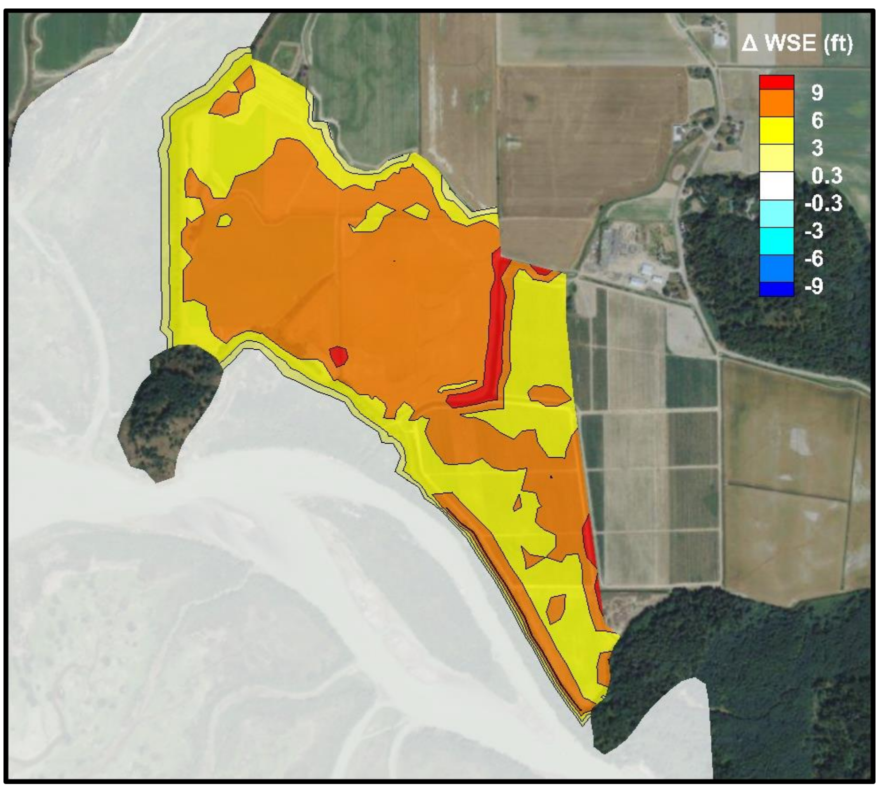


Figure K.52. Contour map of change in WSE for low flow and high tide for Sullivan Hacienda, comparing Climate Change Baseline and Climate Change Projects simulations.

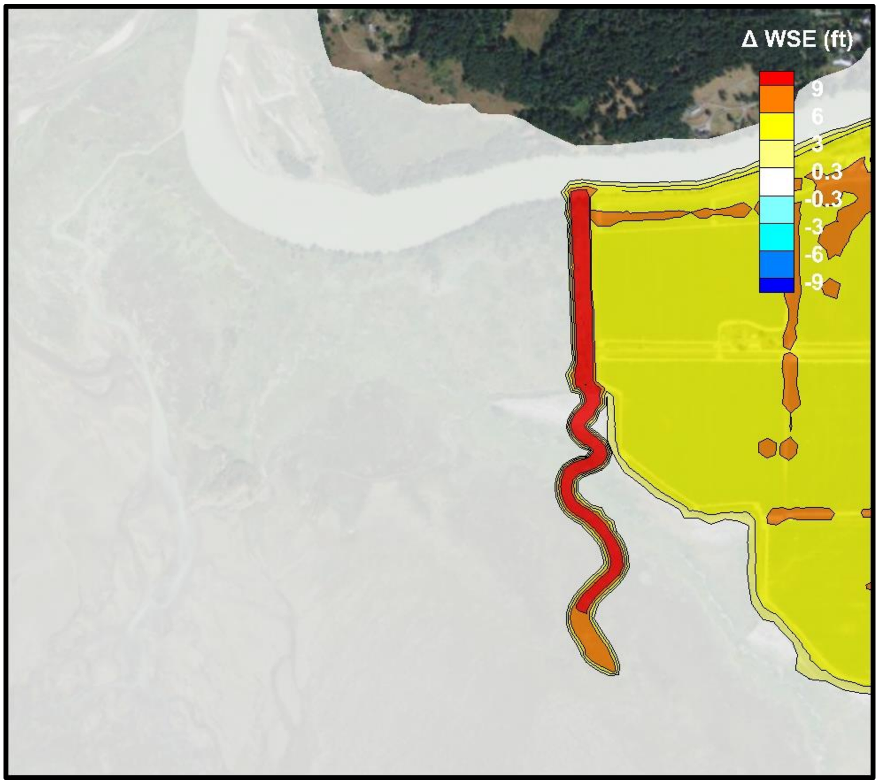


Figure K.53. Contour map of change in WSE for low flow and high tide for Rawlins Road Distributary, comparing Climate Change Baseline and Climate Change Projects simulations.

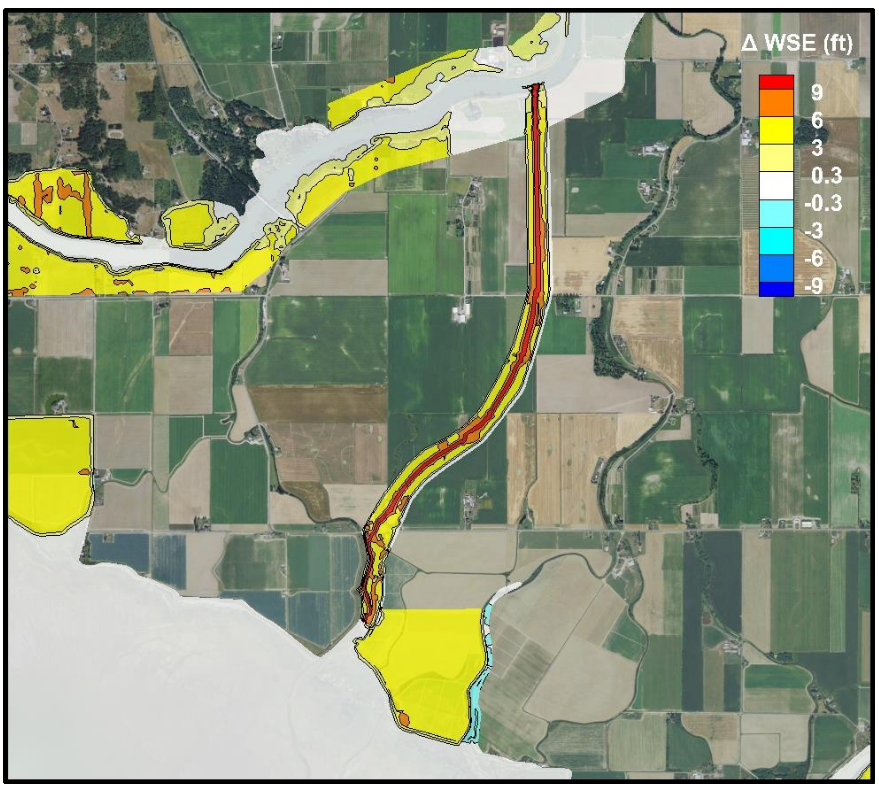


Figure K.54. Contour map of change in WSE for low flow and high tide for Cross Island Connector, comparing Climate Change Baseline and Climate Change Projects simulations.

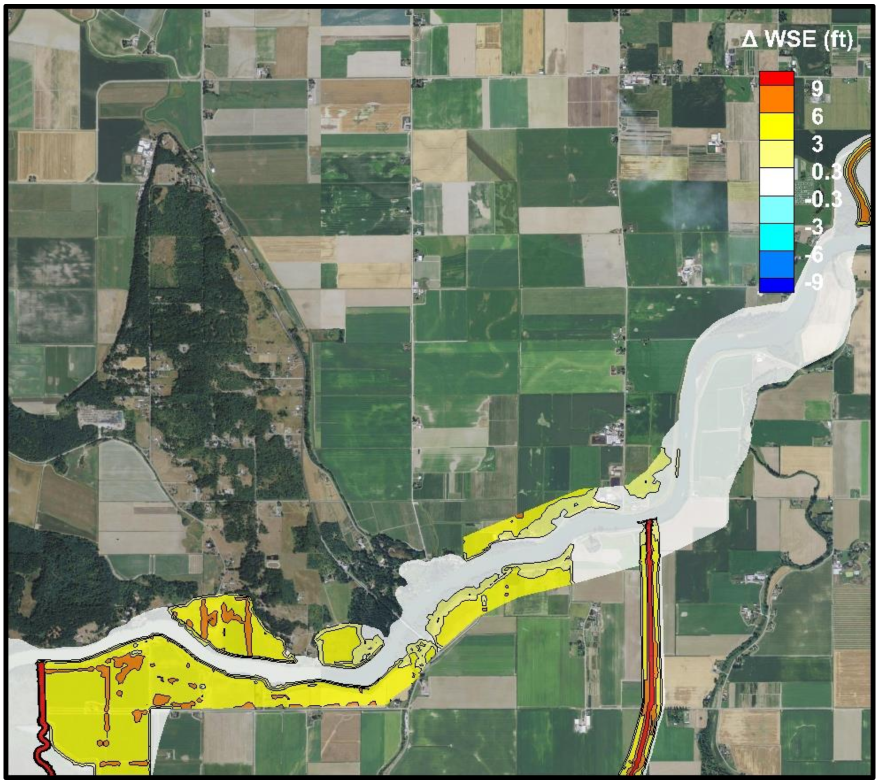


Figure K.55. Contour map of change in WSE for low flow and high tide for NF Levee Setback C, comparing Climate Change Baseline and Climate Change Projects simulations.

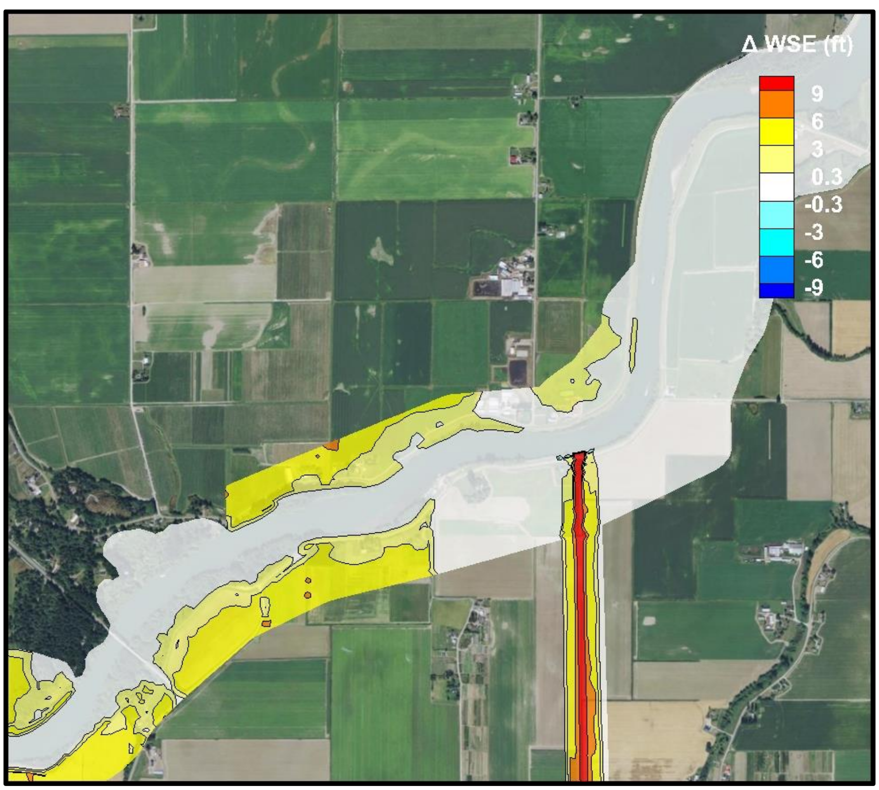


Figure K.56. Contour map of change in WSE for low flow and high tide for NF Right Bank Levee Setback, comparing Climate Change Baseline and Climate Change Projects simulations.

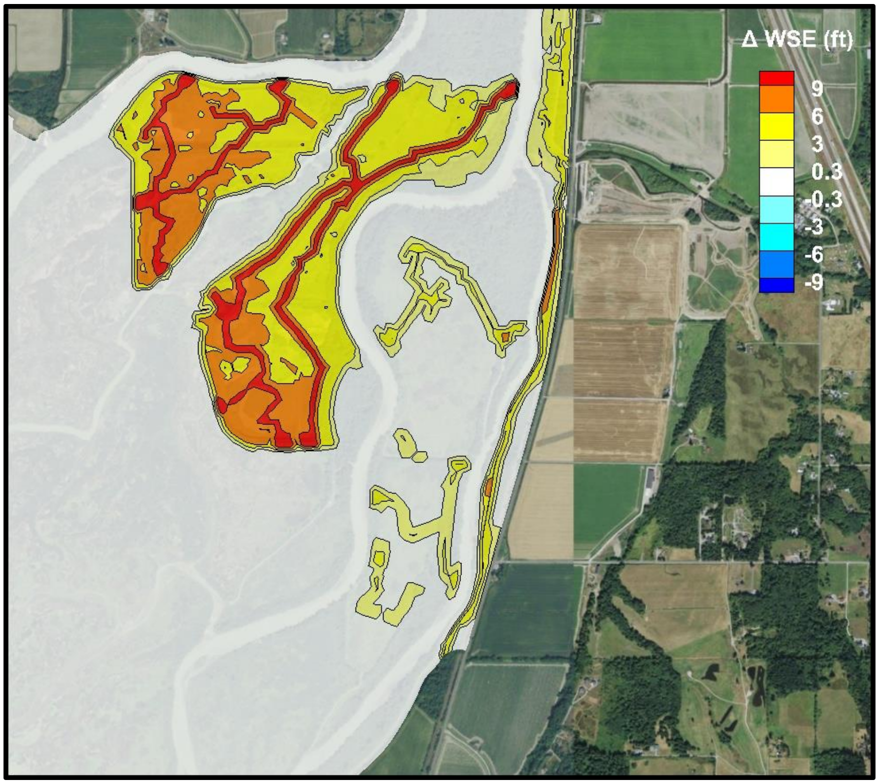


Figure K.57. Contour map of change in WSE for low flow and high tide for Milltown Island, comparing Climate Change Baseline and Climate Change Projects simulations.

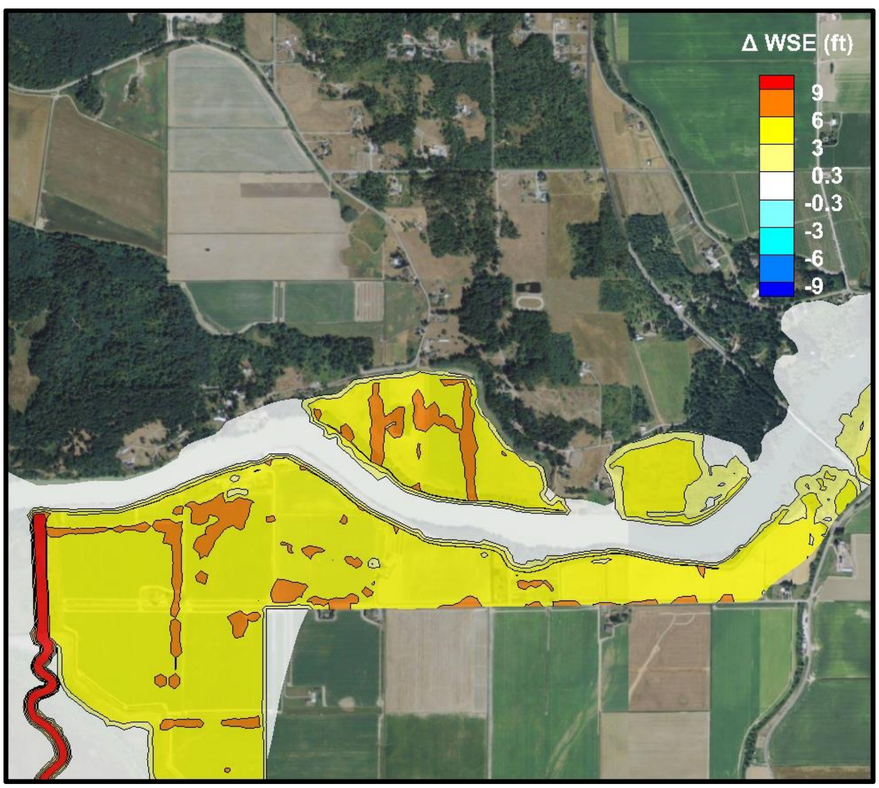


Figure K.58. Contour map of change in WSE for low flow and high tide for Thein Farm, comparing Climate Change Baseline and Climate Change Projects simulations.

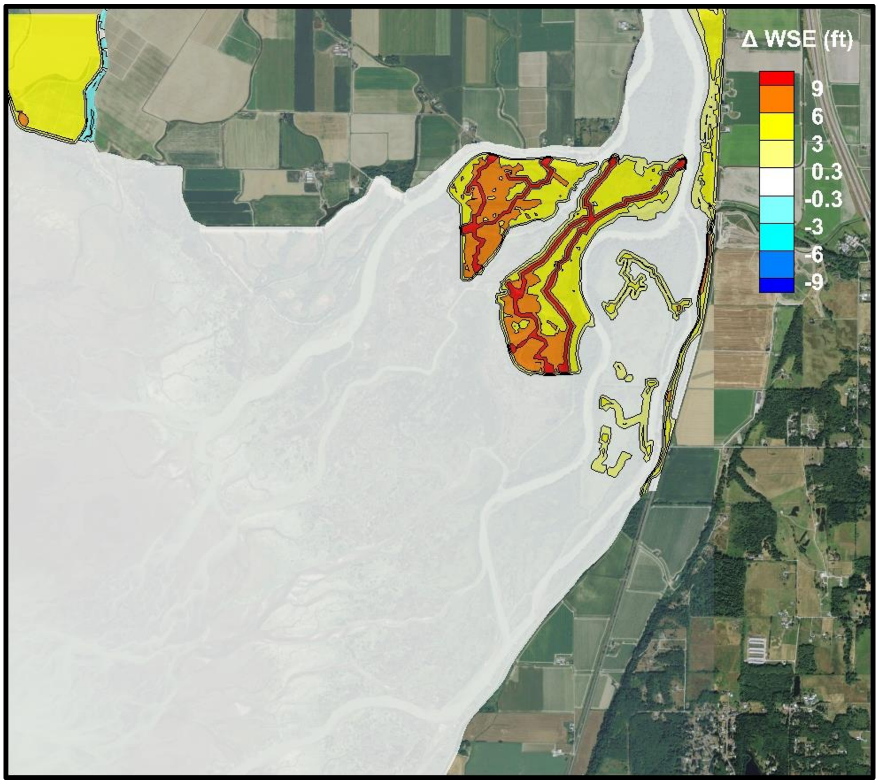


Figure K.59. Contour map of change in WSE for low flow and high tide for Deepwater Slough Phase 2, comparing Climate Change Baseline and Climate Change Projects simulations.

