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LOWER ELWHA RIVER AND WEST ESTUARY ASSESSMENT

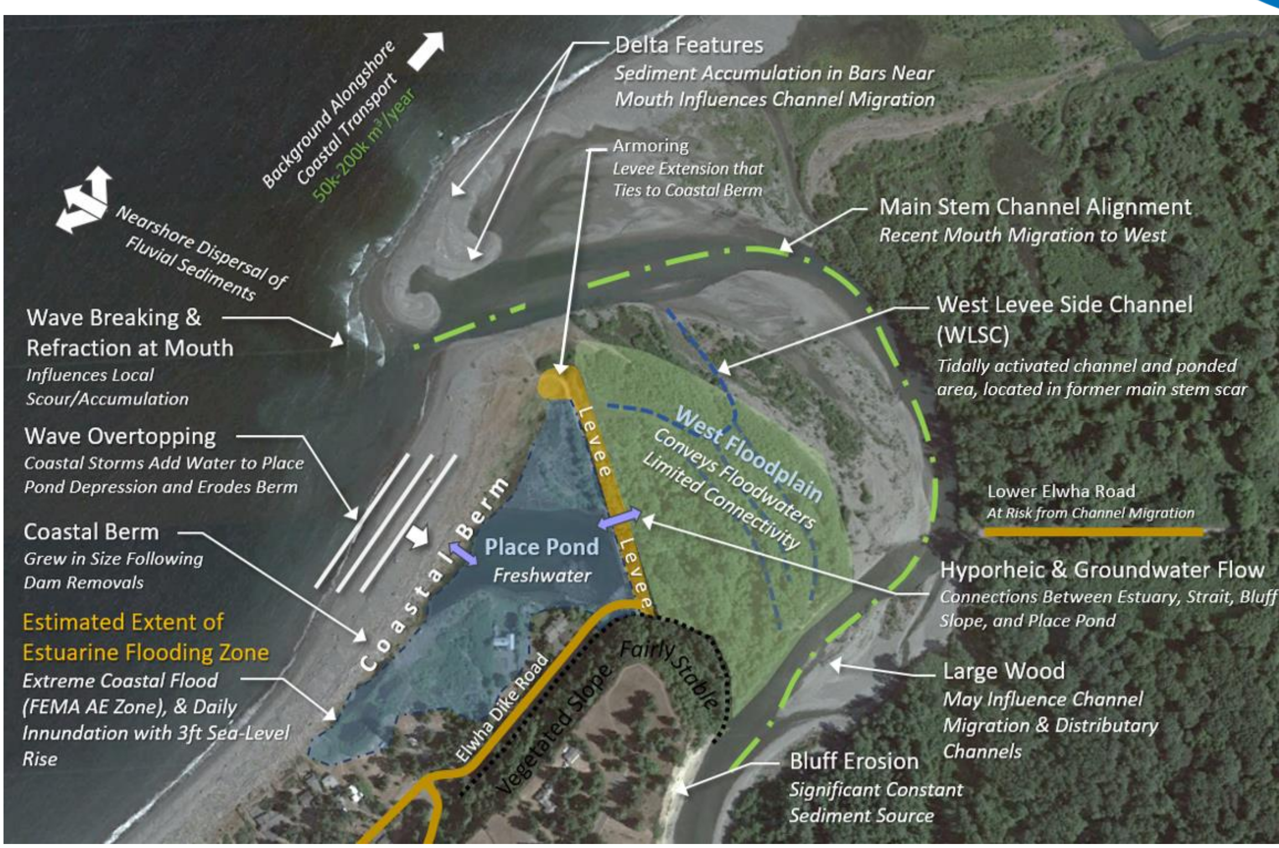
Hydrodynamic Study and Conceptual Model

Prepared for **June 2022**

Coastal Watershed Institute

by Environmental Science Associates

and Natural Systems Design



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EXECUTIVE SUMMARY

Purpose

This study evaluates the potential to restore the historic Elwha River estuary habitats that are disconnected by the Place Road levee. The Elwha River is one of the largest rivers on the Olympic Peninsula and historically supported "legendary" salmon runs (Shared Strategy Development Committee 2007). The Elwha River estuary provides vital habitats for Chinook salmon, in particular, because of their high dependence on estuaries. The Chinook salmon of the Elwha River are especially critical due to their threat of extinction signified by their listing under the Endangered Species Act, their unique qualities, and importance as prey for Southern Resident orca whales. Estuarine rearing habitat is particularly important for juvenile Chinook salmon. Research has shown that the availability of estuarine habitat affects whether juvenile Chinook will remain in the estuary to rear and grow – which increases likelihood of survival to return as adults – versus outmigrating to the nearshore at a smaller size (Beamer et al. 2005; Greene et al. 2021).

The Elwha River Fish Restoration Plan identifies the west levee removal as a significant need and opportunity for restoration (NOAA 2008). Reconnection of this habitat would support increased salmonid health, survival, and population abundance in the Elwha watershed. It has been documented that mature lower river and estuary habitat in Elwha is more functionally valuable than new, immature habitat. Therefore, restoring and improving existing habitat in the west estuary is a higher priority than creating or waiting for new habitat to mature (Shaffer et al 2018).

This study evaluates the hydrodynamics and geomorphology of the lower Elwha River after dam removal and the ongoing role of the Place Road Levee. Place Road Levee, constructed in 1964, separates the western portion of the historic Elwha River estuary, now known as Place Pond, from the modern-day river outlet. The Coastal Watershed Institute (CWI) and the salmon recovery community are interested in the feasibility of restoring a surface water connection to Place Pond that supports fish passage to these critical estuarine habitats, removes artificial fill from the estuary, and does not increase flood risk for adjacent landowners. The assessment described in this report uses applied geomorphology and hydrodynamic modeling to simulate current existing conditions and full or partial levee removal scenarios.

Basic conclusions of this study are summarized below.

- Modification of the Place Road Levee would allow the river to reconnect to an important portion of the Elwha River delta where it historically discharged to Freshwater Bay. This area is currently occupied by Place Pond. Given that the river historically had a distributary channel outlet in this area, it would likely to reoccupy this area again in the future. If reconnection of the historic west estuary were to occur, the tidal prism would provide daily scouring tidal flows to channels in the western floodplain that are currently experiencing sedimentation.

- Of the three restoration alternatives evaluated (full levee removal, half levee removal, and a small 75-foot-wide breach at the northern end of the levee), hydrodynamic modeling predicts negligible differences in water levels and velocities among the alternatives. That is, all of the restoration scenarios have the same implications for water level changes in areas surrounding Place Pond.

- The Place Road Levee currently limits river flooding to the west. Removing the levee would increase flood hazard to eight parcels, two of which are developed with houses. With climate change, an additional two properties would be at increased flood hazard. Properties farther west could benefit from the river regaining access to this area by delivering sustained sediment supply directly to the beachfront properties to maintain wide beach widths into the future. CWI acquired one property that would have been at risk. Advancing these actions for the remaining properties would benefit habitat and potentially reduce flood damage liabilities given that these properties are in a coastal flood hazard zone regardless if the levee remains. The levee offers no protection against coastal hazards. From a habitat function and coastal hazards standpoint, the ideal long-term goal should be to remove infrastructure and completely restore natural habitat-sustaining processes, such that there is no further need for the levee. To proceed with further planning for reconnection of historic west Elwha River estuary habitat, landowners of at-risk parcels will have to be fully satisfied with flood protection mitigation measures (further detailed in Section 7.2.2), and/or at-risk parcels will need to be placed under conservation management.

The river's current (2020-22) alignment has minimized the influence of the Place Road Levee on the main stem channel since the area east of the levee is currently an area of sedimentation and floodplain accretion. However, the levee continues to impact finer-scale surface water hydrodynamics, groundwater exchange, and sediment processes in the west estuary floodplain, particularly in the West Lower River Side Channel (WLRSC). By blocking tidal exchange to the Place Pond area, the levee has reduced the capacity of the WLRSC to flush sediments and makes the WLRSC less resilient to sedimentation. To support the hydrodynamic modeling and geomorphic investigation for this study, a series of supporting calculations and field investigations were conducted. A summary of historic information about Place Road Levee is included in **Section 2** of this report. Publicly available data on coastal water levels, streamflow, waves, tidal currents, meteorology, water quality, and bathymetry were collected, processed, and described in **Section 3**. CWI deployed four water level, conductivity, and temperature loggers in key locations throughout the lower river and historic west estuary area to aid in numerical model calibration and site investigations. The setup of the numerical model is described in **Section 4**, and model results are presented in **Section 5**. **Section 6** provides an analysis of fish habitat under the restoration alternatives assessed in the modeling. In **Section 7,** the model results and geomorphic analysis are interpreted. Section 7 also includes a hazard evaluation for the Place Road Community that investigates risks associated with different hydrologic and geomorphic events, and summarizes possible future pathways for restoration and climate adaptation. The primary questions posed by this study are answered at the end of Section 7.

Site Description & Data Collection

The study area consists of the lower Elwha River north of Fox Point Bluff and the historical west estuary now occupied by the Place Road Levee, Place Pond, and the Place Road Community (**Figure 1**). Major features within the study area are summarized below.

- **Mainstem of the Elwha River** – A meandering-anabranching pool-riffle channel situated within a broad alluvial valley. In the lowest river mile, the modern Elwha River (i.e., post dam removal) is a single channel flanked by gravel bars and vegetated floodplain.
- **The Elwha River Delta** – A dynamic barrier beach delta that extends into the Strait of Juan de Fuca. The delta grew dramatically following dam removal in 2011–2014 and has now diminished somewhat in size from its peak as it approaches equilibrium with more typical sediment loading.
- **Place Road Levee** – A manmade levee constructed by Clallam County in 1964 that separates the existing lower river from the historic western portion of the estuary.
- **Place Pond** – A freshwater pond located to the west of the Place Road Levee and in the historic western portion of the estuary
- **Place Road Community –** A residential development located on the low-lying coastal terrace west of the Place Road Levee and north of Fox Point Bluff.
- **Fox Point Bluff** – An eroding bluff face that supplies sediment to the Elwha River estuary, delta, and nearshore.
- **The Lower Elwha Klallam Tribe Reservation** – Located within the traditional lands of the Klallam people who have used and occupied this area since time immemorial.
- **West Floodplain** – A forested lateral bar associated with the northern-most meander of the lower Elwha River. A series of tidal channels and river overflow channels are incised in the West Floodplain, which provides mature habitat for juvenile salmonids and other estuarine organisms.
- **West Lower River Side Channel (WLRSC) –** A blind tidal channel incised in the West Floodplain that connects to the river's mainstem and ends at the Place Road Levee. The channel has been documented as important fish habitat and is prone to sedimentation.

SOURCE: Google Earth 2021

Figure 1
Study Area

Numerical Modeling

To assess water surface elevations, velocities, and sediment stability in the study area, the project team has developed a 2-dimensional Delft3D hydrodynamic model of the lower Elwha River, including the lower river, estuary, adjacent portion of the Strait of Juan de Fuca, and the Place Road Community (Section 4). The model simulates hydrodynamics by applying a river flow boundary upstream of Fox Point Bluff and tidal water level fluctuations within the Strait of Juan de Fuca. Groundwater flow into and out of Place Pond is approximated using a series of flow connection elements. Observed water levels measured by the CWI loggers in late 2020 and early 2021 were used to calibrate the model.

Three levee modification alternatives were evaluated with the hydrodynamic model and compared to existing site conditions as of September 2020. The potential levee modifications consist of full levee removal from the terminal (northern) end of the levee to the base of Fox Point (Alternative 1), a truncated levee alternative that removes the northern 450 feet of the levee and retains the southern 450 feet of the levee (Alternative 2), and a small levee breach 75 feet in width located at the northern end of the levee (Alternative 3).

Each levee alternative was simulated through six different hydrologic scenarios that covered a range of normal to extreme coastal and fluvial conditions. The scenarios consisted of:

- Scenario 1: 2020-21 Calibration Period.
- Scenario 2: High Estuarine Event (Typical Winter Storm Conditions).
- Scenario 3: Low Estuarine Event (Typical Summer Conditions).
- Scenario 4: 100-year Elwha River Flood.
- Scenario 5: 100-year Coastal Flood.
- Scenario 6: 100-year Elwha River Flood with Climate Change (Year 2100).

Model results in Section 5 show that all three levee modification alternatives convey surface water in and out of Place Pond primarily via the WLRSC. Differences between water levels and velocities are negligible for all three alternatives across the vast majority of the study area for nearly all simulated conditions. This surface water connection results in tidal conditions in Place Pond that are lower than under existing tidal conditions. However, during multiple flood scenarios, the levee modification alternatives result in peak water levels in Place Pond higher than under existing conditions, with a maximum difference between existing and with-levee modification conditions of approximately 2.5 feet for the 100-year fluvial flood. Peak water levels in the Place Pond area remain high for longer under existing conditions, whereas in the levee modification alternatives, water levels in the restored west estuary recede more rapidly following a high-flow event. For the flood Scenarios 2, 5, and 6, these ephemeral but high water level peaks exceed elevations near structures at the nearby 1914 Elwha Dike Road and 1916 Elwha Dike Road parcels under scenarios where the levee is breached, although the modeled inundation near the buildings is shallow. Ground elevations near structures were approximated using LiDAR (described in Section 3.7.3); however, finished floor elevations of the structures were not reported or used in this study.

Hydrodynamic & Geomorphic Interpretation

The lower Elwha River has been shaped by major anthropogenic influences during the 20th and early 21st centuries, including logging, construction of the Elwha and Glines Canyon Dams, channelization, levee construction, development within the historical floodplain, and the recent dam removal.

Natural sediment transport to the study area was disrupted by construction of the Elwha Dam (1913) and Glines Canyon Dam (1927), which starved the delta for alluvial sediments, and significantly altered its form (Draut et al. 2008). Channelization and straightening of the mainstem Elwha River by Clallam County and other private landowners, including dike construction that intercepted a major anabranch of the river, occurred in the 1950s to 1980s. These actions directed flow along the toe of Fox Point Bluff. Construction of the Place Road Levee in 1964 blocked flows from the river and from the ocean into the western historic estuary. Disconnecting the Place Pond area from the estuary also disrupted surface water and sediment transport processes in the area west and immediately east of the levee, as well as affecting groundwater exchange with the main stem and with the Fox Point Bluffs.

As the Elwha River was channelized into a single thread, the concentrated flows encouraged a pair of meander bends to establish in the lower estuary. In the decades following construction of the Place Road Levee, the pair of meander bends have become more sinuous and pronounced. This resulted in bank erosion and lateral migration along the outer bends into Fox Point Bluff (upstream meander) and along the eastern floodplain (downstream meander). A large sediment deposit formed immediately downstream in conjunction with the meander pairs and was subsequently colonized by deciduous trees and established the stable low-lying floodplain surface that exists today as the West Floodplain. The downstream portion of the river (0.25 to 0.5 mile upstream of the outlet) is currently migrating to the east, and the West Floodplain is growing.

Removal of the Elwha and Glines Canyon Dams between 2011 and 2014 contributed a massive delivery of sediment to the Elwha River delta and nearby shorelines, which built out the shoreline and reduced the gradient of the lower river. In response to these changes, the lower river appears to be changing from a single meandering channel to an anabranching morphology (i.e., multiple channel threads and mid-channel vegetated bars). Although the dam removals significantly changed the sediment environment in the lower estuary, the dam removals had a minimal effect on peak flow rates in the river. Dam removal increased the sediment load to the lower estuary. Because the Place Road Levee makes the WLRSC less able to flush incoming sediment, the channel has accumulated sediment since dam removal, impacting highly functional long-term juvenile Chinook and coho habitat.

Today, the Place Road Levee blocks surface water connection of the Elwha River to the historic western estuary, entirely inhibiting fish access to this area. The Place Road Levee precludes the formation of channel or tidal habitat to the west, and significantly reduces the tidal prism exchanged through tidal channels in the west floodplain. This topographic barrier between the current western floodplain and Place Pond limits the available aquatic habitat, blocks potential sediment and nutrient delivery to the west estuary, and inhibits the sediment flushing capacity of channels like the WLRSC. The WLRSC, incised within the West Floodplain, is a relict feature from scour along the northern end of the Place Road Levee (estimated 1980–1990). Today, the WLRSC exists as a blind tidal channel with a limited tidal prism and flow pathway for Elwha River flood waters that overtop the floodplain. Because the presence of the Place Road levee limits tidal conveyance and sediment flushing capacity, the WLRSC is prone to sedimentation. The WLRSC is anticipated to experience further sedimentation as the main channel continues to migrate to the east. While the direct surface water connection is blocked, Place Pond is still influenced by groundwater exchange with both the river and the ocean, which cause water levels to rise during high river stages and high tides.

The planform alignment of the current lower Elwha River is a response to channel modifications and the construction of the Place Road Levee, but the levee itself has minimal influence on the evolution of the mainstem channel meanders or the shape of the western floodplain under the prevailing flow and sediment transport regimes. The Place Road Levee currently has a minor influence on the mainstem channel planform and large-scale estuarine habitat formation. While the construction of the levee and other channel modifications have certainly influenced the lower Elwha River morphology in the past, there is little effect on sediment erosion, deposition, or lateral migration patterns of the current mainstem channel. The West Floodplain first appears on aerial imagery in 1971 and has since aggraded and expanded to its present form. Draut et al. (2008) found the net movement of the left bank of the Elwha River at the West Floodplain between 1939 and 2006 to exceed 650 feet in the eastern direction, although there were periodic episodes of erosion and bank retreat. Recent trends from aerial imagery (2011–2020) indicate that the West Floodplain and adjacent gravel bar have remained stable, although erosion at the downstream end of the upstream meander shows slow translation of the meander pair to the north. The area of greatest change, and likely short-term continued migration, is the shift of the downstream meander to the east.

Although the levee currently has minor influence on the mainstem channel and large-scale hydrodynamic processes within the lower estuary, the levee has influenced and continues to affect finer-scale topographic features within the western floodplain. The construction of the levee blocked tidal exchange between the Place Pond area and the remainder of the estuary, thereby reducing the daily tidal scouring available to maintain tidal channels such as the WLRSC. The levee also influenced the southeast-northwest alignment of these channels in the western portion of the floodplain. The presence of the levee continues to affect hydrodynamics, sediment processes, groundwater exchange in the vicinity of the levee to this day. By blocking tidal exchange between the Place Pond area and the main estuary, the levee has made channels in the west floodplain less resilient to sedimentation by impairing the capacity of these channels to flush sediment. Dam removal increased the sediment load to the lower estuary. Because the Place Road Levee makes the WLRSC less able to flush incoming sediment, the channel has accumulated sediment since dam removal, resulting in reduction in habitat quality and quantity in the WLRSC and adjacent channels. Prior to the dam removals, the WLRSC and other west floodplain channels supported the highest fish species richness, diversity, and density a high and supported the majority of salmonids (Shaffer et al. 2009).

Habitat features in the estuary will continue to shift location over time. The lower Elwha River will re-occupy former channels and abandon current ones. Distributary and tidal channels will also change over time as the primary mainstem channels shift position or orientation. Without reconnection to the tidal prism held in Place Pond, the WLRSC is projected to experience sedimentation as the main channel is currently migrating to the east and the channel has an impaired capacity to flush sediment. Meanwhile, an expansion of intertidal habitat in the eastern tidal lagoon currently extends from the river's outlet past the north end of the Federal Levee, which is a levee that runs north-south along the east side of the Elwha River valley. This eastern intertidal area has been recently formed out of the reworked dam removal sediment deposited in the lower delta. The habitat available in this area is still immature and it will take a number of years until vegetation and tidal channels are able to mature. In addition to the intertidal habitat, new side channels originating from the Elwha River about 1.6 miles upstream of the outlet have been conveying more flow into the eastern tidal lagoon riverside of the Federal Levee.

Were the WLRSC to be connected to Place Pond via a full or partial removal of the levee, water would be conveyed into and out of the pond with every tide cycle through the WLRSC, scouring and flushing sediments on each ebb and flood. The potential tidal prism of the Place Pond basin is approximately 40 acre-feet of water. Conveying such a volume of water would scour the WLRSC until reaching a geomorphically appropriate geometry. This volume of tidal exchange would sustain a channel 6.5 to 9 ft in depth (below mean higher high water) and 35 to 80 feet wide, which is larger than the current channel dimensions of 1 to 1.5 feet in depth and 15 to 20 feet in width). The daily tidal exchange would sustain a persistent tidal channel likely to counteract the sedimentation trends currently observed, despite the main stem channel migration to the east. Historical maps and images indicate that a lagoon connected by a persistent tidal channel has been present in this area under various main channel configurations prior to the construction of the Place Road Levee. While a persistent tidal channel connecting the Place Road area to the rest of the estuary appears to be present in past estuary states, the orientation, location, and shape of the channel would have changed over time and would also dynamically adjust following levee modification.

Existing Hazard Assessment for the Community

The Place Road Levee offers a degree of protection against major fluvial floods. The levee is not managed by the U.S. Army Corps of Engineers (USACE); however, USACE has analyzed the levee and determined it will block the 100-year river flow with 90% confidence. The low-lying Place Pond area is also subject to flooding from coastal flood overtopping from the Strait of Juan de Fuca that is unaffected by the presence of the Place Road Levee. Most of the parcels in the Place Road Community fall within the federally designated coastal flood hazard zone. Extreme high river stages can also elevate water levels in the pond to near-flood conditions via groundwater exchange.

With climate change, the hazard to low-lying parcels in the Place Road Community from coastal flooding and groundwater flooding will become more frequent and more severe. By 2100, 2.8 feet of sea-level rise is projected in the Strait and Freshwater Bay, and peak flows on the Elwha River are expected to increase 35% over existing flows (CIG 2010). Sea-level rise will increase coastal overtopping events and reduce the ability of Place Pond to drain following flood events. Higher coastal flood water levels and wave runup will become more frequent. By 2050, a coastal flood event that has a 100-year return interval today is anticipated to occur as with a 2- to 5-year return interval. Flooding risk to the Place Road Community will increase due to climate change, regardless of any restoration actions along Place Road Levee.

Restoration Implications

As described in Section 7, restoration has implications for habitat and the Place Road Community. All three restoration alternatives analyzed for this study (full levee removal, truncated levee removal, and 75-foot levee breach) would adequately provide juvenile rearing habitat and fish passage into the historic west estuary. Connection to Place Pond would initially occur via the WLRSC, which is currently a topographic low point. The restoration of tidal flows to Place Pond would generate daily tidal scouring forces that would sustain the WLRSC as a persistent tidal channel, and immediately counteract the sedimentation trend observed in the WLRSC since dam removal. More than 6 acres of historic estuarine habitat would become available to fish and other biota under these alternatives. Velocities within the WLRSC would be slow enough to allow juvenile salmonids to access the former pond during portions of the tidal cycle. The orientation, shape, and location of the tidal channel is expected to be dynamic and vary over time.

The direct surface water connection proposed as part of each alternative would also allow high floodwaters into the low-lying portions of the Place Road Community. A total of eight parcels would be affected by higher waters during the 100-year river flood that would be conveyed through the levee opening under existing climate conditions. Of these eight parcels, two have buildings that would be at risk of flooding immediately following a potential levee modification, and one additional parcel has a building that would be at risk of flooding by year 2100 with sea-level rise and increased peak river flow. Flooding near the structures and across much of the inundation area is predicted to be shallow. The largest depth of flooding predicted near a structure is 1.6 feet above LiDAR elevations, which occurs at one house under the 2100 extreme flood conditions. The remaining seven parcels do not have structures that would be at increased risk of flooding due to levee modifications; however, floodwaters would inundate limited portions of these parcels under some flood conditions. Of these parcels with structures, shallow inundation is predicted to occur in some areas that are 30 to upwards of 100 feet away from the edge of structures.

Modeling conducted for this study showed that the length of levee removal or breaching would not significantly affect flood water levels in the pond, and therefore, additional flood risk to the at-risk parcels cannot be abated by changing the length of levee removal.

With complete levee removal, the Elwha River outlet could eventually migrate west of the Place Pond Levee, although this process may take many decades to occur. A full-scale channel avulsion from the existing mainstem alignment to a new outlet west of the existing levee would require an extreme event to initiate the avulsion. Under existing channel migration rates, the mainstem channel could potentially reach the existing levee location in 40 to 90 years without a major avulsion trigger. A truncation of the levee rather than full removal would likely result in a similar outcome over time, with the river eventually migrating west of the levee. A distributary or mainstem reoccupation of the former west outlet would increase the delivery of coastal sediments to the Freshwater Bay shoreline, which have been partially limited by the presence of the levee. Although dam removals delivered a massive volume of sediment that widened beaches in the vicinity of the delta, much of this sediment has already migrated downdrift and beaches are anticipated to narrow over time without a sustained delivery of sediments to Freshwater Bay shores. Wide beaches increase coastal flood resilience and support coastal dune and backshore habitat. A levee modification that consists of a 75-foot breach and levee armoring would likely preclude a distributary channel from forming west of the levee.

Although levee modification would likely to increase flood exposure for a number of parcels west of the levee, there are adaptation measures and flood mitigation actions that could be taken to reduce risk. In order for the historic west estuary to be restored via levee modification, landowners of at-risk parcels will have to be fully satisfied with such flood protection mitigation measures (further detailed in Section 7.2.2), and/or at-risk parcels will need to be placed under conservation management. Acquiring the parcels that would be at additional flood or erosion risk with levee modification is the best option to completely restore the historic west estuary. Other mitigation strategies such as levee setback and structure elevation could achieve restoration goals in the west estuary; however, the extent of restoration may be less complete, and the relative costs of these measures have not yet been assessed. A fish-passable tidegate or culvert alternative has already been assessed and rejected as a feasible restoration strategy (CGS 2009). A tidegate was ruled out by the County in 2009 due to maintenance, management, and ownership concerns. Additionally, a realigned levee was also ruled out at the same time.

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Appendices

1 INTRODUCTION

Coastal Watershed Institute (CWI) has contracted with Environmental Science Associates (ESA) and subconsultants Natural Systems Design (NSD) and Deltares to define the key hydrodynamics of the lower Elwha River post dam removals to understand the current and future defining elements to the west lower river and estuary, and the role of the Place Road Levee. The Place Road Levee, constructed in 1964, separates the historic western portion of the estuary from the modern-day river outlet. The levee was installed by Clallam County at the insistence of the landowners for flood protection at the objection of federal land managers.

Prior to dam removals, Shaffer et al. (2009) documented that the West Floodplain provided the highest level of fish use of the Elwha River estuary. The Place Road Levee disrupted fish access from the Elwha West Lower River Side Channel (WLRSC, formerly titled “West Estuary Side Channel”) to the impounded area (formerly titled “Dudley Pond” and from here forward titled the “Place Pond”). Based on this work, landowners were supportive of providing fish passage through a self-regulating tidegate; however, the Lower Elwha Klallam Tribe and Clallam County deemed the project infeasible due to concerns over tidegate maintenance and flood risk (CGS 2009).

The Elwha River delta is defined by complex marine, riverine, and hyporheic (groundwater) processes that have changed as dam removals delivered upwards of 10 million cubic meters of material to the shoreline. The majority of sediment was predicted and observed to be delivered to the coast within 5 years of dam removal. A decade after dam removals began, CWI is now interested in understanding how the post dam removal lower river hydrodynamics and the role that Place Road Levee are playing in defining and/or threatening critical fish habitat.

CWI is interested in the feasibility of restoration of a surface water connection to Place Pond that supports fish passage to these critical estuarine habitats and removes artificial fill from the estuary, but does not increase risk to adjacent landowners. This objective aligns with the Elwha River Fish Restoration Plan (Ward et al. 2008) and the Puget Sound Salmon Recovery Plan (Shared Strategy Development Committee 2007), which specifically identify full restoration of the historic estuary extent as a priority for salmon population recovery in the watershed. The lower Elwha River supports seven species of anadromous salmonids, two species of lamprey, anadromous eulachon (smelt), and occasional observations of sturgeon (Lincoln et al. 2018; Shaffer et al. 2007, 2017a, 2017b; and others). Among the salmonids, Chinook salmon, steelhead, and bull trout are listed as threatened under the Endangered Species Act (ESA). The river is legendary for producing especially large Chinook salmon. Eulachon are also listed as threatened under the ESA, and Pacific lamprey are a species of concern. The removal of the Elwha and Glines Canyon Dams in 2011 and 2014, respectively, re-opened more than 70 miles of salmonid habitat. The dam removal also re-engaged river processes acting to shape salmon habitats throughout the river and downstream, as well as nearshore habitats beyond the river outlet. The estuarine habitats impacted and disconnected by the Place Road Levee are important habitats for many fish species (Shaffer et al. 2017a, 2017b). Chum and Chinook salmon are the salmonid species who are most dependent on estuaries for rearing during their outmigration (e.g., Healey 1982, Simenstad et al. 1982). Restoring access and function to the habitats west of the Place Road Levee would add to the effectiveness of past restoration efforts in the Elwha River watershed.

Despite the strong interest from the restoration community in the Elwha River, there is limited existing information about the role of the Place Road Levee following dam removals. Modifications to the levee to provide fish passage to Place Pond have been investigated in the past, but these efforts have stopped for a number of reasons, including the lack of understanding of the response of the river following the dam removals and change to flood hazards in the Place Road Community. While a full return to equilibrium in the Elwha River system may take several decades, much of the major geomorphic adjustment to undammed conditions has already occurred, particularly in the lower estuary (Ritchie et al. 2018). With the understanding that conditions in the lower estuary now reflect a dynamic "new normal," this study renews efforts to investigate the Place Road Levee by answering several key questions a decade after dam removal:

- What is the role of the Place Road Levee in lower river hydrodynamics?
- What factors contribute to the hydrologic conditions of Place Pond and the low-lying area west of the Place Road Levee?
- To what extent does the Place Road Levee protect the Place Road Community from current and future flood hazards?
- How does climate change affect future flood hazards to the community?
- Can modifications be made to the levee to improve ecosystem function and allow functional fish access to the historic west estuary while still providing the current level of flood protection to the Place Road Community?
- Are there other adaptation measures that the community could pursue that would increase flood resilience, and allow for habitat uplift?

In addition to exploring these study questions, several questions and concerns posed by community members have been captured in **Appendix A**.

2 SITE DESCRIPTION

2.1 Salmon Recovery Context

The Elwha River is one of the largest rivers on the Olympic Peninsula and is the only one that supported all five species of Pacific salmon, as well as steelhead, native char (bull trout), and cutthroat trout. (Shared Strategy Development Committee 2007). The salmon runs of the Elwha were "legendary" (Shared Strategy Development Committee 2007).

The Chinook salmon of the Elwha River are especially critical due to their threat of extinction signified by their listing under the Endangered Species Act, their unique qualities, and importance as prey for Southern Resident orca whales. Historically, the Elwha River supported especially large-bodied Chinook salmon reported to be as much as 100 lbs (NOAA 2008, Brannon and Hershberger 1984, Roni and Quinn 1995). Another unique aspect of Elwha River Chinook salmon is that they are genetic intermediaries between those in Puget Sound rivers and those in rivers along Washington's outer coast (NOAA 2008).

Elwha River Fall Chinook are among the highest priority stocks for Southern Resident orca whale recovery (NOAA and WDFW 2018). This prioritization is based on data documenting their contribution to the orca whale diets at a time of year when the whales have reduced body condition and their overlap with being in the same areas at the same time of year as the orca whales. As a result, the Elwha River is a key river system for the Southern Resident Orca Task Force's (2019) top recommendation to increase habitat restoration and acquisition in areas where Chinook stocks most benefit the Southern Resident orcas.

Estuarine rearing habitat is particularly important for juvenile Chinook salmon. Juvenile Chinook salmon, as well as chum salmon, are the most dependent on estuary rearing (Simenstad et al. 1982). The availability of estuarine habitats for juvenile Chinook salmon to rear and grow before outmigrating to the Strait of Juan de Fuca and Pacific Ocean will increase their chance of survival to return as adults to spawn (Beamer et al. 2005). Research has shown that the availability of estuarine habitat affects whether juvenile Chinook will remain in the estuary to rear and grow – which increases likelihood of survival to return as adults – versus outmigrating to the nearshore at a smaller size (Beamer et al. 2005; Greene et al. 2021). Increases in estuarine habitat will increase the proportion of the juvenile Chinook salmon who remain in the estuary to rear.