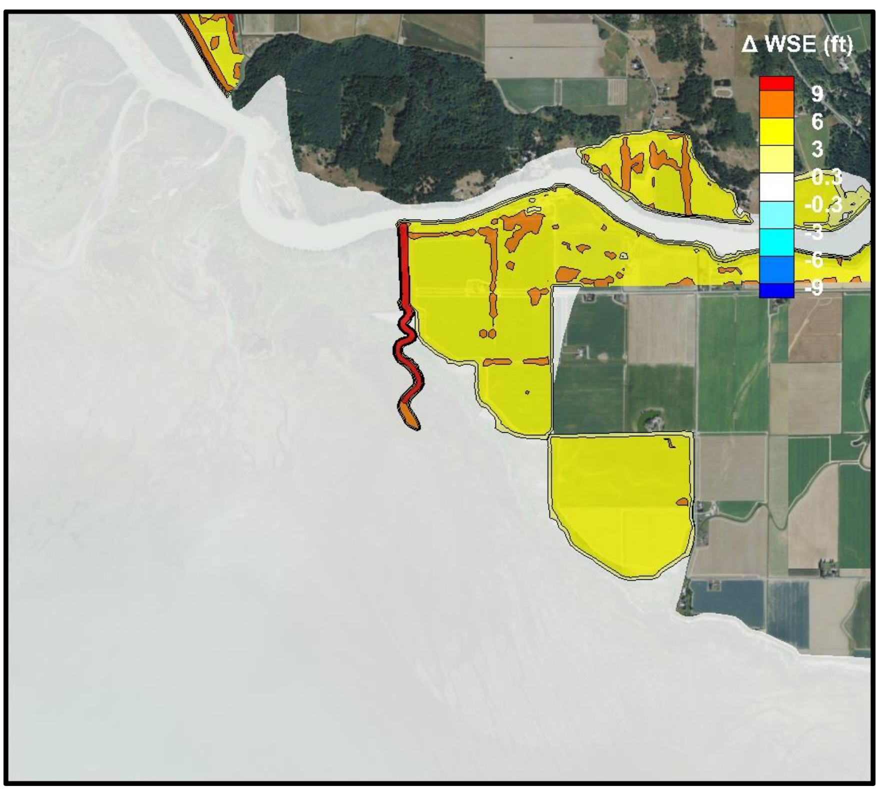


Figure K.60. Contour map of change in WSE for low flow and high tide for Rawlins Road, comparing Climate Change Baseline and Climate Change Projects simulations.

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.

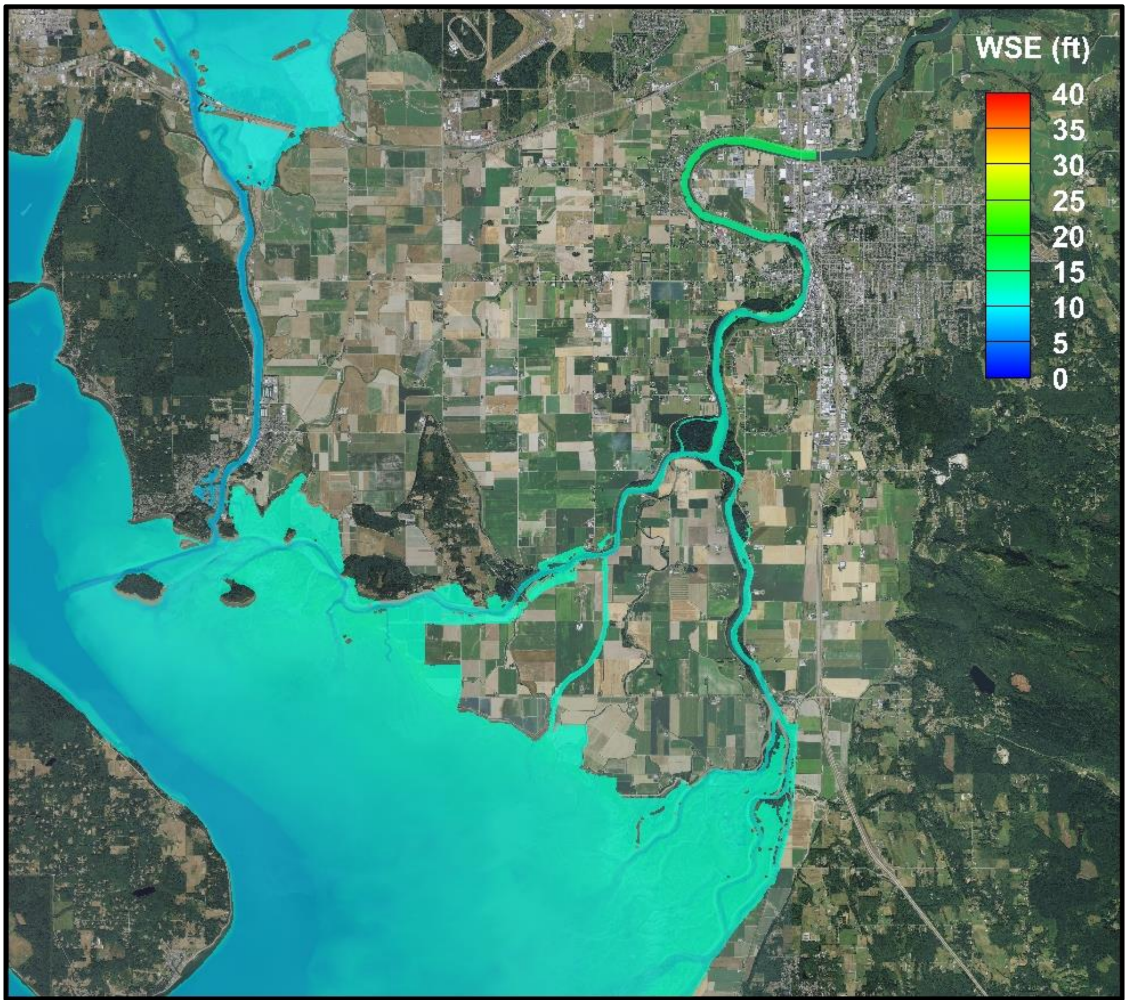


Figure K.61. Contour map of water surface elevation for the full domain during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

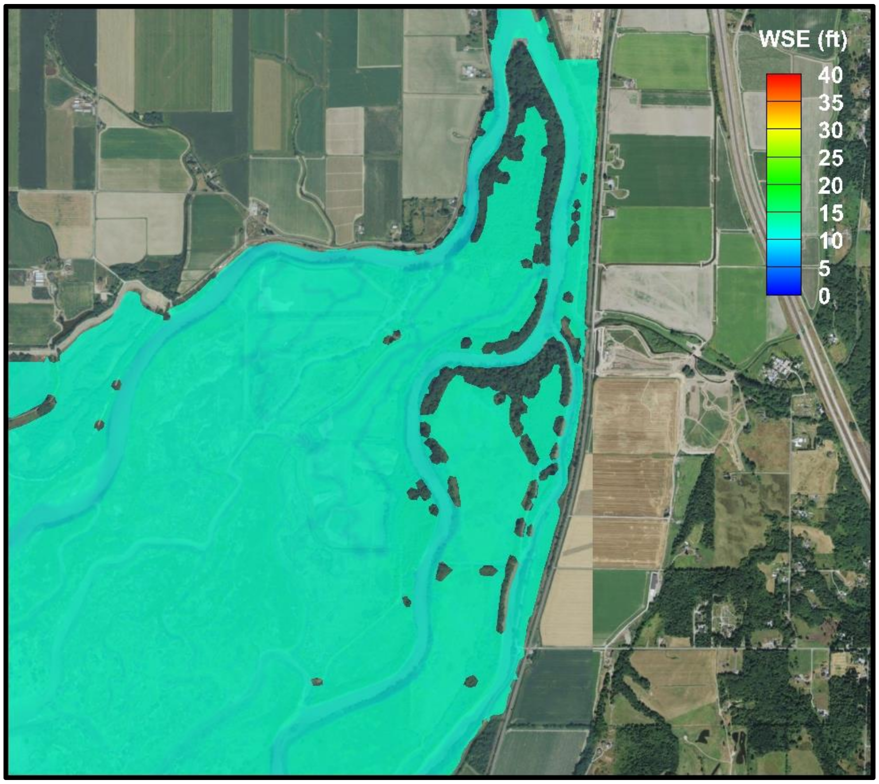


Figure K.62. Contour map of water surface elevation for SF Levee Setbacks 2, 3, and 4 during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

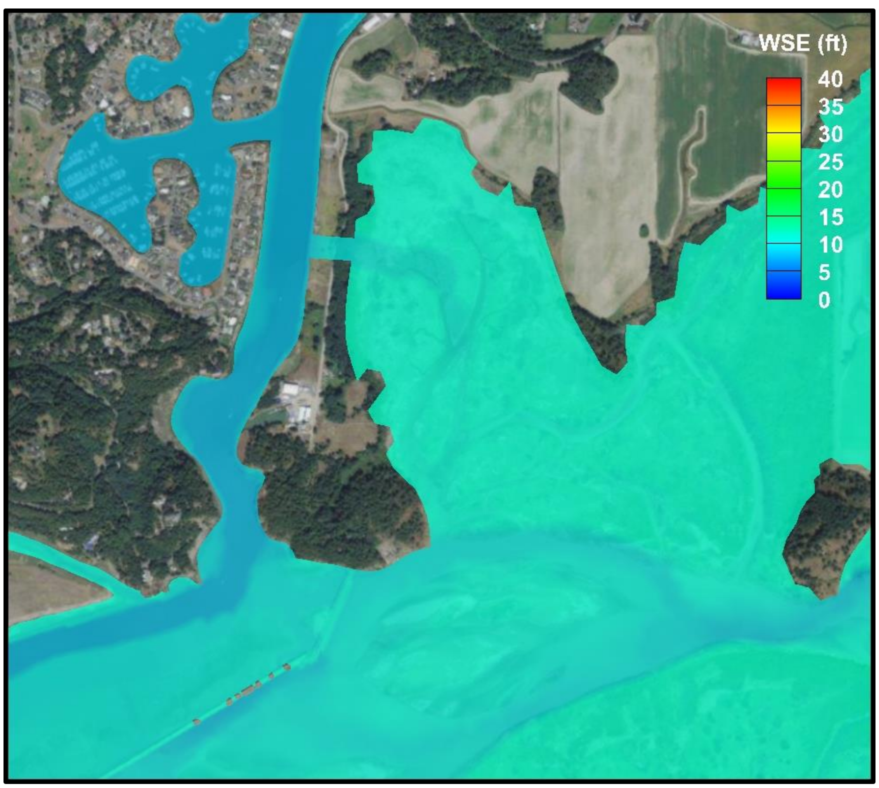


Figure K.63. Contour map of water surface elevation for McGlinn Causeway during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

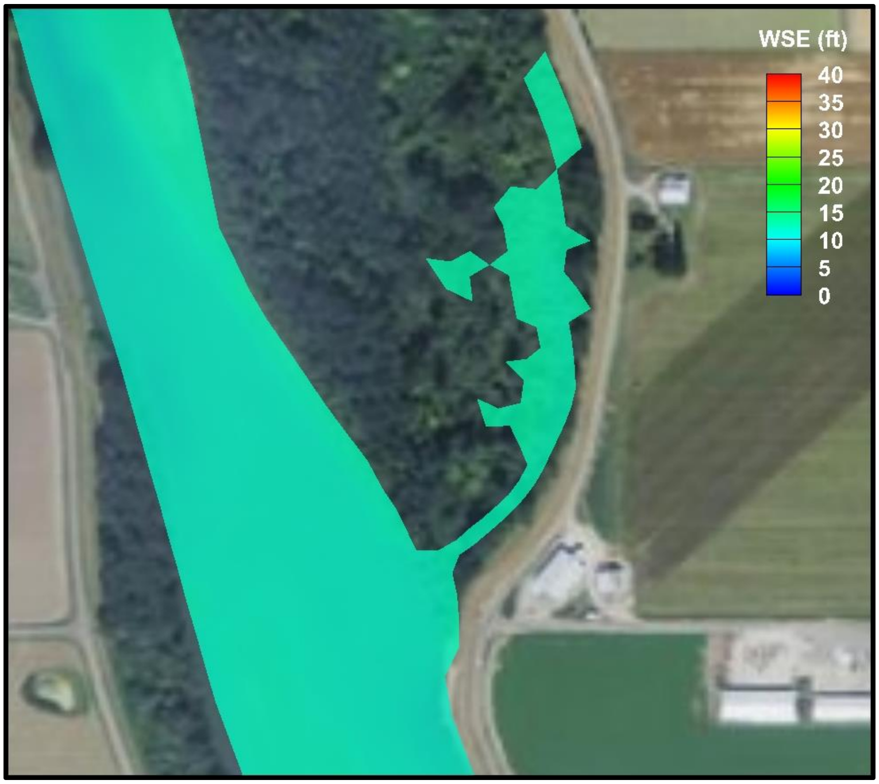


Figure K.64. Contour map of water surface elevation for TNC South Fork during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

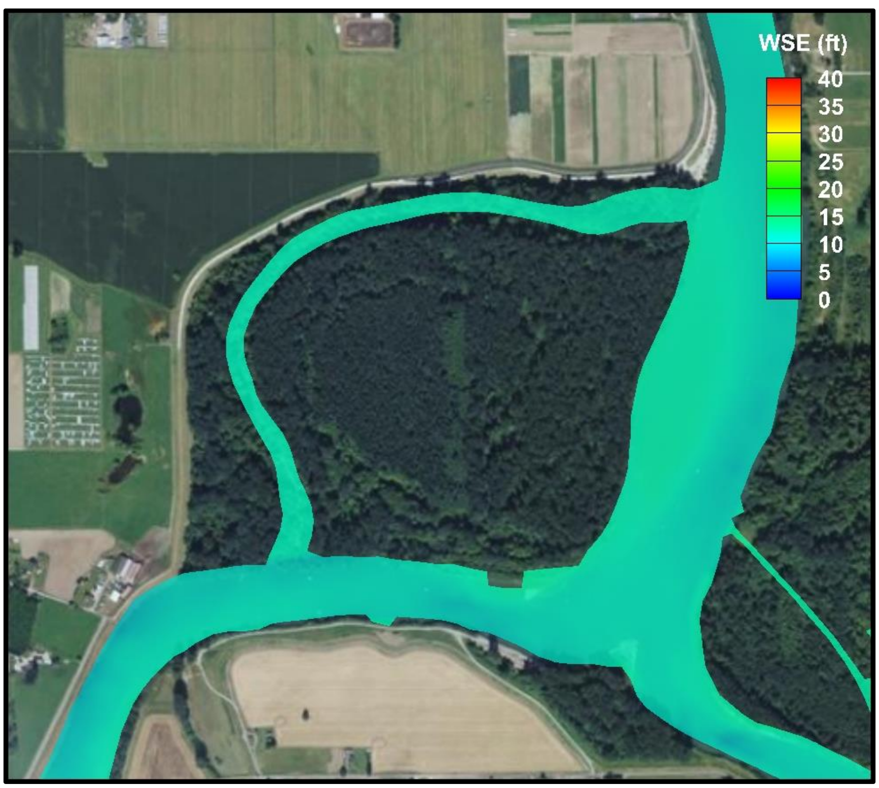


Figure K.65. Contour map of water surface elevation for Cottonwood Island during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

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.

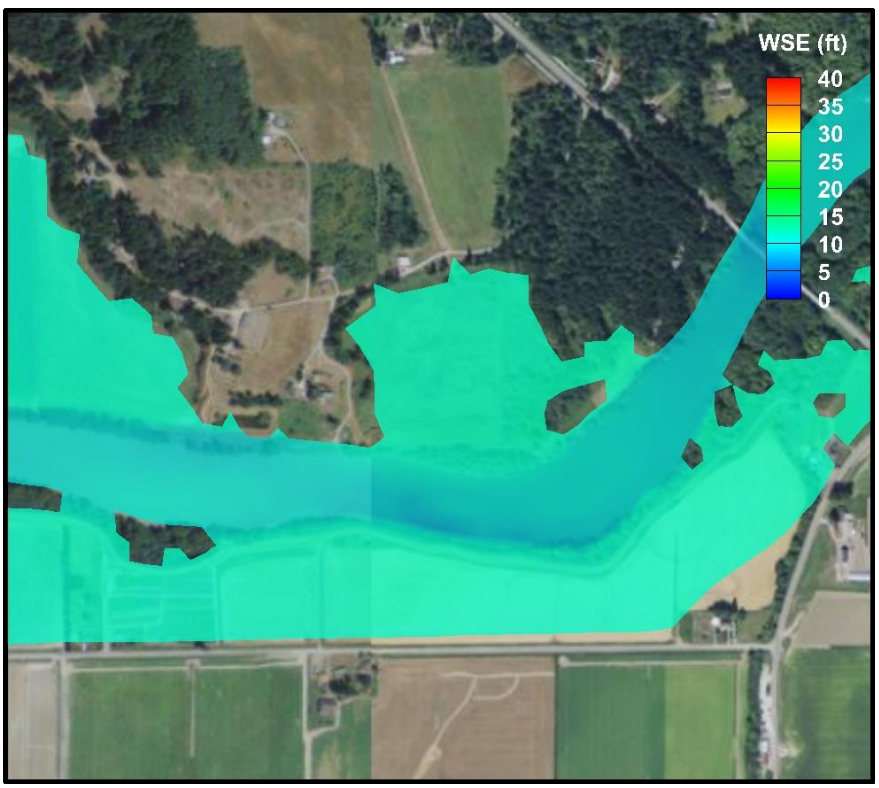


Figure K.67. Contour map of water surface elevation for Pleasant Ridge South during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

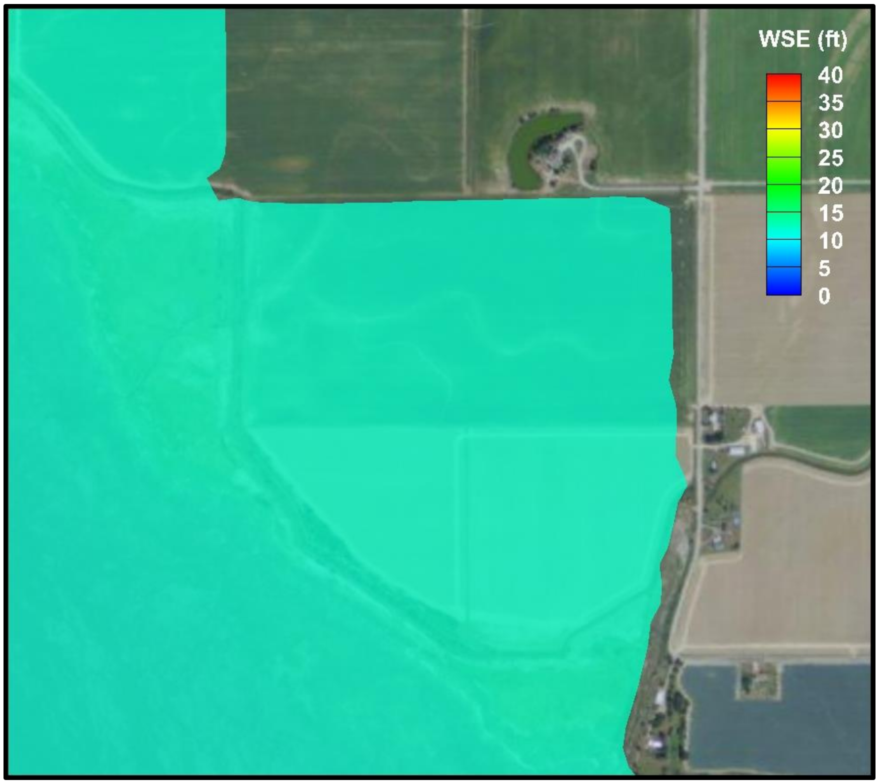


Figure K.68. Contour map of water surface elevation for Hall Sough during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

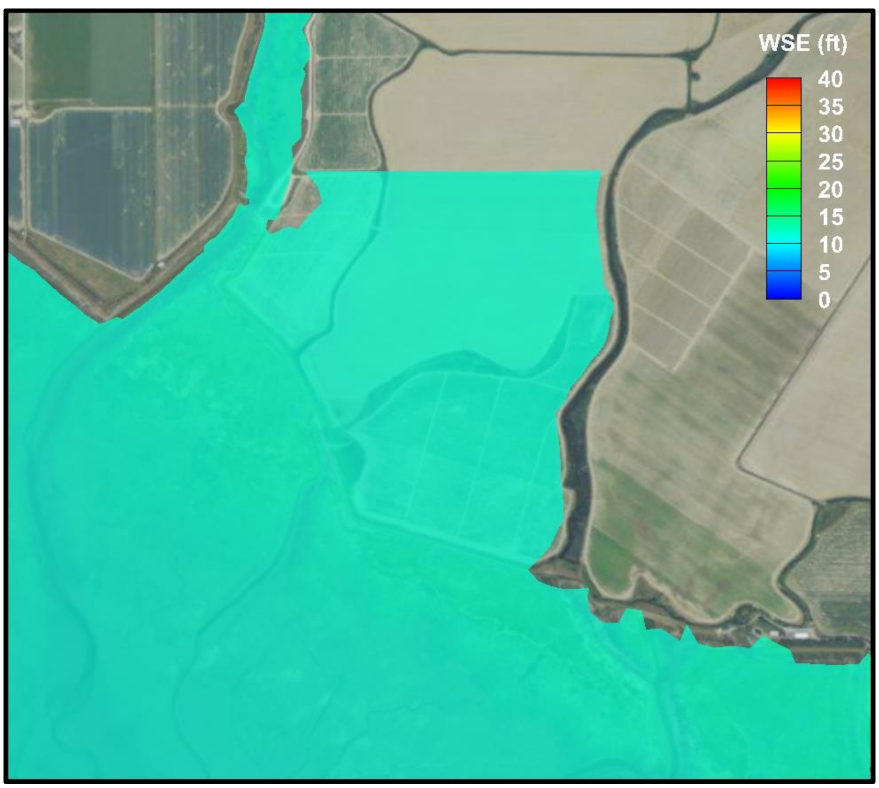


Figure K.69. Contour map of water surface elevation for Fir Island Farm during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

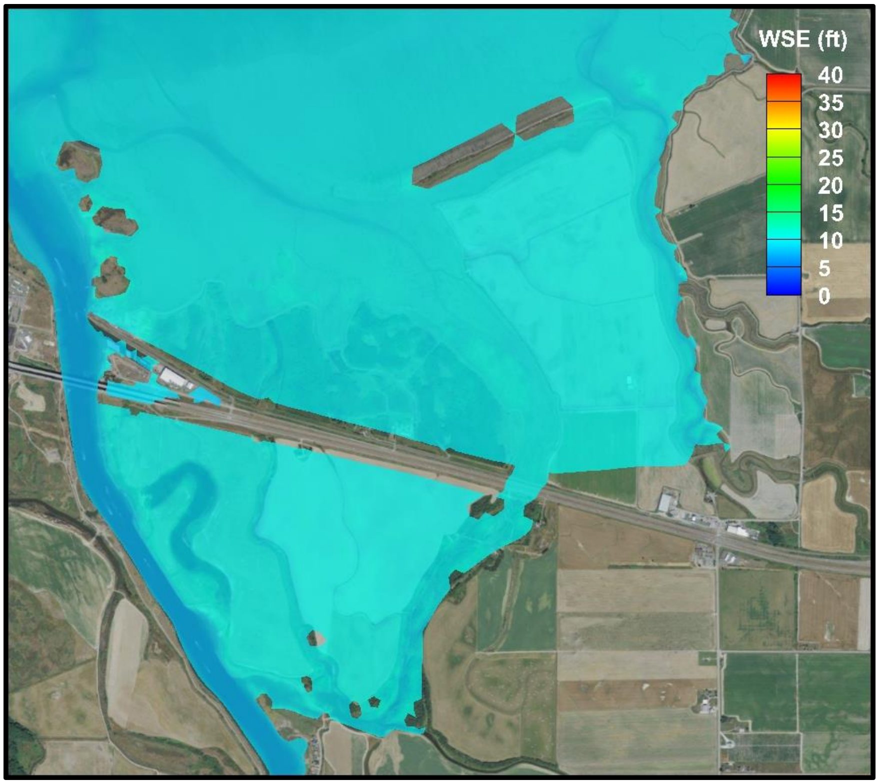


Figure K.70. Contour map of water surface elevation for Telegraph Slough Full during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

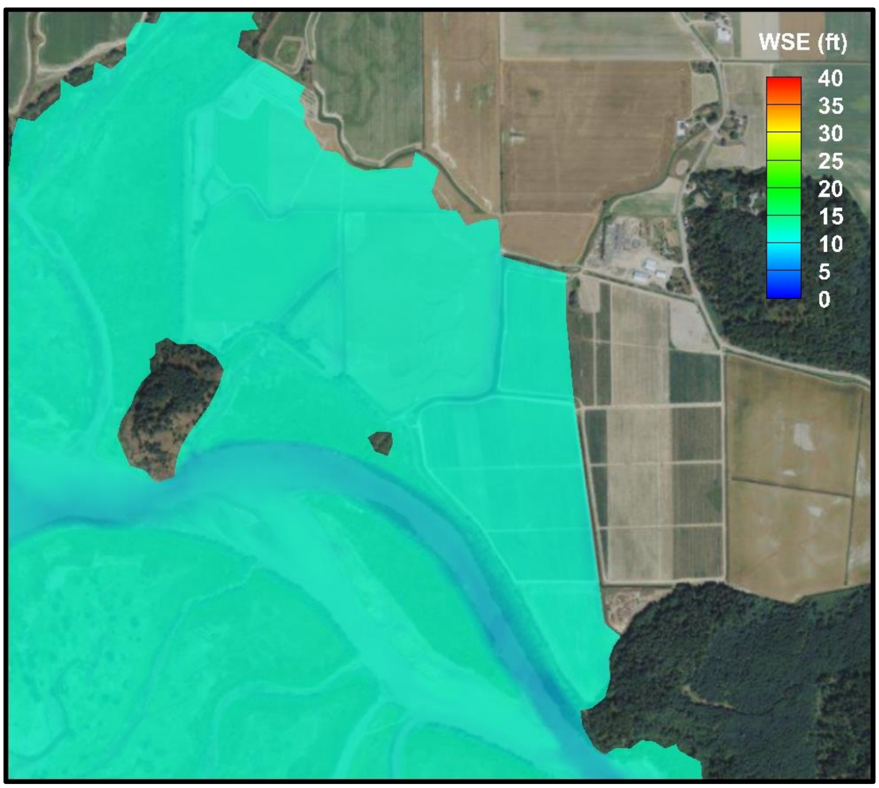


Figure K.71. Contour map of water surface elevation for Sullivan Hacienda during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

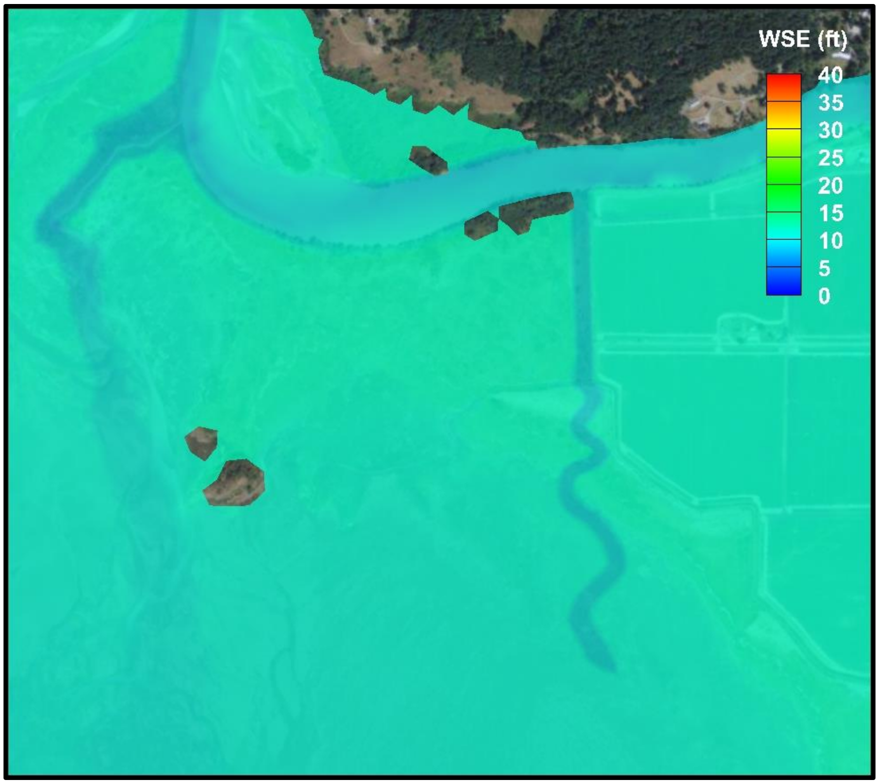


Figure K.72. Contour map of water surface elevation for Rawlins Road Distributary during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

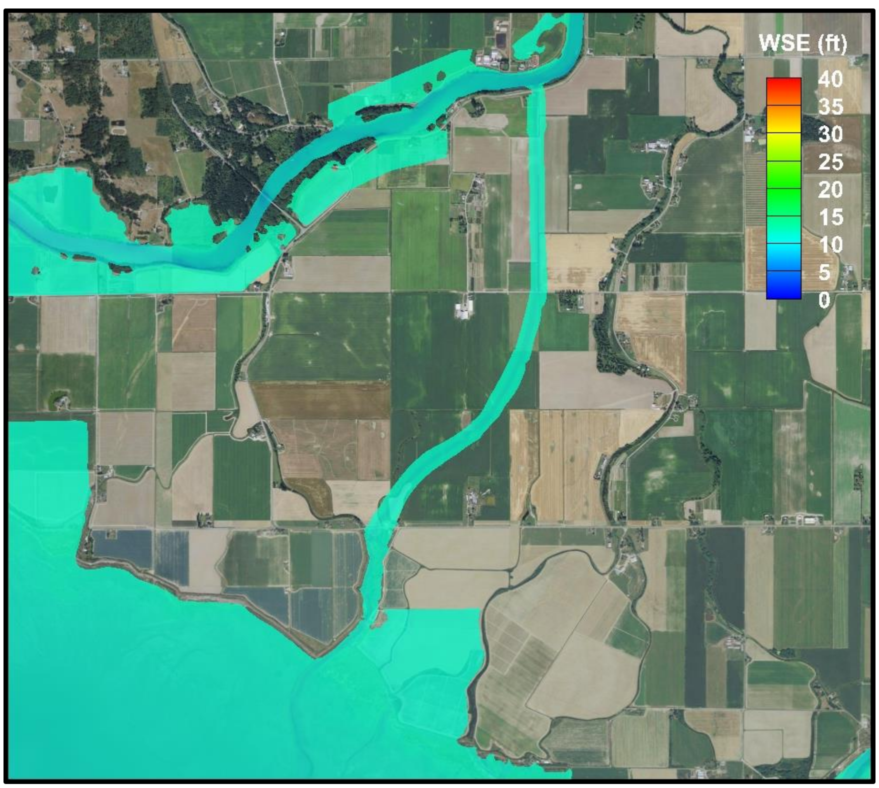


Figure K.73. Contour map of water surface elevation for Cross Island Connector during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

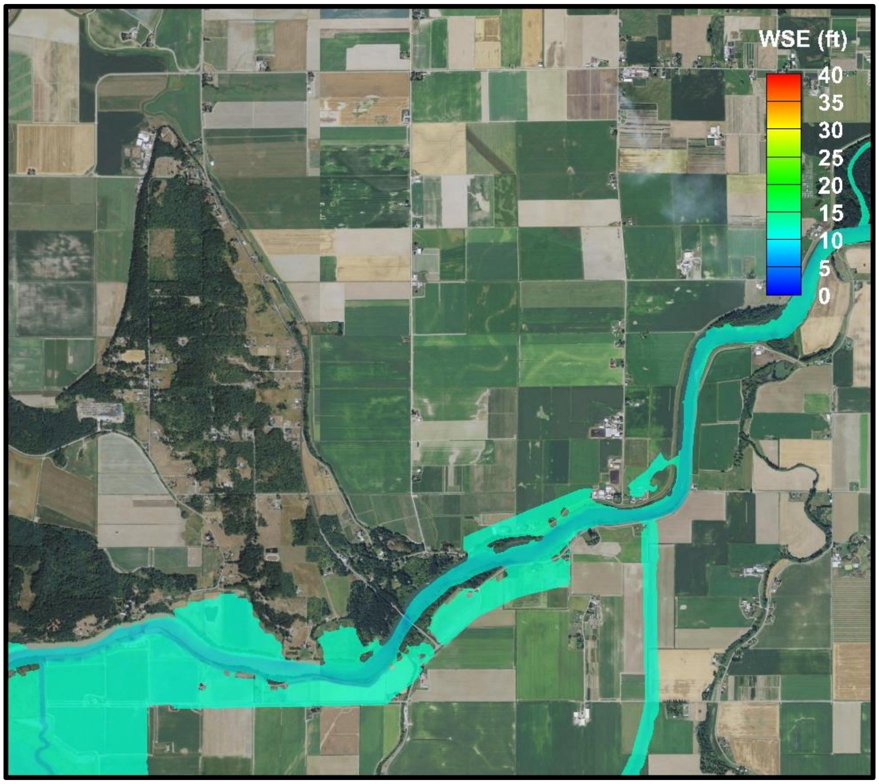


Figure K.74. Contour map of water surface elevation for NF Levee Setback C during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

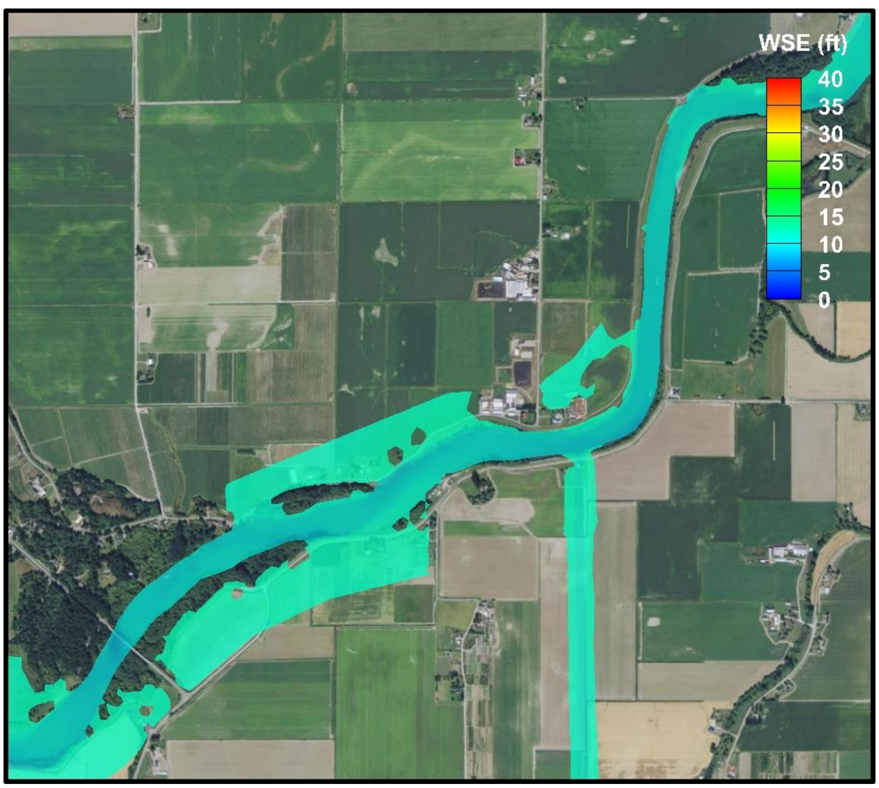


Figure K.75. Contour map of water surface elevation for NF Right Bank Levee Setback during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

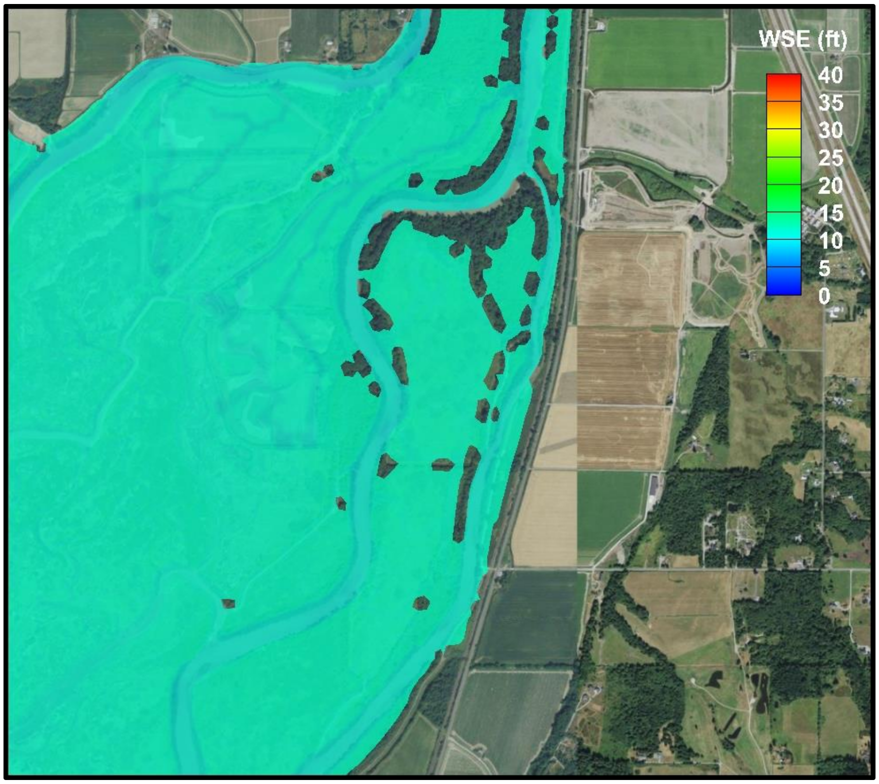


Figure K.76. Contour map of water surface elevation for Milltown Island during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