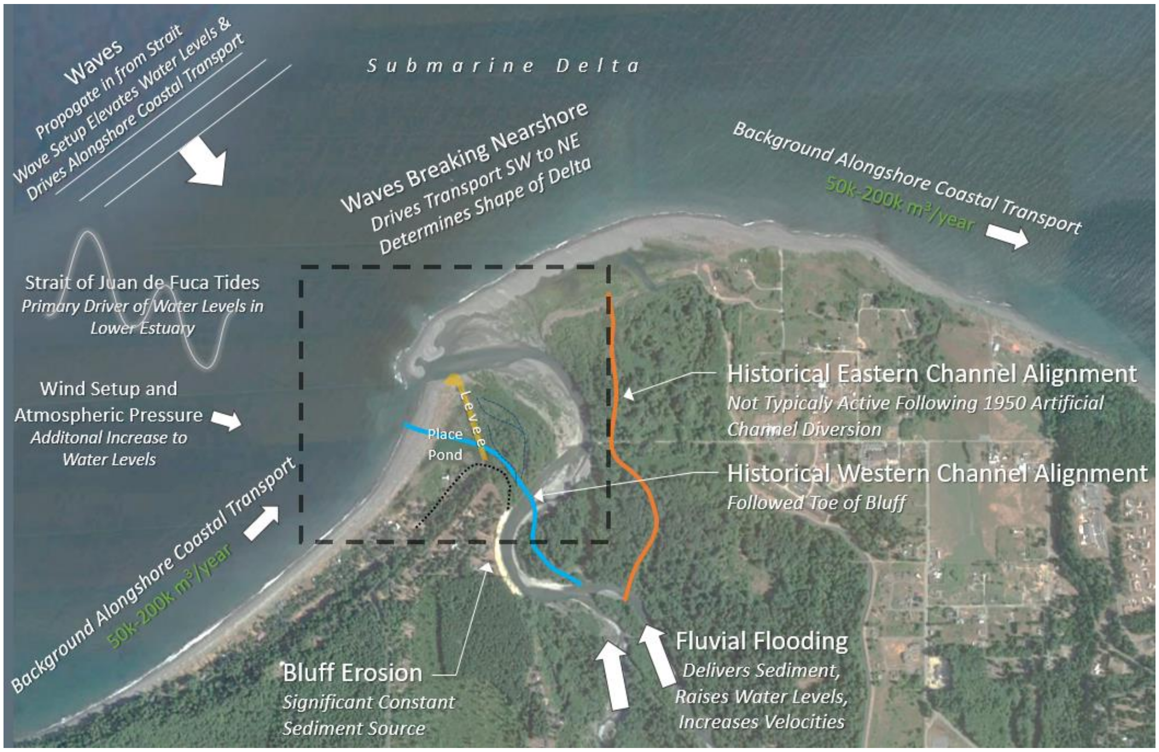
Estuarine habitats are also used by outmigrating juvenile Chinook originating from other river systems (i.e., non-natal Chinook). For example, in the Snohomish River estuary, juvenile Chinook from five major river basins were captured in the estuary (NOAA unpub. data.). Along the nearshore and estuaries of the Strait of Juan de Fuca, genetic tissue sampling by Shaffer et al. (2012) documented juvenile Chinook from as far away as the Columbia River and even the Klamath River. The reliance of juvenile Chinook on estuarine habitats beyond those of their river of origin is further documented in research by Beamer et al. (2006, 2013) in which the fish used estuarine habitats in small creek systems as well. Research has also shown that other salmon species also rely on estuarine habitats other than just their natal river, including chum, pink, and coho salmon (Hirschi et al. 2003, Beamer et al. 2006).

It has been documented that mature lower river and estuary habitat in Elwha is more functionally valuable than new, immature habitat. Therefore, restoring and improving existing habitat in the west estuary is a higher priority than creating or waiting for new habitat to mature (Shaffer et al 2018).

Reconnection of the historic west Elwha estuary is identified as a significant need an opportunity for restoration in the Elwha River Fish Restoration Plan. Reconnection of this habitat would support increased salmonid health, survival, and population abundance in the Elwha watershed.

2.2 Geomorphic Context

The study area is located on the Olympic Peninsula at the Elwha River nearshore, including the lower river, estuary, and Freshwater Bay shorelines. From its headwaters in the Olympic Mountains, the Elwha River flows northward to the Strait of Juan de Fuca. The estuary of the Elwha River where it enters the Strait has been significantly impacted by the construction of, and subsequent removal of, two dams in the upper watershed, which impounded the river’s natural sediment supply and starved the Elwha River delta of sediments for nearly a century. However, the lower river and estuary did not reach its current form, of a single mainstay channel, until the construction of the Place Road Levee (**Figure 2**). This section describes the geomorphology of the Elwha River and estuary, the shoreline surrounding the estuary, and major geomorphic changes.



SOURCE: Google Earth 2021

Figure 2
Geomorphic Context

2.2.1 Modern-Day Conditions

Lower Elwha River Geomorphology

This section presents an abbreviated summary of lower river morphology, which is detailed in **Appendix B,** along with an assessment of channel change and migration, and the influence of the Place Road Levee.

The lower Elwha River is a meandering-anabranching, unconfined pool-riffle channel that is situated within a broad alluvial valley. In the lowest river mile, the modern Elwha River is a single meandering channel that is flanked by gravel bars and vegetated floodplain with an average gradient of 0.3%. In this region, the main channel has a bankfull width of 100 to 150 feet and an alluvial valley bottom (floodplain) width of 5,800 to 6,000 feet. The floodplain is heavily vegetated with conifer trees, although the underlying sediment is composed of alluvial material that is subject to erosion and reworking during high-flow events.

Coastal Geomorphology

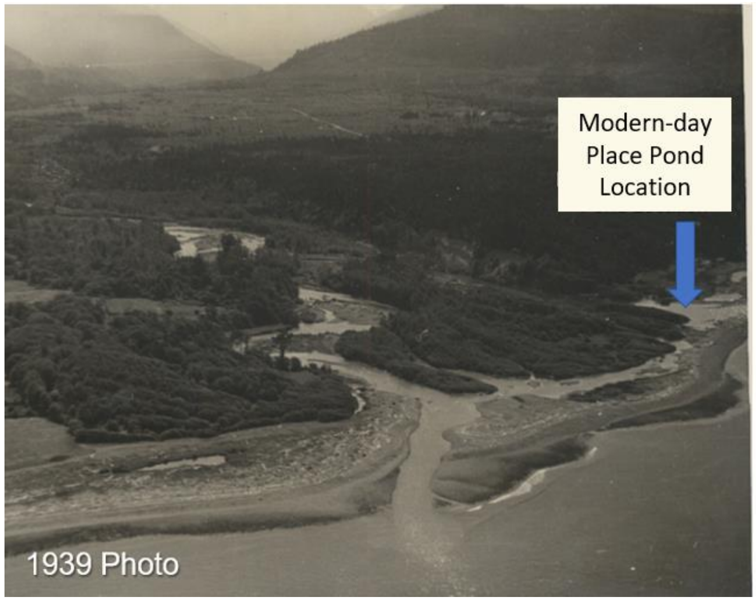
The Elwha River empties into the Strait of Juan de Fuca at the eastern end of Freshwater Bay where the river forms a large fjord estuary. A substantial wave-dominated delta exists at the seaward extent of the estuary, comprised of subaerial and submarine features. The shape of the delta is influenced by tidal currents in the Strait of Juan de Fuca, which have been measured in excess of 3 feet/second off of the Elwha River delta (Gelfenbaum et al. 2009), and swell and wind waves arriving predominantly from the northwest. Waves reaching the delta are typically less than 5 feet in height with peak periods of 9–12 seconds (Gelfenbaum et al. 2009). Tides within the Strait are semidiurnal with a tidal range of approximately 7.2 feet.

Adjacent beach slopes around the delta are typically steep with foreshore slopes of 1:10 (vertical to horizontal) and are comprised of mixed sand and gravel. Beaches in the area are typically backed by an elevated coastal berm. Littoral sediment drift diverges at the river outlet, with most sediment moving to the east in a long drift cell that terminates at Ediz Hook, approximately 7 miles east of the Elwha River outlet. Estimates of sediment transport rates within this cell range from 13,000–260,000 cubic yards/year. To the west of the outlet, a smaller subcell exists within the eastern portion of Freshwater Bay; however, net transport rates in this subcell are negligible (Gelfenbaum et al. 2009, Warrick et al. 2019).

Wave action forms barrier sand bars around and within the river outlet. These sand bars influence river flow patterns and can form backwater estuary areas to either side of the mainstem or channel distributaries. The sand bars periodically form partially enclosed backwater lagoon features and coastal lakes in abandoned river distributary channels (Duda et al. 2011). Beach Lake to the east of the estuary is an example of one such historic features. **Figure 3** illustrates a lagoon-like feature stretching to both the east and west of the primary outlet. An oblique aerial photograph from 1939 shows the backwater lagoon feature stretching from the 1939 western distributary channel outlet to the modern-day location of Place Pond and West Pond (**Figure 4**).

SOURCE: PNPTC 2006

Figure 3
A 1908 map of the lower Elwha River estuary



SOURCE: National Archives 1939

Figure 4
Historic Elwha River estuary

2.2.2 20th Century Geomorphic Change

In the late 1800s and throughout the 1900s, the Elwha River valley was significantly altered by logging, the construction of two dams on the river, construction of several levees, channelization, and, in the 2000s, dam removal.

Dam Construction

Natural sediment transport to the study area was disrupted historically by construction of the Elwha Dam (1913) and Glines Canyon Dam (1927), which starved the delta for alluvial sediments and significantly altered its form (Draut et al. 2008). Along the shoreline, up to 520 feet of shoreline erosion and retreat occurred in the delta between 1939 and 2006 (Warrick et al. 2019). Oral histories from the Lower Elwha Klallam Tribe describe hundreds of meters of shoreline erosions and subsequent habitat change over the delta in the 20th century (Duda et al. 2011). Annual shoreline erosion rates during this time period peaked at around 12.5 feet/year. Erosion of the delta subsequently increased the river's gradient immediately upstream of its outlet.

Following dam construction, locally eroding glacial bluffs of Fox Point, located between river mile 0.5 and 0.75, provided the majority of sediments to the lower Elwha River until demolition of the Elwha Dam in 2012 and Glines Canyon Dam in 2014.

Levee Construction and Channelization

The Elwha River has a history of lateral channel mobility across the entire width of the valley floor, as evidenced by relict channel features and erosion along its valley walls shown in Figure 5. Over recent geologic history (the last several thousand years) up until the early 20th century, the river had active channels across much of the lower valley. Construction of the Federal Levee, which is located along the eastern floodplain margin, and Place Road Levee reduced the river's floodplain to less than half of its natural width.

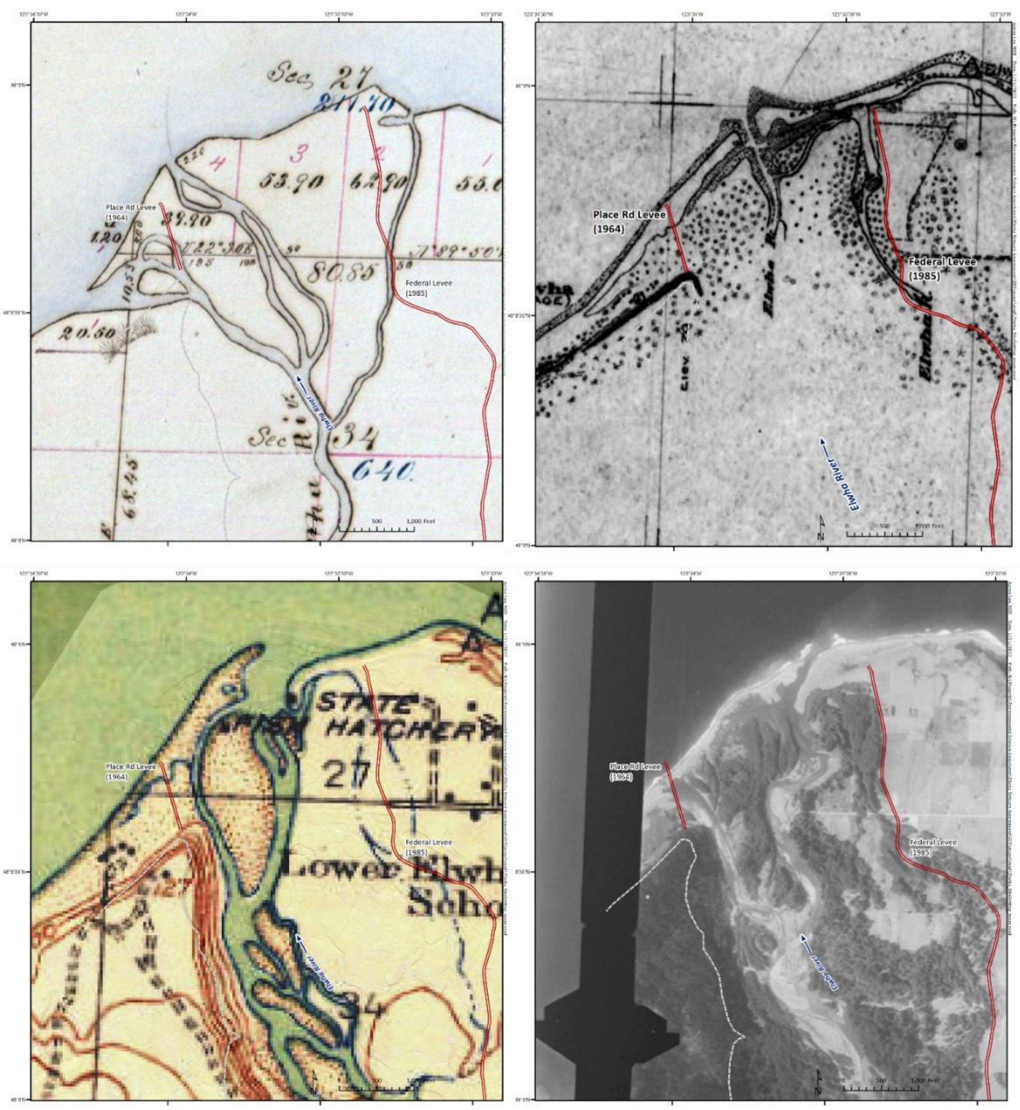
The Place Road Levee was constructed in 1964. The levee cut off the mainstem outlet of the river, which flowed due west just north of Fox Point Bluff, a similar alignment to the western distributary channel mapped in 1872 (**Figure 6**). Place Pond is situated in the former location of the western distributary channel.

The Federal Levee on the east side of the lower river extends 1.8 miles from the pre-dam shoreline at the Strait of Juan de Fuca up to the State rearing channel. The Federal Levee cut off a distributary channel in the delta and confined the alignment of Bosco Creek to the estuary, reducing the available habitat area and confining flood flows to a narrower floodplain corridor (**Figure 5**, **Figure 6**). Prior to dam removal, the Federal Levee was raised and rock revetment added to prevent channel migration from eroding the levee.

Channelization and straightening of the mainstem Elwha River sponsored by Clallam County, including dike construction that intentionally cut-off of the eastern distributary channel, occurred in the 1950s to 1980s (Pohl 1999; Warrick and Stevens 2011). These actions further concentrated the stream power in the lower Elwha River and directed flow along the toe of Fox Point Bluff.

As the Elwha River eroded into Fox Point Bluff, a pair of meander bends established and continued to amplify over time. A large sediment deposit formed immediately downstream in conjunction with the meander pairs and was subsequently colonized by vegetation. Aerial photographs indicate that around 1990, the river flowed directly along the northern end of the Place Road Levee. The WLRSC is likely a remnant scour feature from the former mainstem Elwha River and exists today as a floodplain pond connected by smaller tidal channels.

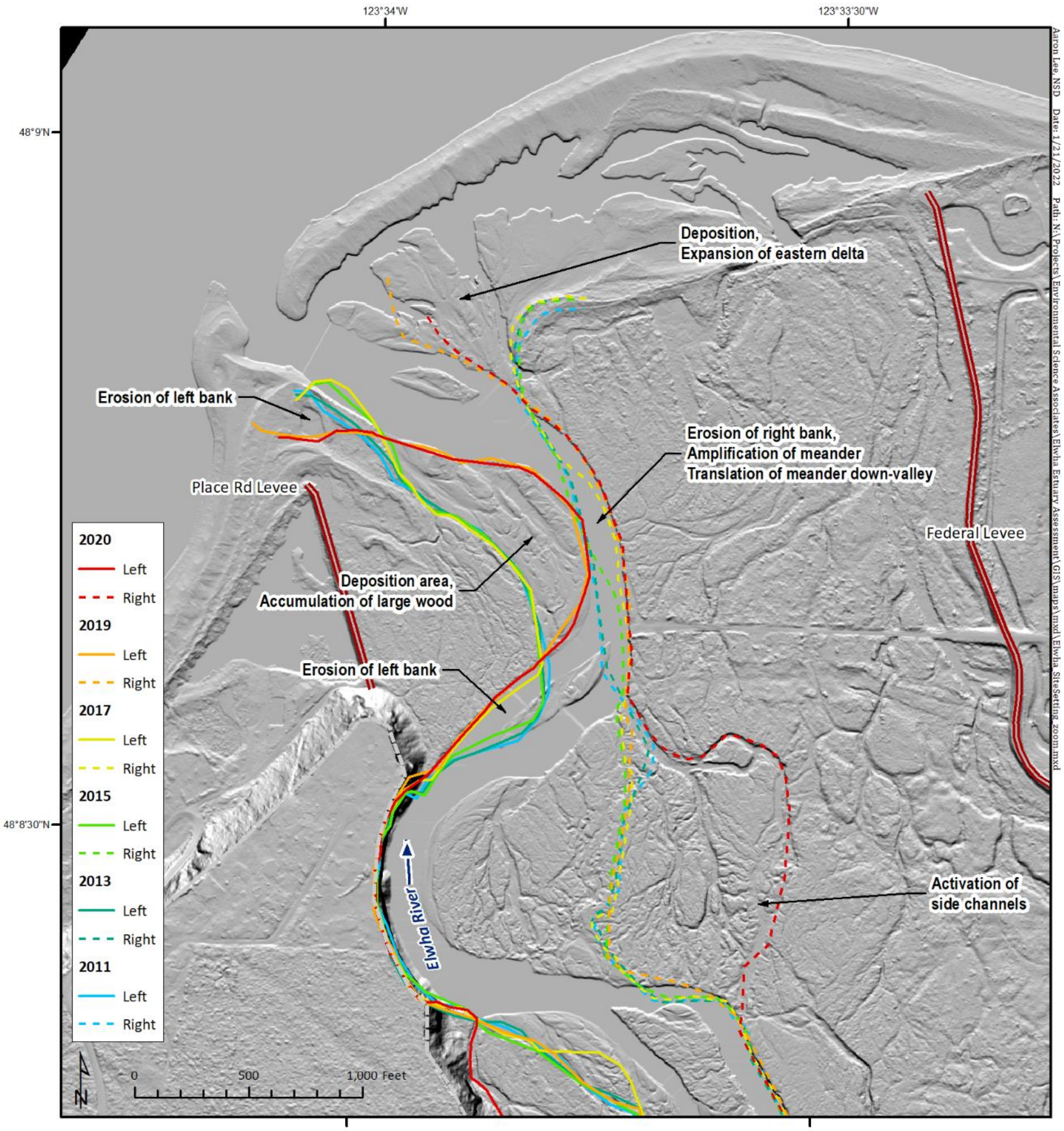
Following construction of the Place Road Levee in 1964, the low-lying western estuary area was separated from the mainstem of the river and the rest of the estuary. Sediments carried by the river were historically deposited along the Freshwater Bay shoreline west of the current Place Road Levee. The construction of the levee removed this source of beach sediments and has contributed to a narrowing of beaches in the eastern portion of Freshwater Bay. The massive volume of sediments released by the dam removals built back beaches near the modern-day delta. However, the long-term supply of sediments to shorelines west of the Place Road Levee has been reduced by blocking distributary flows through the west estuary, and beach widths are anticipated to narrow in this area over time as the sediments deposited by the dam removals continue to migrate eastward.



SOURCE: NSD

Figure 5

Historical maps and aerial photograph of the Elwha River outlet. Figures are ordered in chronological order from top-left to bottom-right (1872, 1908, 1919, and 1939). Note that all figures are referenced to the same coordinates. Place Rd Levee and the Federal Levee are shown in red



SOURCE: NSD

Figure 6
Channel traces of left (solid line) and right (dashed line) bank alignments from 2011 to 2020 aerial photographs. Bank lines are delineated at the streamward edge of unvegetated floodplain and represent conditions at the time of image collection.

Dam Removal

The removal of the dams released 18 million tons of sediments to the coast in the first 5 years following dam removal (Warrick et al. 2019), spurring a rapid adjustment of the delta and building of coastal shorelines in the study area. The delta accreted hundreds of meters during the years following dam removal, and rebuilt beaches along Freshwater Bay. Many areas in the delta accumulated more than 13 feet in elevation (Warrick et al. 2015B). As a result, the lower river gradient flattened.

2.3 Place Road Levee and Place Pond

The Place Road Levee separates the west lower Elwha River side channel from the historic western lobe of the estuary. Place Pond and the smaller West Pond now occupy the low-lying historic western estuary, along with two developed residential lots. Place Road Levee and Place Pond have been referred to by different names, including the "Westside Levee" and "Dudley Pond."

2.3.1 Place Road Levee

Existing Conditions

The Place Road Levee is a roughly trapezoidal levee extending from the tip of Fox Point Bluff north-northwest approximately 900 feet. The levee is approximately 12 to 17 feet high relative to adjacent ground elevations, and its crest elevations range from 17.1 feet North American Vertical Datum of 1988 (NAVD88) at the south end of the levee to 14.4 feet near the terminal end (U.S. Army Corps of Engineers [USACE] 2011). The levee is faced with riprap along its river side, with rock sizes ranging from 48-inch minus at the north end to 24-inch minus at the south end. The levee was constructed using in-situ materials from the riverbed and shoreline during construction, and as such, the bulk of the levee consists of alluvial sand, gravel, and silt. Accordingly, under-seepage rates through the levee are inferred to be high (USACE 2011).

The levee occupies two properties, one belonging to a private landowner and the other to the Lower Elwha Klallam Tribe. The levee is located within the traditional lands of the Klallam (S'Klallam) people, *nəxʷsƛ̓áyəm̓ (strong people)*, whose descendants are part of today's federally recognized Lower Elwha Klallam Tribe, Jamestown S'Klallam Tribe, and Port Gamble S'Klallam Tribe (Lane 1975; Suttles 1990). Indigenous groups that lived along the Elwha River and its tributaries have used this area since time immemorial for various levels of habitation and resource gathering. This area is partially within the Lower Elwha Klallam Reservation and has been central to Elwha lifeways throughout the Tribe's existence. The estuary of the Elwha River has served the needs of the people from whom the river takes its name since their creation. Eight previously recorded village sites and/or place names are located within the study area, along with six previously recorded archeological sites and two cemeteries (ESA 2020). The importance of the Elwha River estuary, and the associated beaches, to the Lower Elwha Klallam Tribe cannot be overstated

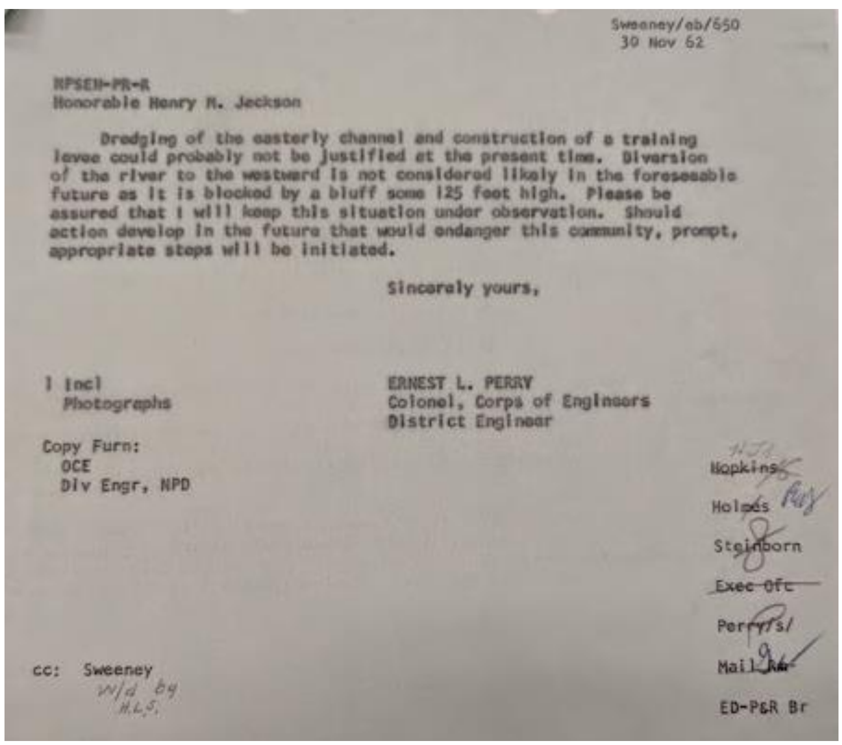
The USACE takes no management authority over the levee, and the levee is not a certified flood control levee. However, the USACE has provided technical guidance and design in support of the levee over the years, and estimates that the existing levee will withhold a 100-year river flow with 90% confidence (USACE 2011).

History

The following summary of the history of the Place Road Levee was prepared by Jamie Michel, CWI, with contributions from ESA.

Throughout the late 1950s and early 1960s, multiple Place Road Community property owners contacted Clallam County Commissioners and U.S. Senators to ask for help to address erosion concerns along Place Road (**Figure 7**). As a result, the USACE was repeatedly engaged to assess any flood hazard that would necessitate a flood protection levee. At that time, there were no homes built east of the “T” at the bottom of the Place Road hill, and the Koniseki (now Klapstein) home was the easternmost developed parcel. The USACE conducted multiple site visits during the early 1960s and determined that there was no flood hazard to established homes to warrant construction of a flood protection levee (**Figures 7 to 9**).

Without USACE support, Clallam County financed the construction of the Place Road Levee with a $7,500 flood control appropriation in May 1964. The levee was built without permits and without consultation with the Lower Elwha Klallam Tribe, despite the fact that half of the levee was constructed on top of Lower Elwha Klallam Tribal land and the strong cultural importance of the region to the Tribe (ESA 2020; Gilpin et al. 2010; Nelson 2006; Ferland 2010; Mass 1983; and others). Beginning in the 1970s, seven additional homes were built between Konizeski and the levee.



Sweeney/eb/650
30 Nov 62

NPSEN-PR-R
Honorable Henry M. Jackson

Dredging of the easterly channel and construction of a training levee could probably not be justified at the present time. Diversion of the river to the westward is not considered likely in the foreseeable future as it is blocked by a bluff some 125 feet high. Please be assured that I will keep this situation under observation. Should action develop in the future that would endanger this community, prompt, appropriate steps will be initiated.

Sincerely yours,

1 Incl
Photographs

ERNEST L. PERRY
Colonel, Corps of Engineers
District Engineer

Copy Furn:
OCE
Div Engr, NPD

Hopkins
Holmes
Steinborn
Exec Ofc
Perry/s/
Mail Rm
ED-P&R Br

cc: Sweeney
w/d by H.L.S.

Figure 7
1962 USACE letter to Senator Jackson describing that construction of a training levee is not justified

MILITARY BUNKER FALLS OVER CLIFF-- A former military concrete installation tumbled from this 200 foot high cliff when heavy waters from the Elwha river tore thousands of yards of dirt away from the banks. All that remains of the building can be seen in the foreground of this picture where only the steps that went down into the bunker remain.

Commissioners disagree with river report

Dec. 12, '62

Results of a Corps of Engineer's inspection on Elwha River damage near "The Place" was reported on by county commissioners yesterday.

The commissioners adjudged the report as "very unsatisfactory."

After residents of "The Place" complained of the possible danger to their property by the river, commissioners sent a letter to Senator Henry M. Jackson and Congressman Jack Westland requesting action on the problem.

The letter, asking that "the Corps of Engineers dredge the easterly channel and construct a training levee," resulted in an inspection of the area by the engineers.

Their report states that the proposed work on the river "could probably not be justified at the present time."

The report further stated that "division of the river westward is not considered likely in the foreseeable future as it is blocked by a bluff 125 feet high."

Commissioners said they "emphatically disagree with the corps observation" and will draft a letter to them "requesting that the Elwha be included in any future planning on rivers."

ARMY ENGINEER REPORT MISLEADING:

FLOOD DANGER GROWS

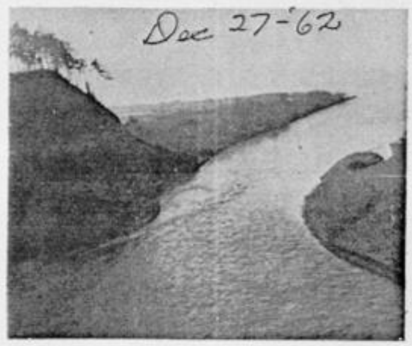
- by Del Price

When it was reported by this paper that residents of The Place at the mouth of the Elwha river were in danger of being flooded out of their homes by the changing course of the river, it was thought at that time the Army Engineers were goind to take action to save these 27 homes from destruction. With the river eating away the banks on the west side at an alarming rate, it is obvious that measures have to be taken immediately to save the homes, the PUD lines, the telephone lines and the country road from flood. A small cemetary also faces innundation.

County Commissioner Critchfield told residents he wanted the problem solved immediately and placed a call to Senator Jackson, outlining the danger. Senator Jackson contacted the Army Engineers office and two men from Seattle came up the next morning to survey the damage. They expressed concern over the situation and returned to Seattle saying a report would be forthcoming. Residents took heart that something would be done.

The report was made, but somehow it contained the mistaken impression that no danger existed because the community "is protected by a bluff 125 feet high." (See complete letter to Senator Jackson in last weeks SN)

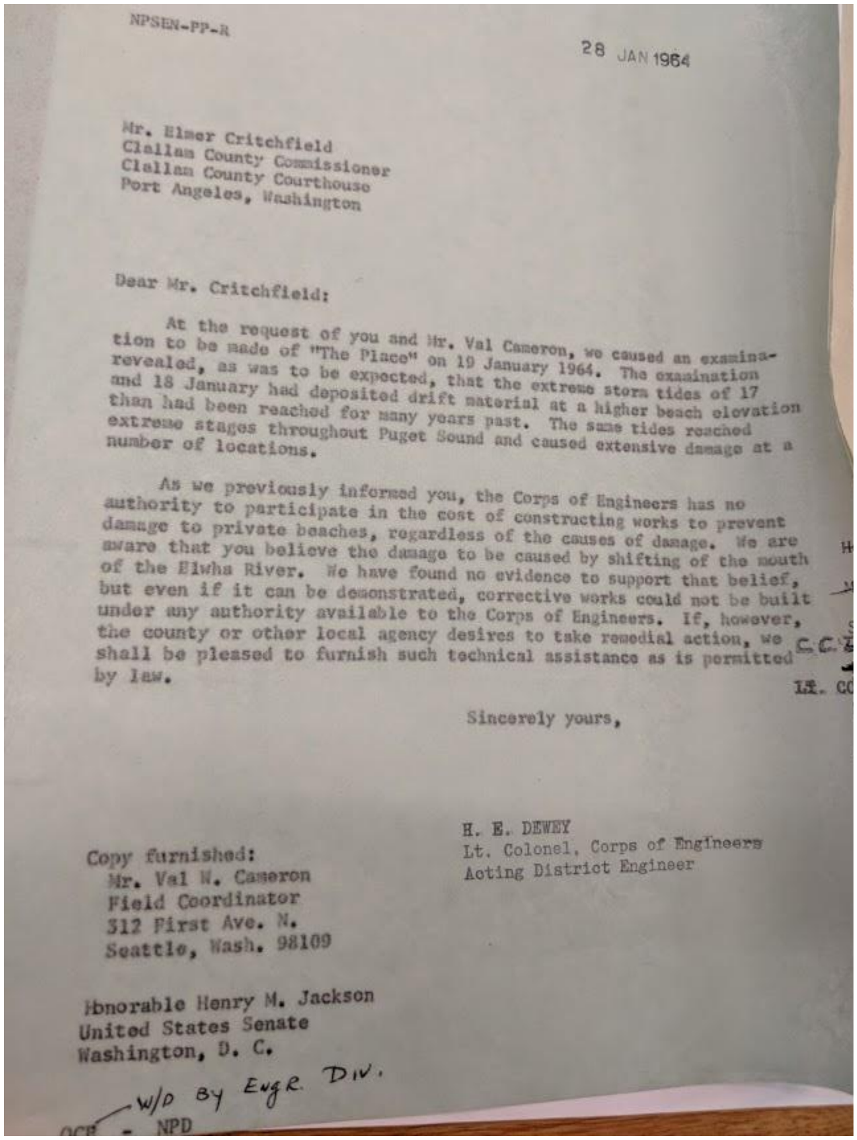
These aerial photos show what the real situation is and prove that somehow the Engineer's report got way off the track. Commissioner Critchfield is sending a notice to the Engineers that another examination



This photo shows how the Elwha river is moving West where it meets the Strait of Juan De Fuca. Note the large deposit of dirt which fell recently from the bank when a former military bunker fell into the river. You can see all that is keeping the river from moving directly West is a small projection of land which is being washed away.