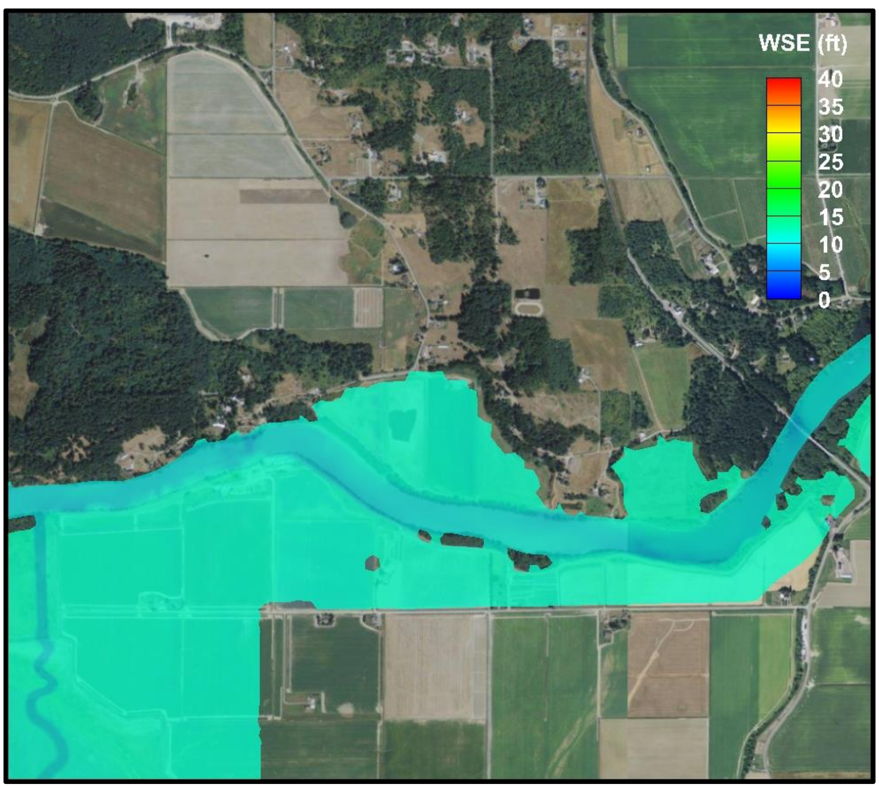


Figure K.77. Contour map of water surface elevation for Thein Farm during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

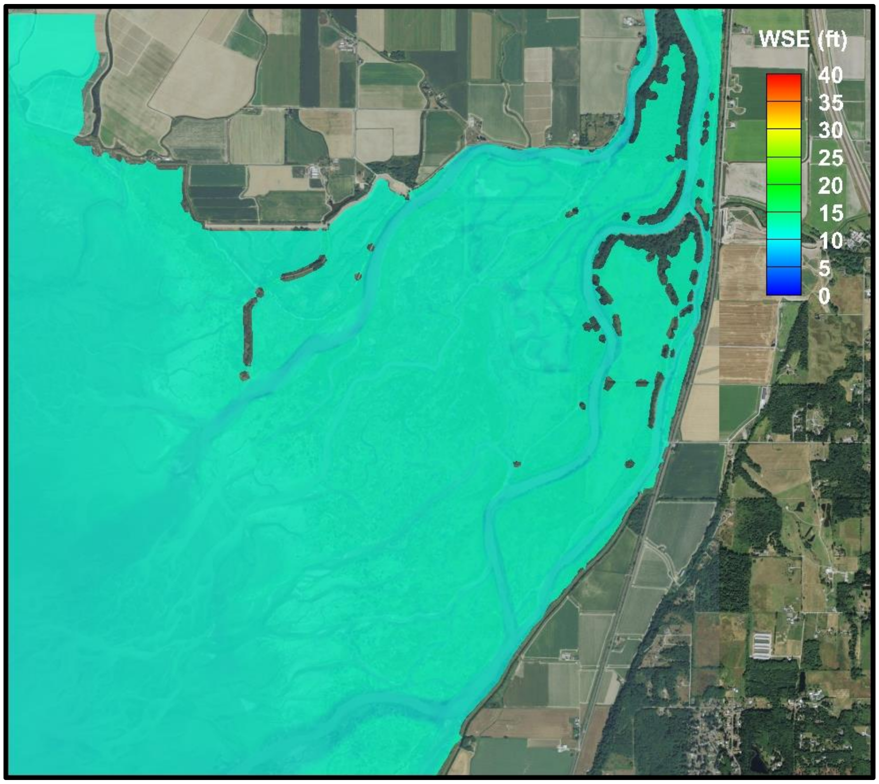


Figure K.78. Contour map of water surface elevation for Deepwater Slough Phase 2 during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

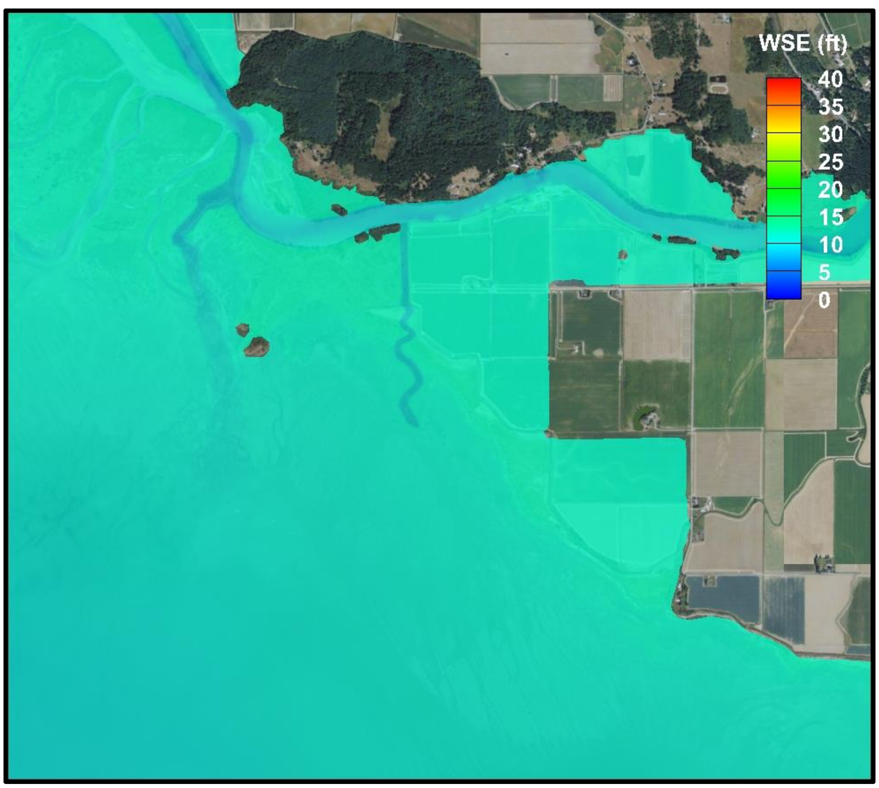


Figure K.79. Contour map of water surface elevation for Rawlins Road during the 2080 Climate Change with Projects simulation with low flow and future high spring tide.

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.

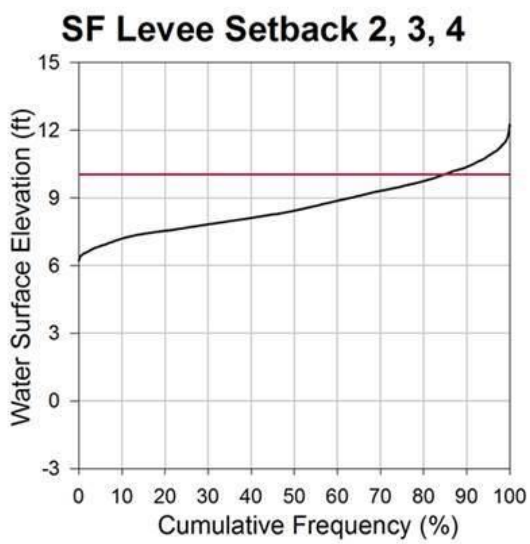


Figure K.80. Cumulative frequency plot and corresponding map for SF Levee Setbacks 2, 3, and 4 during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

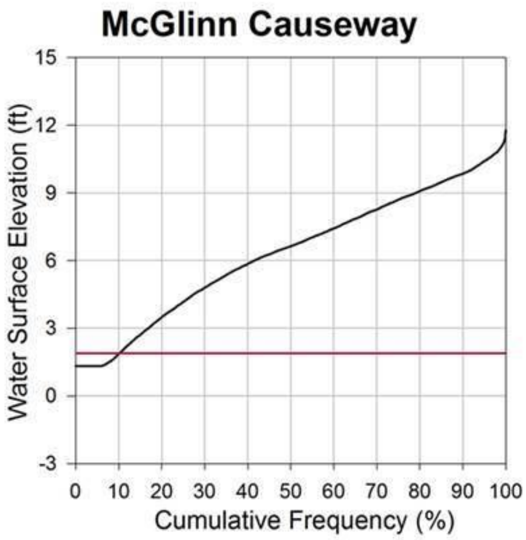


Figure K.81. Cumulative frequency plot and corresponding map for McGlinn Causeway during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

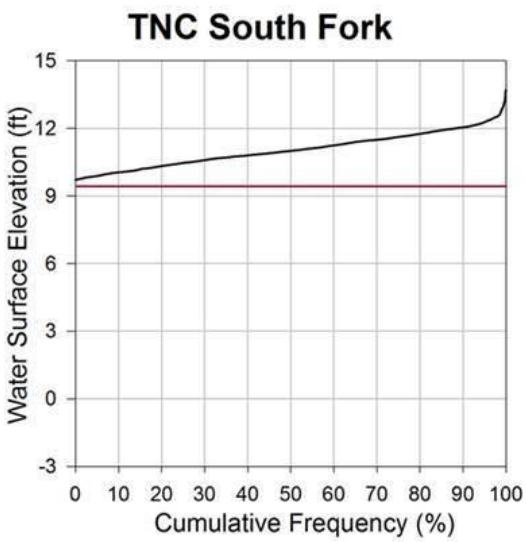


Figure K.82. Cumulative frequency plot and corresponding map for TNC South Fork during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

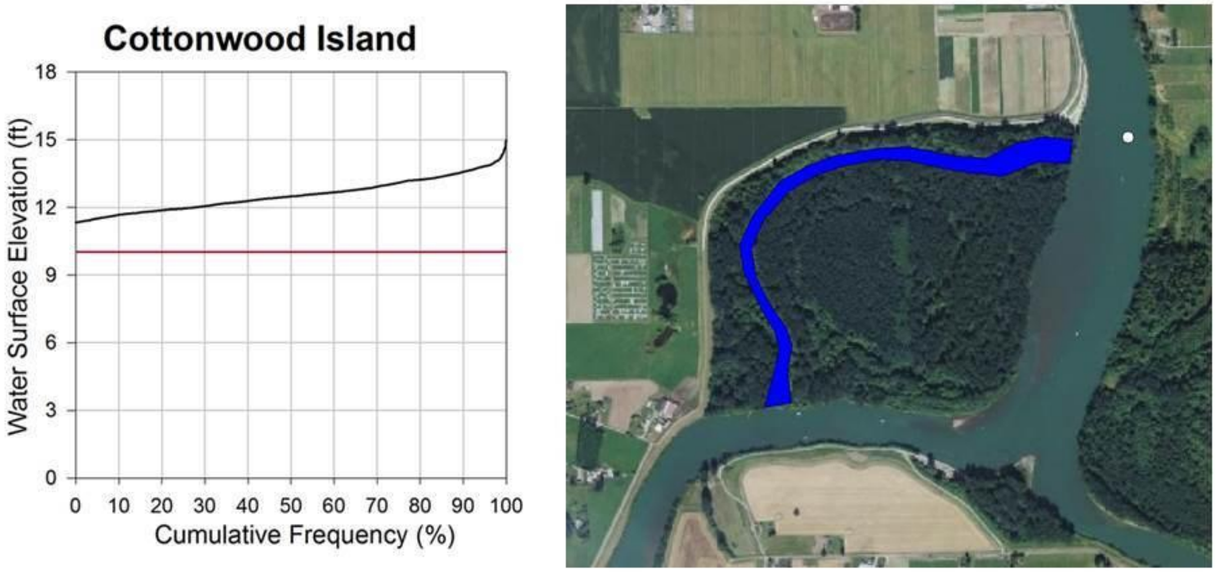


Figure K.83. Cumulative frequency plot and corresponding map for Cottonwood Island during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

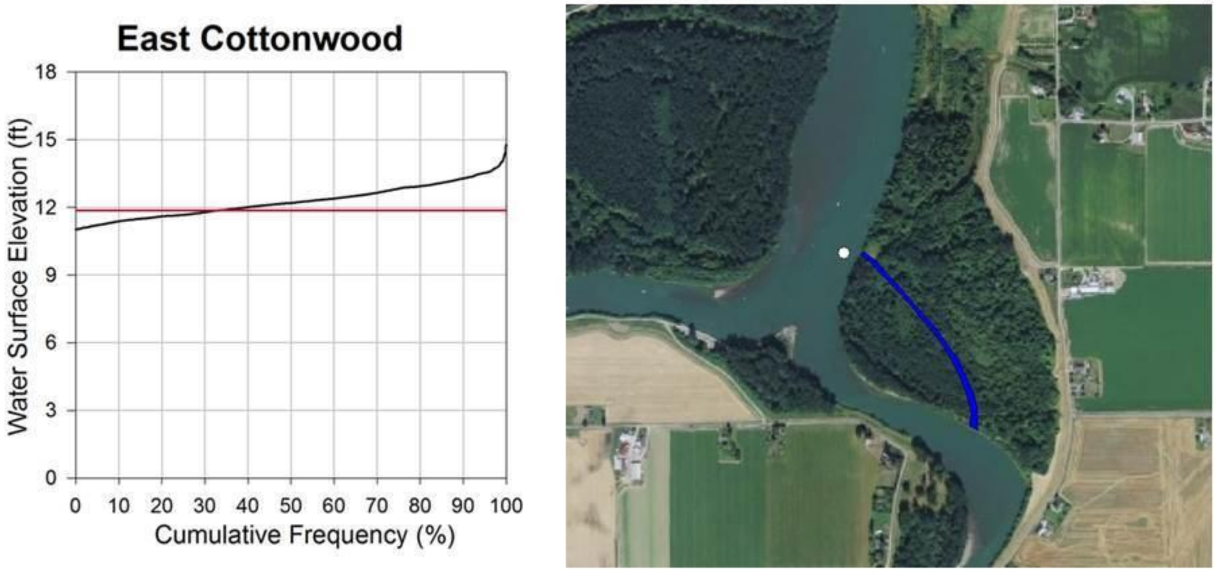


Figure K.84. Cumulative frequency plot and corresponding map for East Cottonwood during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

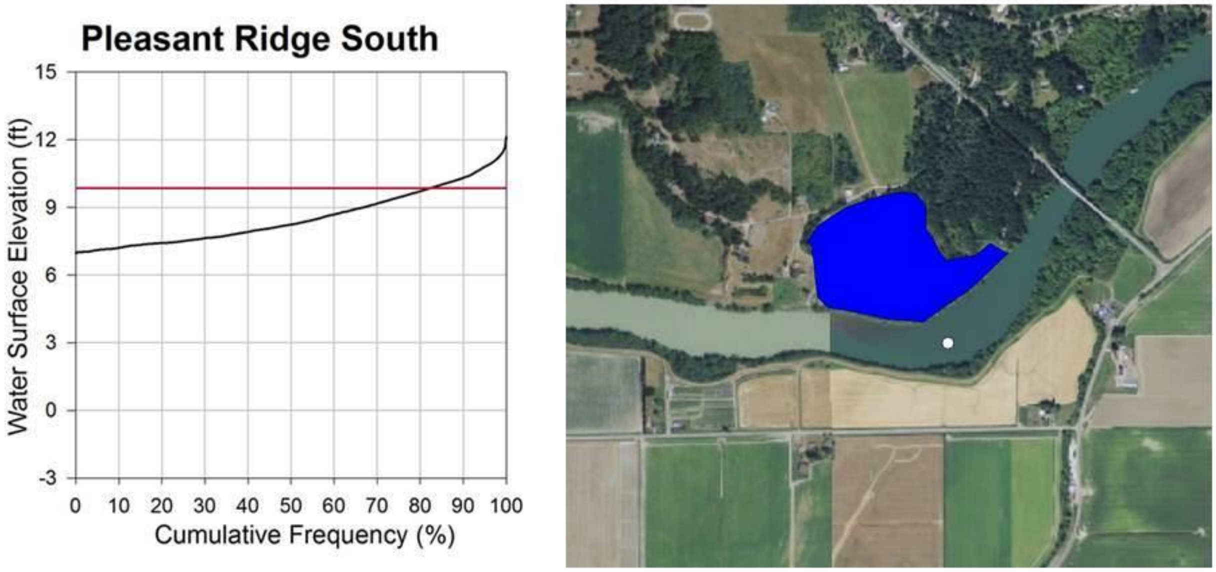


Figure K.85. Cumulative frequency plot and corresponding map for Pleasant Ridge South during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

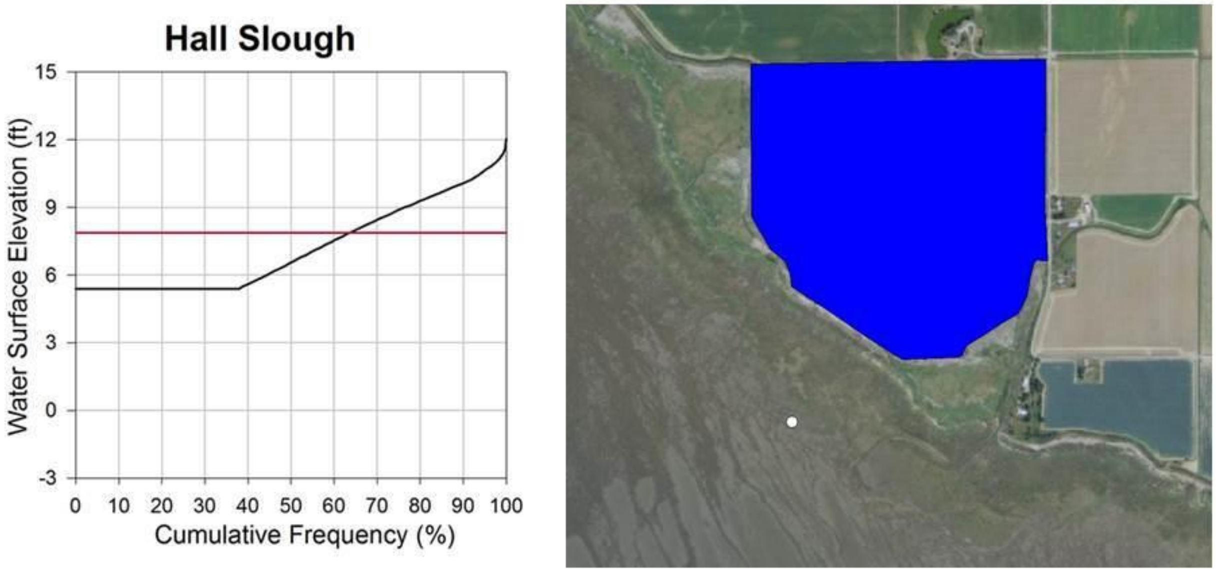


Figure K.86. Cumulative frequency plot and corresponding map for Hall Slough during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