This photo demonstrates how shifting dirt is building up a spit of land which in turn is turning the river Westward toward the 27 homes at The Place. At one time the river ran over a bed on the extreme left side of this picture, but recently it has shifted sharply to the West. One resident who has watched the river for 20 years says that a high river plus a high tide would

Figure 8
Collection of 1962 news articles about Place Road Community flooding and USACE report



NPSEN-PP-R

28 JAN 1964

Mr. Elmer Critchfield
Clallam County Commissioner
Clallam County Courthouse
Port Angeles, Washington

Dear Mr. Critchfield:

At the request of you and Mr. Val Cameron, we caused an examination to be made of "The Place" on 19 January 1964. The examination revealed, as was to be expected, that the extreme storm tides of 17 and 18 January had deposited drift material at a higher beach elevation than had been reached for many years past. The same tides reached extreme stages throughout Puget Sound and caused extensive damage at a number of locations.

As we previously informed you, the Corps of Engineers has no authority to participate in the cost of constructing works to prevent damage to private beaches, regardless of the causes of damage. We are aware that you believe the damage to be caused by shifting of the mouth of the Elwha River. We have found no evidence to support that belief, but even if it can be demonstrated, corrective works could not be built under any authority available to the Corps of Engineers. If, however, the county or other local agency desires to take remedial action, we shall be pleased to furnish such technical assistance as is permitted by law.

Sincerely yours,

H. E. DEWEY
Lt. Colonel, Corps of Engineers
Acting District Engineer

Copy furnished:
Mr. Val W. Cameron
Field Coordinator
312 First Ave. N.
Seattle, Wash. 98109

Honorable Henry M. Jackson
United States Senate
Washington, D. C.

w/o by EngR. Div.
NPD

Figure 9
1964 USACE Letter to Clallam County regarding the prospective construction of the Place Road Levee

The original construction of the levee in 1964 was completed by pushing up alluvial material (sand, gravel, cobbles) until the river was diverted (**Figure 10, Figure 11**). Several years later in 1970, the levee was reshaped into a trapezoidal cross-section, and riprap was added along its length. Over the following 15 years, the levee was not maintained and vegetation became well established along its length. Then, in 1986, a flood eroded the north end of the levee, allowing floodwaters to reach Place Pond. The County completed armoring repairs at the tip of the levee. Also in 1986, the Place Flood Control Zone District was formed pursuant to Clallam County Road Resolution CR 67 (USACE 2011). A copy of a letter describing the Place Flood Control Zone District is provided for reference as **Appendix C** of this document.

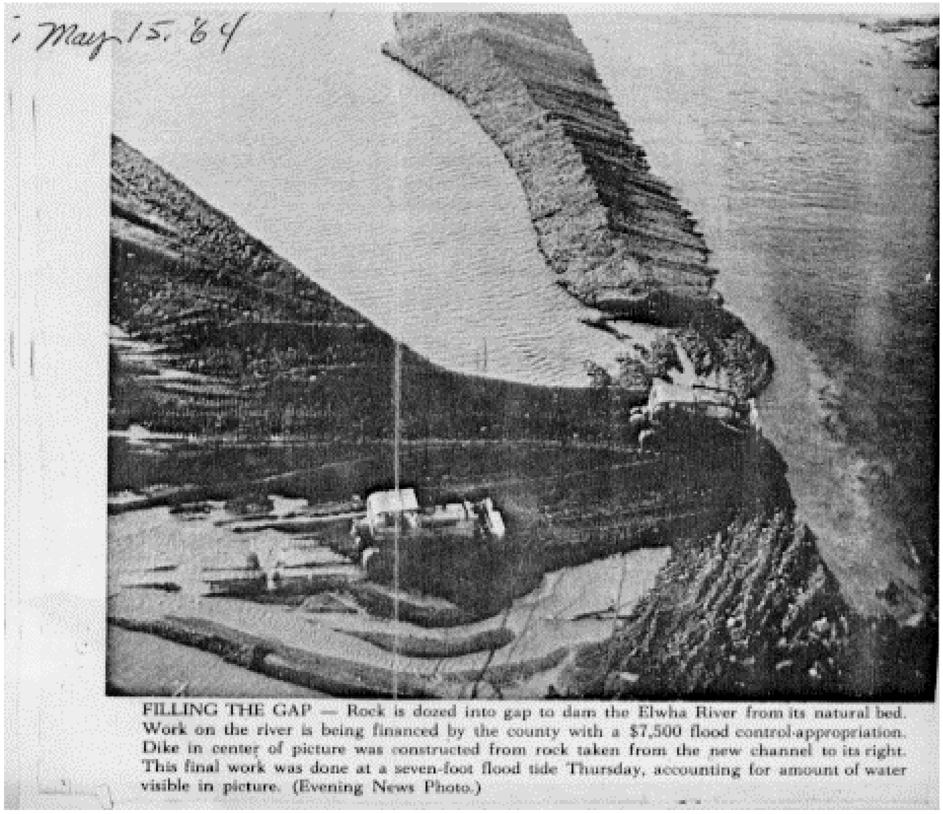
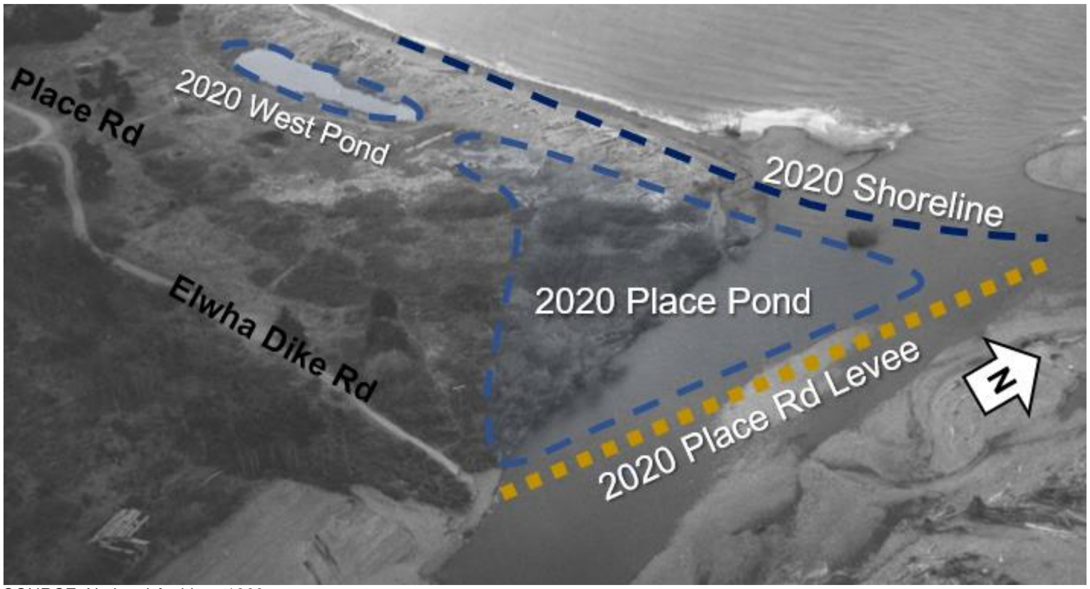


Figure 10
Place Road Levee Construction

In 2003, as part of the planning process for dam removal on the Elwha River, the National Park Service contacted the USACE to ensure that the levee was capable of protecting homes built along Place Road from the unknowns of the soon-to-be undammed river. The USACE proposed several options for managing flood hazards in the Place Road Community. These options included realigning the levee as a setback levee closer to Elwha Dike Road, removing the levee and elevating the low-lying structures in-place, and raising the levee in-place (USACE 2003). In 2006, stakeholders (including property owners, the National Park Service, USACE, Clallam County, and the Lower Elwha Klallam Tribe) agreed to widen (to the west) and raise the levee in-place. Despite developing the levee modification plans, the USACE still did not take management interest in the Place Road Levee (the Place Road Levee today is not a Federal Flood Protection Levee).

Following the decision to raise the levee in-place, the Washington Department of Fish and Wildlife (WDFW) and Clallam County requested modification to the proposed levee improvement to include fish passage into the historic west estuary area. In 2009, Clallam County conducted a pre-dam removal levee fish passage feasibility study; however, fish passage was not included when the levee was raised and widened in 2009–2010 (USACE 2011).



SOURCE: National Archives 1960s

Figure 11
Early 1960s Elwha River Outlet, prior to levee construction with overlay of modern-day shoreline, levee, and existing the Place Pond

Flooding West of the Levee

Following construction of the levee, relatively few instances of flooding in the Place Road Community west of the levee have been reported. In 1986, floodwaters eroded and breached the northern tip of the levee, allowing water from the estuary to enter Place Pond. During this flood, no damages to properties were reported; however, Clallam County promptly conducted repairs to the northern tip of the levee. One of the largest observed lower river flood events in recent history occurred in 2007 when an estimated 40-year flow peaked on the Elwha River. Despite this major event, no flooding in Place Pond was reported, although evidence of seepage through the levee was observed.

Evidence of wave overwash is visible on the pond side of the beach berm fronting Place Pond. Residents reported coastal flooding and overtopping of the coastal berm in the 1970s (**Figure 12**). No flooding in Place Pond or West Pond as a result of wave overwash has been reported in recent years. Similarly, drainage issues from precipitation on the west side of the levee have not been reported to be problematic, although no permanent drain for surface water exists to convey water from the west side of the levee to the east side (USACE 2011).

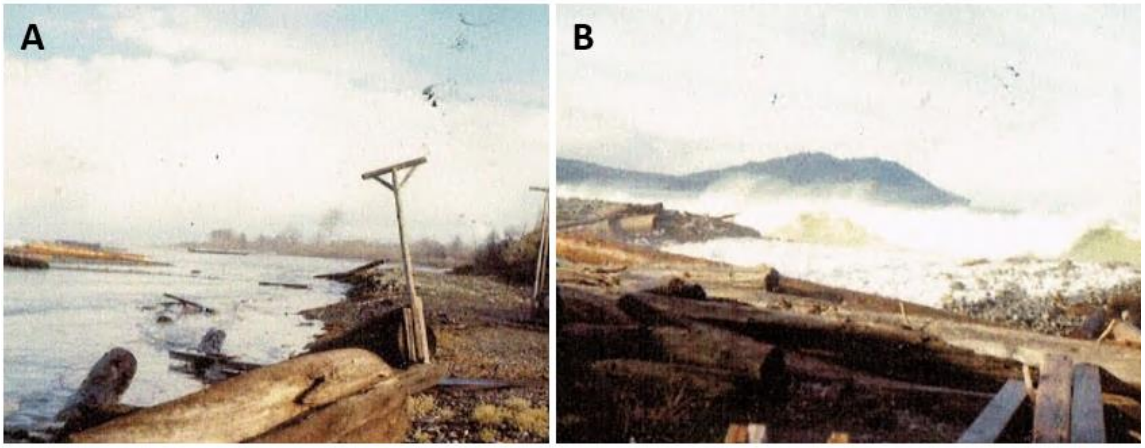


Photo provided by CWI, 2020

Figure 12
Photos taken of Place Pond showing wave overtopping and coastal flooding. Photo A faces east forward the outlet of the Elwha. Posts are clotheslines. Photo B faces offshore toward the Strait of Juan de Fuca.

The Place Pond area includes portions of the two residential parcels adjacent to Place Pond and portions of Elwha Dike Road. These low-lying areas are located within the Federal Emergency Management Agency (FEMA) flood zone (see Section 3.8 for more information). The USACE reports that the most significant hazards under existing conditions are from large coastal storms or tsunami events, for which the existing levee provides little to no protection (USACE 2011). See Section 7.2 for more details on flood hazard analysis.

2.3.2 Place Pond

Place Pond occupies the former river channel scar that was isolated from the mainstem and eastern portion of the estuary following the construction of the Place Road Levee (**Figure 13**). The pond area also served as a source for levee construction materials.

Source: Draut et al 2011

Figure 13
Aerial image of the lower river following levee construction in 1965

A continuous coastal beach berm separates the pond from the Strait of Juan de Fuca. The pond is relatively shallow, although no detailed survey or bathymetry information is available. Bottom elevations are estimated to be around 0 feet NAVD88 (USACE 2011). Sediment from the modern-day Place Pond and vicinity was used for the construction of the Place Road Levee, which likely lowered elevations in the pond below the natural bed elevations.

The pond is freshwater (Foley et al. 2015), although water levels in the pond fluctuate daily in response to changing tidal elevations in the Strait of Juan de Fuca and in response to high river flow events on the Elwha River. Water levels range over approximately 5 feet seasonally, with the lowest water levels observed in the summer and the highest water levels observed during winter storms. High waves and tides can directly overtop the beach berm and reach Place Pond during coastal storms.

Current fish use in Place Pond is dominated by three-spine stickleback as opposed to the wide range of fish including Chinook, coho, and chum salmon, steelhead, and bull trout documented on the eastern side of levee. Place Pond primarily supports macrophytic vegetation.

2.3.3 Previous Studies on Place Road Levee

Between 2003 and 2011, the USACE investigated the Place Road Levee as part of levee flood improvement efforts. From 2003 to 2005, the USACE developed conceptual design alternatives and cost estimates for Place Road Levee modification options to manage flood hazard in the Place Road Community at the request of Clallam County and the National Park Service (USACE 2005). Options developed by the USACE included two alternative levee setback alignments, levee removal with elevating private homes, and elevating the existing levee in-place. As described in Section 2.3.1, stakeholders decided to pursue elevation of existing levee in-place following the production of that document. The levee was elevated in 2009 through 2010. A hydraulic study (USACE 2009) and construction documentation (USACE 2011) provide details on the levee modification design.

In 2009, Coastal Geologic Services (CGS) assessed the levee for potential habitat improvement efforts (CGS 2009). The study evaluated potential fish passage access to Place Pond by way of a truncated levee, a smaller open channel through the levee, or a channel plus a tidegate. The study concluded that an unrestricted fish passage solution (i.e., a truncated levee or open channel passage) would subject low-lying properties around Place Pond to flooding at around a 3-year return period flood. Recommended habitat improvement actions included acquiring low-lying properties and removing the levee, or construction of a setback levee nearer to the existing houses.

Several previous studies have listed the importance of the Elwha River nearshore for fish use, and the Place Road Levee for river nearshore function (Shaffer et al. 2009, 2017a, 2017b; Foley et al. 2017). The levee and the isolated west estuary were also considered tangentially in various U.S. Geological Survey (USGS) studies focused on the estuary’s response to dam removals (Draut et al. 2011; Duda et al. 2008, 2011, 2010; Foley et al. 2015; Foley and Warrick 2017; Glefenbaum et al. 2009, 2015; Magirl et al. 2015; Ritchie et al. 2018; Warrick et al. 2015A , Warrick et al. 2015B). However, no analysis has been done specifically addressing the Place Road Levee and lower river hydrodynamics, including channel migration and flooding, during the post-dam removal period.

3 SITE CONDITIONS & DATA COLLECTION

Local and regional datasets were collected and reviewed to support the development of conceptual and numerical models of the lower Elwha River system. Data gathered for this study include water level records, climate change projections, streamflow data, meteorological data, wave records, bathymetry and topography datasets, and existing flood mapping. Section 3 describes the relevant information in these datasets.

3.1 Water Levels

Water levels, including coastal tides and local water levels in the lower Elwha River estuary, have been recorded as part of this study and as part of ongoing public data collection efforts. Local water levels in the estuary and Place Pond have been collected by CWI, ESA, and NSD as part of this study, and previously by USGS in 2009-2010 and USACE in 2008-2009 (Duda et al. 2011, USACE 2011). A long-term tide gage at Port Angeles has been operated by the National Oceanic and Atmospheric Administration (NOAA) continuously since 1975 (**Figure 14**).

3.1.1 Coastal Water Levels

Surface water levels in the lower estuary are controlled by ocean tides in the Strait of Juan de Fuca and river flow. Changes in ocean water levels occur daily due to astronomic tides, which are water level fluctuations caused by forces between the astronomic bodies of the earth, the sun, and the moon. The Strait of Juan de Fuca experiences semidiurnal tides, with each day having two high and two low tides of unequal heights. The influence of the tides extends from the outlet of the river up through river mile 0.28 to 0.65, depending on streamflow conditions (USACE 2009). Groundwater elevations are also tidally and fluvially influenced (Duda et al. 2011). Identifying the behavior of and controls on water levels within Place Pond is a key aspect of this study.

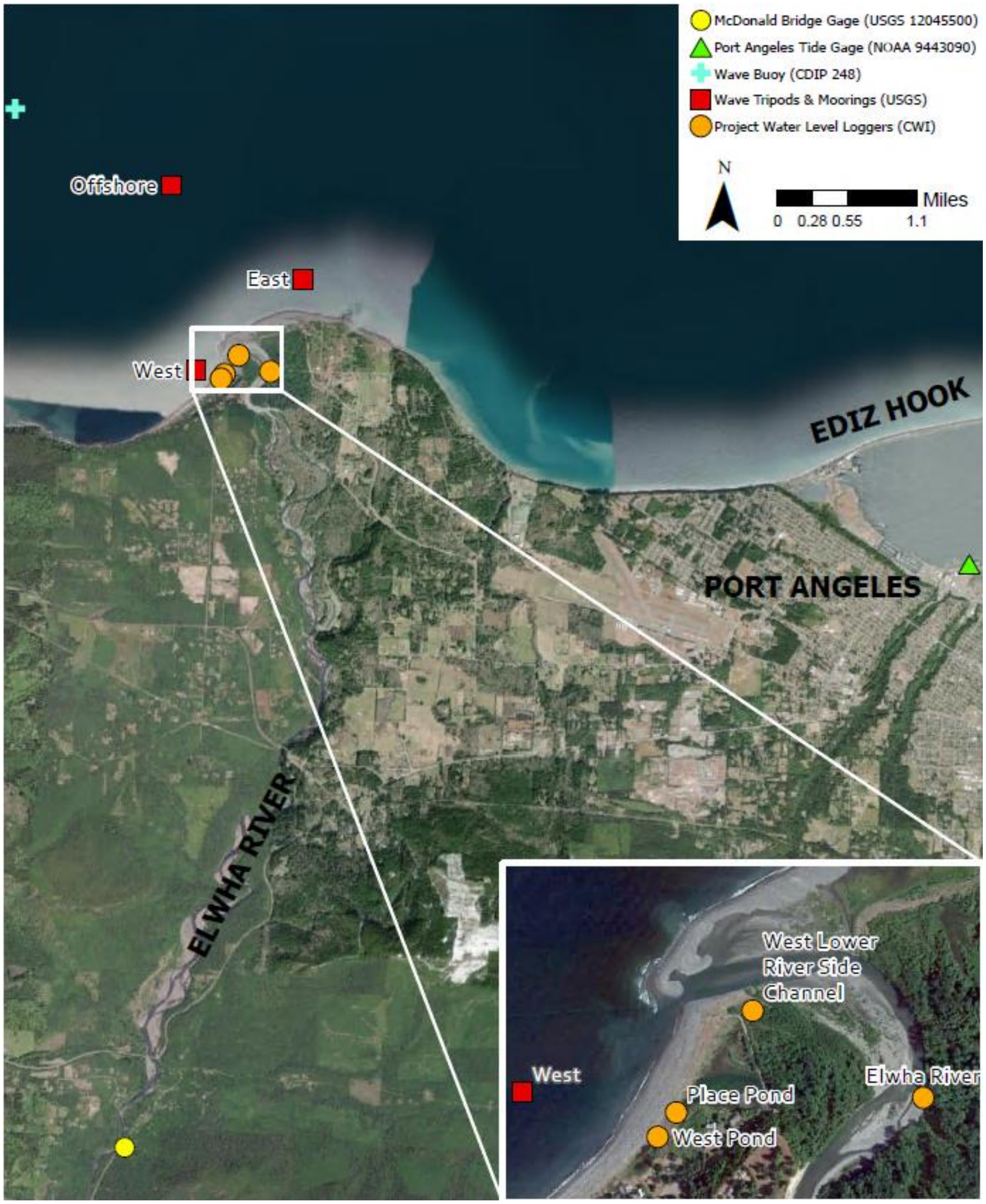
Tidal Datums

Common tidal datums, which are representative statistics calculated from the continually changing tidal water levels, include:

- Mean higher high water (MHHW) – Average of each day’s highest tide.
- Mean sea level (MSL) – Average of all stages of the tide.
- Mean lower low water (MLLW) – Average of each day’s lowest tide.

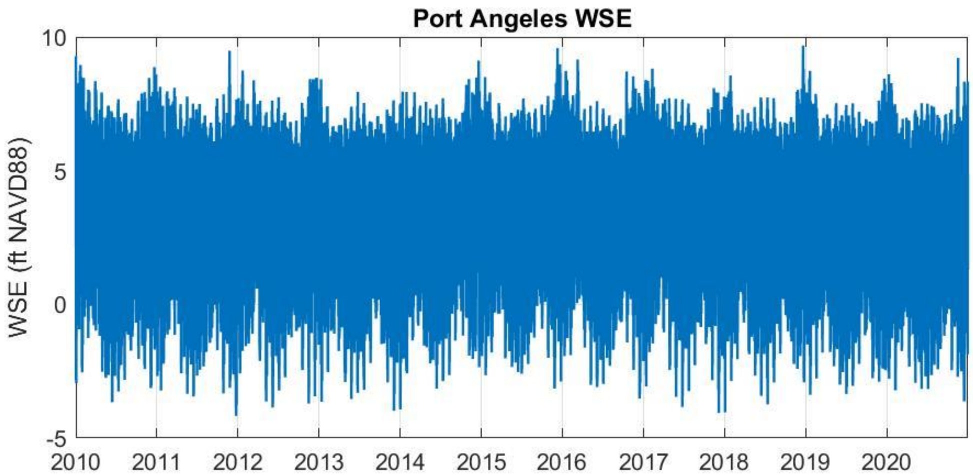
NOAA has maintained a tidal observation station in Port Angeles (Station 9444090) since 1975 (**Figure 14**). The station is approximately 6 miles from the project site and has been used by the USGS, USACE, and other organizations to approximate tidal water levels at the Elwha River estuary. The water surface elevation (WSE) record from 2010 through 2020 is shown in **Figure**

15, and tidal datums from the Port Angeles gage are shown in **Table 1**. Elevations are presented in the NAVD88.



Source: ESRI Imagery 2022

Figure 14
Gaging stations near the study area



SOURCE: NOAA NOS #9444090

Figure 15
Tide record at Port Angeles (2010–2021)

TABLE 1
PORT ANGELES TIDAL DATUMS

Tidal Datum	Water Level (feet NAVD88)
Mean Higher High Water (MHHW)	6.64
Mean Sea Level (MSL)	3.82
Mean Lower Low Water (MLLW)	-0.43

SOURCE: NOAA NOS 9444090

The astronomic tide range varies by several feet from its mean values on about a 2-week cycle, with larger tide ranges called “spring” tides and smaller tide ranges called “neap” tides. “King tides,” the largest spring tides of the year, usually occur in December or January and are approximately 1.5 to 2 feet higher than MHHW.

Extreme Still Water Levels from Tides

Extreme[1] still water levels at the project site were calculated from the 45-year gage record at Port Angeles. Still water levels (SWLs) include fluctuations on coastal water levels generated by astronomical tides, wind, regional ocean dynamics, and atmospheric pressure, but exclude the effect of waves on water levels. **Table 2** presents return-period SWLs calculated via an extreme value analysis.

[1] Major events are often described in terms of their likelihood to occur during a period of time. For example, the 100-year return interval flood is anticipated to occur approximately once in 100 years, and has a corresponding 1-percent chance of occurring annually.

TABLE 2
EXTREME STILL WATER LEVELS

Recurrence Interval	Elevation (ft NAVD88) – Port Angeles
1-year	7.96
2-year	9.01
5-year	9.41
10-year	9.63
20-year	9.81
50-year	10.01
100-year	10.14
Highest Astronomical Tide	8.64
Highest Observed (2003)	10.07

Sea-Level Rise

Due to climate change caused by human greenhouse gas emissions, local sea levels at the study area are anticipated to rise over the next century and beyond. Elevated sea levels in Freshwater Bay will increase coastal water levels, resulting in increased occurrence of waves overtopping the coastal berm and long-term inland migration of the beach face. Increasing sea levels also increase groundwater elevations in the lower estuary and Place Pond, which may limit drainage of water out of Place Pond.

The University of Washington Climate Impacts Group (UW CIG) has developed local projections for sea-level rise along Washington shorelines, including the effect of vertical land movement (Miller et al. 2018). Across the north Olympic Peninsula, isostatic rebound is causing a slight increase in land elevations over time, which results in slightly less relative sea-level rise. At the outlet of the Elwha River, UW CIG estimates there is a 50% likelihood that at least 0.5 foot of sea-level rise will occur by 2050, and that there is a 50% likelihood that 1.6 feet of rise will occur by 2100. These estimates assume a high greenhouse gas emission scenario (RCP 8.5). There is a low probability (1% chance) that sea-level rise will reach much higher levels of up to 1.2 feet by 2050 and 4.5 feet by 2100. Higher rates of sea-level rise are theoretically possible as well. Under a low emission scenario (RCP 4.5), the 50% likelihood estimates at 2050 and 2100 are 0.4 foot and 1.2 feet, respectively.

For the purposes of this study, the 10% likelihood estimates was considered when assessing future conditions. The Washington Coastal Resilience Network recommends using the 0.1% to 17% likelihood estimates when evaluating hazards to properties neighboring prospective restoration sites. The 10% likelihood estimate was chosen for this project as it is within in the middle of the 0.1 to 17% range:

- **0.8 foot** of sea-level rise by **2050**
- **2.8 feet** of sea-level rise by **2100**

3.1.2 Groundwater

The groundwater environment in the lower river is understood to be a complex, layered system consisting of a coastal saline aquifer, overlain by a brackish aquifer, and topped by a freshwater aquifer that exchanges water with the Elwha River bed. In general, water flows from the Elwha, into the fluvial aquifer, which then discharges out to the ocean through the beach.

Information on groundwater change following dam removal and recent groundwater sampling post dam removal is not available. In general, groundwater hydrology in the lower river valley has likely remained unchanged following dam removal, although local changes due to sediment deposition are possible. Before the dam removals, a groundwater study of the lower estuary was prepared by Pacific Groundwater Group in 2005 on behalf of the Lower Elwha Klallam Tribe. The study described that in the lower valley, alluvium overlays a bedrock layer, which constrains the aquifer vertically resulting in high hydraulic connectivity. Aquifer transmissivity increases moving downstream in the valley. Sampling conducted as part of this study showed that at the mainstem of the river, groundwater signals are driven by changes in river stage, although a small tidal signal is presenting. Moving farther away from the mainstem to the west and to the east, the groundwater response to river stage decreases and groundwater elevations are dominated by tidal fluctuations. Surface water bodies in the study area (including the Elwha River, the west estuary, Place Pond, and the Strait) are hydraulically linked by this groundwater connection. Additional information about the groundwater connection between Place Pond, the Elwha River, and the Strait of Juan de Fuca are provided in the following Section 3.1.3 and in the conceptual model described in Section 7.1.

3.1.3 Local Surface Water Levels

Water levels within the Elwha River estuary have been collected as part of this project and previously by others. This section describes water surface records that are available for the lower river and west estuary.

2020–2021 Measurements

As part of this study, four water level loggers were installed within the study area in September 2020. Sensors were installed in areas critical to the calibration of the hydrodynamic model and the development of a conceptual understanding of water movement within the study area: Place Pond, the lower Elwha River, and the WLRSC (**Figure 16**). The loggers record water surface level, temperature, and conductivity every 15 minutes.

Figure 17 displays the recorded water levels, temperature, and conductivity recorded by the loggers for the monitoring duration. **Figure 18** is a detail over 2 days intended to show the lag time between tides, peak flows, and increased water levels in Place Pond. **Figure 19** is a detail of a typical late summer period captured by the loggers, and **Figure 20** is a typical winter high-flow period. **Figure 21** is a period of high wave activity that appears to result in seawater from the Strait entering Place Pond via beach groundwater forcing or overtopping.

The data collected and displayed in **Figures 17 through 21** show that all water bodies measured have tidal signals that correspond to tidal water levels in the Strait of Juan de Fuca. The signal is muted and lagged to various degrees. While the lower Elwha River has a tidal response that is nearly coincident with Port Angeles tides, the tidal signal in Place Pond lags behind the response in the river typically by around 4 to 6 hours (**Figure 18**, left). Place Pond generally displays only a single diurnal tidal signal, which varies less than 0.5 foot in response to daily tidal fluctuations. A tidal signal is present nearly every day in Place Pond, regardless of the presence or lack of a tidal signal at the lower Elwha River station (a tidal signal is not apparent in the Elwha River during high river flows), suggesting that groundwater forcing from the Strait directly to Place Pond is an important contribution to pond levels.

The pond water levels also rise and fall in response to high flows on the river. Seasonally, pond water levels respond to higher stages on the lower Elwha River by fluctuating up to 5 feet from summertime low flows to peak winter precipitation events. Water levels rise in Place Pond at a slightly slower rate than the river as the river stage rises. The peak water level response in Place Pond from high flows is also lagged relative to the lower river by up to 10 hours, depending on the tide level at the time of the peak flow (**Figure 18**, right). The falling limb of the fluvial flood event falls more steeply in Place Pond than in in the mainstem of the river, which is likely caused by drainage through the coastal berm at low tides. Note that water levels at the lower Elwha River logger station are higher than those observed in Place Pond or in WLRSC because the Elwha River station is located roughly 0.5 river mile upstream on the Elwha River, and the other logging stations are within roughly 600 feet of the Strait of Juan de Fuca.

The lagged water surface response of Place Pond to changes in Strait of Juan de Fuca tides and high flows on the Elwha River is characteristic of a groundwater connection. Water takes time to move through the soil pores along a gradient in pressure, resulting in a delay in peak water levels.

The eastern end of Place Pond typically has slightly higher water levels than the western zone, especially during high tides and high-flow events on the Elwha River. Conductivities are also lower in the eastern end of Place Pond. These trends suggest that Place Pond immediately adjacent to the Place Road Levee has a stronger hydraulic connection to the Elwha River when compared to the western end of Place Pond. This is consistent with eastern Place Pond’s closer proximity to the Elwha River, and the Pacific Groundwater Group (2005) finding that the influence of river stage on groundwater elevations decreases moving laterally away from the river.

Place Pond exhibits periods of elevated salinity that are likely caused by wave overtopping across or coastal forcing of seawater through the beach berm. **Figure 21** highlights an example period where wave heights in Freshwater Bay are high, corresponding to a small spike in Place Pond conductivity. Despite periods of increased conductivity, the salinity in Place Pond remains within the freshwater designation of <2 parts per thousand (ppt).

Water level trends in the WLRSC are more complex than in Place Pond. The WLRSC appears to have a stronger connection to the lower river, especially during high-flow periods. A lag is not observed between Elwha River water levels or Port Townsend tides and the WLRSC, suggesting that the degree of connection is much higher than in Place Pond. During certain stages, a surface water connection to the WLRSC appears to exist. This is evident when WLRSC levels match tidal elevations closely on the rising and falling limb of each high tide. An example of this occurs in early January 2021 in **Figure 20.** At other times, however, the behavior of water levels in the WLRSC is more similar to that of Place Pond, with little daily variation in water surface elevations, and an even-more muted tidal signal than in Place Pond. At times when tidal elevations are low, the water level in the WLRSC can be lower than that of Place Pond, with little to no tidal signal.

Evaluation of the WLRSC water levels is difficult because water level information is not available in the mainstem immediately adjacent to the WLRSC entrance. The water surface gradient between the lower Elwha River logging station and the Strait of Juan de Fuca is assumed to be linear, which would imply that water levels in the main channel near the entrance to the WLRSC are lower than the Elwha River logging station and more similar to the Port Townsend tides. **Figure 22** shows the WLRSC elevations plotted against the Port Angeles station tides. At tide levels above 6 feet, the WLRSC elevations nearly match tidal elevations 1:1, but below 6 feet NAVD88 tides, the WLRSC elevations vary widely, although never dropping down below a base elevation of approximately 5 feet NAVD88. The highest water levels observed in the WLRSC occur during the highest tides. A high point in the channel bathymetry may prevent a direct surface water connection until levels in the mainstem are sufficient highly.

The data collected to date suggest that elevations in the WLRSC are controlled by water levels in the lowest portion of the river, near the outlet where water levels are nearly equal to the Port Angles tides. A surface water connection to the WLRSC is likely present when tides in the Strait of Juan de Fuca are above approximately 6.5 feet NAVD88. Salinities in the WLRSC remain fresh throughout the year, closely matching salinities in the lower Elwha River station. This suggests that little to no water from the Strait of Juan de Fuca is entering the WLRSC via wave overwash or saline groundwater exchange.

Figure 23 plots water level exceedance graphs for the measured stations. The exceedance graphs show that generally, the Place Pond and WLRSC water levels are perched somewhat above the Strait of Juan de Fuca tides for most tidal levels. The record is too short to draw significant statistical conclusions about elevation, but generally west and eastern portions of the Place Pond have similar water level distributions, while the WLRSC reaches higher levels at the <2% exceedance interval and slightly lower levels between the 2 and 40% exceedance interval.

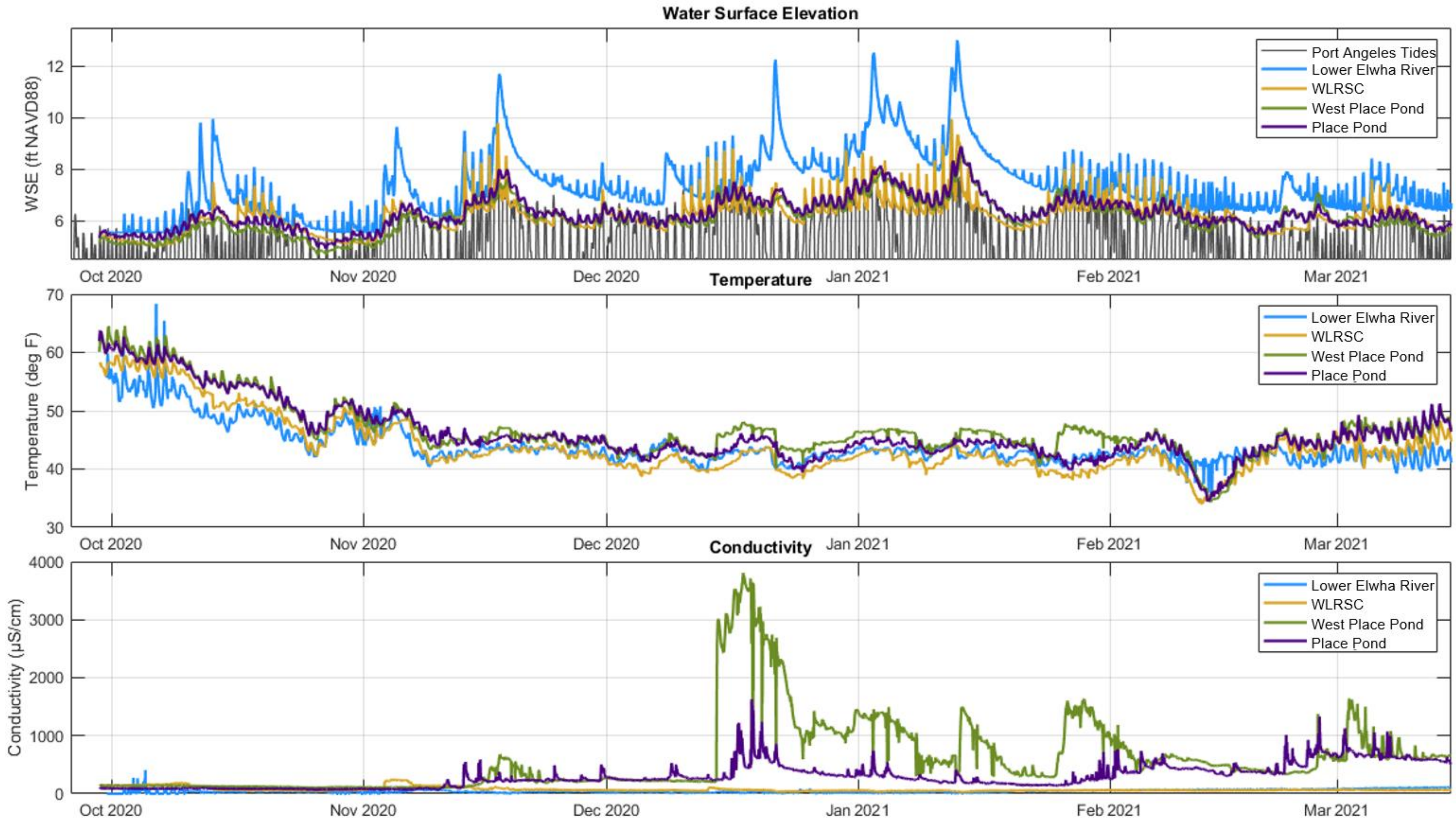
The extended lag time between peak river flows and peak Place Pond elevations, and the fact that Place Pond is often higher in elevation than the WLRSC, suggests that Place Pond may be hydraulically connected via groundwater higher up in the Elwha River than compared to the WLRSC. Groundwater flow may be traveling from southeast to northwest through the West Floodplain and seeping through the levee along the southern end.

Other Records

Additional pre-dam removal water level records were collected by the USGS (Duda et al. 2011) and USACE (2011). A summary of these records is provided in **Appendix D**.

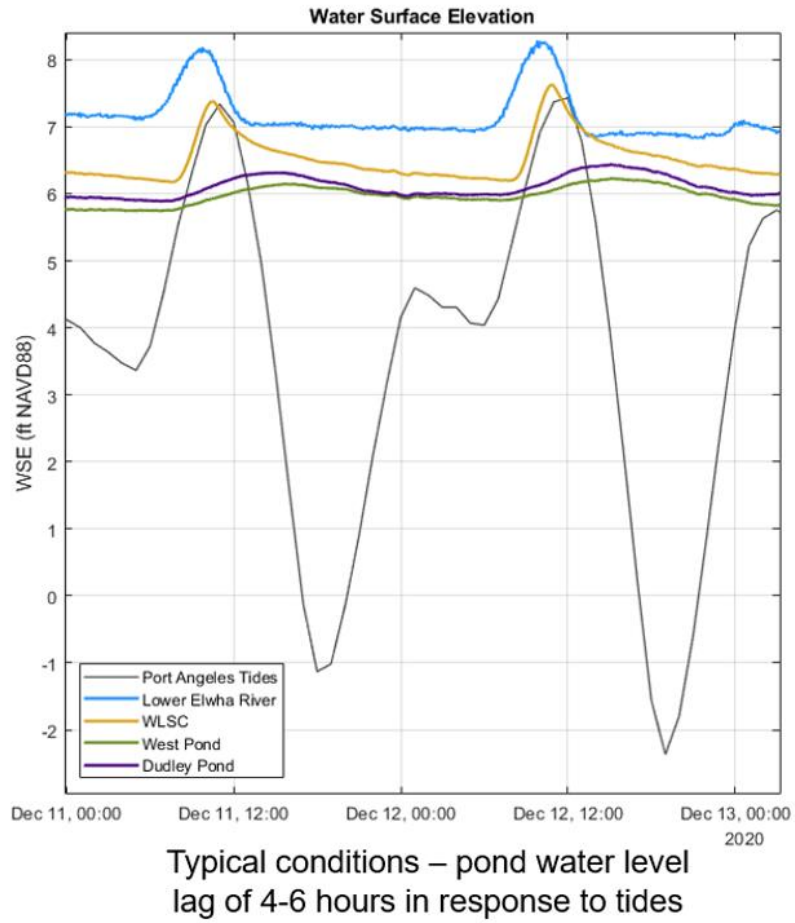
SOURCE: ESA & NSD 2020

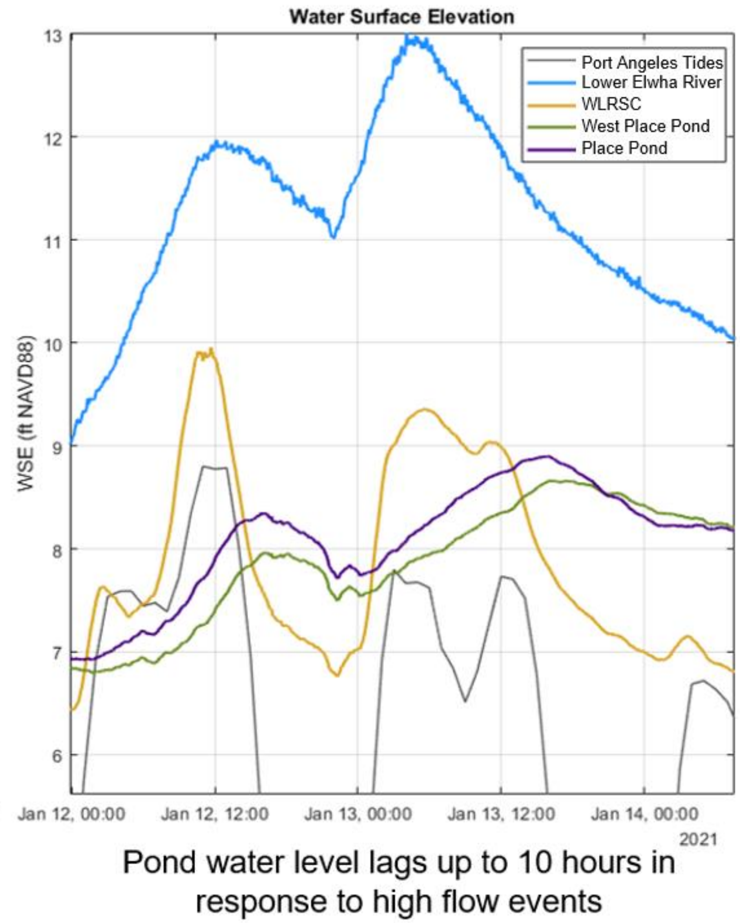
Figure 16
Logger installation (top panel) and locations (bottom panel)



SOURCE: ESA & NSD 2020

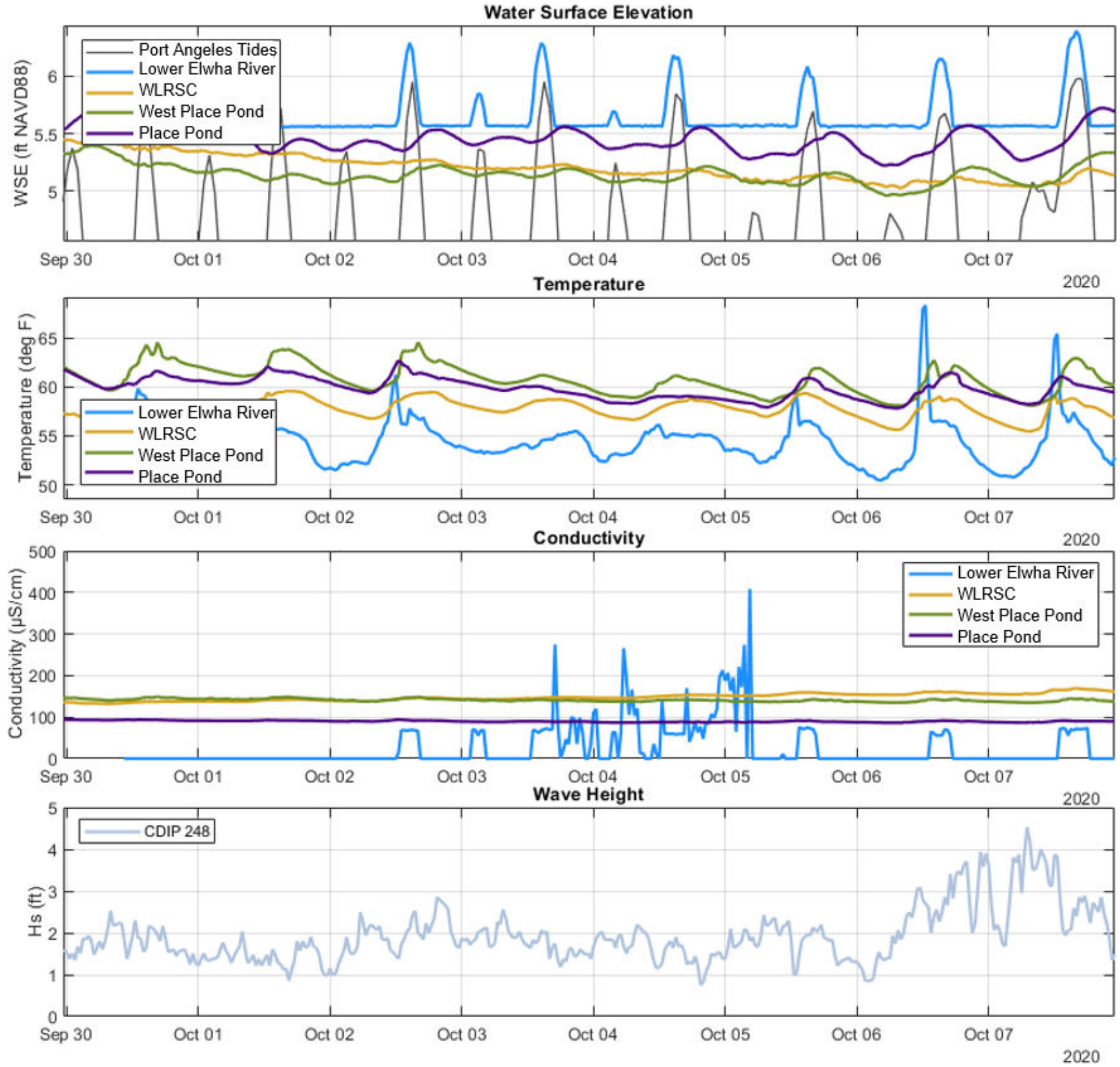
Figure 17
Water level logger data





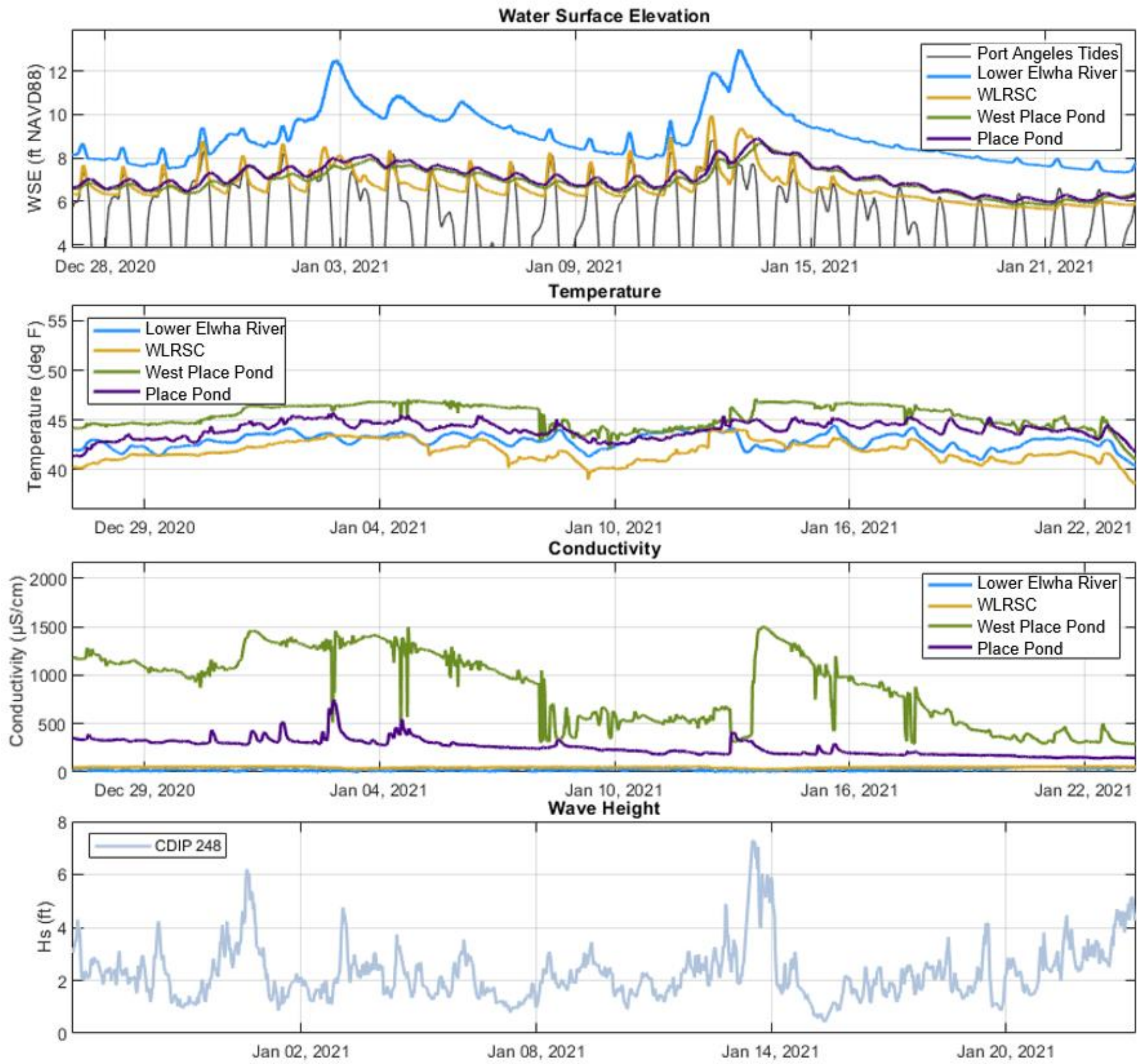
SOURCE: ESA & NSD 2020

Figure 18
Water level logger data
Water level responses across two tidal periods



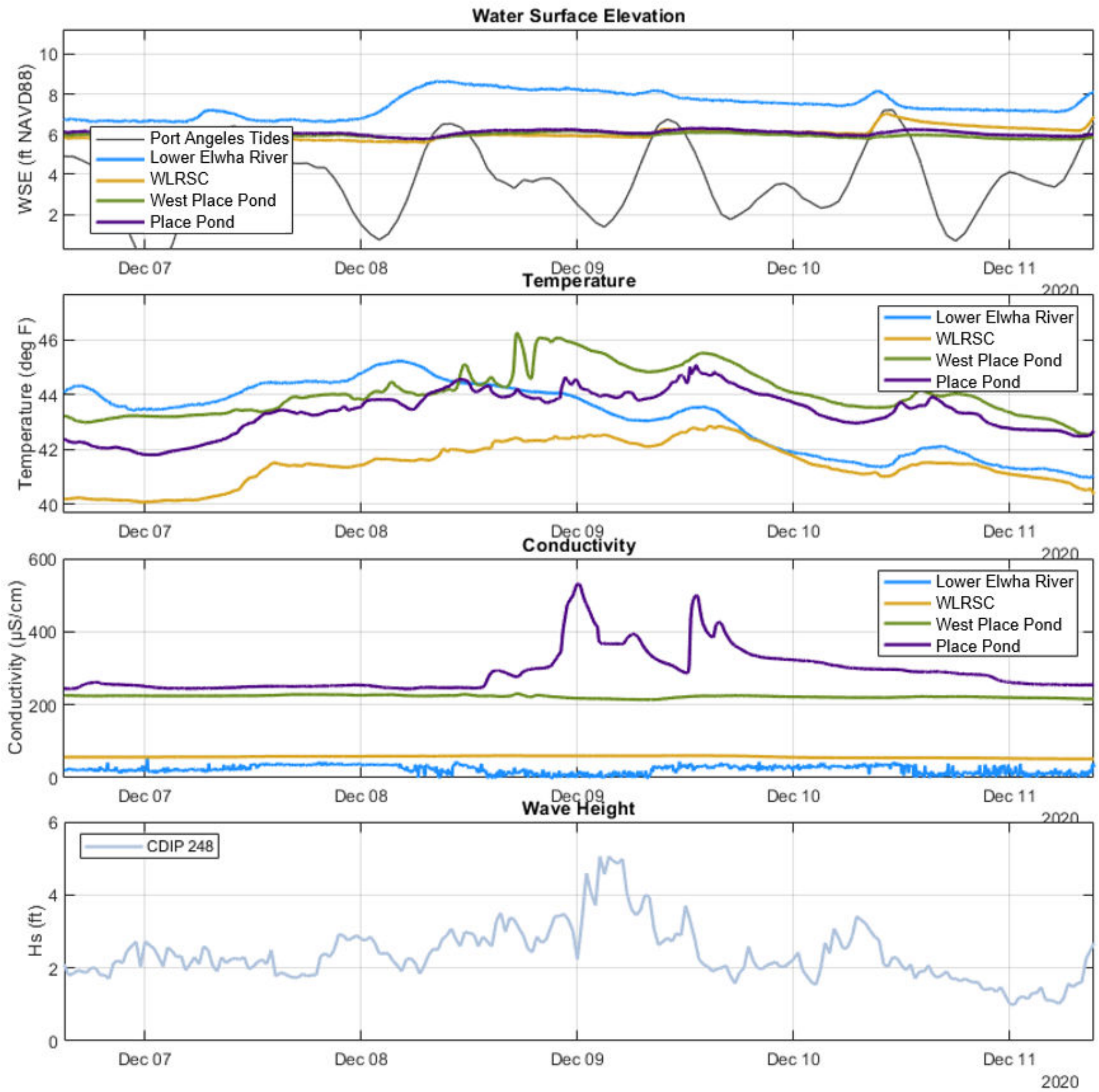
SOURCE: ESA & NSD 2020

Figure 19
Late summer water level detail



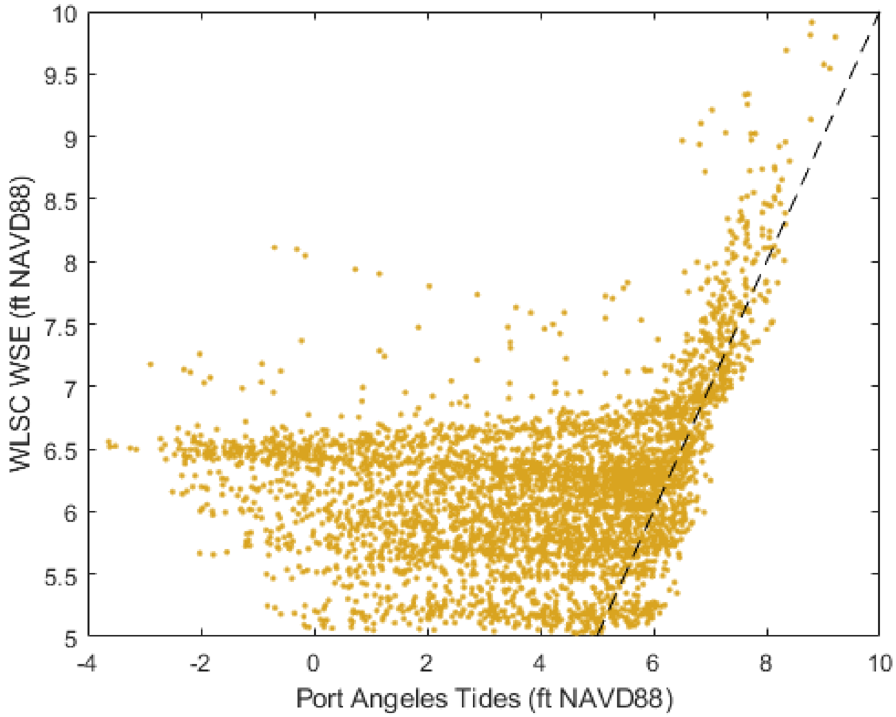
SOURCE: ESA & NSD 2020

Figure 20
Winter high-flow water level detail



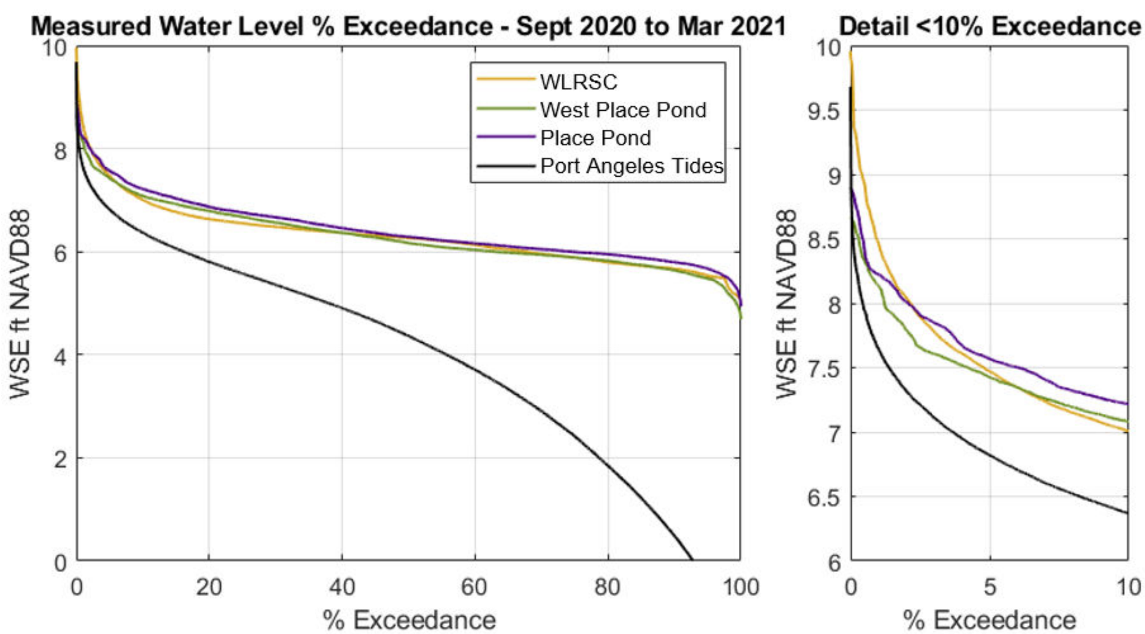
SOURCE: ESA & NSD 2020

Figure 21
Potential wave overtopping water level detail



SOURCE: ESA & NSD 2020

Figure 22
WLRSC water levels relative to tides



SOURCE: ESA & NSD 2020

Figure 23
Water level percent exceedance graphs

3.2 Waves

Wave data referenced for this study include a long-term buoy at the entrance to the Strait of Juan de Fuca, a buoy installed in Freshwater Bay, and local sensors deployed at the Elwha River delta. Details on wave conditions and the wave data used for this study are provided in **Appendix E**.

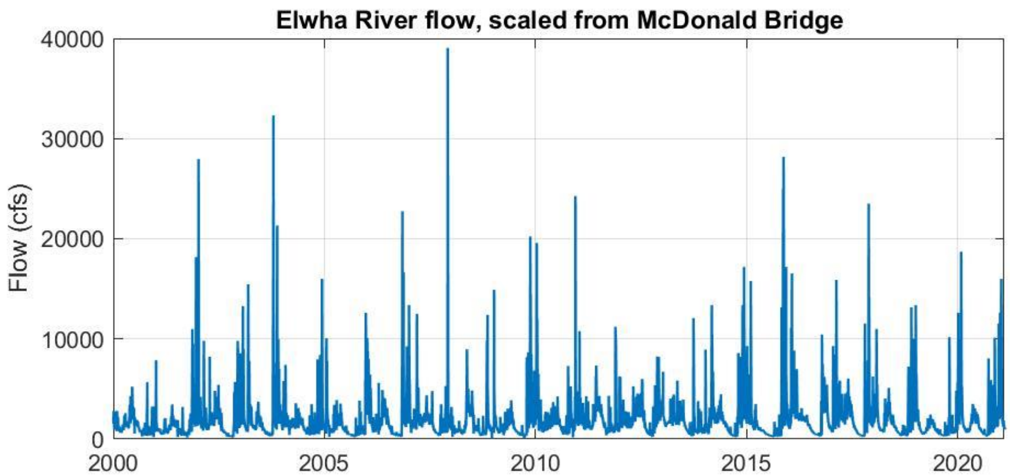
3.3 Tidal Currents

Tidal currents in the Strait of Juan de Fuca near the shore can be large, as the relatively narrow body of water conveys much of the tidal exchange between Puget Sound and the Pacific Ocean. During tidal flood, currents near the Elwha River estuary are predominantly to the east, and reverse directions to the west on ebb tides. These tidal currents can reach up to 3 feet/second, and are influenced by the shape of the large submarine delta (Gelfenbaum et al. 2009). The headland formed by the delta causes currents to arc around the headland, generating large transient eddies to both the east and west of the delta. The residual currents in these eddies reach up to 1.3 feet/second (Gelfenbaum et al. 2009). Within the nearshore, waves drive longshore currents.

Although tidal currents that form around the delta are relatively high, large-scale residual tidal currents in the Strait of Juan de Fuca are not a key physical process inside of the estuary or in Place Pond, where local instantaneous velocities driven by tidal motion and river flow determine sediment transport and flow pathways.

3.4 Streamflow

The lowest elevation, continually operated streamflow gage on the Elwha River is located at McDonald Bridge (USGS Gage 12045500 at McDonald Bridge at river mile 8.6) and has been operating since 1987. The gage is located downstream of the former dam sites but upstream of several small tributaries that contribute to increased flow at the outlet of the river. To correct for the increased catchment area and tributary contributions, the McDonald Bridge flow rates were scaled by a factor of 1.088 to represent Elwha River outlet flows, following the USGS methodology described in Magirl et al. (2015). Scaled flow rates from 2000 to 2021 are presented in **Figure 24**. Because the Elwha and Glines Canyon Dams were operated as run-of-the-river (meaning that flows were continually released as they entered the reservoir with little to no storage of peak flows), flow patterns before and after dam removal are similar.



SOURCE: ESA & NSD 2020

Figure 24
Scaled streamflow at McDonald Bridge Gage

3.4.1 Extreme Flows

Scaled annual maximum flow rates from the McDonald Bridge gage were acquired and ranked across the period of record (1987–2020). Extreme flow rates were calculated by applying a frequency analysis to the ranked annual maximum flows (**Table 3**). At the outlet of the Elwha River, the 100-year return interval flow is estimated to be 42,750 cubic feet per second (cfs), and the top two highest observed flow rates occurred in November 1897 (+100-year flood) and December 2007 (approximately 50-year flood) (Duda et al. 2011).

Extreme flow rates at the river outlet were also analyzed by the USACE as part of the Elwha Westside Levee Modification Project (USACE 2011) and as part of the FEMA preliminary Flood Insurance Study (FEMA 2019). These values are provided for reference in **Table 3**. Predicted extreme flow rates in the post-dam removal era are expected to be approximately the same as those calculated during the pre dam removal era. This is because the dams were operated as run-of-the-river, which causes little to no effect on extreme flow rates.

TABLE 3
EXTREME FLOW RATES AT THE OUTLET OF THE ELWHA RIVER, 1987-2020
(SCALED FROM MCDONALD BRIDGE USGS GAGE 12045500)

Return Interval	Flow (cfs)
1-year	5,092
2-year	15,943
5-year	23,328
10-year	28,132
20-year	32,678
50-year	38,473
100-year	42,750
100-year (USACE 2011)	47,587
100-year (FEMA 2019)	45,000
500-year	52,422
Peak Flood Date	Flow (cfs)
Dec. 3, 2007	39,059
Nov. 18, 1897	41,600

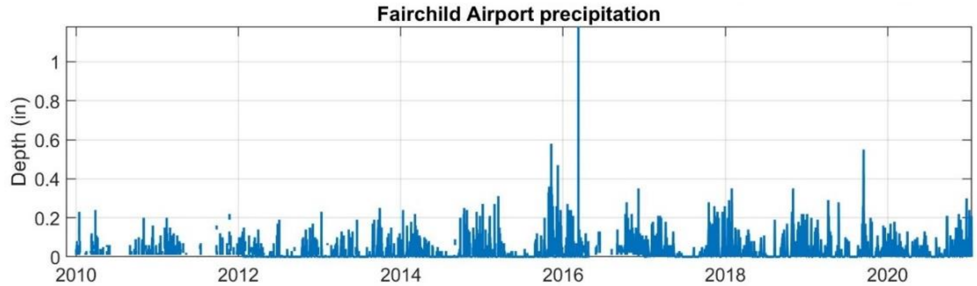
3.4.2 Climate Change and Streamflow

Climate is the long-term average of weather over a given area. Global climate model (GCM) outputs can be combined with historical observations to assist with translating large-scale patterns into more localized projections at a smaller scale, a process called downscaling. The International Panel on Climate Change (IPCC) uses a series of scenarios termed Representative Concentration Pathways (RCPs) created in 2010. The current emissions trajectory most closely follows RCP 8.5, where the increase in carbon dioxide and other greenhouse gases is projected to increase annual temperatures and precipitation intensity during the wet months. By 2099, the projected increase to 100-year recurrence interval peak flow on the Elwha River is approximately 35%, from 42,750 to 58,000 cfs (CIG 2010). Projected increases to peak flow magnitudes are a result of the ratio between the simulated historical record and average of 10 GCM hybrid delta scenarios (Hamlet et al. 2010).