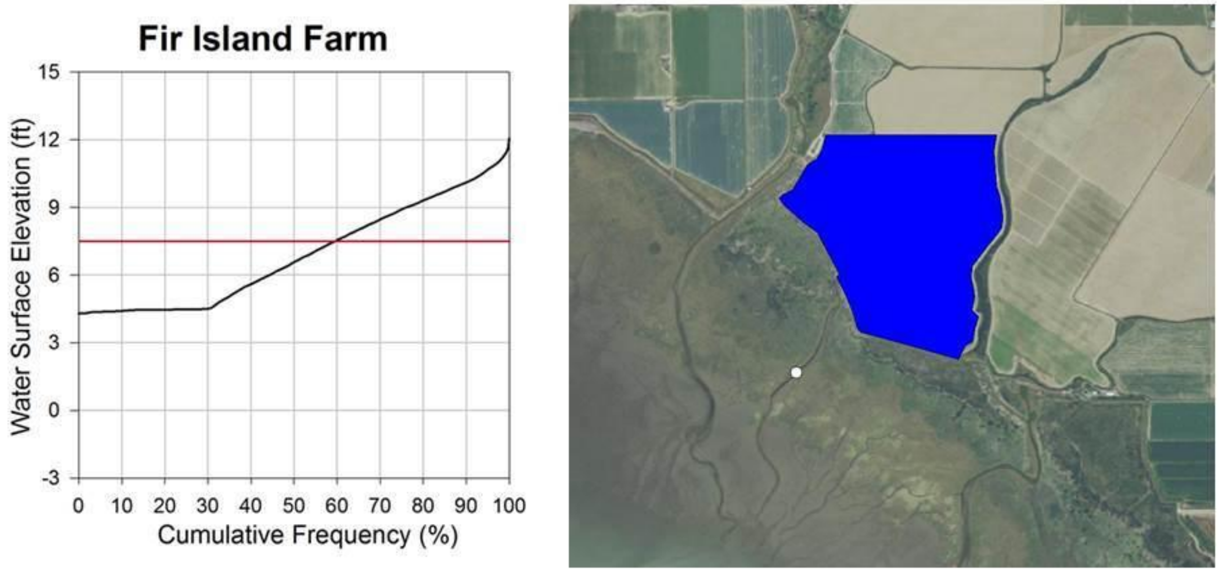


Figure K.87. Cumulative frequency plot and corresponding map for Fir Island Farm during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

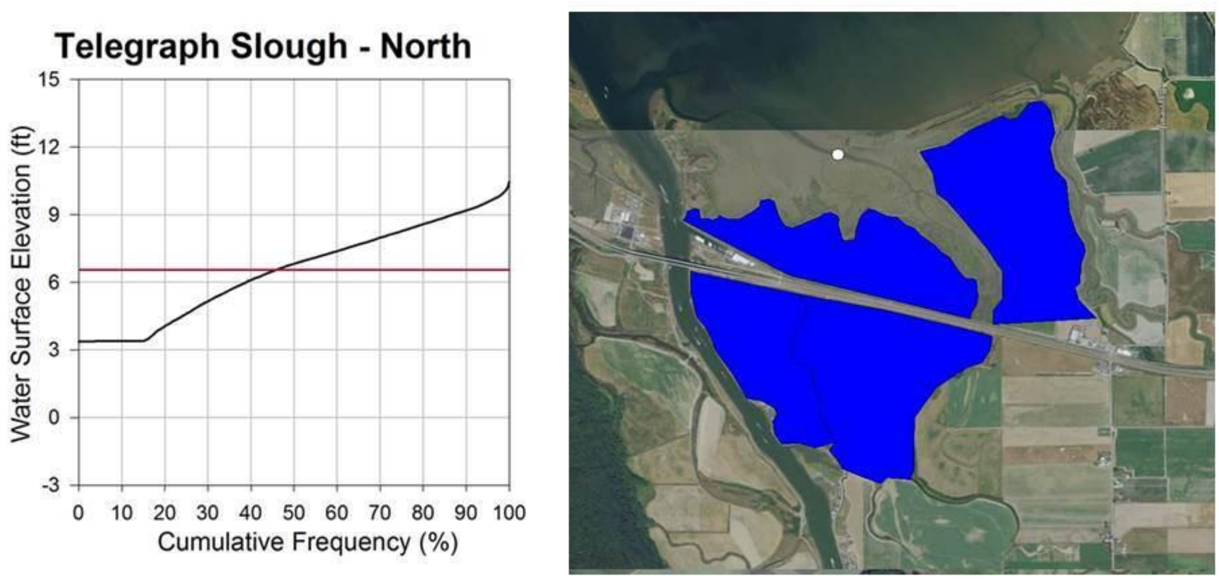


Figure K.88. Cumulative frequency plot and corresponding map for Telegraph Slough (north) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

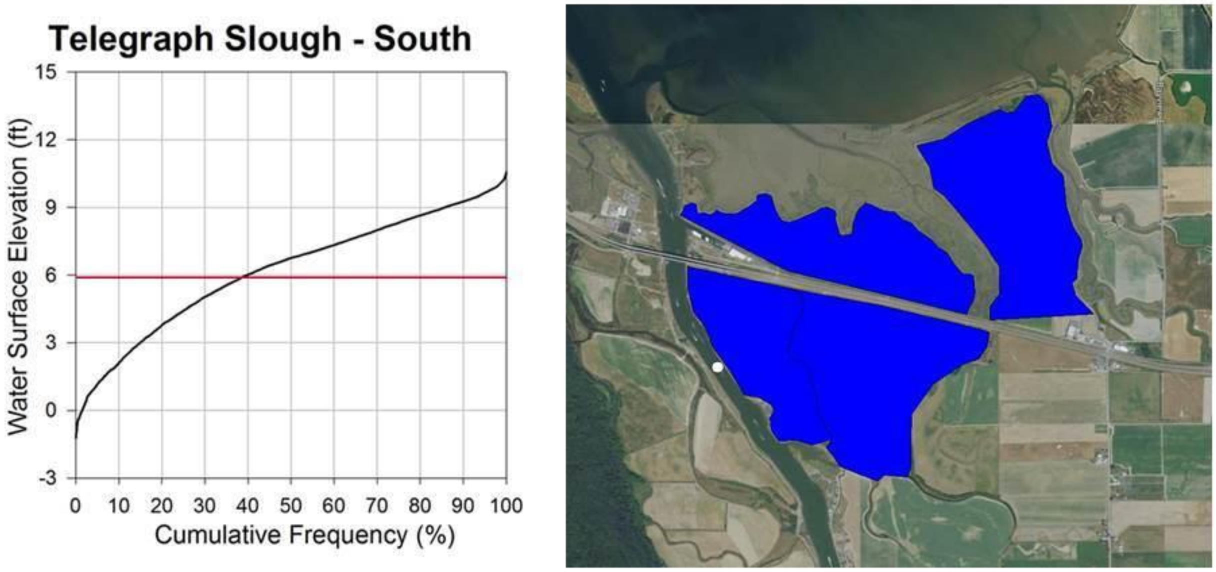


Figure K.89. Cumulative frequency plot and corresponding map for Telegraph Slough (south) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

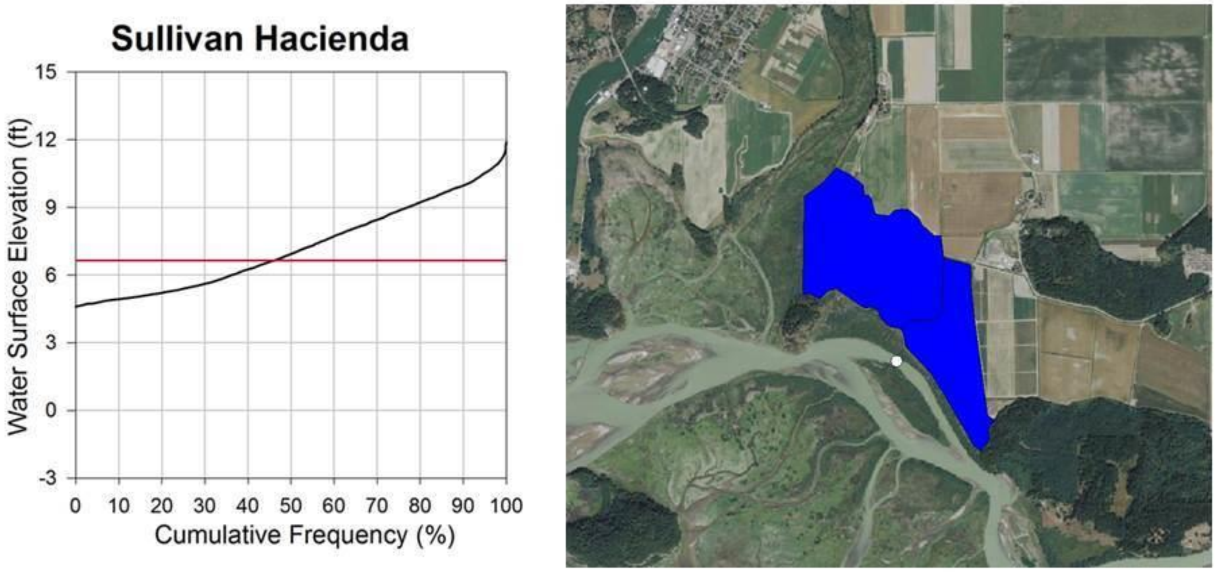


Figure K.90. Cumulative frequency plot and corresponding map for Sullivan Hacienda during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

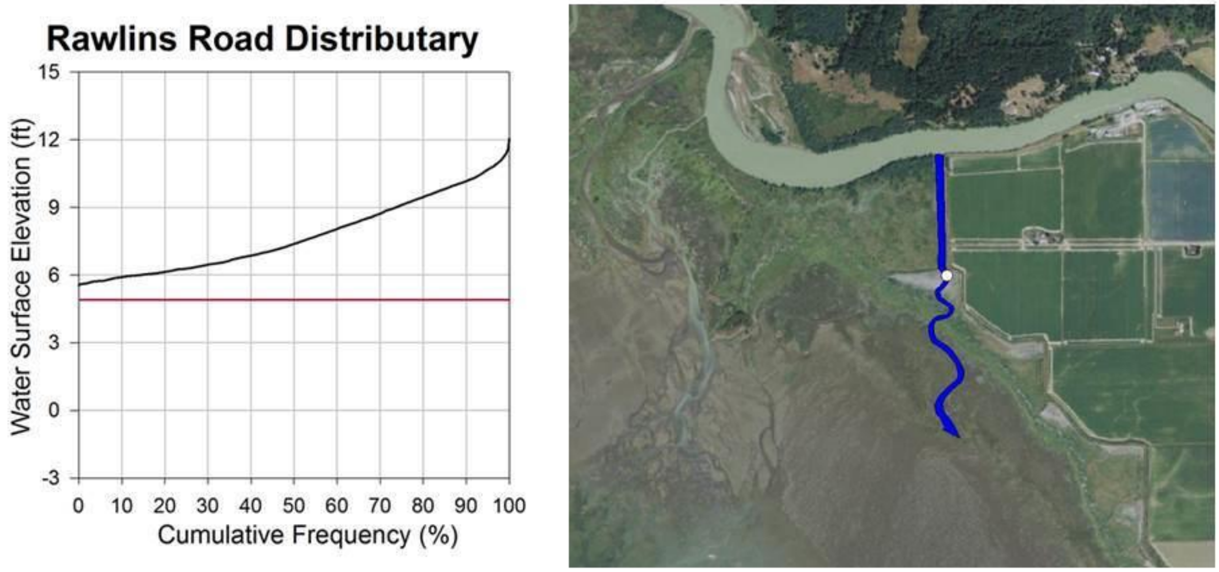


Figure K.91. Cumulative frequency plot and corresponding map for Rawlins Road Distributary during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

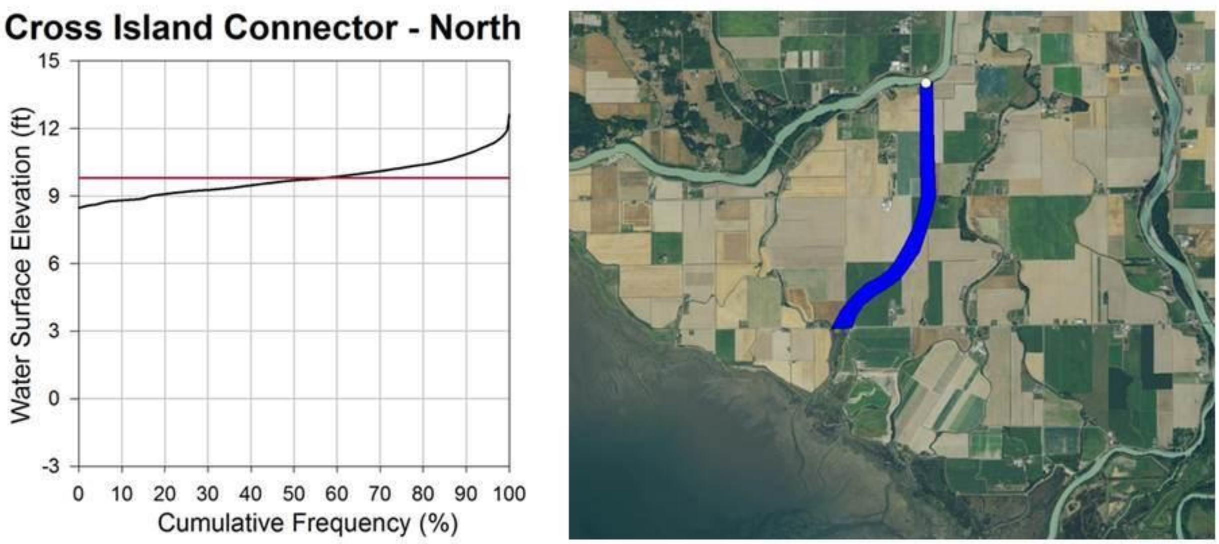


Figure K.92. Cumulative frequency plot and corresponding map for Cross Island Connector (north) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

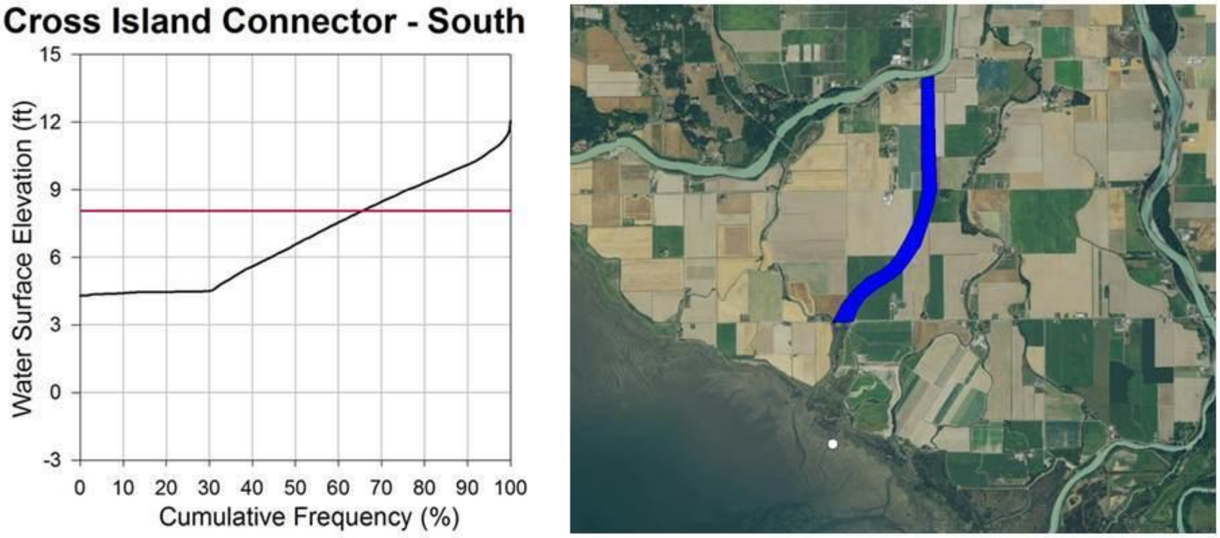


Figure K.93. Cumulative frequency plot and corresponding map for Cross Island Connector (south) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

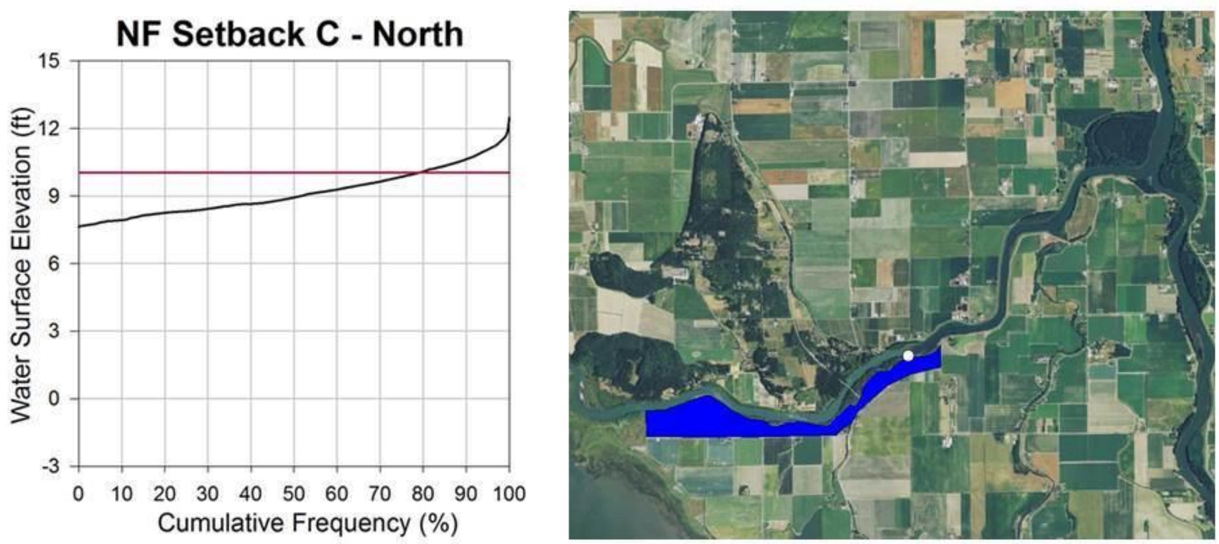


Figure K.94. Cumulative frequency plot and corresponding map for NF Levee Setback C (north) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