3.5 Meteorology

3.5.1 Precipitation

Hourly precipitation data are available from the William R. Fairchild International Airport in Port Angeles from 1981 until present (**Figure 25**). However, the Elwha River basin receives dramatically variable rainfall amounts across the basin, with the upper watershed receiving more than five times the annual rainfall as the river outlet (Duda et al. 2011). Therefore, the Fairchild Airport gage likely underestimates the precipitation in the basin overall, although it is representative for the area surrounding the lower estuary.

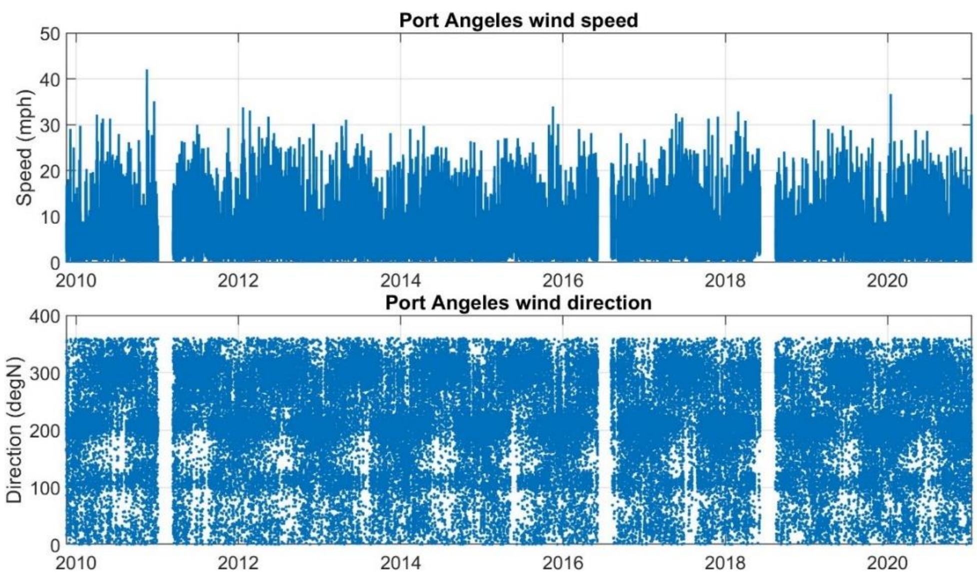


SOURCE: IEM 2021

Figure 25
Fairchild International Airport hourly precipitation

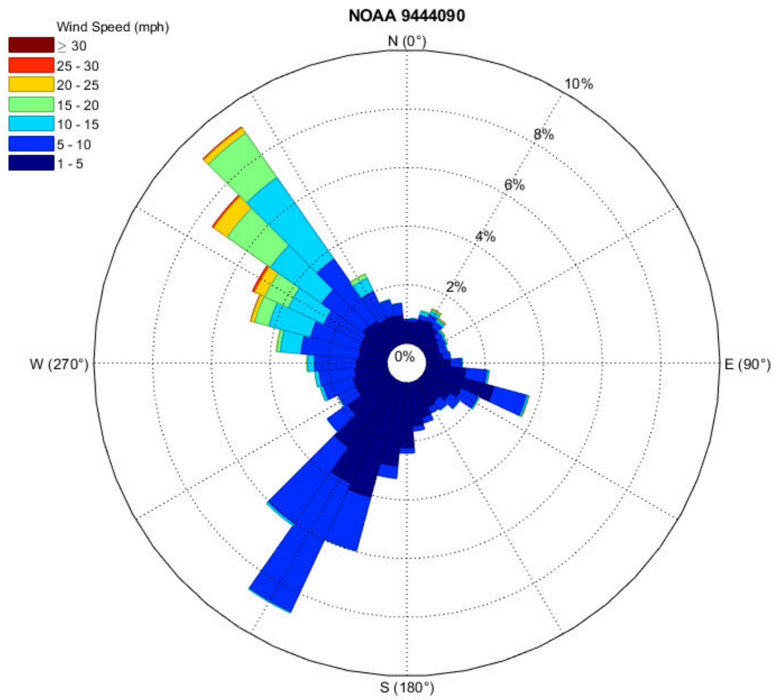
3.5.2 Wind

Wind data are available near the project site at the Port Angeles NOAA Tide Gage (#9444090). Peak 2-minute wind speeds reach 30 to 40 miles per hour (mph) and arrive from the northwest. **Figure 26** presents hourly wind speed and direction data, while **Figure 27** displays a wind rose for the station.



SOURCE: NOAA 2020

Figure 26
Wind speed and direction time series



SOURCE: NOAA 2020

Figure 27
Wind rose

3.6 Water Quality

Temperature and salinity data have been collected in Place Pond and in the WLRSC as part of this study and as part of previous efforts described in Section 3.1.3. The Lower Elwha Klallam Tribe has also operated water temperature and conductivity recorders in Place Pond since 2010.

Temperature trends in Place Pond are typical of shallow, temperate ponds. Temperatures rise and fall diurnally and seasonally. In summer, surface water temperatures regularly exceed 60 degrees F and have been measured as high as 70 degree F. These temperatures are often 10 degrees warmer than those measured in the lower mainstem of the Elwha River. No information is available about stratification in Place Pond, but it is likely that at least Place Pond is seasonally stratified in the summer, with colder water present at the bottom of the lake. The shallow lakes are likely mixed during the fall through spring.

The two sampling locations in Place Pond are also predominately freshwater. In Place Pond, maximum salinities of up to 2 ppt have been recorded, although typical salinities are less than 0.5 ppt. West Pond has a shorter period of record overall since it has not been measured by the Tribe, but appears to be slightly more saline than Place Pond (**Figures 17, 18, 19, and 20**).

Previous measurements by USGS (Duda et al. 2011) found that salinity in the WLRSC was brackish, ranging from 5 to 10 ppt. Following dam removal, however, salinities in the lower river have become fresher (Foley et al. 2015). The recent September 2020 to present deployment by CWI found that salinities were less than 0.1 ppt throughout the period of record and nearly matched the salinities in the lower Elwha River, suggesting that groundwater and surface water connectivity with the Strait of Juan de Fuca has lessened since the prior to dam removals and that connectivity with the lower Elwha River has increased.

No other water quality data (such as nutrient levels) have been collected in Place Pond, West Pond, or in the West Floodplain. Prior USGS efforts (Foley et al. 2017) have sampled nutrients and other water quality information in the main channel and in the east estuary, but did not cover the west estuary sites. Prior to dam removals, Place Pond is known to have algae blooms (Nelson 2011; **Figure 28**), although none have been observed since shortly after dam removal (Shaffer n.d.). Parcels bordering the pond have septic systems that may impact water quality in the pond.

SOURCE: J. Duda, 2007

Figure 28
Macroalgae bloom in Place Pond in 2007

3.7 Bathymetry

3.7.1 Field Data Collection

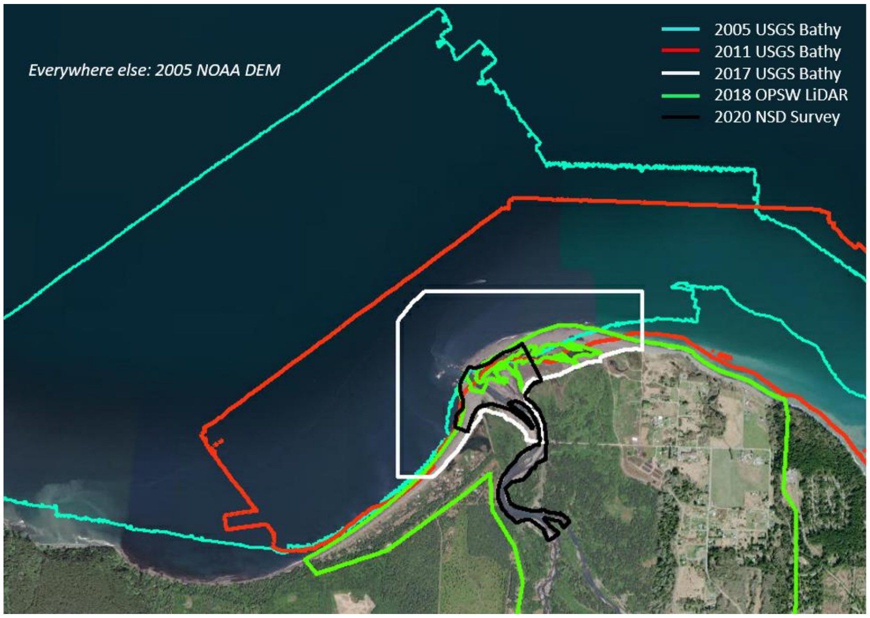
In September 2020, NSD performed a limited ground elevation survey in the lower Elwha River channel, floodplain, and delta, and along the shoreline of Freshwater Bay. Cross sections were collected in the Elwha River from the outlet up to approximately halfway up the length of the Fox Point Bluff. Detailed survey information was not able to be collected within the dense vegetation of the West Floodplain; however, estimates of channel widths and depths were collected wherever possible. The survey also included beach profiles along the eastern part of Freshwater Bay and across the barrier sand bars east of the outlet.

3.7.2 Fall 2020 Merged Topobathy

ESA developed a single, high-resolution merged surface for hydrodynamic modeling that approximates conditions in the lower estuary and nearshore in late 2020. Multiple bathymetry and topographic data sources were combined, including a 2005 NOAA Digital Elevation Model (NOAA 2005), a 2005 USGS bathymetry survey, a 2011 USGS bathymetry survey, a 2017 USGS bathymetry survey (USGS 2005, 2011, Stevens et al. 2017), Olympics North OPSW Light Detection and Ranging (LiDAR) survey (Quantum Spatial 2018), and a ground survey conducted by NSD in September 2020 as part of this project. Corrections to the 2018 LiDAR were applied in some areas of the west estuary to better match NSD survey points in ponded areas and along heavily vegetated channels in the West Floodplain. The main portion of Place Pond was deepened to 0 feet NAVD88 for consistency with USACE (2009), although no survey data are available throughout most of the pond.

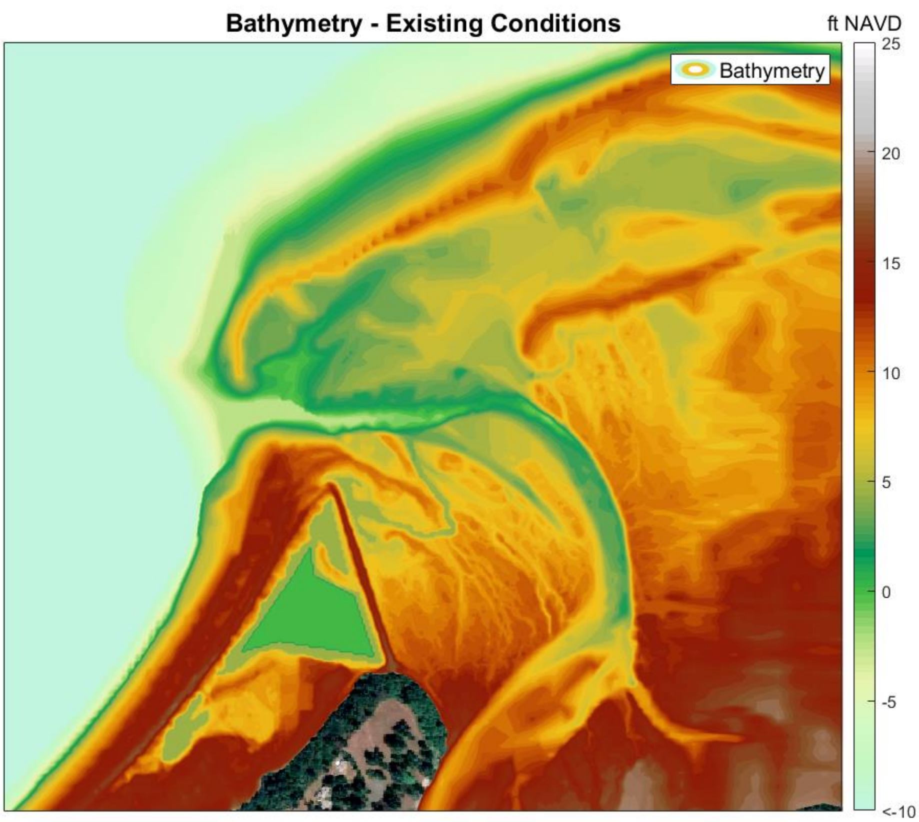
The footprints of the layered datasets are provided in **Figure 29**, and **Figure 30** shows the final merged surface applied in the hydrodynamic model. A topographic cross-section passing through Place Pond is provided in **Figure 31**, which illustrates the typical steep intertidal beach slope of 1:8 (vertical to horizontal) and a gentler offshore slope of 1:30. The beach berm that separates Freshwater Bay from the coastal floodplain crests at around 16–17 feet NAVD88. Residential development is located on a terrace at about 13 feet NAVD88, inland of the low-lying ponded areas and seaward of Fox Point Bluff.

In addition to the 3D topography, CWI has been periodically recording the approximate horizontal position of the beach scarp and river channel edge, along with storm observations of wrack lines (**Figure 32**).



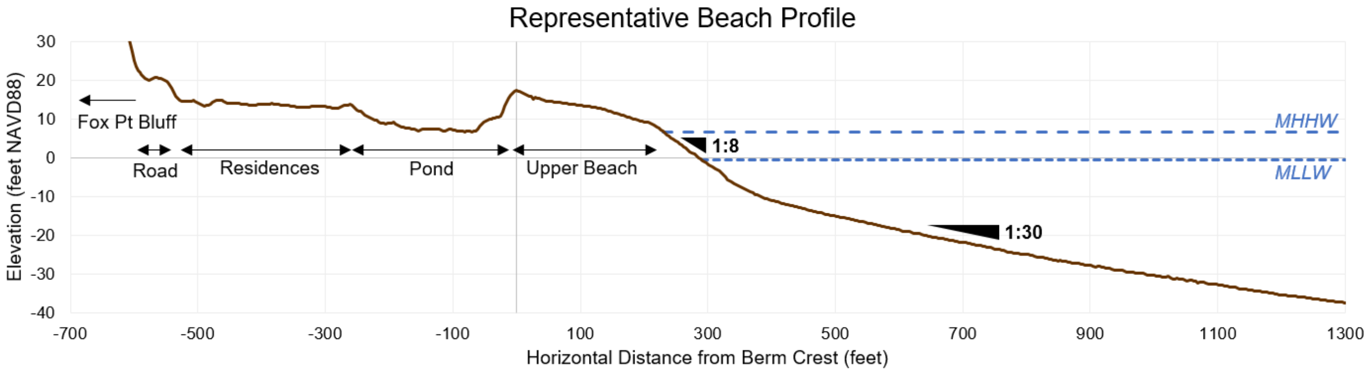
SOURCE: NOAA, USGS, Quantum Spatial, NSD

Figure 29
Footprints of data sources used in surface construction



SOURCE: NOAA, USGS, OPSW, NSD

Figure 30
Merged elevation model



SOURCE: NOAA, USGS, OPSW, NSD

Figure 31
Typical beach profile through study area

SOURCE: CWI

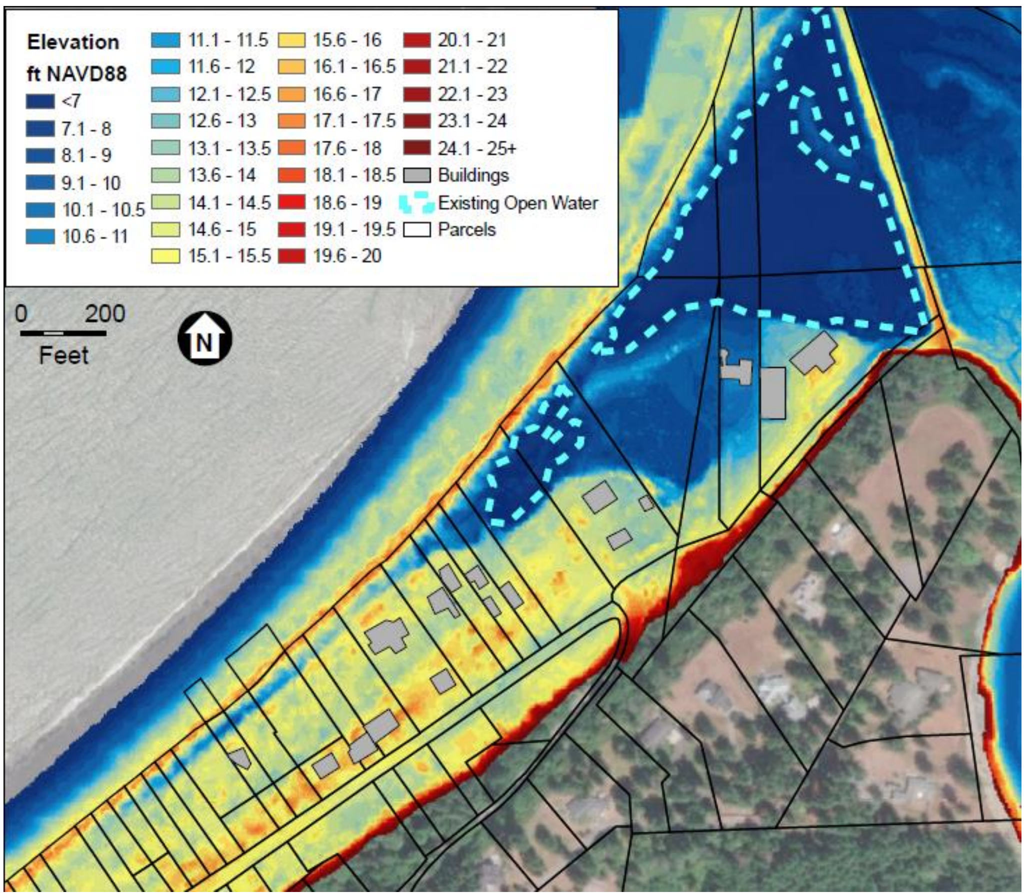
Figure 32
Beach scarp change and storm wrack lines in 2021–2022

3.7.3 Low Elevation Areas of Concern

Within the study area, buildings and infrastructure exist in low elevation areas that may be vulnerable to flooding. The elevations of these building and pieces of infrastructure are referred to throughout the remainder of this document when describing predicted water surface elevations in Place Pond. **Figure 33** details elevations in 1-foot increments with tax parcel and approximate structure footprint overlays.

- **1914 Elwha Dike Road** – Private residence located between 10.3 and 11 feet NAVD88[2].
- **1916 Elwha Dike Road** – Private residence located between 12 and 16 feet NAVD88[2]. Residence includes a tennis court at an elevation of 11–14 feet NAVD88.
- **Low point at eastern end of Elwha Dike Road** – 10.2 feet NAVD88.

All other parcels west of 1914 Elwha Dike Road are higher in elevation, generally located between 13 and 17 feet NAVD88. Key elevations are summarized in **Table 4**.



SOURCE: NOAA, USGS, OPSW, NSD

Figure 33
Place Pond area elevation detail

[2] Building elevations represent approximate, LiDAR-based estimated bare-earth elevations at the structure location and not finished floor elevations.

TABLE 4
GROUND ELEVATIONS NEAR STRUCTURES IN PLACE ROAD COMMUNITY

Parcel No.	Address	Lowest Ground Elevation Near Structures (ft NAVD88)	Structure Within Existing FEMA Flood Zone?
74515	1916 Elwha Dike Road	12	Yes
74522	1914 Elwha Dike Road	10.3	Yes
74523	N/A	Undeveloped	N/A
74301	1912 Place Road	Undeveloped	N/A
74302	1922 Place Road	13.2 (Buildings Removed Oct 2021)	No
74296	1924 Place Road	Undeveloped	N/A
74303	1962 Place Road	15.2	Yes
74304	1974 Place Road	13.5	Yes
74305	1984 Place Road	14.4	Yes
75306	2006 Place Road	13.9	Yes
74300	2026 Place Road	14	Yes
82535	2052 Place Road	17.2	No

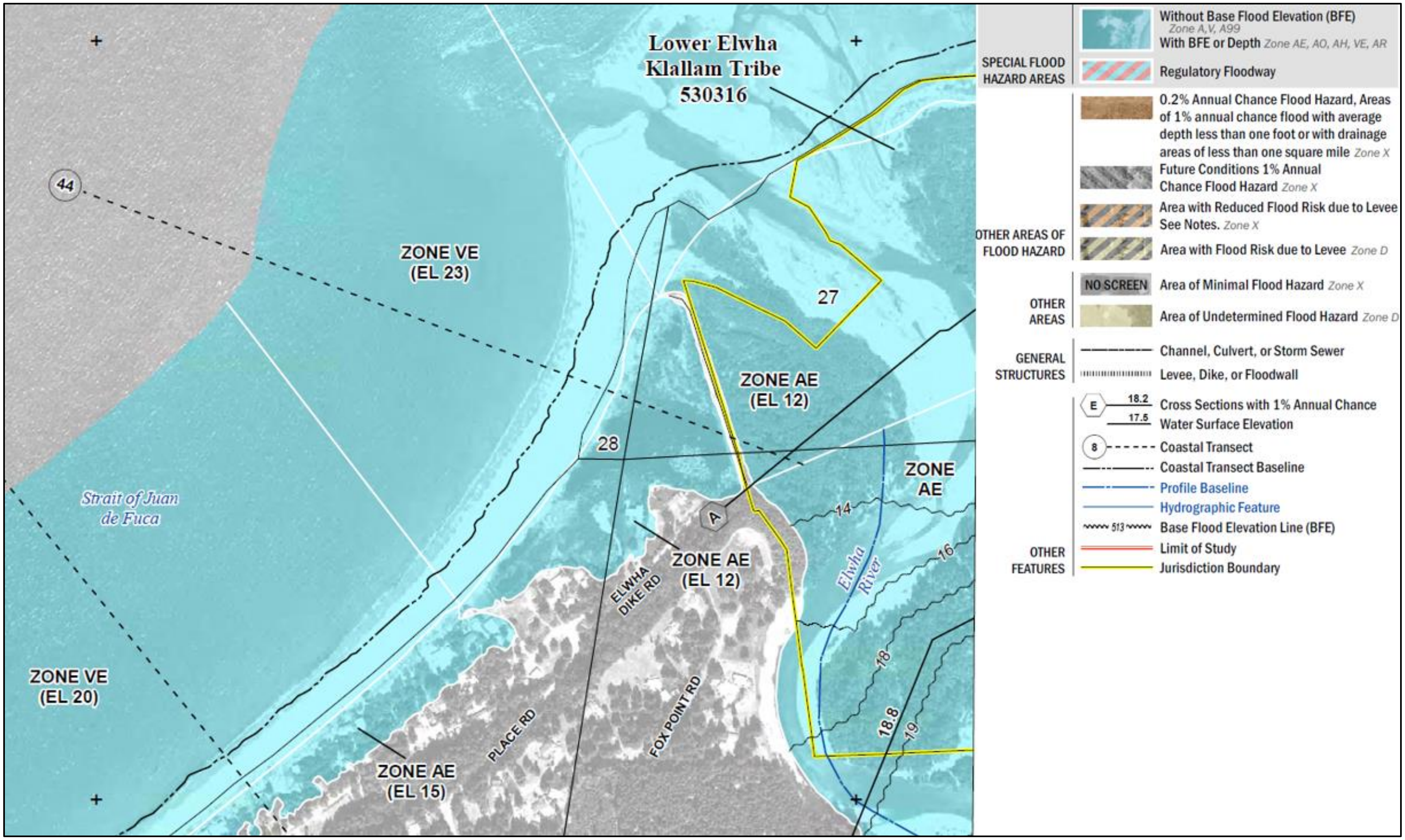
3.8 Existing FEMA Flood Mapping

The Federal Emergency Management Agency (FEMA) produces Flood Insurance Rate Maps (FIRMs) and Flood Insurance Studies (FIS) for areas at risk of flooding. A recent update to the FIS and FIRM for the Elwha River area was released in October 2019[3]. **Figure 34** is the FIRM for the Place Pond area, showing the elevation and extent of the FEMA-predicted 100-year flood.

The area around Place Pond is mapped as an AE Zone with a Base Flood Elevation (BFE) of 12 feet NAVD88. An AE Zone indicates that the area is subject to inundation during the 100-year return period flood (1% annual chance flood) and that water surface elevations are anticipated to reach 12 feet NAVD88. Within the AE Zone, the BFE of 12 feet NAVD88 exceeds the LiDAR elevations adjacent to 1914 Elwha Dike Road, the tennis court at 1916 Elwha Dike Road, the low point at the eastern end of Elwha Dike Road, and the northeast corner of the residential lot at 1916 Elwha Dike Road. Many parcels to the west of West Pond are also located within an AE Zone, with a BFE of 15 feet NAVD88.

The shore seaward of the coastal berm is mapped as a VE Zone with a BFE of 23 feet NAVD. A VE Zone indicates that the area is subject to high-energy waves. Within the VE Zone, total water levels, which include wave runup, can reach the Base Flood Elevation. The coastal beach berm fronting Place Pond reaches a maximum elevation of 15.5–17.5 feet NAVD88. Since the VE Zone BFE is 23 feet NAVD, runup and overtopping across the berm into Place Pond and West Pond would be expected.

[3] Flooding of the Elwha River was predicted using the hydraulic model HEC-2 and gage analysis in 2001 and was updated in 2010. Coastal flooding at the outlet of the Elwha River was analyzed using several methods. An ADCIRC model was used to evaluate still water tidal elevations, and a SWAN model was used to predict nearshore wind wave and swell wave parameters in 2015. Wave setup and wave runup details were then calculated using the TAW Method and the Direct Integration Method (DIM) in 2015.



SOURCE: FEMA

Figure 34
Place Pond area FIRM

3.9 Tsunami Mapping

Shorelines along the Washington Coast and the Salish Sea may experience tsunamis generated by a major earthquake along the Cascadia Subduction Zone or along the Aleutian Subduction Zone. The Washington State Department of Natural Resources (WDNR) maps areas of the shoreline as tsunami hazard zone areas. The yellow region in **Figure 35** indicates that all of the study area is within the tsunami hazard zone (Randall et al. 2021). Under a large Cascadia Subduction Zone earthquake, the entire coastal terrace along Freshwater Bay would be inundated up to 30 feet in depth, while a smaller tsunami associated with an Aleutian Subduction Zone Earthquake could cause minor flooding, which may or may not overtop the coastal berm, depending on the tide level at the time of the event. Additional details on tsunami hazard in the Place Road Community are discussed in Section 7.2.

SOURCE: WA DNR

Figure 35
Tsunami Hazard Zone (yellow).

3.10 Existing Fish Use

A number of studies over the decades have documented fish use of the Elwha River estuary and response to dam removals (see Shaffer et al. 2008b, 2009, 2018; Quinn et al. 2013a, 2013b; Shaffer et al. 2017a, 2017b; Lincoln et al. 2018). The lower portion of the Elwha River still supports Chinook, coho, pink, and chum salmon salmon; however, this is an incomplete list (Schalk et al. 1996). Many salmon species use the nearshore including the lower Elwha River, estuary, and Freshwater Bay shorelines, including those outmigrating or returning to the river, as well as those migrating to/from other watersheds. The estuary also offers productive habitats used by many other marine fish species including eulachon and lamprey. Sampling in the east estuary has documented Chinook, coho, and chum salmon; steelhead; and bull trout presence. However, in the isolated Place Pond, fish use is dominated by three-spine stickleback (Shaffer et al. 2009; CWI n.d.). No fish passage to Place Pond exists between the mainstem of the Elwha River or the Strait of Juan de Fuca, except for limited incidental wave overwash.

4 NUMERICAL MODEL

4.1 Model Selection

To assess water surface elevations, velocities, and sediment stability in the study area, the project team has developed a 2-dimensional Delft3D hydrodynamic model of the lower Elwha River, including the lower river, estuary, nearshore, and the Place Road Community. Delft3D is an industry-standard hydrodynamic modeling suite that excels at calculating non-steady flow, waves, and transport in complex tidal environments. Delft3D is developed by Deltares (Deltares 2011).

Delft3D has also been used by the USGS to study the Elwha River estuary as part of planning efforts for the Elwha and Glines Canyon Dam removals (Gelfenbaum et al. 2009, Gelfenbaum et al. 2015). At the onset of this project, ESA investigated the ability of these models to address the key questions posed by this study identified in Section 1. However, the Delft3D models developed by USGS were created and calibrated with a focus on tidal circulation and sedimentation patterns within the Strait of Juan de Fuca and the Elwha River delta. The ability of the USGS models to investigate flooding and habitat suitability in the lower Elwha floodplain including the area west of the Place Road Levee is limited because the low-lying floodplain areas to the east and west of the river channel were not included in the model domains, and the models were not calibrated for local estuarine water levels (Warrick, J. & Gelfenbaum G., pers. communication, 2020). Accordingly, these existing models are not well-suited to help answer the primary questions of this study.

Therefore, for this study, ESA developed a new Delft3D model of the lower Elwha estuary and floodplain targeted at representing the physical processes that influence Place Road Levee and the community west of the levee. To the extent possible, ESA's Delft3D model for this study using the similar domain extents, model parameterization, and inputs as the 2015 USGS model (as described in Gelfenbaum et al. 2015). Details on the model configuration are provided in Section 4.2.

4.2 Model Configuration

The Elwha Estuary Delft3D model is a hydrodynamic model run in two-dimensional mode on a structured grid. Details on the model configuration, including the model domain, bathymetry, boundary conditions, and other model parameters are described below. The model has been calibrated against observed water levels in late 2020 and early 2021 measured within the estuary. Several hydrologic and topographic scenarios have been developed at the request of CWI to investigate various conditions experienced in the lower estuary.

At the onset of the project, a large Strait of Juan de Fuca Grid and a smaller, nested Elwha Estuary Grid were developed as a coupled hydrodynamic-wave model. However, given the limited influence of tidal currents and waves on water levels within the interior of the estuary, the Elwha Estuary Grid was run as a stand-alone, flow-only model for this document, with the boundary conditions and model parameters as described below. The main mechanism for propagation of water level differences in the estuary due to waves would be from wave radiation stresses. The effects of radiation stresses are relatively small for typical waves in the Strait of Juan de Fuca. Large radiation stresses will influence sediment transport along the shoreline. However, the Elwha Estuary model has been run as a fixed-bed model that does not directly simulate sediment transport, although the potential for sediment transport can be inferred from velocities in the hydrodynamic model. These simplifications improve computational efficiency while still capturing the most important hydrodynamics in the area of interest, which are primary driven by tides and river flow rates. As part of future efforts, the Elwha Estuary Grid could be nested within the larger Strait of Juan de Fuca Grid with waves activated. Details on the limitations of the model are provided in Section 5.6.

4.2.1 Domain Extent and Grid

The extent of the model domain developed for this project is similar to the nested domain described in Gelfenbaum et al 2015, modified to include the lower estuary floodplain, eastern Place Road properties, and lower river channel. The domain extends from offshore of the subtidal Elwha River delta upstream to approximately river mile 0.65 at roughly the midpoint of the Fox Point Bluff (**Figure 36**). This river mile corresponds approximately to the furthest influence of the tides (USACE 2009) and covers the region where recent topographic and bathymetry data are available. On the seaward side, the model extends offshore approximately to the location of CDIP Buoy 248, described in Section 3.2.

The grid itself is a structured, rectilinear grid with approximately 77,000 grid cells. Grid cell sizes range from the largest size of approximately 300 feet by 300 feet in the offshore region, to 10 feet by 10 feet within the primary area of interest (Figure 36).

SOURCE: ESA

Figure 36
Model grid

4.2.2 Bathymetry

Development of existing condition bathymetry for the Delft3D model is described in Section 3.7. The merged topography surface was interpolated to the model grid using Delft3D's grid triangular interpolation tools.

To prepare the surface for hydrodynamic modeling, narrow channels in the West Floodplain including the WLRSC were widened to include a minimum of two grid cells in width to ensure full connectivity between each adjacent cell in the channel. High points in the model topography inside the WLRSC were also flattened out to simulate fully conveyance through the channel, which naturally scours during flood flows. As a result, some channels in the model have slightly larger bottom widths than surveyed on site. Similarly, the outlet of the river, which was surveyed during low-flow conditions, was artificially widened in the upper intertidal zone in the model grid to reduce over-constriction of river flows exiting the outlet. Because the model uses a fixed bed, the outlet is not free to naturally widen during high-flow events. Repeat surveys have shown that the outlet of the Elwha widens in response to large flow events (USACE 2009). Initial model runs showed the low-flow bathymetry at the outlet was causing unrealistically large changes in water surface elevations and velocities at the narrowest part of the outlet. Widening the opening solved these issues, and still resulted in good calibration results at the lower Elwha River logger station and the WLRSC logger station, as discussed below in Section 4.3. The depth in the main potion of Place Pond was also deepened to 0 feet NAVD88, following the reported depth in USACE (2009), although survey data are not available in the pond.