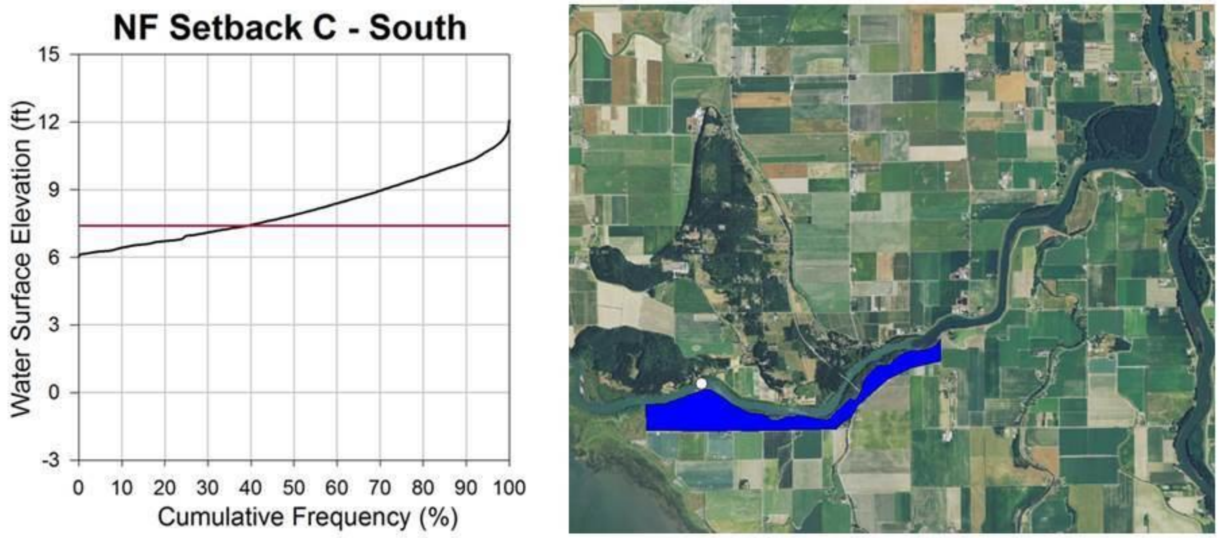


Figure K.95. Cumulative frequency plot and corresponding map for NF Levee Setback C (south) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

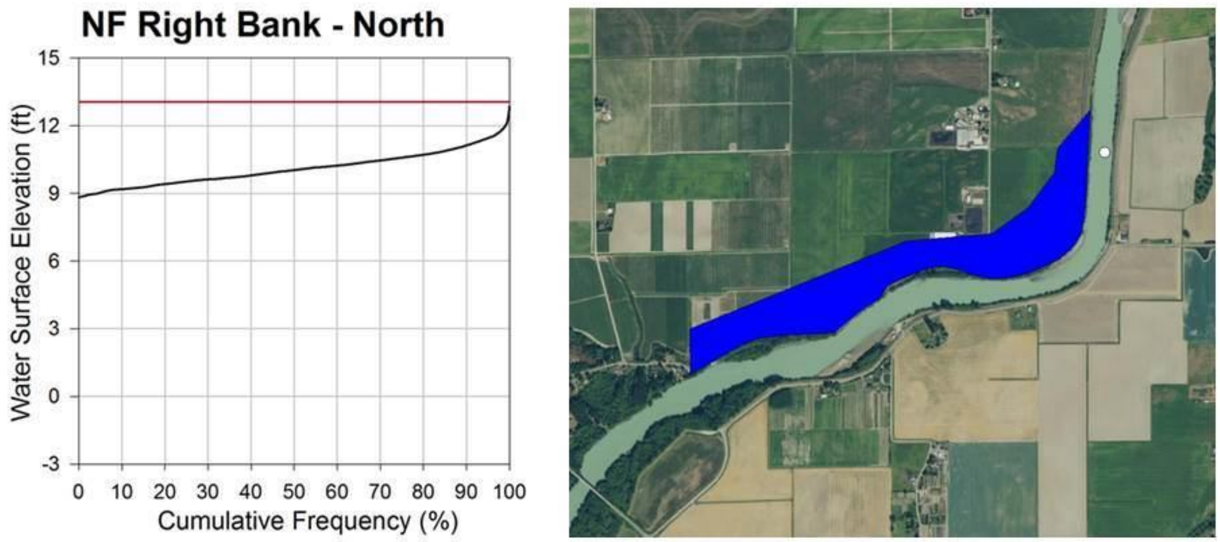


Figure K.96. Cumulative frequency plot and corresponding map for NF Right Bank Levee Setback (north) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

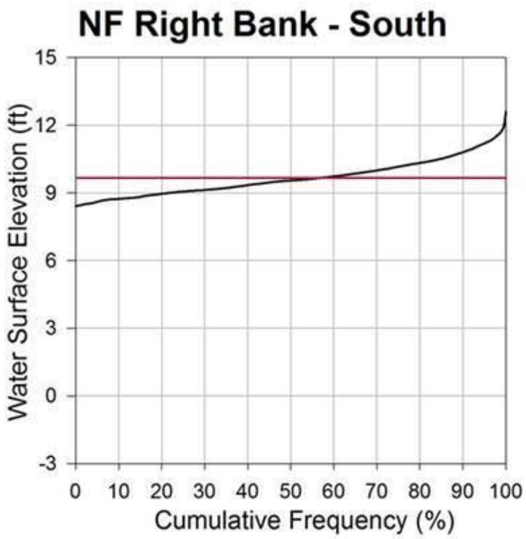


Figure K.97. Cumulative frequency plot and corresponding map for NF Right Bank Levee Setback (south) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

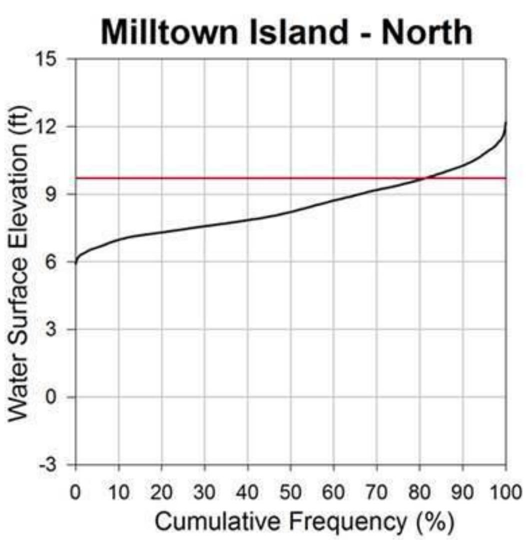


Figure K.98. Cumulative frequency plot and corresponding map for Milltown Island (north) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

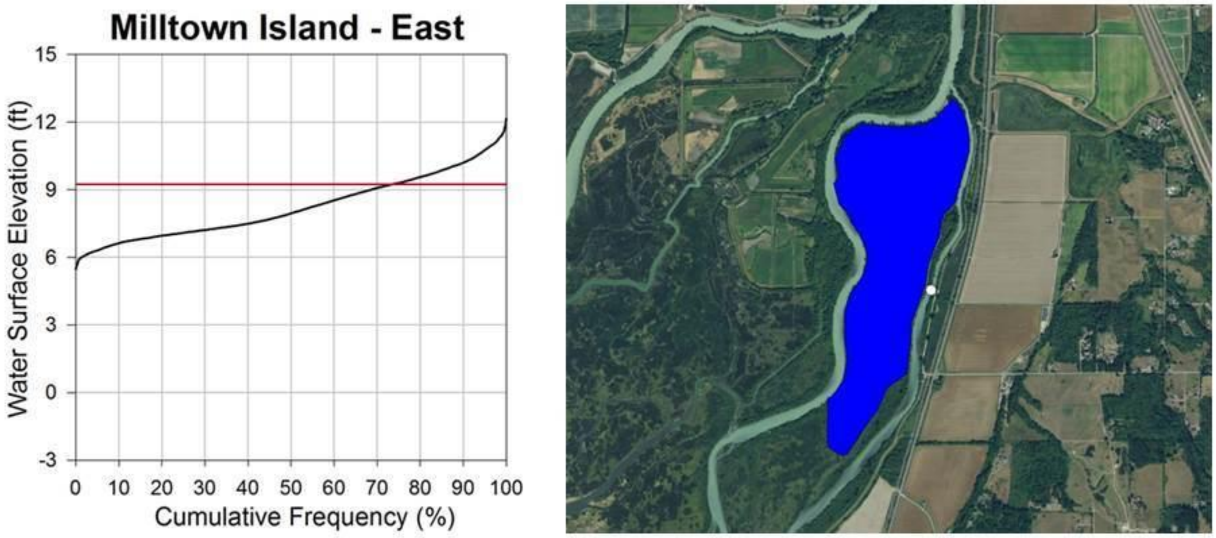


Figure K.99. Cumulative frequency plot and corresponding map for Milltown Island (east) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

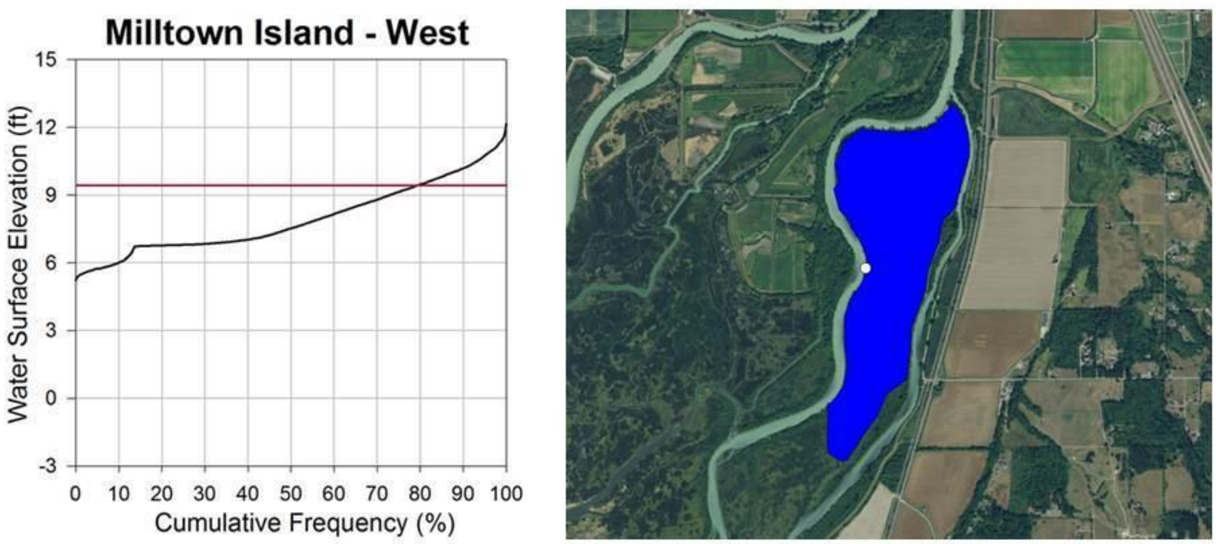


Figure K.100. Cumulative frequency plot and corresponding map for Milltown Island (west) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

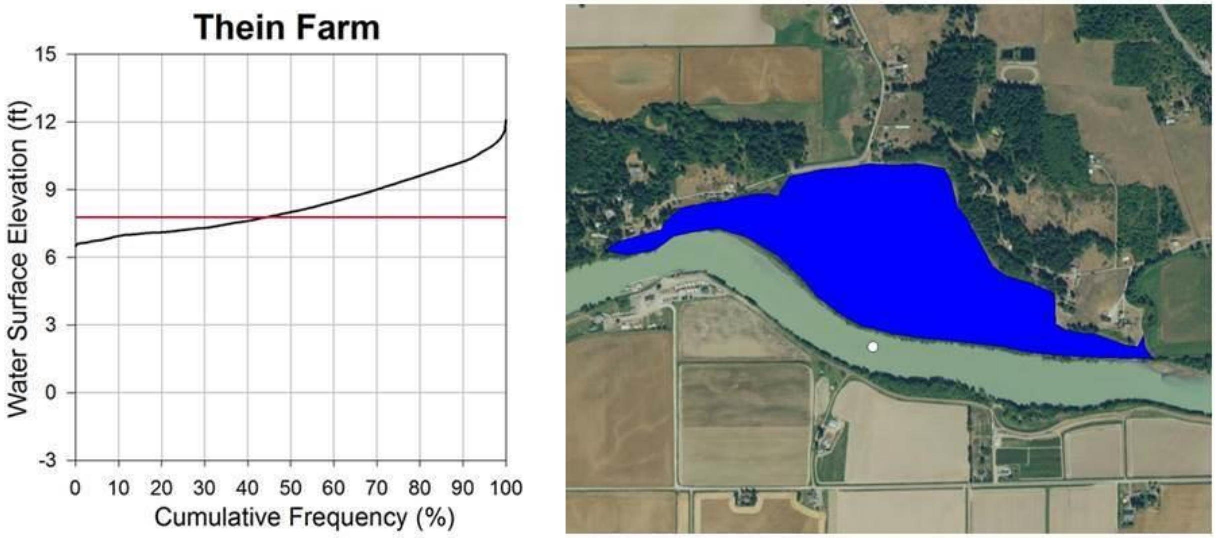


Figure K.101. Cumulative frequency plot and corresponding map for Thein Farm during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

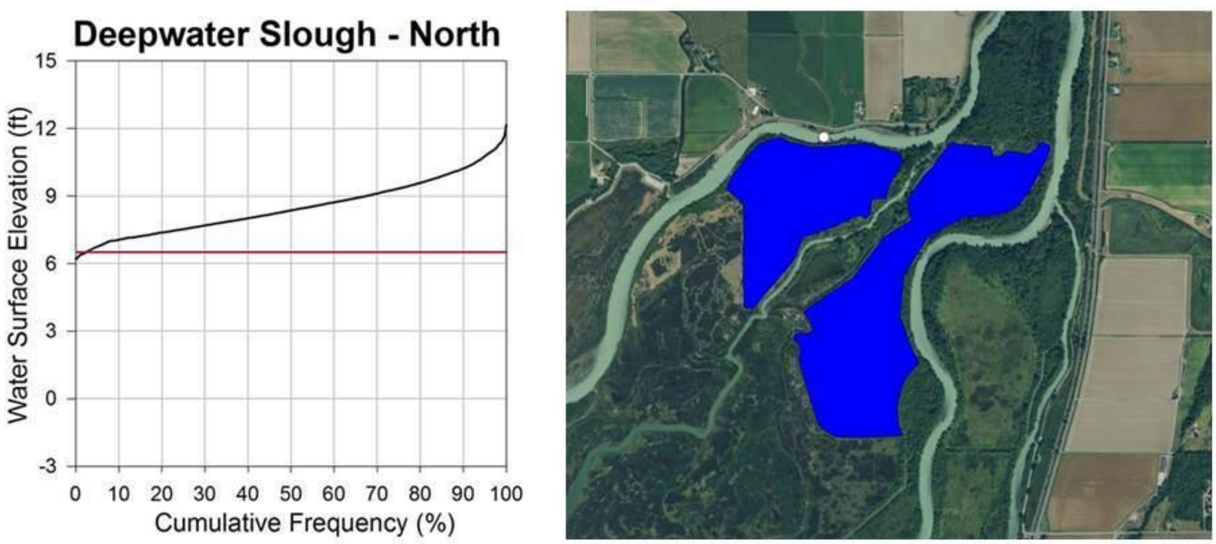


Figure K.102. Cumulative frequency plot and corresponding map for Deepwater Slough (north) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

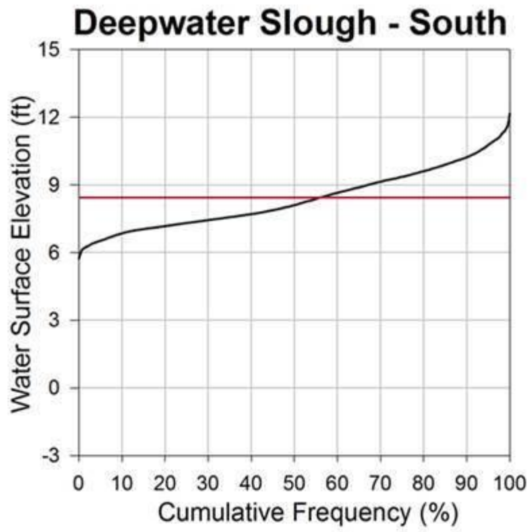


Figure K.103. Cumulative frequency plot and corresponding map for Deepwater Slough (south) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

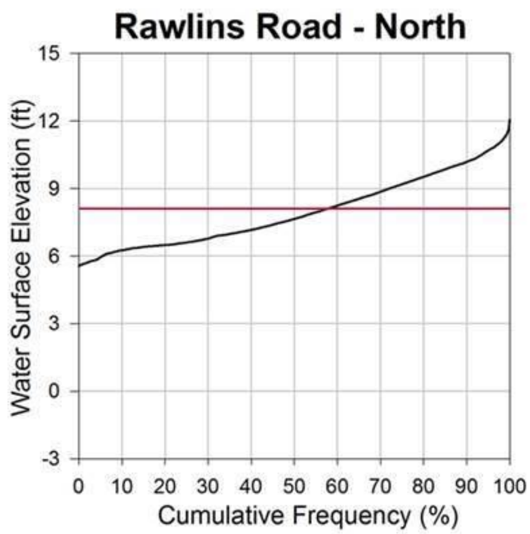


Figure K.104. Cumulative frequency plot and corresponding map for Rawlins Road (north) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

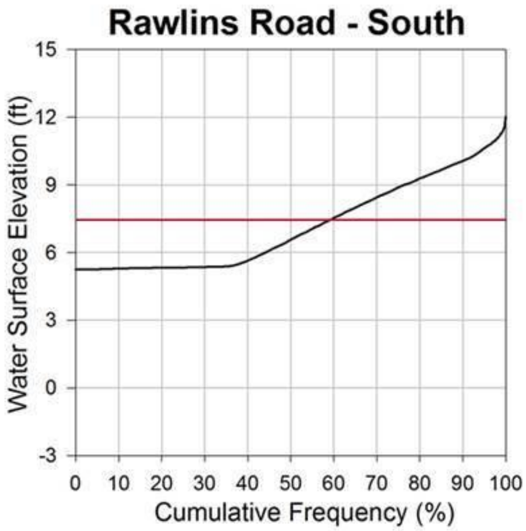


Figure K.105. Cumulative frequency plot and corresponding map for Rawlins Road (south) during the 2080 Climate Change with Project simulation. The specific location is designated by the white dot on the map. The red line indicates a typical elevation on the restoration project concept.

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.

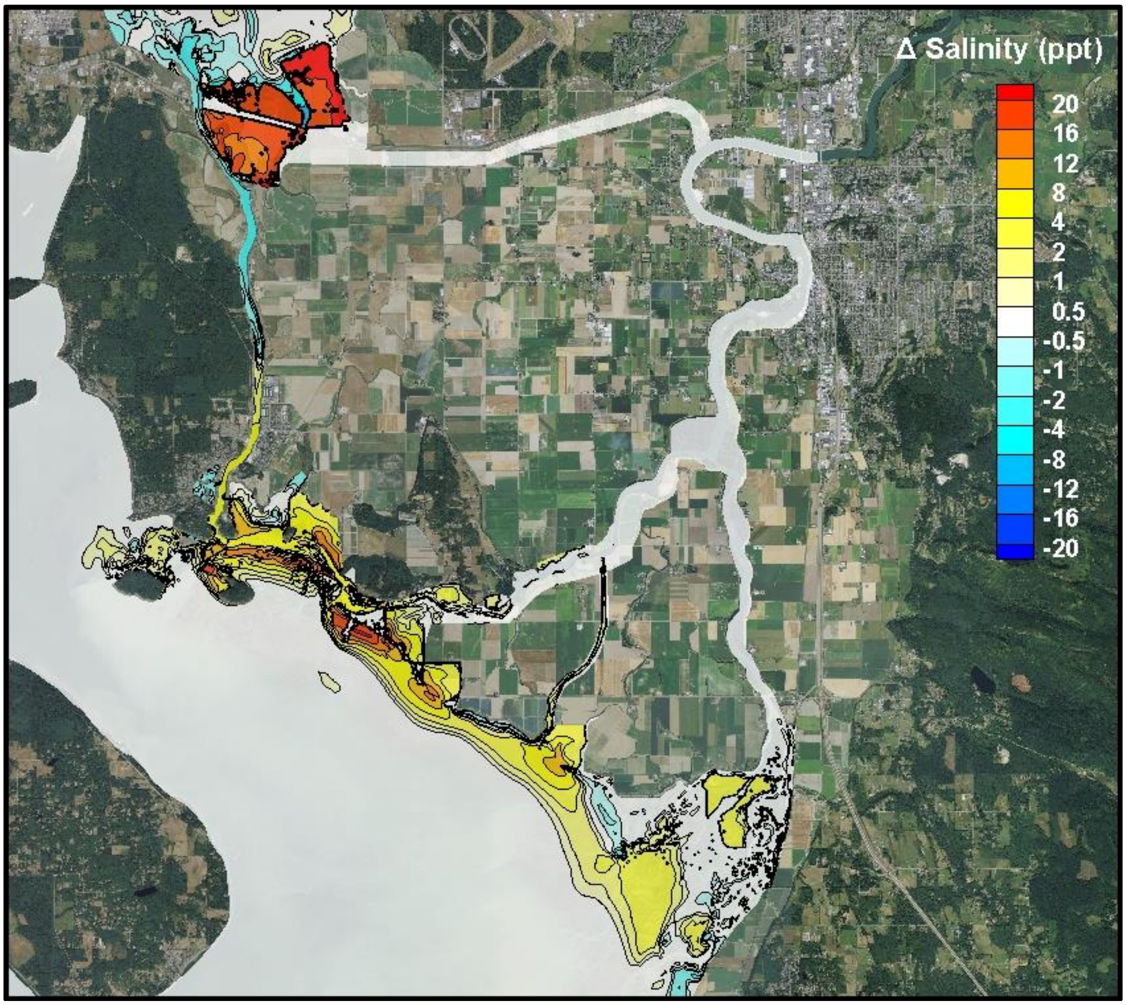


Figure K.106. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation with low flow and high tide.

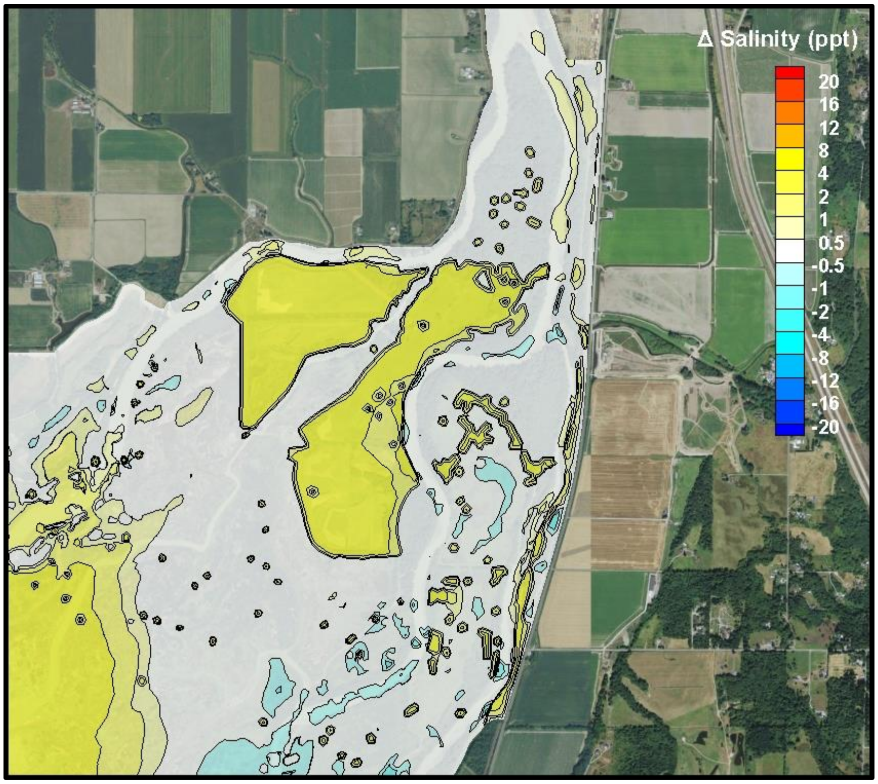


Figure K.107. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for SF Levee Setback 2, 3, 4 with low flow and high tide

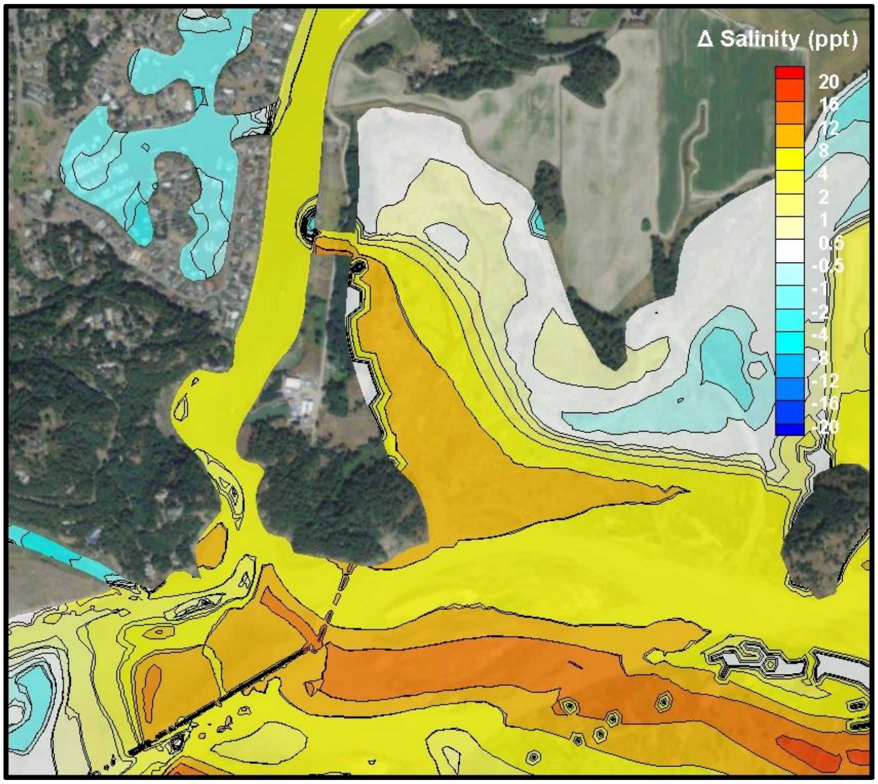


Figure K.108. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for McGlinn Causeway with low flow and high tide

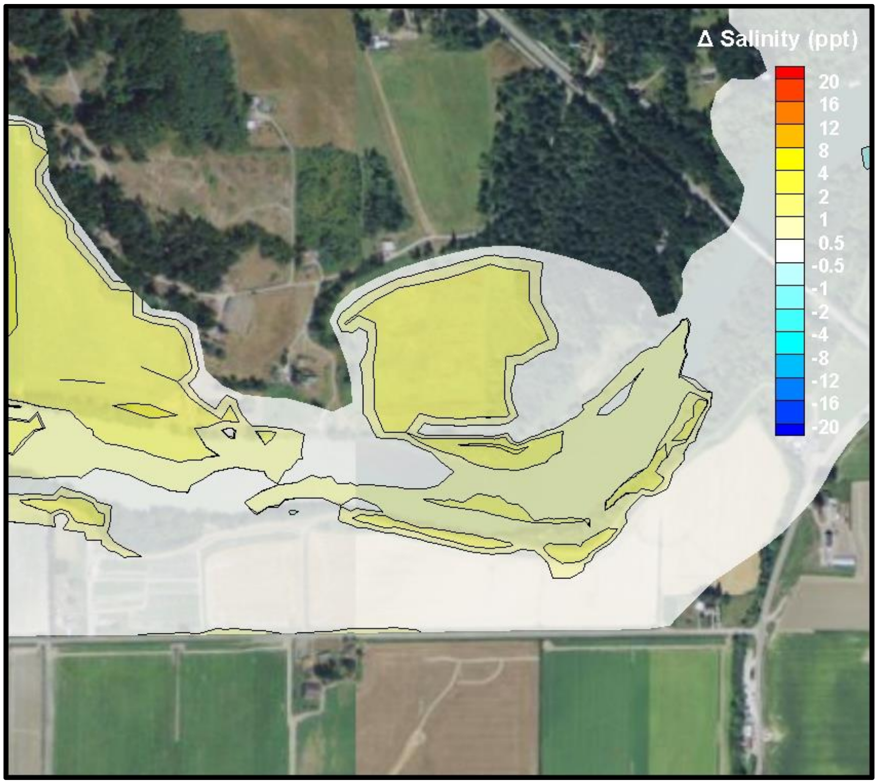


Figure K.109. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Pleasant Ridge South with low flow and high tide

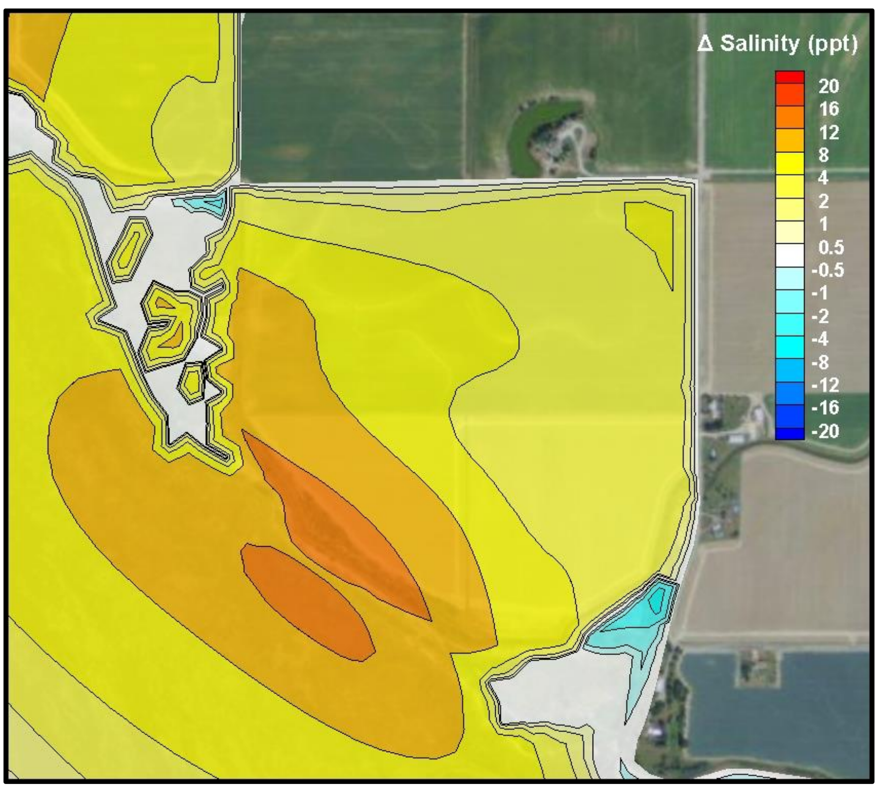


Figure K.110. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Hall Slough with low flow and high tide

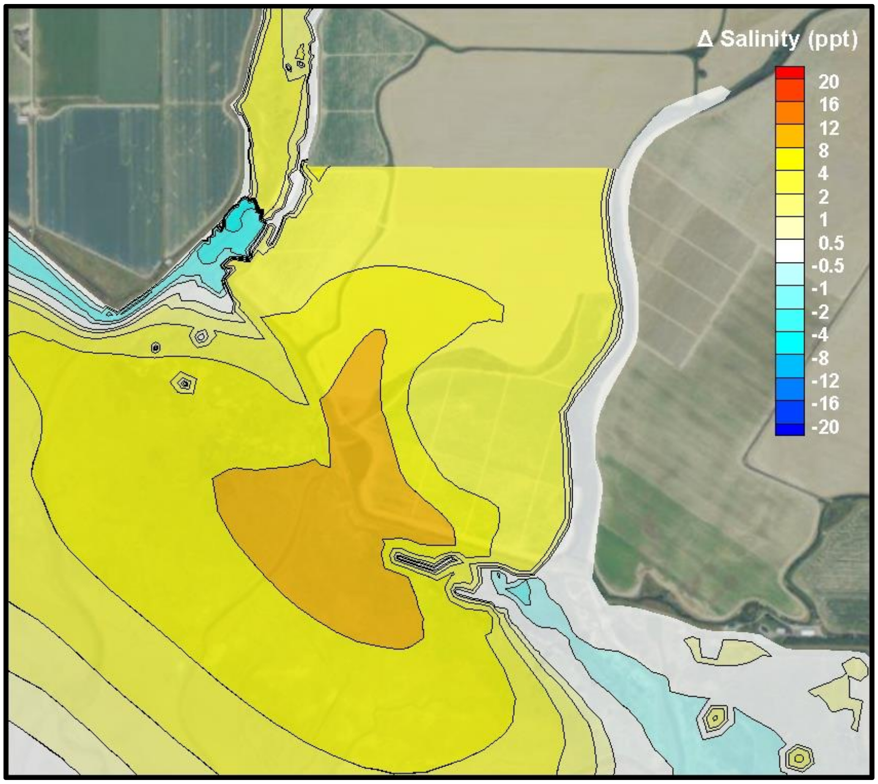


Figure K.111. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Fir Island Farm with low flow and high tide

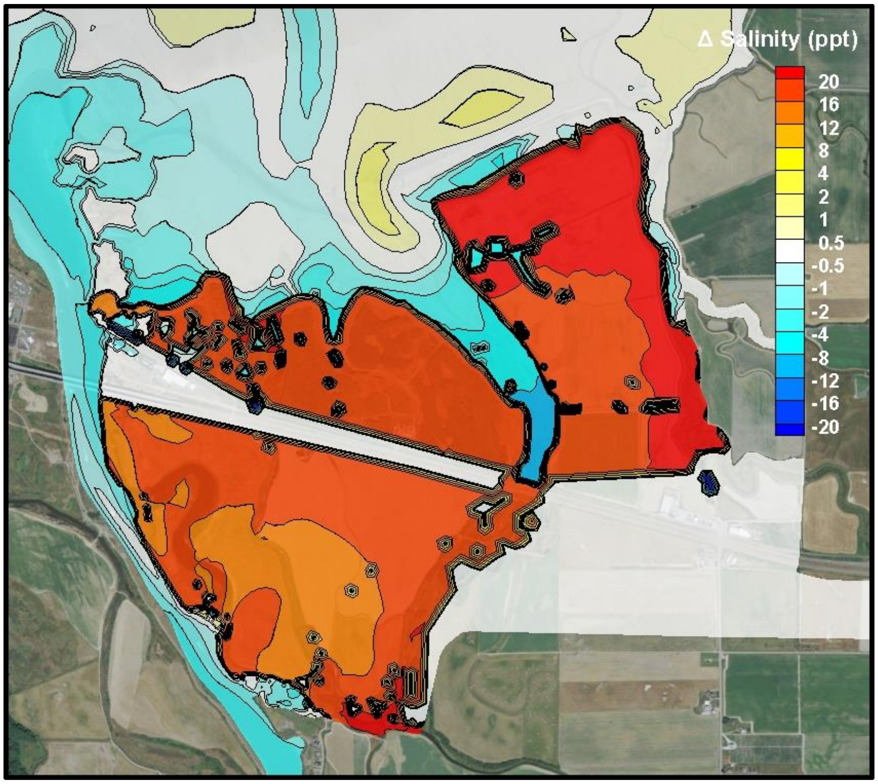


Figure K.112. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Telegraph Slough Full with low flow and high tide

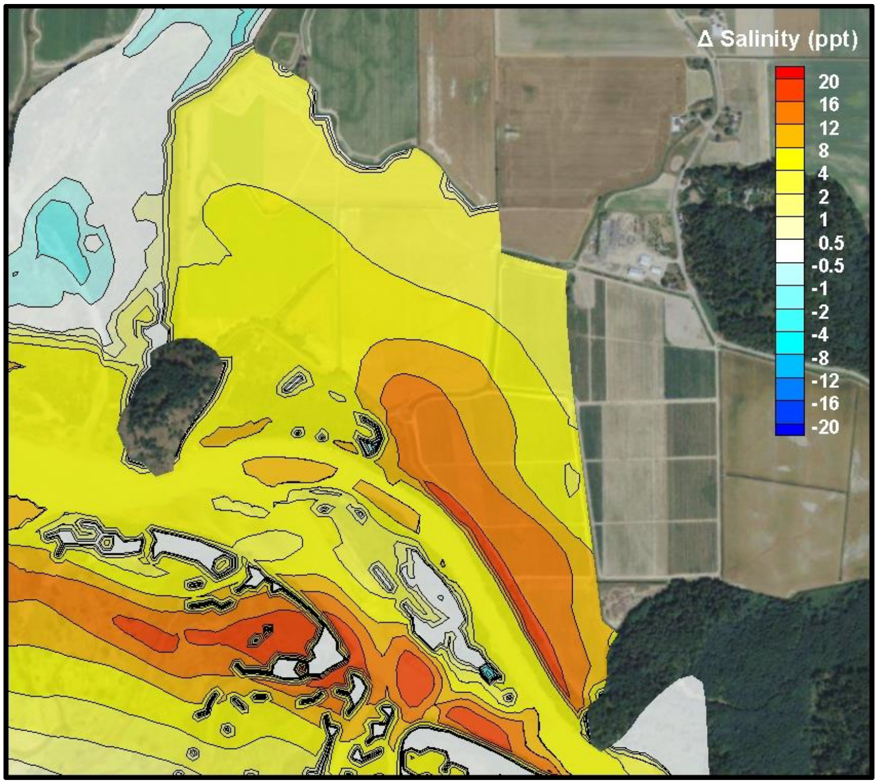


Figure K.113. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Sullivan Hacienda with low flow and high tide