4.2.3 Boundary Conditions

Tides

Hourly tidal water levels conditions are applied as a time series along the north, west, and east coastal boundaries of the model domain, as shown in Figure 32. The hourly tide data are sourced from the Port Angeles Tide Gage, as described in Section 3.1. No tidal velocity boundaries are applied at the edges of the model domain.

Flow

The Elwha River flow is modeled as a point discharge located at the southern boundary of the model domain within the mainstem channel. Discharge rates are updated every 15 minutes. Input data for the flow rates uses the scaled McDonald Bridge USGS Gage, described in Section 3.4.

Wind

In the hydrodynamic model, surface winds were included to account for their contribution to local current velocities, and to a lesser extent, changes in the water surface elevation from wind-driven setup. Wind is uniformly applied throughout the model domain using the wind data collected at the Port Angeles Tide Gage station described in Section 3.5.2.

Precipitation

At this time, precipitation has not been directly included in the model, as the drainage basin of the Place Pond is small (<10 acres) and the contribution of rainfall within the small basin is anticipated to be small relative to daily changes in pond water surface elevation forced by groundwater exchange. Drainage issues in Place Pond have not been reported to USACE (2011) although there are no formal drainage pathways from the Place Pond area to the Strait. The soils in the pond area and Place Road Levee are mapped as quaternary alluvium, which suggests that infiltration rates are high and that runoff to the pond is minimal.

4.2.4 Groundwater Flow

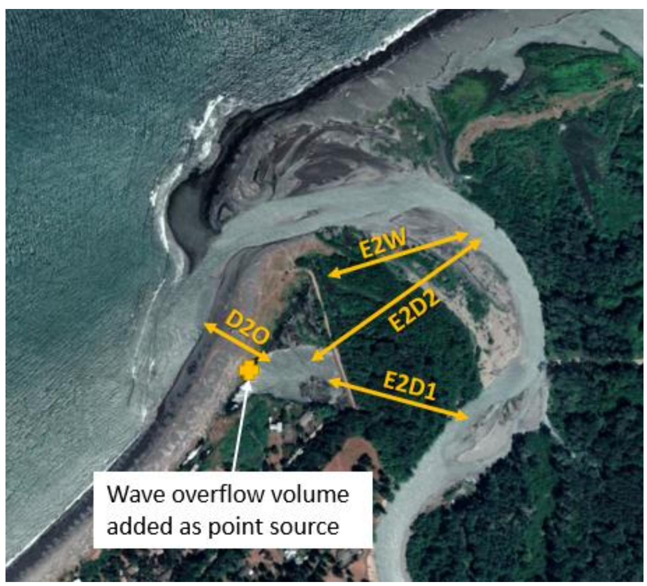
Place Pond does not have a surface water connection to the lower river or with Freshwater Bay. However, Place Pond water levels are influenced both by changes in river stage and in Freshwater Bay tides, as described in Section 3.1 and Section 7.1.

Delft3D does not natively model groundwater flows. To represent groundwater flow between the river to the pond and between the pond and the Bay, ESA included several two-way “Type D” water conveyance elements in the model (**Figure 37**). In Delft3D, these elements are typically used to simulate flow through culverts, however, they can be adapted to represent any flows that are conveyed between two distant grid cells, are forced by water level differences, and are subject to energy losses due to friction along the length of conveyance.

The rate of water exchange through the conveyance elements, and the subsequent change in water surface elevations in Place Pond and in the WLRSC are highly sensitive to the elements' nominal cross-sectional flow area, friction coefficient, elevation, and intake locations. Note that these values are nominal in the sense that they are selected as part of model calibration to represent flows that re-create the observed water levels in Place Pond and WLRSCS. In the absence of detailed subsurface data and the capacity of Delft3D to solve groundwater flow equations, this approach is sufficient for this study. These parameters were adjusted during the calibration process to tune the modeled water surface elevations in Place Pond and the WLRSC to match observed water levels (**Table 5**). To develop the initial sizing for the conveyance element prior to calibration refinements, ESA used a simple groundwater box model with flow as a function of the square root of head difference to estimate conveyance element sizes.

TABLE 5
CONVEYANCE ELEMENT TABLE

Element Name	Cross-Sectional Area (sq ft)	Invert Elevation (ft NAVD88)	Friction Coefficient
E2D1	1.7	4.9	0.035
E2D2	1.7	4.9	0.035
E2W	0.2	2.0	0.035
D2O	6.8	4.8	0.035



SOURCE: ESA

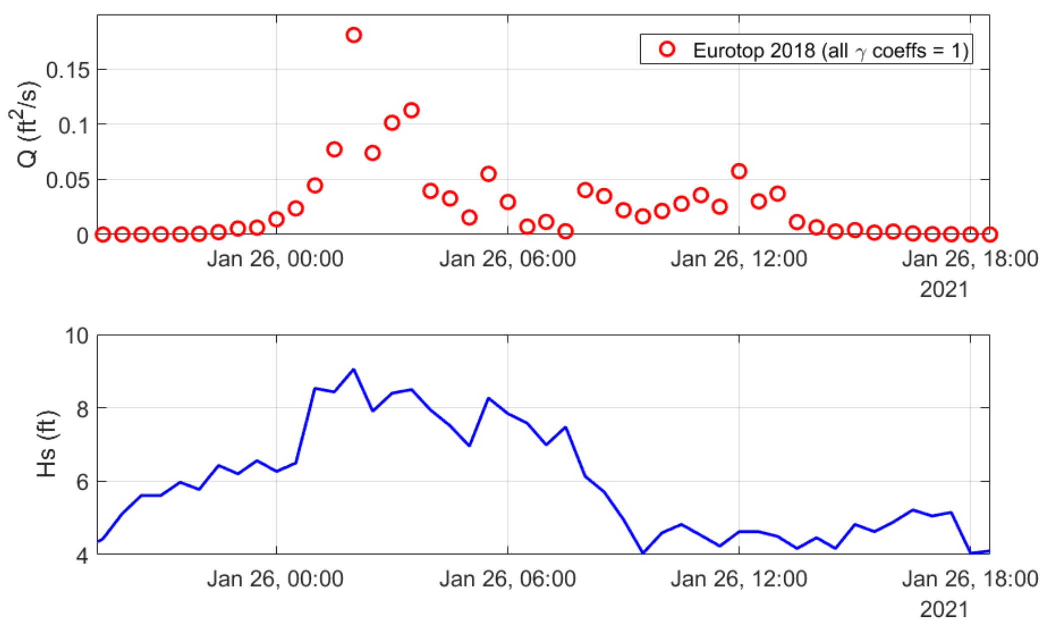
Figure 37
Approximate locations of groundwater conveyance elements in the model.

4.2.5 Waves & Wave Overtopping

Wave overtopping has been observed, in the form of overwash splays on the backside of the beach berm between Place Pond and the Strait. This type of flow process cannot be resolved in the Delft3D model. However, nearshore wave overtopping of the coastal berm into Place Pond and West Pond is represented in the model as a point discharge on the pond side of the coastal berm. This is accomplished by calculating a time series of the wave overtopping rate along the typical beach profile presented in **Figure 38**, following the methods in EurOtop (2018) for Equations 5.12 and 5.13.

The overtopping rate is calculated using the wave heights measured at CDIP buoy 248. The EurOtop method accepts a wave height at the toe of the beach slope to perform the overtopping calculations. To estimate this wave height, the breaker height at the beach slope toe (which is located at approximately -10 feet NAVD88 offshore of the coastal berm) was calculated. If the offshore wave height was greater than the breaker height, the offshore wave height was substituted for a conservative assumption of overtopping rates. During periods where the CDIP buoy is unavailable, nearshore waves are predicted using an approximate linear scaling from NDBC buoy 46087 to the Elwha River delta, which varies by incident wave angle at the NDBC buoy. The calculated overtopping rates are then formatted as a discharge file for input into the hydrodynamic model. By doing so, the model represents water level changes in Place Pond due to wave overwash.

An example period in January 2020 shows the wave heights at the toe of the slope and the corresponding input overwash volume to Place Pond. This event is estimated to have contributed around 33,000 cubic feet of water to Place Pond over a typical overwash length of approximately 15 feet (observed on site and from aerial imagery), which corresponds to less than a 2" increase in pond levels over the roughly 200,000 square-foot pond.



SOURCE: ESA

Figure 38
Wave overwash time series predicted at the berm

4.2.6 Other Model Parameters

Bed roughness was represented using a uniform Chezy coefficient of 60 $m^{1/2}$/s across the model domain. This value was tuned slightly during the calibration process to achieve better fit between the observed and modeled lower Elwha stage data. A value of 60 $m^{1/2}$/s achieved the best fit.

A uniform horizontal eddy viscosity of 2 m^2/sec was applied across the model domain. The model was simulated using a timestep of 6 seconds, which I consistent with prior USGS Delft3d models.

4.3 Calibration

To assess the hydrodynamic model's capacity to replicate observed water levels and currents, several modeling runs that predicted past conditions were compared with observed water levels and current velocities. Calibration was performed between simulated water levels and observed water levels at the lower Elwha River logger, Place Pond logger, and WLRSC logger during an observation period in November 2020 and in January 2021. In particular, calibration efforts focused on matching peak water levels, diurnal tidal patterns in pond water levels, water level trends on the rising and falling limb of storms, and the extent of surface water inundation relative to documented records and aerial photos. The November 2020 period includes an event with a 3-year tide and typical (<1-year) flow, while the January 2021 event with a 1-year flow and a 1-year tide.

Figure 39 compares the modeled and observed water levels at the lower Elwha River logger, the Place Pond logger, and the Port Angeles tides throughout the simulation period. The model closely predicts peak water levels and trends in the lower river and in Place Pond. The diurnal variation in water levels in Place Pond is not as strong in the simulated elevations as in the observed elevations, indicating that exchange of groundwater between the coastal berm may be greater than what is represented in the model. The model also does not accurately capture the lag time in the Place Pond tidal signal. This is because approximating groundwater flow through individual conveyance elements in the model results in more rapid flow exchange than actual groundwater flow, which typically flows slowly through soil pores. However, in general, hourly errors between simulated and observed water levels are less than 0.5 foot.

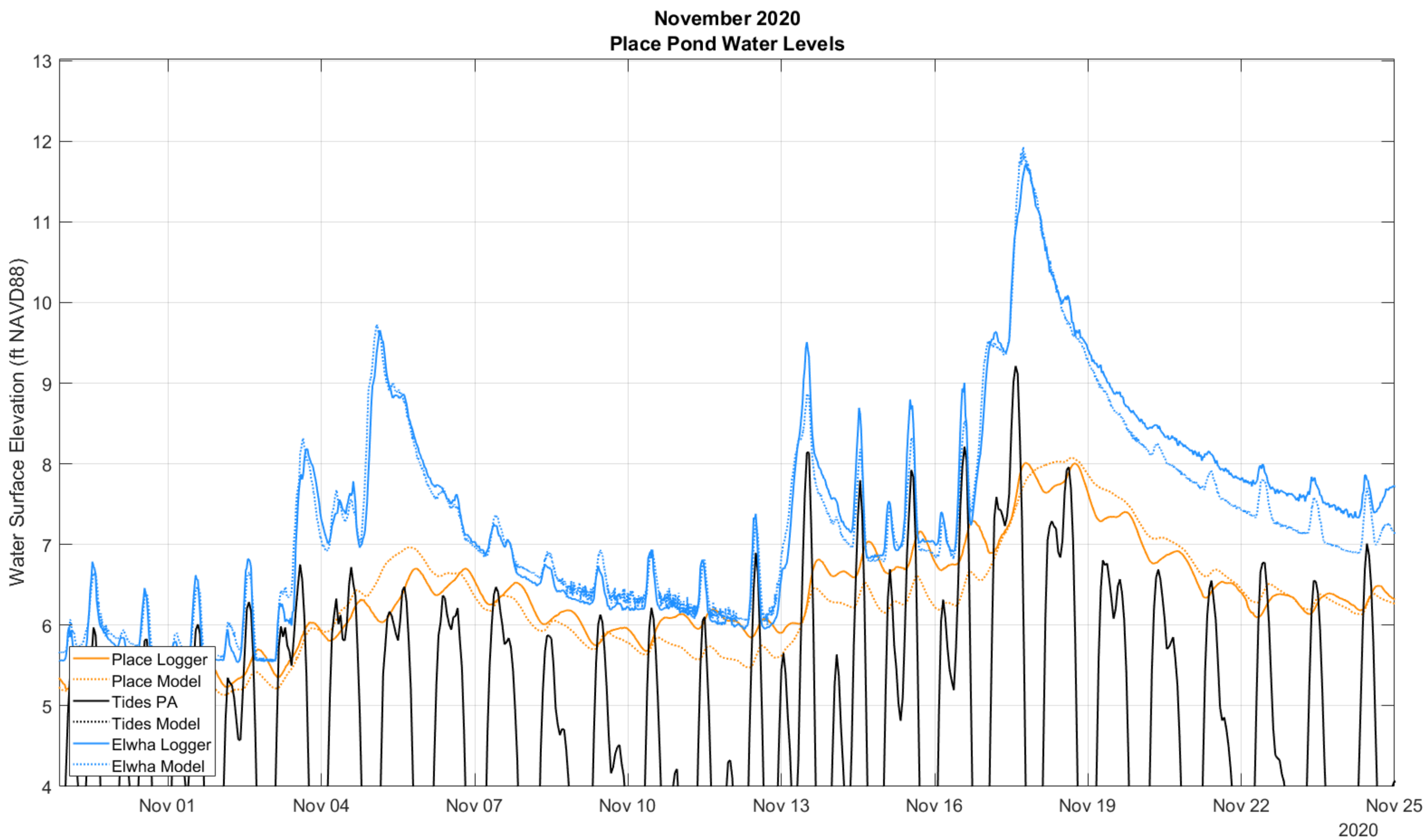
Figure 40 presents the modeled and observed water levels at the WLRSC logger. The WLRSC fit during this calibration period is poorer than those observed in Place Pond. Although peak water levels are generally within 0.25 foot between modeled and observed, the receding limb water levels have errors of up to 1 foot. This may be in part due to the more complex groundwater and surface water conditions at near WLRSC, which is located much closer to the active channel and to Freshwater Bay than Place Pond. The simplified conveyance elements may not accurately capture the complex groundwater dynamics on the river side of the levee, although the WLRSC fit is much improved during the January 2021 period (**Figure 42**). An alternative explanation for the poor fit is that at the beginning of the November 2020 period, the entrance channel to WLRSC may have been clogged with sediments, fallen leaves, and other debris, resulting in slow or blocked drainage out of the ponded WLRSC area. The series of high tides and flows between

November 13 and November 18 may have scoured the WLRSC entrance channel, as the error between modeled and observed is much improved after the high-flow event.

In the January 2021 calibration period shown in Figures 41 and 42 exhibits similar trends as the November 2020 period. In general, Place Pond errors are less than 0.5 foot with peak pond elevations matching closely. The fit is much closer between the WLRSC logger and modeled data for the January 2021 period, with some timing errors on the January 13 and 14 high tide peaks.

Figure 43a and **Figure 43b** chart the modeled data versus the logger data for the lower Elwha River and Place Pond locations. The graphs show good agreement for both the lower Elwha River logger station and the Place Pond station, with some conservative over prediction of Place Pond water levels at interim elevations. Peak Place Pond water levels have good agreement.

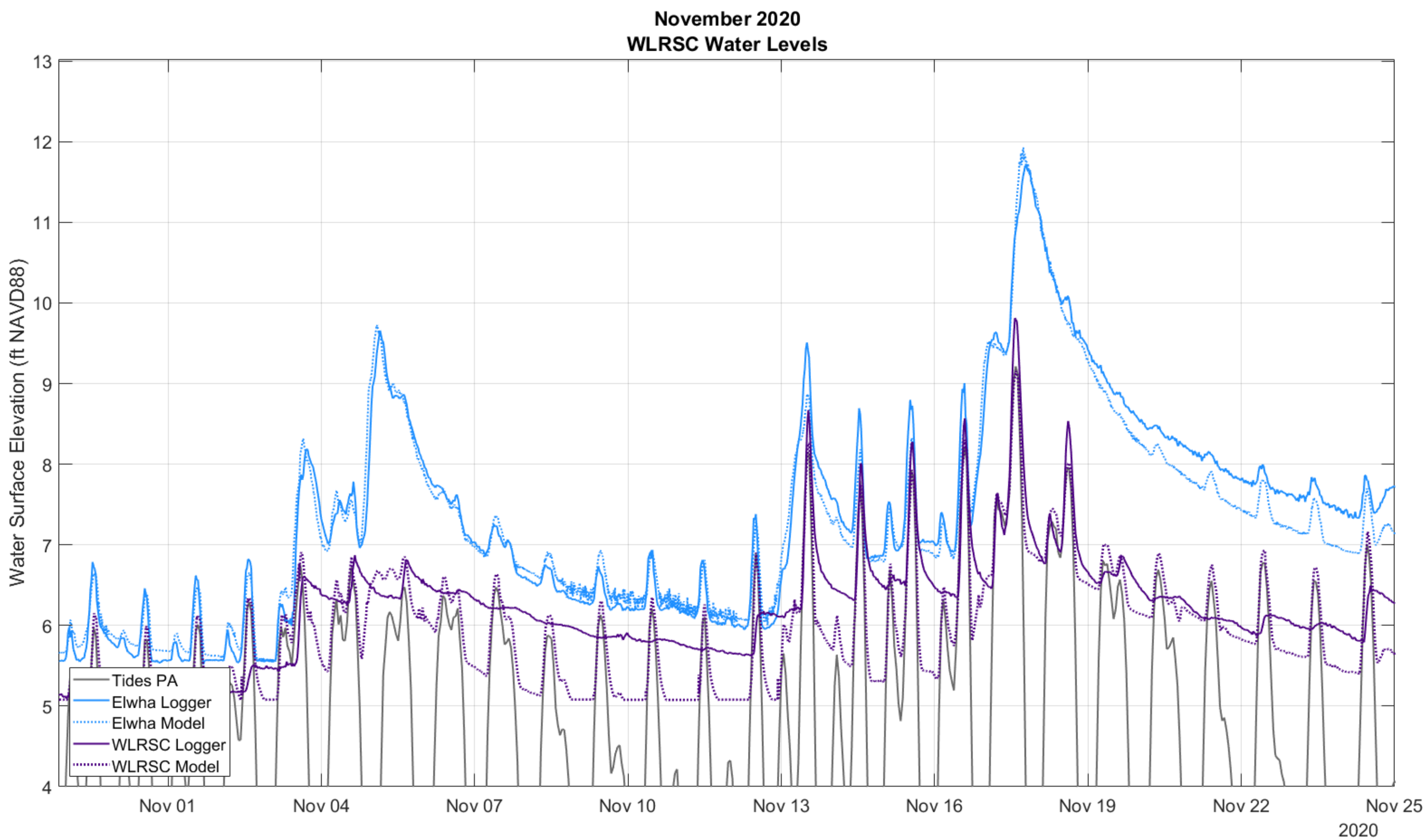
Figure 44 compares a satellite image taken on January 15, 2021, 2 days after the peak flow event simulated by the model. The right pane of the figure plots the modeled surface water elevations and extents, which closely match the extents visible in the satellite photo.



SOURCE: ESA

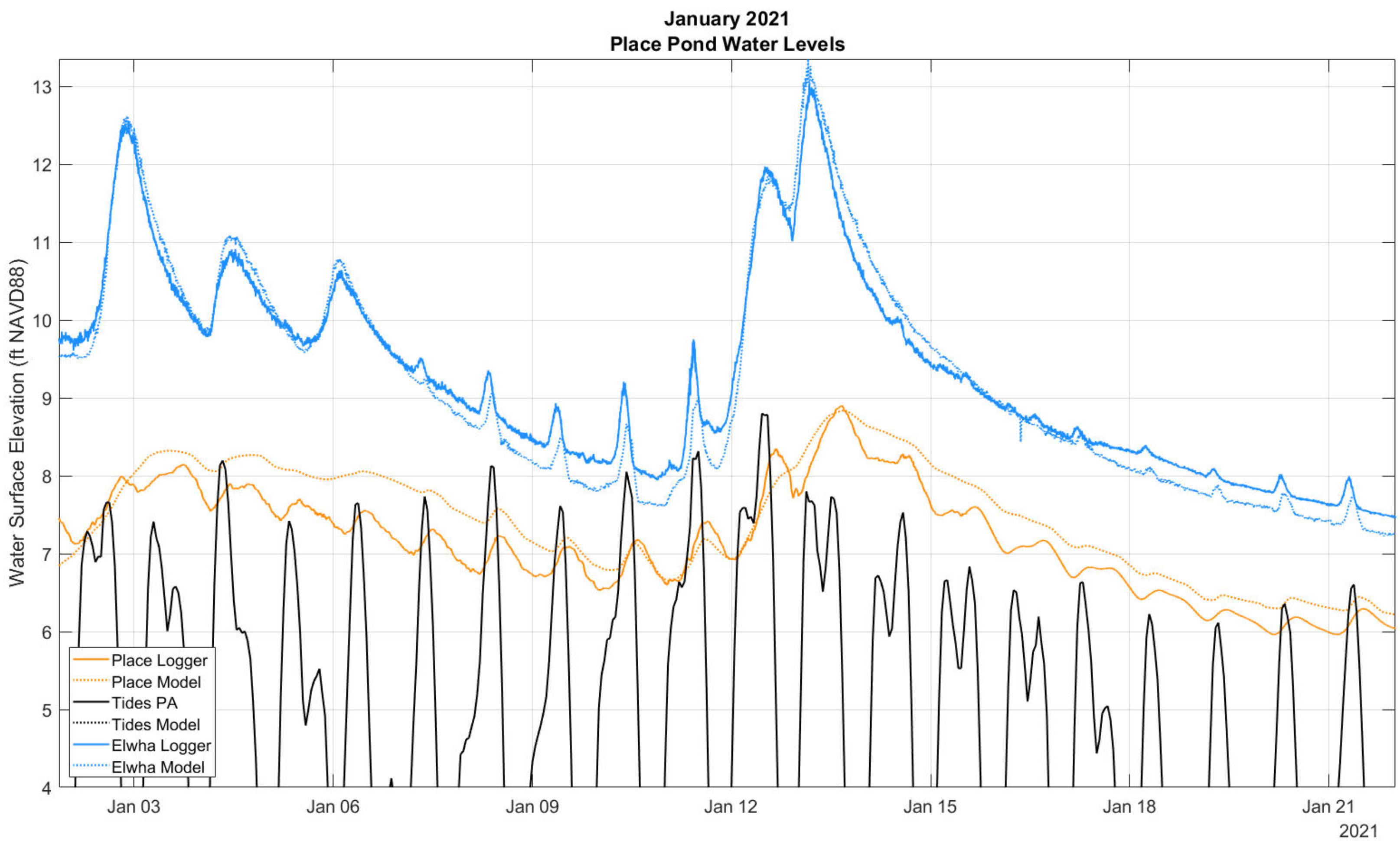
Figure 39

November 2020 Calibration Period. Place Pond water levels in orange, Elwha stage levels in blue, and Port Angeles tides in black. Solid lines are observed levels, and dotted lines are simulated levels.



SOURCE: ESA

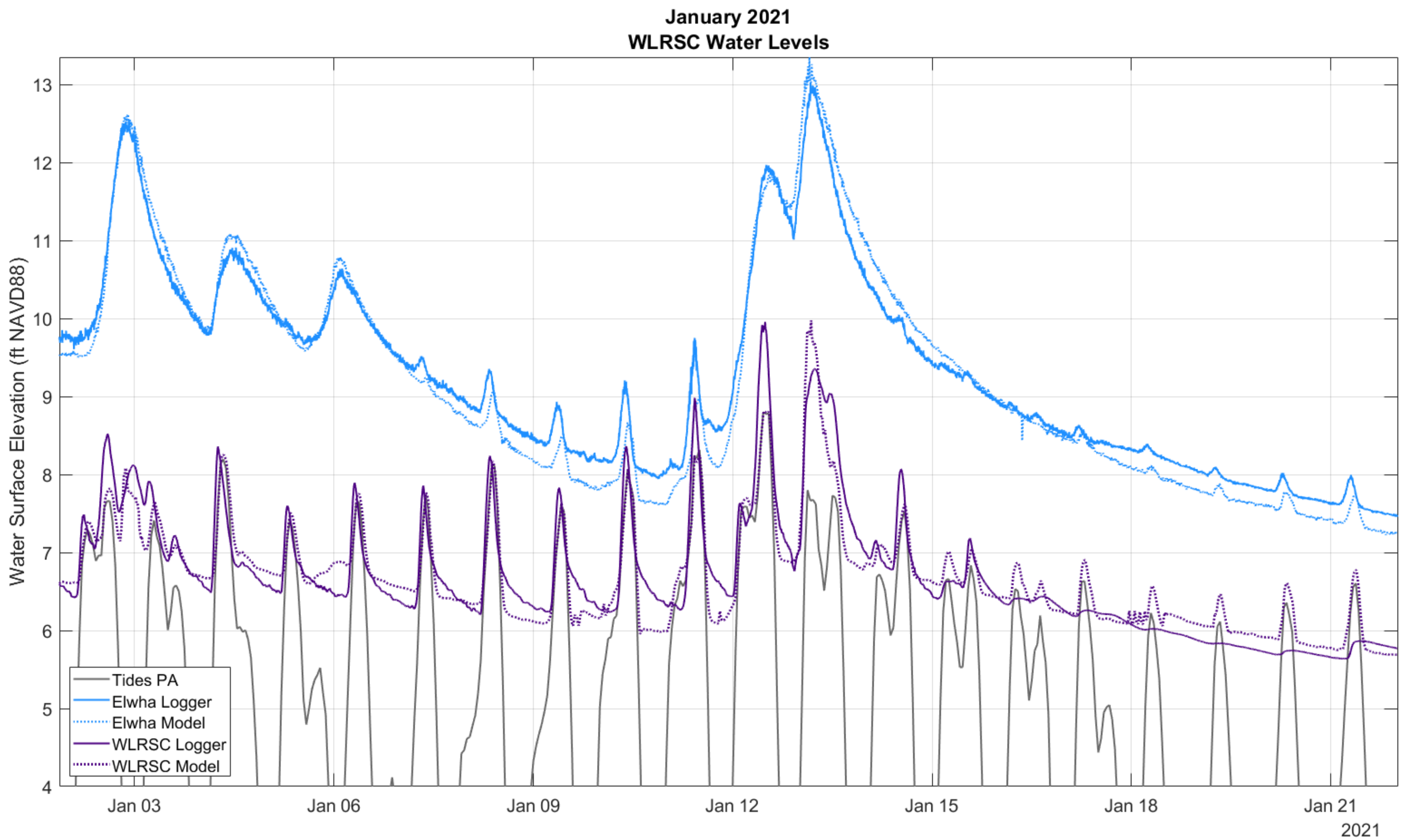
Figure 40
November 2020 Calibration Period. WLRSC water levels in orange, Elwha stage levels in blue, and Port Angeles tides in black. Solid lines are observed levels, and dotted lines are simulated levels.



SOURCE: ESA

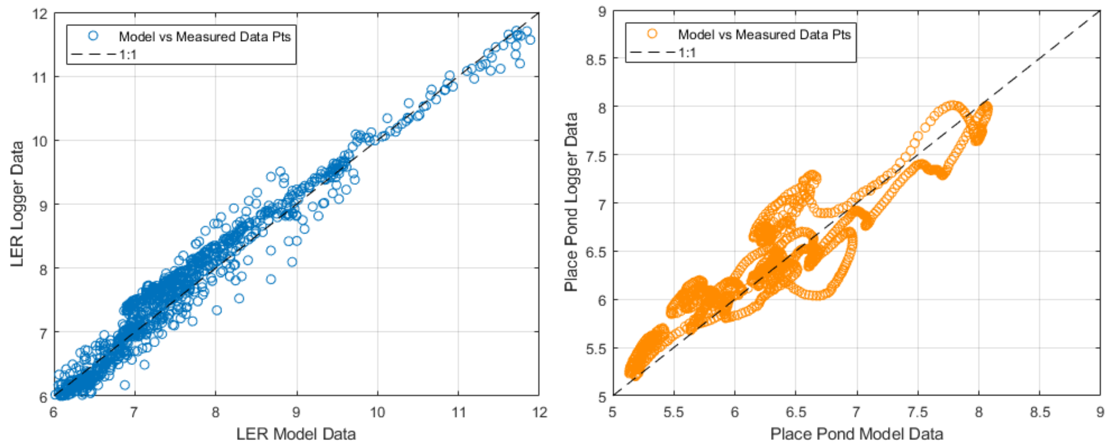
Figure 41

January 2021 Calibration Period. Place Pond water levels in orange, Elwha stage levels in blue, and Port Angeles tides in black. Solid lines are observed levels, and dotted lines are simulated levels.



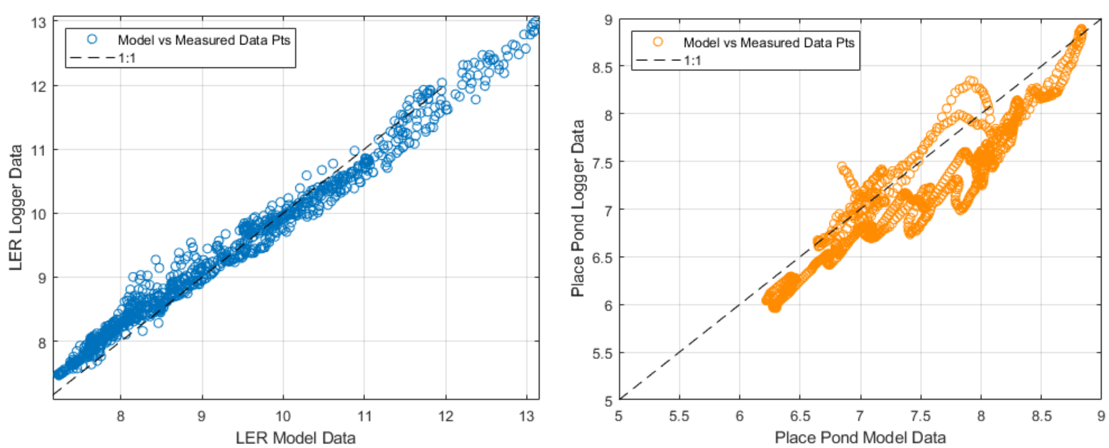
SOURCE: ESA

Figure 42
January 2021 Calibration Period. WLRSC water levels in orange, Elwha stage levels in blue, and Port Angeles tides in black. Solid lines are observed levels, and dotted lines are simulated levels.



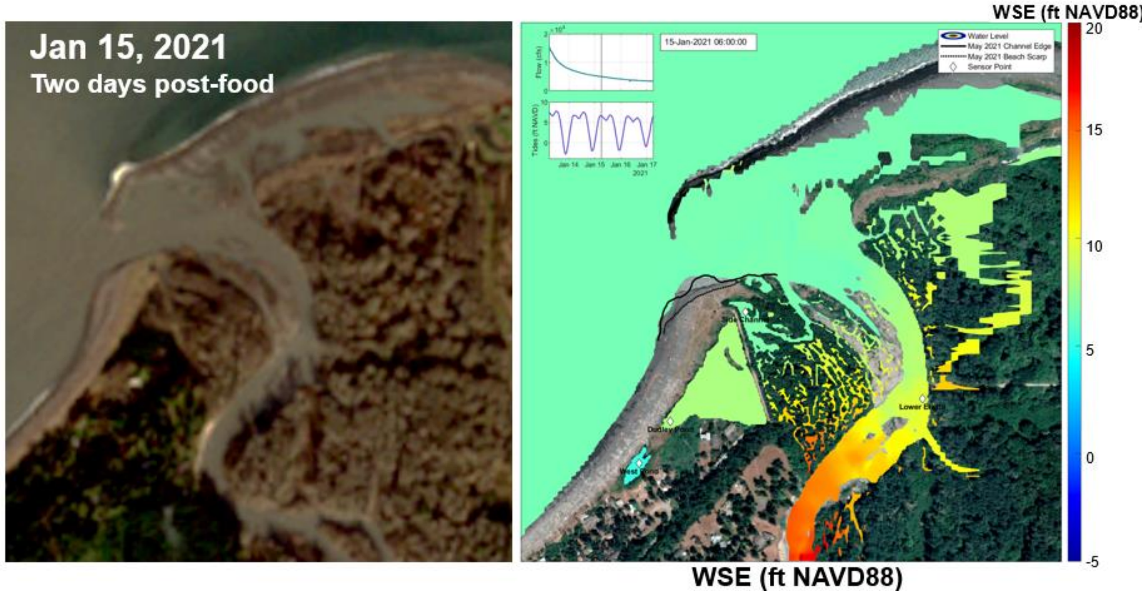
SOURCE: ESA

Figure 43a
November 2020 Lower Elwha River (left) and Place Pond (right) modeled vs measured data.



SOURCE: ESA

Figure 43b
January 2021 Lower Elwha River (left) and Place Pond (right) modeled vs measured data.



SOURCE: Landsat 2021

Figure 44
January 2021 inundation extent as observed from satellite imagery (left) and as modeled (right).

4.4 Model Scenarios

A collection of hydrologic model scenarios was developed to investigate the role of the Place Road Levee under various conditions in the lower river. Two design alternatives for modifications to the levee that would enable fish passage to Place Pond, in addition to existing conditions topography, were assessed under the hydrologic scenarios. Additional model scenarios, which may include both hydrologic scenarios and bathymetric cases, are expected to be identified following the submittal of this draft document. Include channel migration.

4.4.1 Hydrologic Scenarios

A range of hydrologic scenarios were developed to investigate the function of the Place Road Levee relative to the lower river channel, and the flood hazard to the Place Road Community under a variety of estuarine conditions. Selected scenarios are identified in **Table 6** and cover a full range of conditions in the estuary, from low-flow dry season conditions to extreme storm events.

Scenario 1 consists of separate two time periods during the water level logger deployment that include a range of typical tides and flow rates, as well as a few high-flow events, for calibration purposes. Scenario 2 is a period of combined relatively high river flows along with high coastal water levels. This combination event is used to assess flood hazard to the Place Road Community under the different bathymetric cases. Scenario 3 is a dry season simulation that includes low river flow and summertime tides. The dry season simulation is relevant for assessing connectivity to Place Pond under the design alternatives, and to bracket the range of considered hydrologic conditions. Scenario 4 and Scenario 5 represent extreme fluvial and tidal events, respectively, and are used to assess flood hazard to the Place Road Community. Scenario 6 repeats the same flood flow as Scenario 4, but with predicted climate change in the year 2100 (35% increased river flood flows, and 2.8 feet of sea-level rise).

To select a representative time period for each simulation, ESA reviewed the time series records and identified a time period in which tides, flows, waves, and meteorological conditions fit the scenario. Model inputs for this time period were then assembled and simulated in the model. For the 100-year Elwha Flow scenario and the 100-year coastal flood scenario, a representative time series was artificially constructed by scaling a smaller observed event to the 100-year peak flow or tidal elevation value (i.e., a 100-year flow event did not actually occur in November 2015, nor did a 100-year coastal flood occur in 2018).

For the 100-year coastal flood scenario (Scenario 4), the simulated conditions use the 100-year still water tide, which neglects the contributions of wave runup and overtopping to the total water level. Note that although the modeled scenarios include the extreme forcing parameters (i.e., the 100-year tidal water level and the 100-year fluvial flow level), the 100-year response water level in the pond has not been simulated, which may result in higher water levels in the pond than generated by the 100-year still water level tide or the 100-year fluvial flow separately.

TABLE 6
HYDROLOGIC SCENARIOS

Scenario Number	Cases	Modeled Time Periods
1a	Calibration - Comparison with Installed Sensors Fall 2020	Oct 29 to Nov 12, 2020
1b	Calibration - Comparison with Installed Sensors Winter 2021	Jan 1 to Jan 22, 2021
2	Documented High-Flow Event with High Fluvial Energy and High Marine Energy	Jan 28 to Feb 4, 2020
3	Dry Season with Low Fluvial Energy and Low Marine Energy	Sep 4 to Sep 11, 2020
4	Extreme High River Flow (100-year Elwha Flow)	Nov 12 to Nov 19, 2015[1]
5	Extreme Tidal Water Levels (100-year Coastal Flood)	Dec 16 to Dec 23, 2018[2]
6	Extreme High River Flow (100-year Flow) with Climate Change	2100

[1]The 100-year flow time series was artificially constructed using estimates of extreme streamflow, the Dec. 2007 hydrograph, and Nov. 2015 tides.
[2]The 100-year coastal flood time series was artificially constructed using estimates of extreme tidal elevation and Dec. 2018 tides.

4.4.2 Bathymetry Alternatives

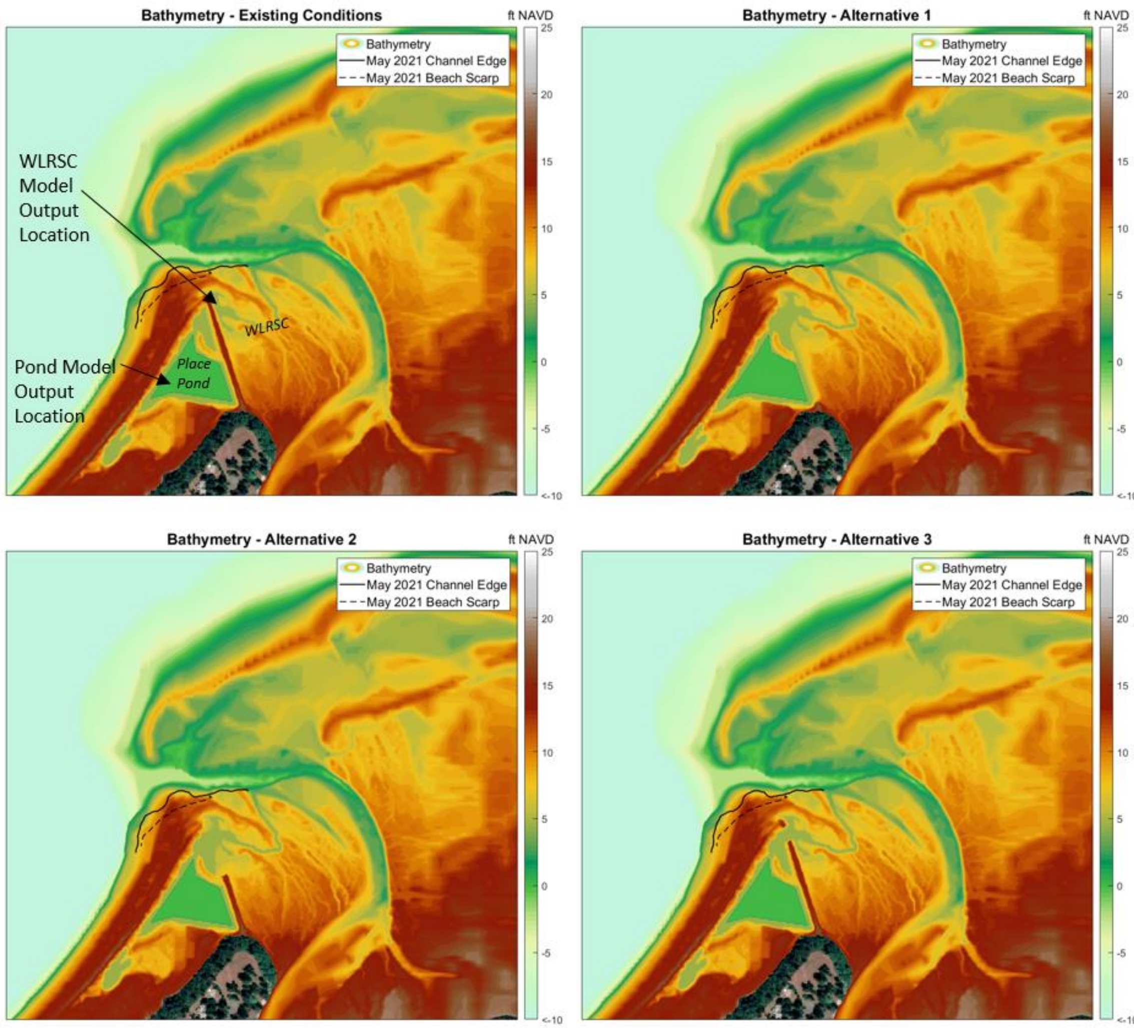
For each hydrologic scenario, three bathymetric alternatives were simulated with the model (**Table 7, Figure 45**). Existing conditions, which represents the surveyed ground conditions in the fall of 2020, represents the base case. Alternative 1, Alternative 2, and Alternative 3 are modifications to existing conditions that include varying degrees of removal of the Place Road Levee and Terminal Rock. Alternative 1 considers the full removal of the levee from the terminal end to the tie-in with Fox Point. Alternative 2 removes the seaward half of the levee and terminal rock, while retaining the southern 400 feet of levee and connection to Elwha Dike Road. Alternative 3 removes only the northernmost 75 feet of levee and terminal rock.

In October 2021 the fill at the eastern edge of western end of Place Pond was removed, reducing the water surface level required for surface water connectivity between within Place Pond. This adjustment is not expected to result in significant changes to the water levels or circulation in Place Pond, given the relatively small volume of fill removed.

TABLE 7
BATHYMETRY ALTERNATIVES

Bathymetry Case	Label	Configuration
Existing Conditions[1]	EC	Represents surveyed conditions as of Fall 2020
Alternative 1	Alt 1	Surveyed conditions as of Fall 2020 with entire Place Road Levee removed
Alternative 2	Alt 2	Surveyed conditions as of Fall 2020 with northern half of Place Road Levee removed
Alternative 3	Alt 3	Surveyed conditions as of Fall 2020 with northern 75 ft of Place Road Levee removed

Alternative 3 was only simulated for hydrologic Scenario 1b, 4, and 5. The hydraulic response of the model under Alternative 3 is highly similar to Alternative 2 under the evaluated scenarios. The response of Alternative 3 for the remaining hydrologic scenarios is assumed to be similar to that of Alternative 2.



SOURCE: ESA

Figure 45
Bathymetry cases

5 NUMERICAL MODEL RESULTS

This section presents the results of the hydrodynamic model runs for each of the five hydrologic scenarios identified in Table 6. Results for each scenario include a comparison of water levels in Place Pond among the different bathymetric cases. **Appendix F** includes 2d plots of peak water levels for each scenario described below.

For each model run described below, the bed elevations have been fixed in the model, including Place Road Levee. Doing so assumes that the levee does not fail under simulated conditions. Although USACE has assessed that the levee will withhold floodwaters for the 100-year river flood with a 90% confidence, the levee is not a certified levee. USACE has stated that, at a minimum, the levee would need to brushed and grubbed in order to apply for certification. Other structural or geotechnical improvements could be required by USACE for certification.

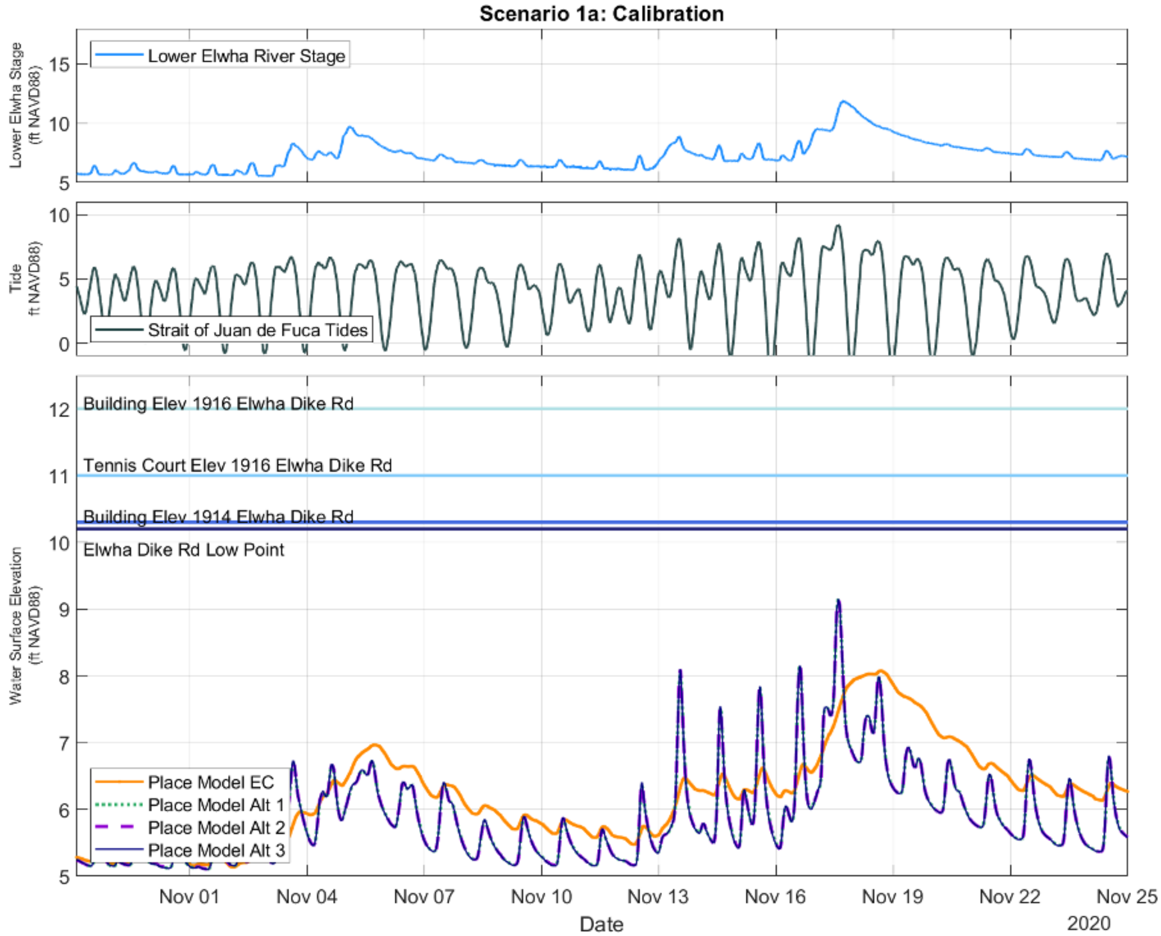
5.1 Scenario 1 – 2020-2021 Calibration Period

A detailed discussion of the calibration results is provided in Section 4.3. However, the calibration runs also provide useful information related to water levels in Place Pond under typical wintertime conditions and provide a useful for comparison between the different bathymetry cases.

Scenario 1a represents a typical fall storm with an annual flow event that occurs simultaneously with a 3-year return period tide. **Figure 46** plots the simulated water levels in Place Pond under Existing Conditions, Alternative 1, and Alternative 2.

Under Existing Conditions, water levels in Place Pond respond modestly (less than 0.5 foot) to daily tidal variations and more significantly (several feet) to multi-day variations in river stage. The response of pond water levels to increasing high flows is lagged several hours, and the water level slowly recedes as a high-flow event passes.

There is negligible difference between the water levels in Place Pond under the Alternative 1 and Alternative 2 model runs. This is primarily because the WLRSC conveys the vast majority of flow into and out of Place Pond under the open alternatives, with little to no sheet flow occurring along the southern half of the levee (removed under Alternative 1) where West Floodplain elevations are relatively high. Under both alternatives, water levels in the pond are more dynamic than under Existing Conditions, rising and falling up to several feet each day. In general, average water levels trend lower under these alternatives, although high tides and high-flow events cause brief (<4 hour) increases in water levels in the pond that exceed Existing Conditions elevations by up to 2 feet.



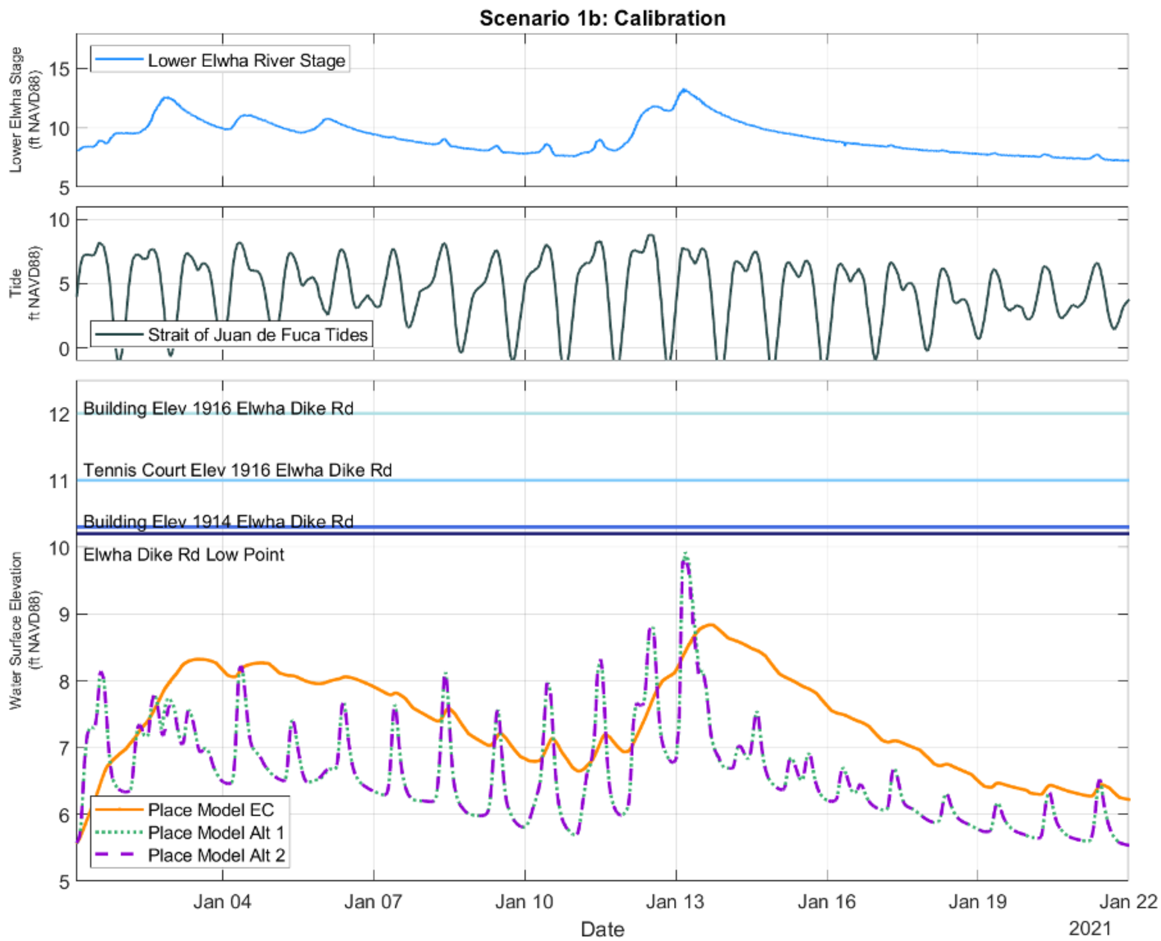
SOURCE: ESA

Figure 46
Scenario 1a model results

Scenario 1b represents a winter fall storm with an annual flow event that occurs at a King Tide (annual) event. **Figure 47** plots the simulated water levels in Place Pond under Existing Conditions, Alternative 1, Alternative 2, and Alternative 3.

Like Scenario 1a, under Existing Conditions, water levels in Place Pond vary gradually in response to high flows on the Elwha rising up to nearly 9 feet NAVD88 and slowly receeding over the ocurse of several days to around 6 feet NAVD88.

Under Alternatives 1, 2, and 3, water levels in the pond vary daily up to several feet. On January 13, water levels in the pond are simulated as reaching nearly 10 feet NAVD88 for a brief (<2 hour duration), rapidly receeding back to 6.5 feet NAVD88 over a few hours. Like Scenario 1a, average water levels under the action alternatives are lower than under Existing Conditions, but peak water levels are nearly 1 foot higher.

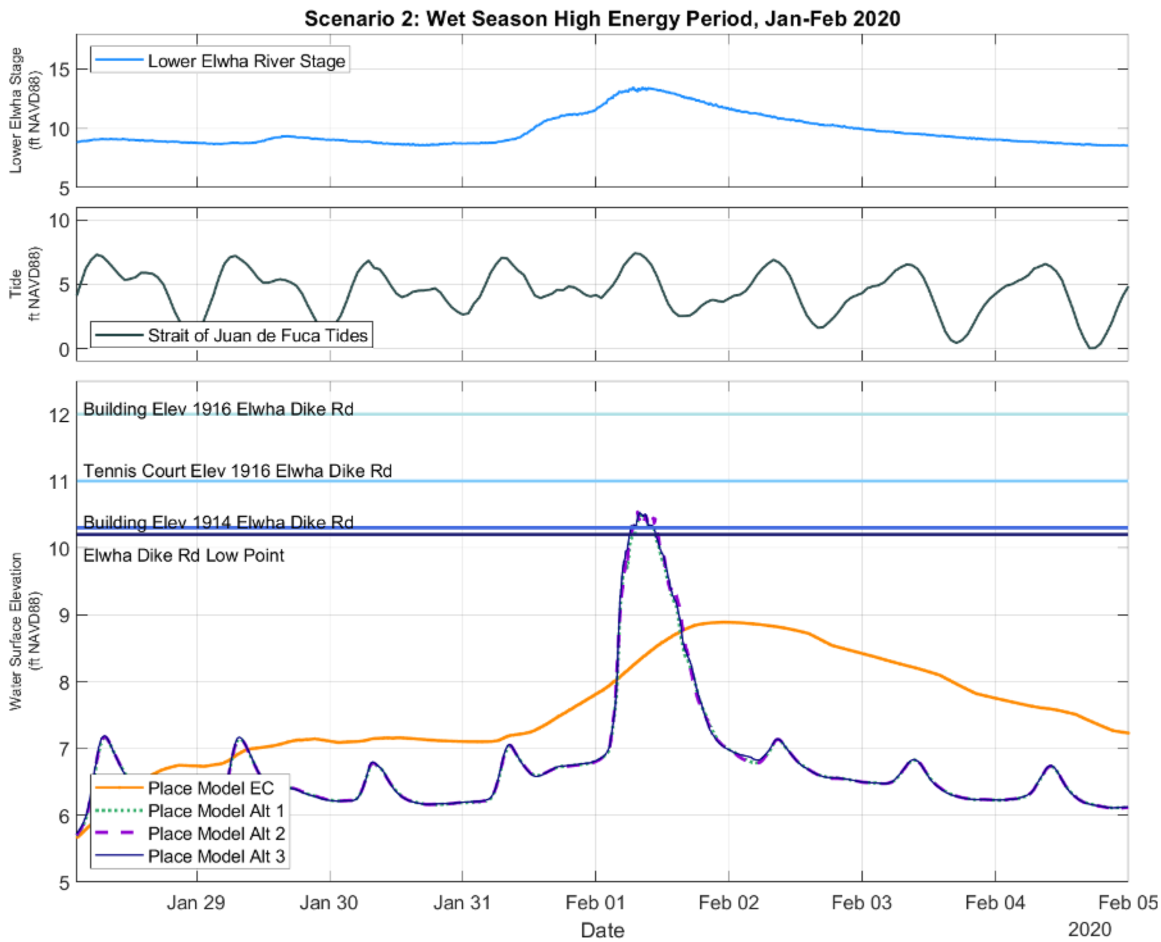


SOURCE: ESA

Figure 47
Scenario 1b model results

5.2 Scenario 2 – High Estuarine Event

Scenario 2 is a relatively common high estuarine water level event that includes both a high river flow event (a 3-year event) at the same time as a King Tide (annual event). **Figure 48** plots the simulated water levels in Place Pond under Existing Conditions, Alternative 1, and Alternative 2.



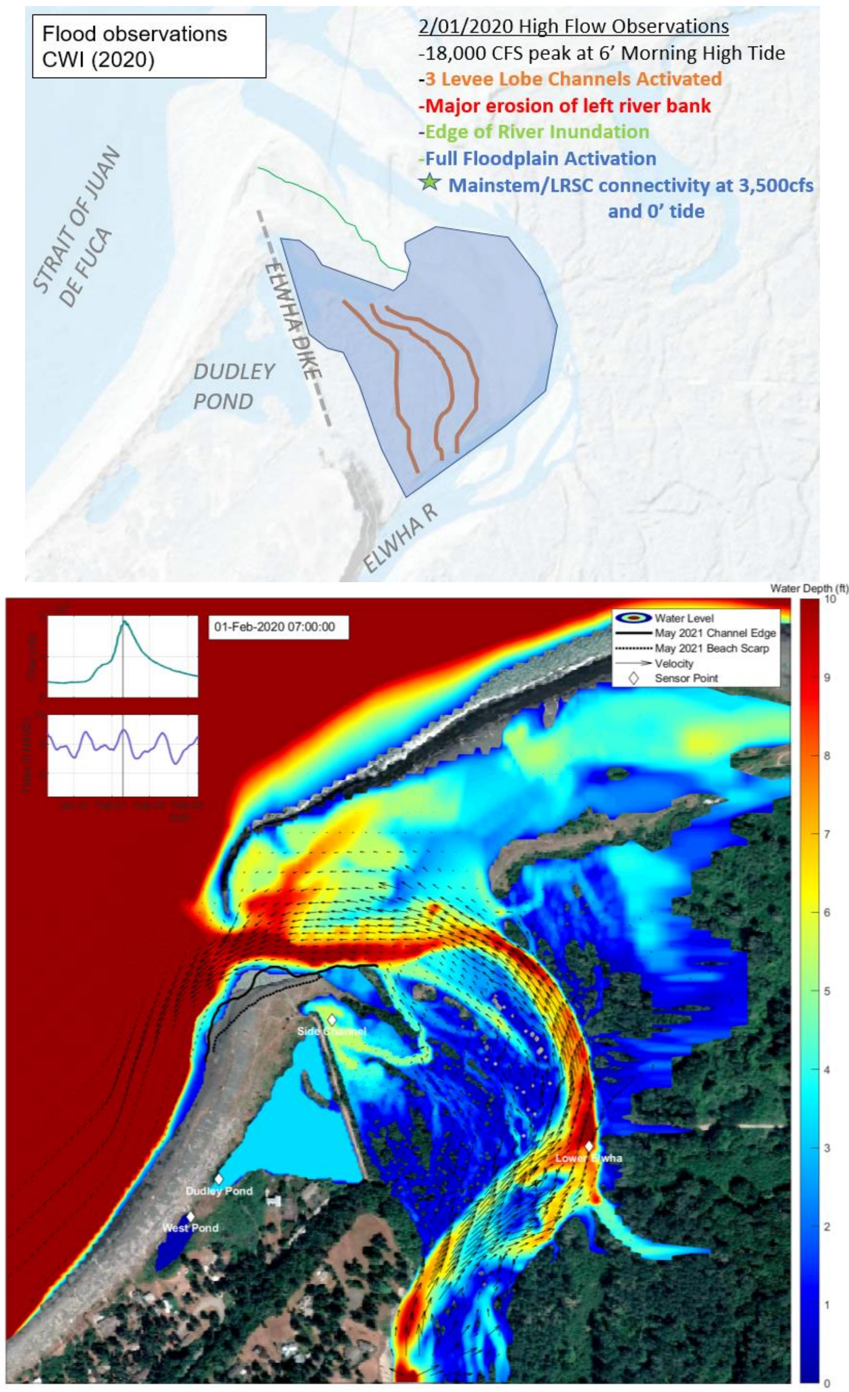
SOURCE: ESA

Figure 48
Scenario 2 model results

Under Existing Conditions, peak water levels rise gradually in response to the high river flow event on February 1 after about a 1-day lag. The water levels remain high and slowly recede over the next several days. No flooding is anticipated to occur with the peak water level in the pond reaching approximately 9 feet NAVD88. In February 2020, CWI documented this flood event on the ground. CWI observed that much of the West Floodplain (east of the levee and west of the mainstem) was activated, including three floodplain channels (**Figure 49**, top). The model predicts a similar floodplain engagement with shallow inundation (~1 foot) over much of the floodplain, and activation of several channels including the WLRSC (Figure 49, bottom).

No discernable differences can be observed between Alternatives 1, 2, and 3 in terms of water levels in Place Pond. Under these action alternatives, peak water levels in the pond reach approximately 10.5 feet NAVD88 at the time of the peak river flow event on February 1, which is around 1.5 feet higher than under existing conditions. Because water levels in the pond have a direct surface connection to the elevated water levels in the lower estuary, low-lying area around Place Pond is projected to be flooded for a brief duration (~3 hours). Water levels will exceed ground elevations at the low point of Elwha Dike Road and at the residence at 1914 Elwha Dike

Road. Peak water levels in the pond rise rapidly on February 1, but quickly recede during the following low tide, and continue to fall throughout the receding limb of the flow event. With the exception of the peak event, water levels in the pond under Alternatives 1 and 2 are generally lower than those observed under existing conditions.



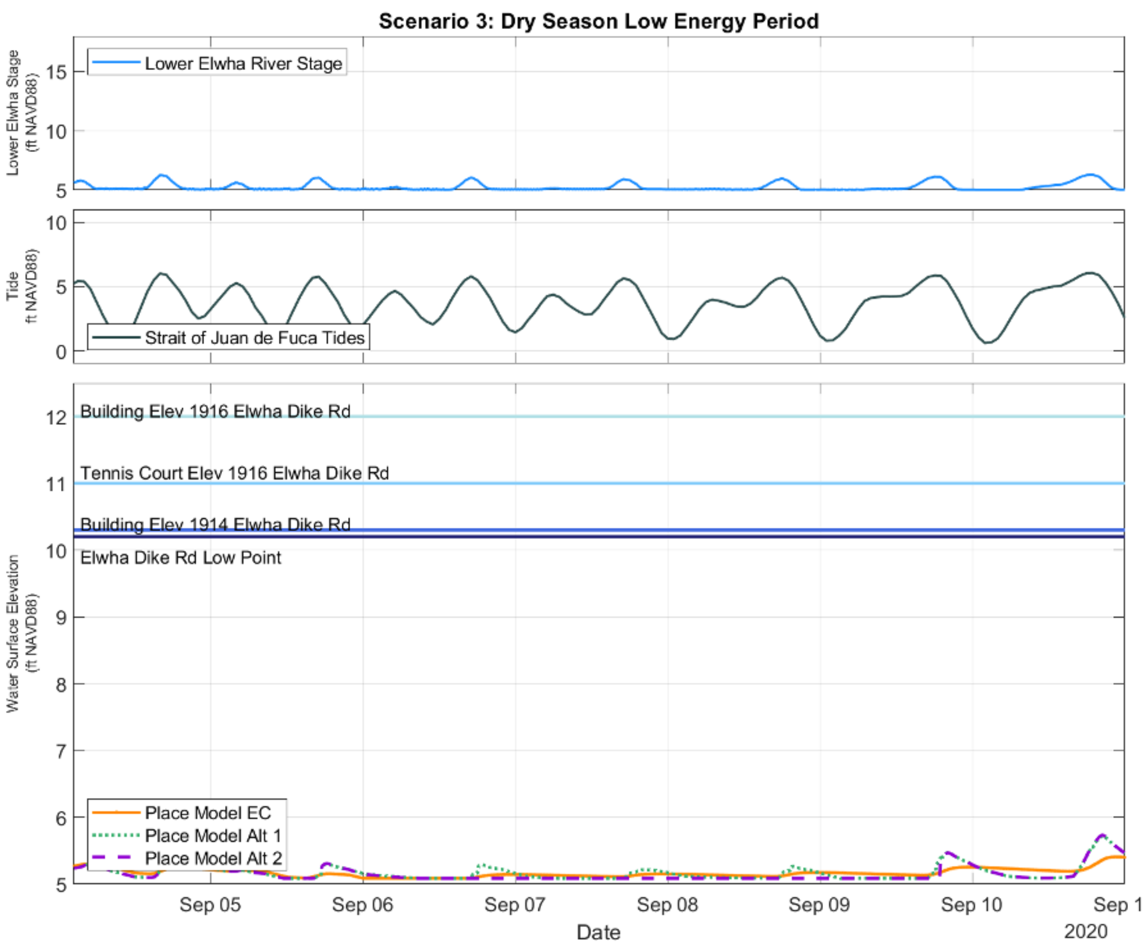
SOURCE: CWI, ESA

Figure 49
Scenario 2 ground observations during actual event (top) and modeled depth of inundation for Existing Conditions

5.3 Scenario 3 – Low Estuarine Event

Scenario 3 is a dry season event that simulates conditions that occur throughout much of the late summer in the Elwha estuary. **Figure 50** plots the simulated water levels in Place Pond under Existing Conditions, Alternative 1, and Alternative 2.

In general, water levels are unremarkable under these conditions. There is little difference between Existing Conditions, Alternative 1, and Alternative 2. Water levels in Place Pond remain below 6 feet NAVD88 throughout the modeling period, and no flooding is anticipated.