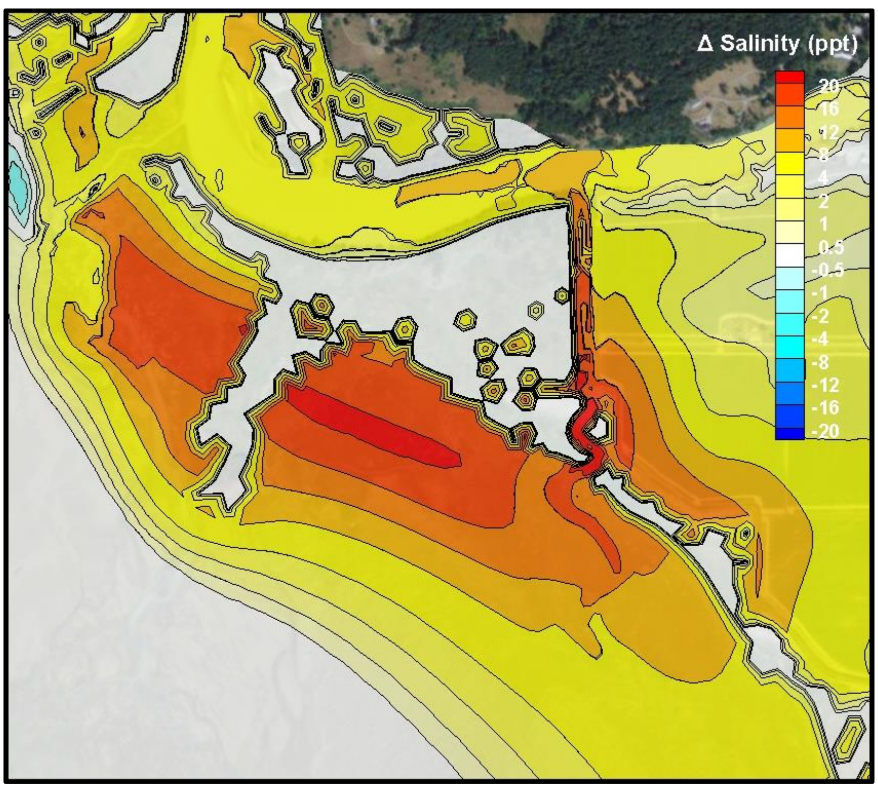


Figure K.114. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Rawlins Distributary with low flow and high tide

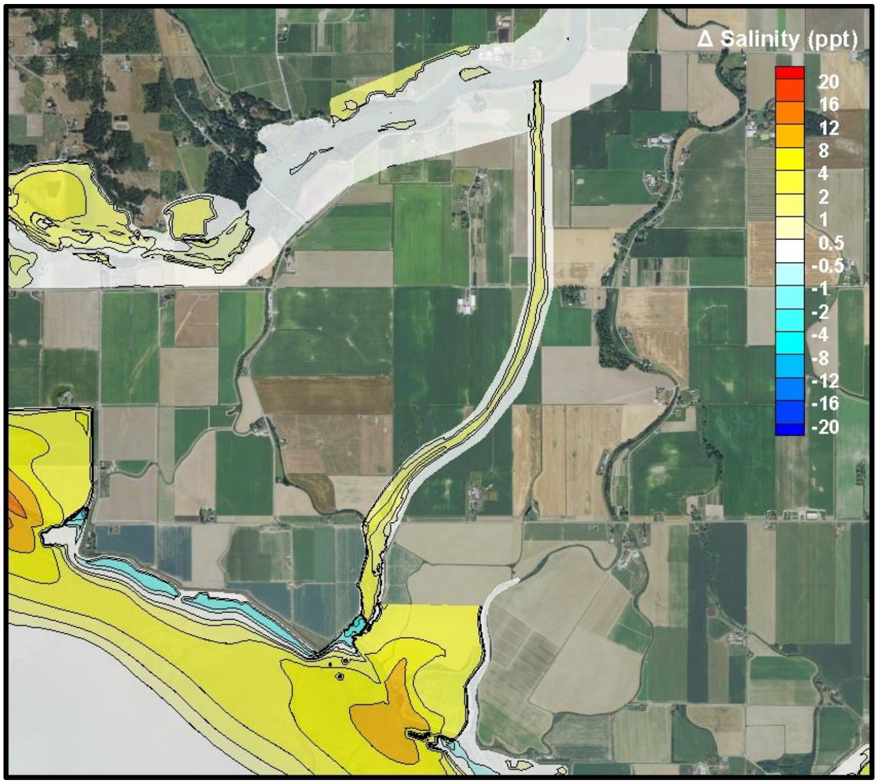


Figure K.115. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Cross Island Connector with low flow and high tide

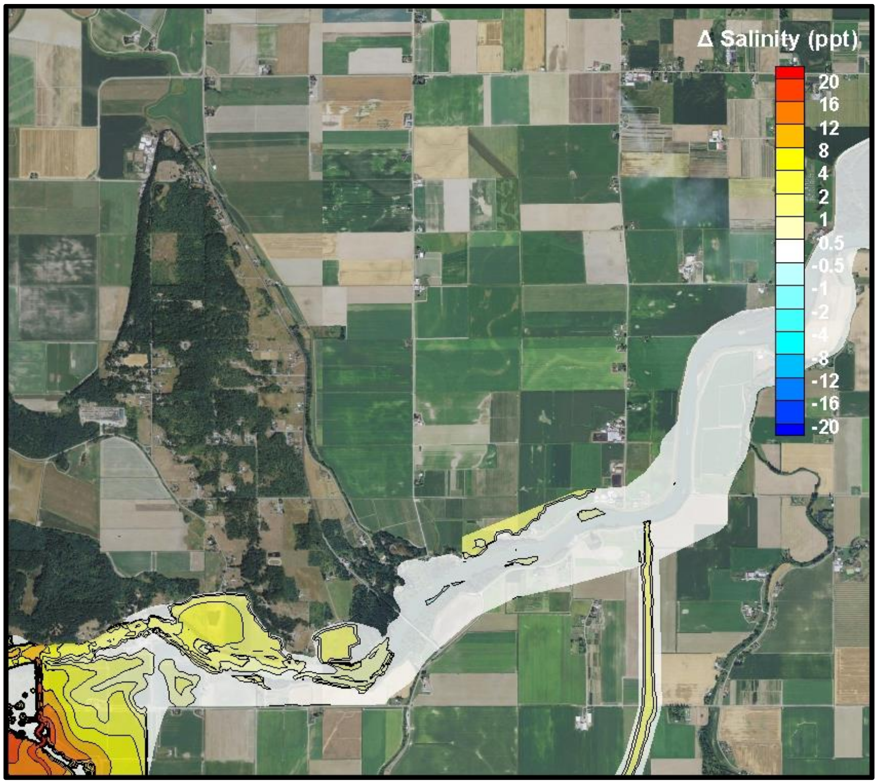


Figure K.116. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for NF Levee Setback C with low flow and high tide

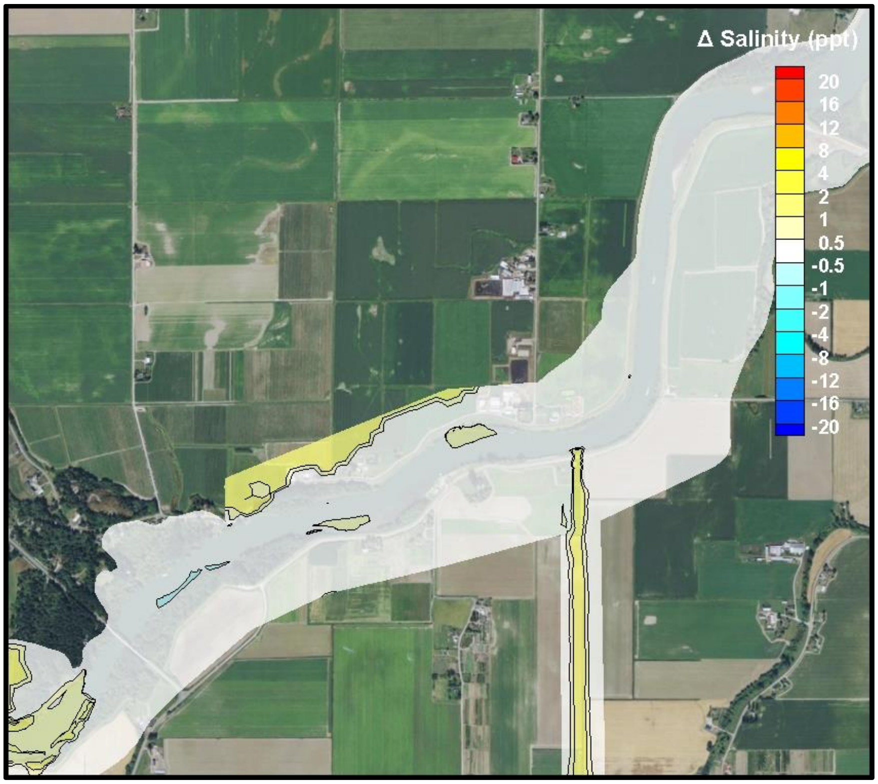


Figure K.117. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for NF Right Bank Levee Setback with low flow and high tide

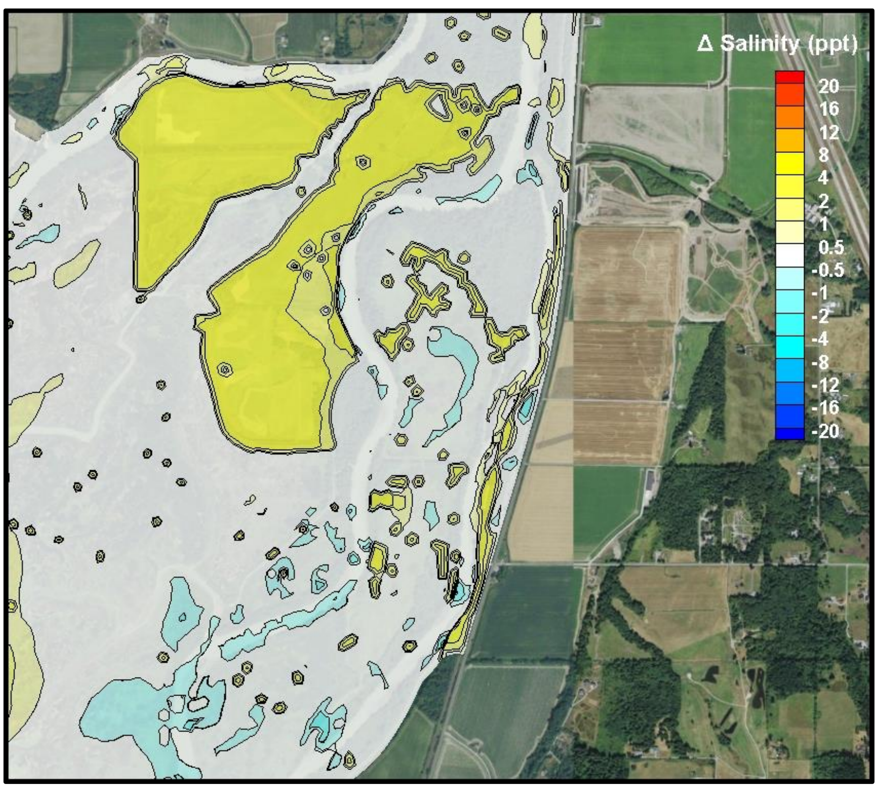


Figure K.118. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Milltown Island with low flow and high tide

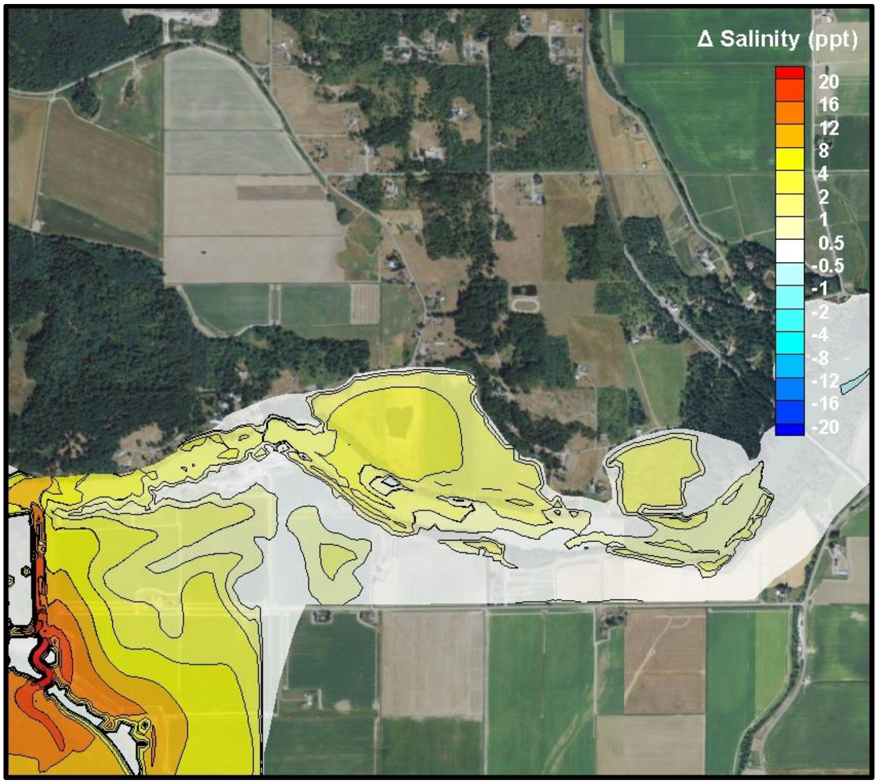


Figure K.119. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Thein Farm with low flow and high tide

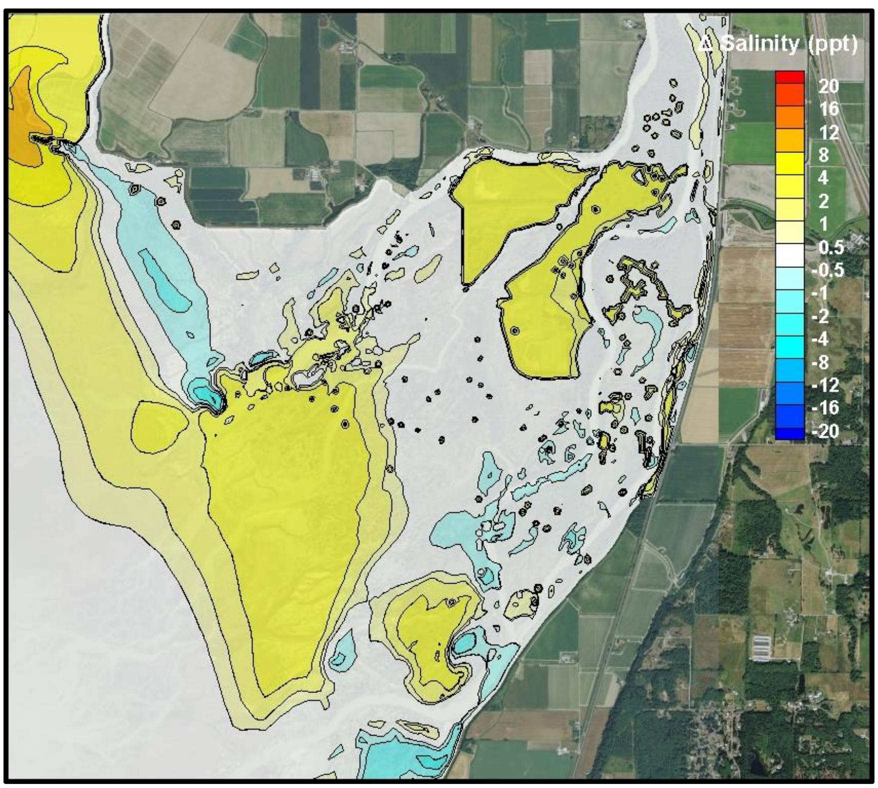


Figure K.120. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Deepwater Slough Phase 2 with low flow and high tide

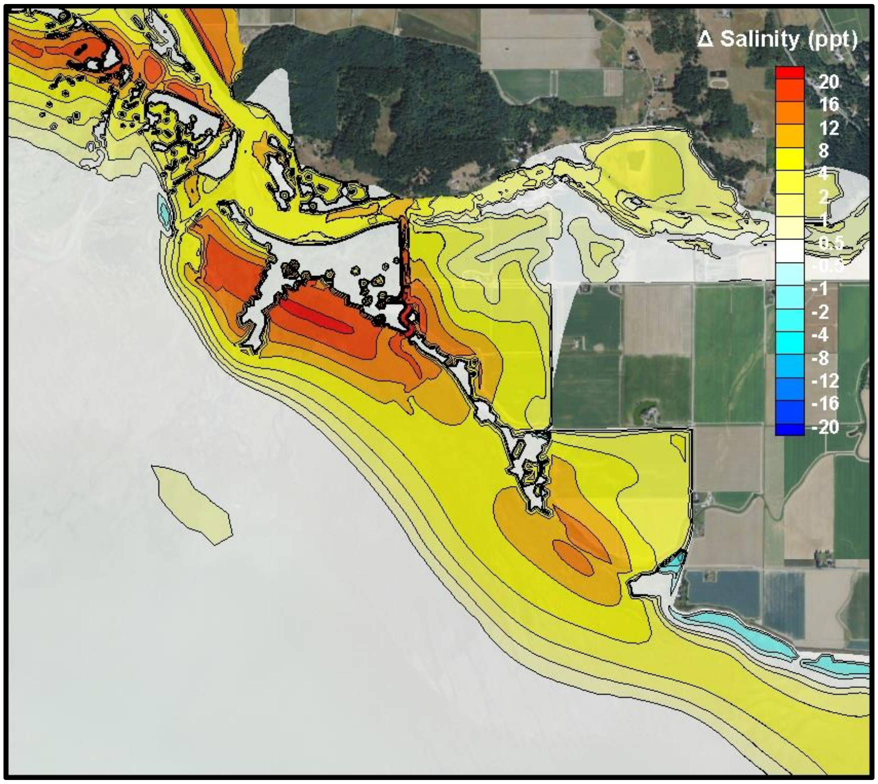


Figure K.121. Contour map of change in salinity from the Climate Change Baseline to Climate Change Projects simulation for Rawlins Road with low flow and high tide

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