SOURCE: ESA

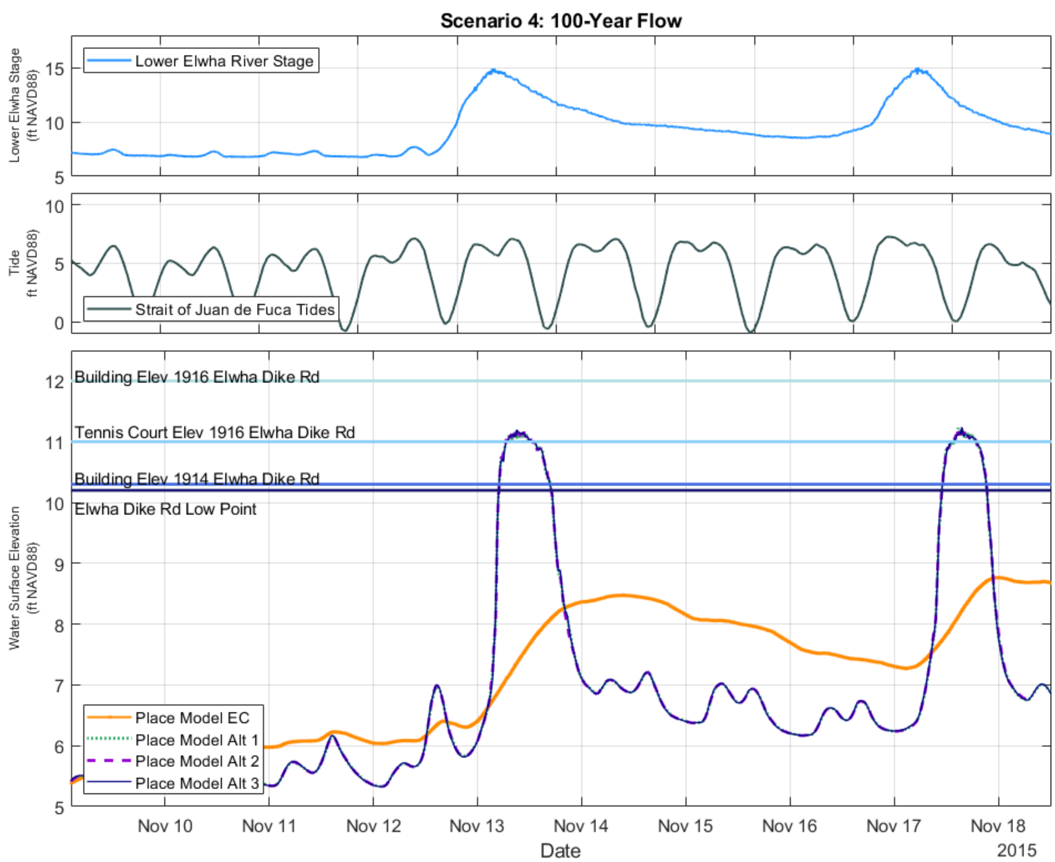
Figure 50
Scenario 3 model results

5.4 Scenario 4 – 100-Year Elwha Flood

Scenario 4 represents an extreme 100-year flow on the Elwha River at the same time as a King Tide (annual event). The 100-year flow for this event occurs on November 18, although the two flood events observed days apart are similar in magnitude. **Figure 51** plots the simulated water levels in Place Pond under Existing Conditions, Alternative 1, Alternative 2, and Alternative 3.

Under existing conditions, water levels rise gradually to approximately 8.5 feet NAVD88 in response to the first peak event on November 13, with a one day lagged response. The water levels in the pond remain high for 24 hours and slowly recede, until rising again in response to the second flow event, eventually reaching 8.8 feet NAVD88.

The water levels in Place Pond under Alternatives 1, 2, and 3 are similar to existing conditions until the first event on November 13, where water levels rapidly climb from 6 feet NAVD88 to over 11 feet NAVD88 over the course of about 6 hours. Water levels remain elevated above 10 feet NAVD88 for about 12 hours before rapidly receding. The pattern is repeated for the November 18 event, with water levels again exceeding 11 feet NAVD88. For both events, water levels will exceed ground elevations at the low point at the eastern end of Elwha Dike Road, the residence at 1914 Elwha Dike Road, and the tennis court at 1916 Elwha Dike Road.



SOURCE: ESA

Figure 51
Scenario 4 model results

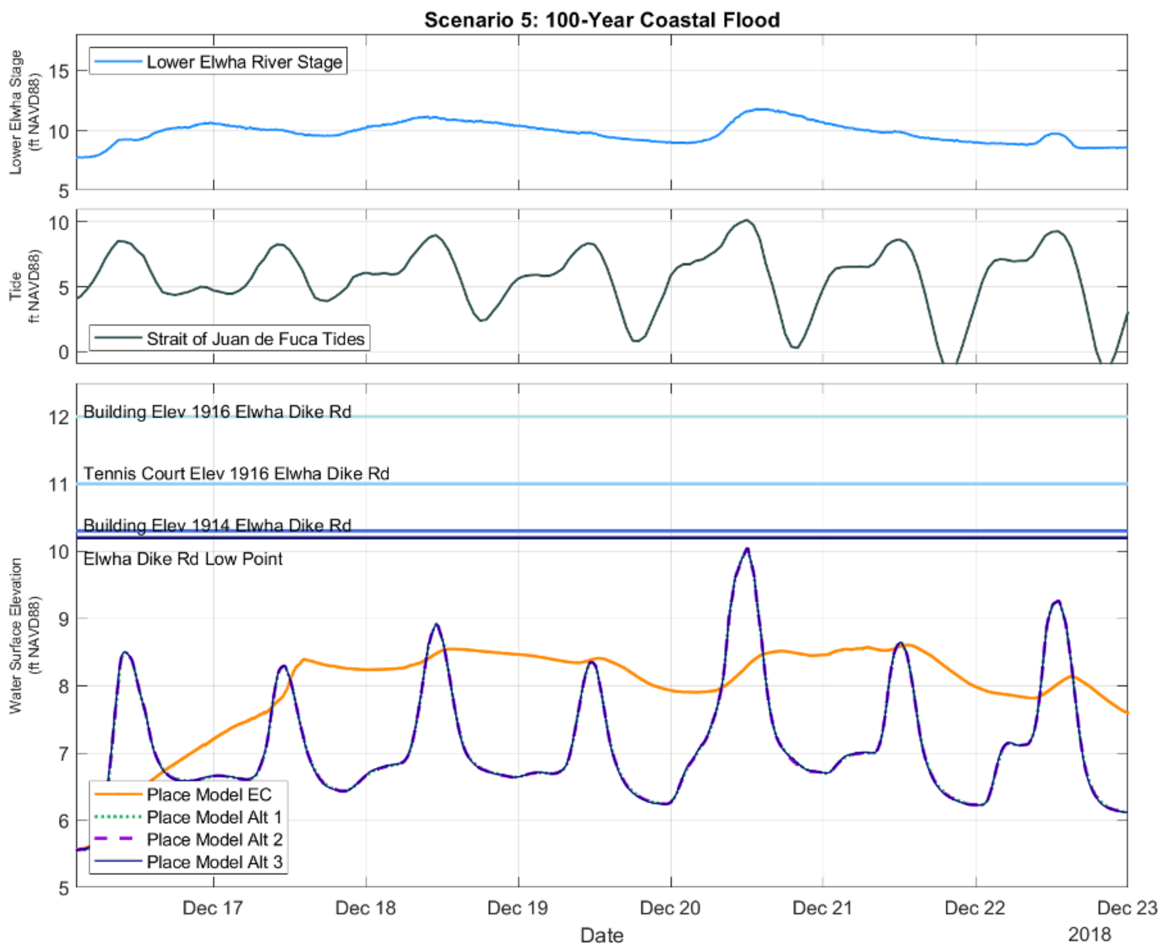
5.5 Scenario 5 – 100-Year Coastal Flood

Scenario 5 represents an extreme 100-year coastal flood at the same time as a 2-year flow event on the Elwha. **Figure 52** plots the simulated water levels in Place Pond under Existing Conditions, Alternative 1, Alternative 2, and Alternative 3.

Under Existing Conditions, water levels in Place Pond gradually rise and remain between 8 and 8.5 feet NAVD99 for much of the model duration. There is minimal daily variation in water levels, and minimal response to the actual 100-year event itself.

Under Alternatives 1 and 2, water levels in the pond are more dynamic, rising and falling several feet each day. On December 20 during the peak 100-year coastal flood, water levels reach 10.0 feet NAVD88. Although no flooding of infrastructure is anticipated, the low point in Elwha Dike Road and the water level is close to exceeding ground elevations near the house at 1914 Elwha Dike Road and the low point on Elwha Dike Road.

The 100-year coastal flood simulated under Scenario 5 is the 100-year still water level event, which neglects the contributions to the total water level by wave setup, wind setup, wave runup, and overtopping. In contrast, the FEMA maps for the area represent the 100-year total water level including setup and wave effects (Figure 34), which shows flood elevations extended across the parcel at 1914 Elwha Dike Road and parts of 1916 Elwha Dike Road under existing conditions at a base flood elevation of 12 feet NAVD88. Therefore, Scenario 5 likely under-predicts the actual existing extreme coastal flood risk in the Place Road Community. Alternative 1, 2, and 3 are likely similarly under-predicted, and would be expected to be even greater than under the existing conditions.



SOURCE: ESA

Figure 52
Scenario 5 model results

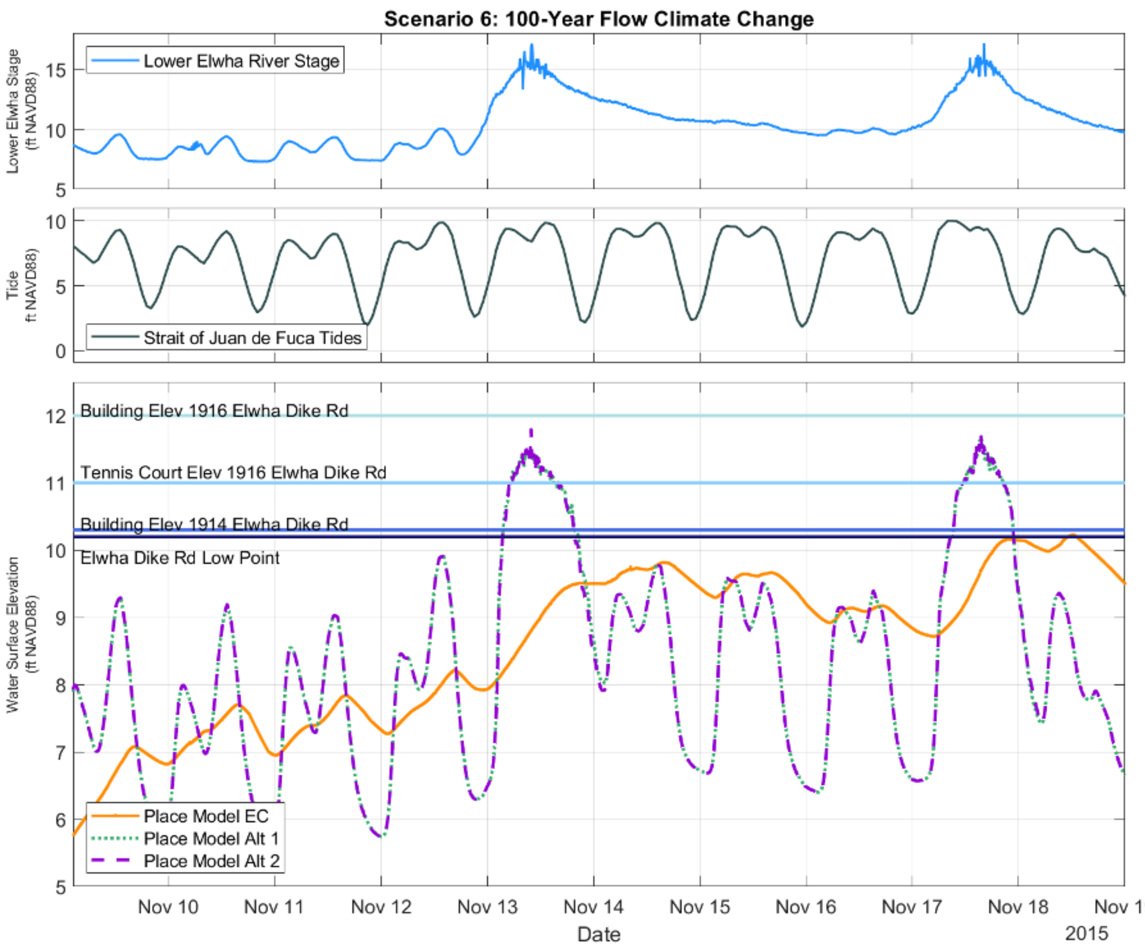
5.6 Scenario 6 – 100-Year Elwha Flood with Climate Change

Scenario 6 represents an extreme 100-year flow on the Elwha River at the same time as a King Tide (annual event) under predicted climate change conditions in 2100 (35% increase in streamflow over existing flows and 2.8 feet in sea-level rise). **Figure 53** plots the simulated water levels in Place Pond under Existing Conditions, Alternative 1, and Alternative 2.

Under existing conditions, water levels rise gradually to approximately 9.8 feet NAVD88 in response to the first peak event on November 13, with a one day lagged response. The water levels in the pond remain high for 24 hours and slowly recede, until rising again in response to the second flow event, eventually reaching 10.2 feet NAVD88.

Daily tidal elevations are higher under Alternatives 1 and 2 when compared to existing conditions for the first several days of the model run. The tidal excursion within Place Pond for Scenario 6 is significantly higher than the Scenario 4 model run (modern-day conditions).

On November 13, the water levels in Place Pond under Alternatives 1 and 2 climb from around 6 feet NAVD88 to over 11.5 feet NAVD88 over the course of about 6 hours. The water levels remain elevated above 10 feet NAVD88 for about 12 hours before rapidly receding. The pattern is repeated for the November 18 event, with water levels again briefly reaching 11.8 feet NAVD88. For both of these events, water levels will exceed ground elevations at the low point at the eastern end of Elwha Dike Road, the residence at 1914 Elwha Dike Road, and the tennis court at 1916 Elwha Dike Road. Rapid water level variations in the alternatives at the top of the peak floods are noise or instabilities related to the construction of water flowing out of the mainstem outlet. With increased flows under climate change, the outlet is likely to scour further than what is represented in the bathymetry described in Section 4.4.2.



SOURCE: ESA

Figure 53
Scenario 6 model results

5.7 Limitations

The numerical modeling prepared for this study has several limitations:

1. The model does not directly simulate sediment transport, and instead uses a fixed bed. The Elwha River delta in particular is known to be highly dynamic, with sand bars forming and

reshaping over the course of a storm event. While the Delft3D model is capable of modeling sediment transport, calibration of such models are complex and limited recent calibration datasets are available. The potential for sediment transport can be inferred from velocities in the hydrodynamic model without direct simulation of transport. However, by fixing the bed, the model is unable represent changes to the outlet which may have an influence on water levels within the estuary. However, artificially widening the bathymetry at the outlet mitigates this limitation. In addition, the flow path connecting the river's mainstem to Place Pond through the Place Pond Levee may also scour and deepen. This change would increase the connectivity at lower tidal water levels, but probably not substantially affect the peak water levels during flood events. The fixed bed assumption is appropriate for the focus of this study, which is the comparative analysis of hazards in the Place Road Community under different levee configurations.

2. Running the model with a fixed bed also inherently assumes that barriers such as Place Road Levee and the coastal berm remain intact throughout the duration of the model run. Place Road Levee is an uncertified levee, and could experience failure during an extreme event. Similarly, it is possible that the coastal berm could erode substantially during a major event and offer reduced protection from coastal flooding. Although these events are unlikely, the fixed bed model implies that the levee and berm provide a greater degree of protection to the Place Road Community than may actually exist.

3. The model domain is limited in size and does not simulate tides throughout the entire Strait of Juan de Fuca, thereby missing tidal currents and large-scale eddying motion off of the delta. These tidal currents are assumed to contribute negligibly to water levels within the estuary.

4. The model does directly simulate waves directly. The influence of waves on water levels within the estuary are limited. However, wave setup, runup, and overtopping likely influences the water levels in Place Pond. The contribution of water from wave overtopping is included in a simple manner as a point source to Place Pond (Section 4.2.5). The simulation of overtopping may warrant refinement as part of future model updates.

5. Scenario 5 is intended to simulate flood hazard under an extreme coastal event. However, the 100-year still water level tide neglects wave contributions to water levels described in the previous bullet and likely underpredicts actual flood hazard from an extreme coastal event. Accordingly, the 100-year total water level mapped by FEMA in the Place Road Community is higher in elevation and larger in area than the flooding simulated by Scenario 5. Scenario 5 may warrant refinement as part of future model updates.

6. The hydrologic scenarios selected as part of the model runs do not capture all conditions that may be experienced at the study site, and are intended to bracket the range of likely extreme conditions and one scenario with climate change.

7. Base (existing condition) bathymetry and topography used in the model is based on best-available datasets as of September 2021. Natural changes to river morphology and alignment could affect modeled water levels in the west estuary.

6 FISH HABITAT EVALUATION

Restoring the natural connection to aquatic habitats in the western portion of the estuary for juvenile salmon is a primary goal of the proposed restoration. Estuaries provide productive rearing habitats for juvenile salmon and support rapid growth before the fish outmigrate to the marine nearshore and ocean (Healey 1982). Estuaries also provide a critical link in anadromous salmon life history as outmigrating salmon smolts undergo the physiological transition necessary as they move from freshwater to saltwater (Levings 2016). Juvenile chum and Chinook salmon are the two salmonid species known to be most dependent on estuarine rearing during outmigration from their natal rivers (Healey 1982; Simenstad et al. 1982; Groot and Margolis 1991). Research in the Elwha River estuary has documented its use by a diverse community of salmonids and nearshore fish (Duda et al. 2011; Shaffer et al. 2017a). Juvenile salmon comprise the largest portion of the fish community in the Elwha River estuary from January through August (Shaffer et al. 2017a).

6.1 Quantity and Quality of Restored Estuarine Habitats

The reconnection of the historic estuarine habitats west of the Place Road Levee would greatly expand the estuarine rearing habitats available to juvenile salmonids. The area of the restored habitats available for fish would vary depending on water levels. Under typical river flows during the winter and spring rearing by juvenile salmonids, there would be approximately 6.4 acres of estuarine habitat west of the existing levee. The area of inundated estuarine habitats would expand to approximately 8.3 acres during higher river flows that occur approximately once per year.

The restored historic estuarine habitats would be expected to provide high quality rearing conditions for juvenile salmon. Estuaries produce abundant prey for juvenile salmon and provide shallow water habitats that serve as a refuge from larger fish predators who occupy deeper water. The connection between the restored habitats and the rest of the estuary is expected to result in similar water quality conditions in all parts of the estuary. The restored habitats will flush regularly through the natural tidal cycling. Under typical spring river flow and tidal conditions, it is expected that more than 30% of the water volume in the restored habitats at high tide will drain during low tide. During higher river flows, such as those that occur approximately once per year, it is expected that nearly 50% of the water volume in the restored habitats at high tide will drain during low tide This degree of flushing should keep water quality in the estuary as good as it is elsewhere in the estuary. During lower river flows during the late summer, less exchange is expected (approximately 13% of the volume between high and low tide), but not to a point where water quality in the restored habitats would differ substantially from the rest of the estuary.

6.2 Fish Access to the Restored Estuarine Habitats

For fish the size of juvenile salmonids, their ability to move into estuarine habitats varies throughout the tidal cycle. In a habitat area connected to the rest of the estuary by a relatively narrow channel, such as barrier lagoons, there tends to be a portion of time during the falling tide when outgoing velocities are too high for the fish to move upstream against. This type of discontinuous access for juvenile salmonids during the tidal cycle is expected in the restored habitats as the large inundation area in the pond is expected to be connected at lower flows by a single outlet channel to the rest of the estuary. Although there may be periods of time when juvenile salmon would not be able to move into the restored habitats, several acres of habitat will remain inundated and provide productive rearing habitat for fish who entered the habitats already.

To evaluate the accessibility of the restored habitats for juvenile salmonids, estimates from the hydrodynamic model on water depths, velocities, and flow direction were evaluated relative to the swimming abilities of juvenile salmon. The model outputs evaluated are from the channel included in the model to connect the western estuary habitats in Place Pond to the mainstem of the river. While this approach provides some insights on fish access, there are some limitations to the usefulness of the model outputs. Importantly, the modeled channel is a simple channel, uniformly 30 feet wide, that would naturally change shape and elevation in response to water flows over time. The channel adjustments that would occur as natural processes act on it, coupled with a more refined channel design during engineering design, are expected to improve habitat connectivity. Thus, the model outputs are considered to conservatively estimate (i.e., are more likely to underestimate) fish accessibility. The model outputs are most useful for comparing how fish access may differ among alternatives and during different river stages.

The ability of juvenile salmonids to move into the restored habitats is dependent upon their swimming abilities and water depth preferences. For this evaluation of fish access to restored habitats in the western portion of the Elwha River estuary, 1.0 foot per second (ft/s) was used as the maximum velocity threshold. This is based on a Muckleshoot Indian Tribe report noted in Barnard et al. (2013), which found in a review of ten references that the maximum velocity for juvenile salmon passage through culverts was 1.0 ft/s, with a range of 0.5 to 2.0 ft/s. This is slightly lower than the recommended design criteria by Powers et al. (1997) for juvenile salmon greater than 60 mm in size. The lower velocity threshold of the Muckleshoot Indian Tribe will be more protective of juvenile chum salmon, which were reported by Shaffer et al. (2017a) to generally range in size from 30 mm to 50 mm during their peak outmigration in February and March.

This evaluation of fish access to the restored habitats in the western portion of the Elwha River estuary used 1.3 feet as the minimum depth threshold. This is based on the study by Hering et al. (2010), which documented that 94% of juvenile Chinook salmon detections in estuarine marsh habitats occurred when water depths were ≥1.3 feet.

The accessibility of the aquatic habitats in the currently disconnected western portion of the estuary was evaluated during three river flows meaningful for juvenile salmon: (1) during representative rearing conditions; (2) during representative low-flow conditions; and (3) during high river flows that occur approximately once per year (i.e., 1-year recurrence interval flows). Elwha River flows for each of these conditions were estimated using monthly average streamflow data for the river mouth between 1987 and 2020 (see Section 3.4 for the method for estimating flows at the river mouth).

The rearing period for chum salmon in the Elwha River estuary is between December and June, with a peak in February and March (Shaffer et al. 2017a). Chinook salmon tend to remain in the river for longer before outmigrating to the estuary. Juvenile Chinook outmigration from the river peaks in mid-March, with a second peak in June (Duda et al. 2011), although small numbers outmigrate in all months of the year. The average of the monthly averages for flows at the river mouth from December through June between 1987 and 2020 were 1,969 cfs. Flows during the peak chum salmon outmigration in February and March averaged 1,604 cfs. Flows during the peak Chinook salmon outmigrations between March and June averaged 1,826 cfs.

For typical low-flow conditions, the average of the monthly averages for flows at the river mouth were lowest in September (526 cfs). The lowest monthly average flow in September was 350 cfs during the period of record. As shown in **Table 3**, the 1-year recurrence interval flow at the river mouth is 5,092 cfs.

Each of the three river flow conditions was evaluated throughout a full mixed semidiurnal tidal cycle lasting approximately 25 hours and including two high tides and two low tides. **Table 8** identifies the three time periods used in the evaluation.

TABLE 8
TIME PERIODS EVALUATED TO ESTIMATE FISH ACCESS TO RESTORED HABITATS

Evaluation Period	Representative Rearing Flows	Representative Low Flows	1-Year Recurrence Flows
Start Date/Time	February 14, 2020 at 1900 hrs	September 6, 2020 at 0500 hrs	January 31, 2020 at 0000 hrs
End Date/Time	February 15, 2020 at 1950 hrs	September 7, 2020 at 0550 hrs	February 1, 2020 at 0050 hrs
River Flow Average (cfs)	1,829	367	6,028
River Flow Range (cfs)	1,773 – 1,904	356 – 70	3,754 – 10,151
Tide Elevation Range (ft NAVD 88)	0.7 – 7.2	1.4 – 5.8	2.6 – 7.1

In each of the river flow conditions evaluated, the fish access results were consistent between the alternatives. That is, fish access to the habitats was the same where all of the levee, half of the levee, or a small section at the northern was removed.

During representative rearing conditions, fish access to the restored habitats would be controlled by estimated water depths in the entrance channel. Suitable depths and velocities for fish access were estimated during only 19% or just under 5 hours of the 25-hour evaluation period. Estimated water velocities in the tidal channel were ≤1.0 ft/s during more than 23 hours of the tidal cycle.

Channel depths were ≥1.3 feet for only 20% or 5 hours. Water depths were ≥0.5 foot in the channel throughout the evaluation period, but per the findings of Hering et al. (2010), these depths are too shallow for most juvenile Chinook salmon to use the habitats.

During representative low-flow rearing conditions, water depths in the channel were too low to provide juvenile salmon access to the restored habitats. Water depths did not exceed 1.07 feet at any time during the evaluation period. Unsurprisingly, this also corresponded with low estimated velocities in the channel (maximum 0.42 ft/s).

During high flows that occur approximately once per year, fish access was controlled by estimated water depths in the entrance channel. Suitable depths and velocities for fish access were estimated during 74% or approximately 18.5 hours. Estimated water velocities in the tidal channel were ≤1.0 ft/s during more than 23 hours of the tidal cycle. Channel depths were ≥1.3 feet for 92% of the time evaluated.

In addition to suitable water depths and velocities for fish movement into estuarine marshes, the direction of flow is particularly important. Studies of juvenile salmon movements into estuarine marsh habitats indicate that most of their movement into the habitats occurs during the rising tide when water is flowing into the habitats. In fact, Hering et al. (2010) found that approximately 80% of the juvenile Chinook salmon movements into estuarine marshes occurred during flooding tides. This finding is corroborated by a WDFW study evaluating fish movements in river estuaries (WDFW n.d.). Based on the elevation of the channel connection to the restored habitats, it is expected that the water direction will be into the restored habitats – and most favorable for juvenile salmon movement into the habitats – during approximately 30% of the tidal cycle.

7 INTERPRETATION

Section 7.1 presents a conceptual model of surface water and groundwater movement within the lower estuary, with a focus on the historic west estuary. Section 7.1.1 expands on that conceptual model by presenting a current understanding of the impacts of potential levee modifications. Section 7.2 details several individual flood hazards for the Place Road Community, along with potential adaptation strategies and considerations for future mitigation.

7.1 Conceptual Model of Lower River

The conceptual model of the lower Elwha River estuary is based on scientific literature and observations recorded during this study. Within the lower Elwha River, water surface elevations decrease approximate linearly from upstream to downstream along the mainstem. The water surface or stage in the river is influenced by the river flow rates as well as tidal elevation. The maximum extent of tidal influence reaches approximately halfway along the length of Fox Point Bluff. Upstream of Fox Point Bluff, a tidal signal is not likely to be observed in the river stage.

At the outlet of the river, barrier sand bars and shoals are formed as the river deposits sediments and waves shape these sediment deposits. Sand bars at the outlet are highly dynamic and constantly changing. Incoming wave parameters, including the wave height, period, and angle of approach, influence the shape of the sand bars along with river flow rates. When river flows are low, the outlet narrows as waves build up sand bars that encroach on the river outlet, causing a contraction in the river outlet opening. Surveys of the outlet show that following high-flow events, sediment is eroded from the outlet, widening and deepening the opening as higher flow rates are conveyed (USACE 2009). Periodically, the outlet may breach through the barrier sand bar in a new location.

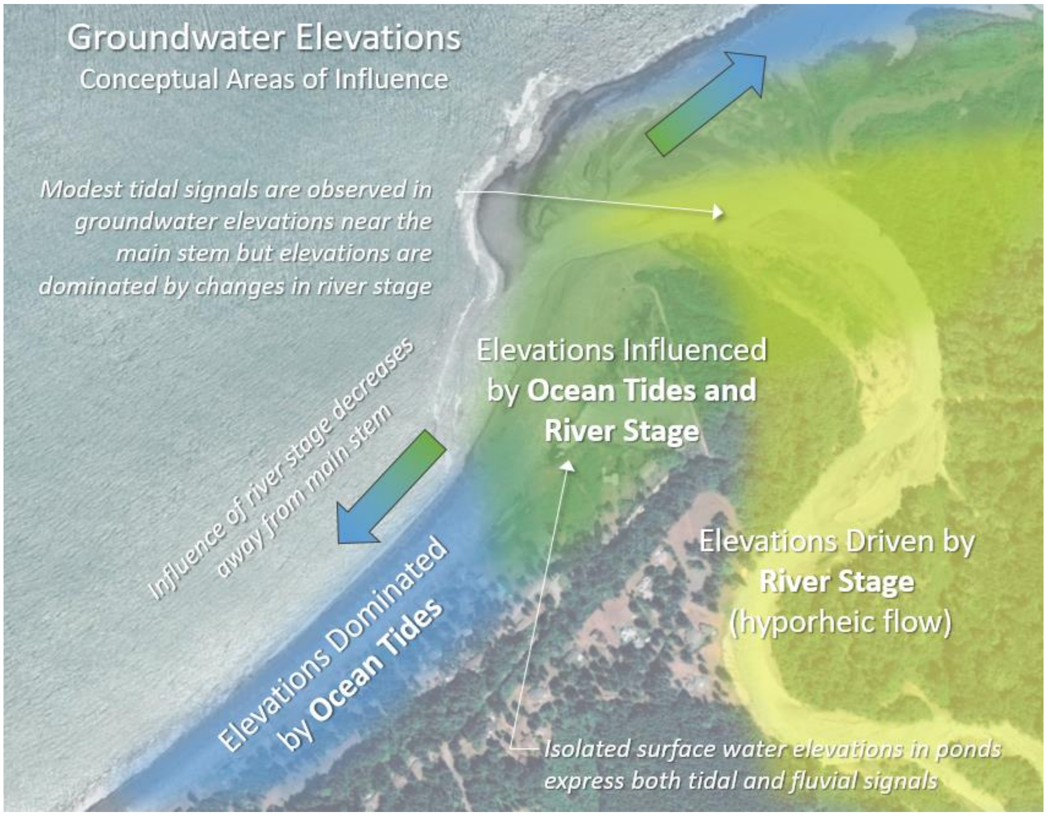
Removal of the Elwha and Glines Canyon Dams contributed a massive volume of sediment to the Elwha River delta and nearby shorelines, which is described in detail by many recent studies by USGS and others. The sediment delivery built out the subaerial and submarine delta and many shorelines in the area. The build-out of the delta also pushed the freshwater plume farther out into the Strait of Juan de Fuca, causing somewhat fresher conditions and reduced tidal range within the lower estuary (Foley and Warrick 2017). In the several years following dam removal, the outlet and delta were extremely dynamic as sediments were sorted and transported through the delta and down the drift cell. However, in recent years, the shoreline's response to the dam removal disturbance has waned (Ritchie et al. 2018). In addition to sediment transported from the formerly dammed reservoirs and upper watershed, the Fox Point Bluff provides a local sediment source to the lower estuary. Although the dam removals significantly changed the sediment environment in the lower estuary, the dam removals had little to no effect on peak flow rates in the river. However, with climate change, peak flows are anticipated to increase 35% by the end of the century (CIG 2010).

The West Floodplain is a forested lateral bar associated with the northern-most meander of the Elwha River. Channel modifications, such as straightening of the mainstem along Place Road Levee and construction of levees that cut off an anabranch channel to the east during the 1950s–1980s, induced the development of two channel meander bends in the lower Elwha River. In the decades following construction of the Place Road Levee, the pair of meander bends have amplified in sinuosity, which resulted in bank erosion and lateral migration along the outer bends into Fox Point Bluff (upstream meander) and along the eastern floodplain (downstream meander). Deciduous trees have colonized the western bar and established the stable low-lying floodplain surface that exists today.

At the terminus of Fox Point Bluff when flow overtops the west bank, flow spreads across the floodplain with low velocity and deposits fine sediment. The positive feedback between erosion of the bluff and subsequent aggradation of the Western Floodplain surface results in the eastward expansion of the bar and continued meander amplification of the downstream meander. Place Road Levee currently restricts flow and sediment from reaching Place Pond and the western delta during flood events. Aerial imagery from 2011–2020 indicates an average rate of down-valley meander translation of 5–10 feet per year. Assuming that baseline conditions remain relatively steady, the Elwha River could abut Place Road Levee in 40–90 years. The increased delivery of sediment and debris from the upper basin will likely shift the Elwha River planform from meandering to anabranching type. Meander cutoffs and channel avulsions are generally associated with anabranching rivers, although their likelihood of occurrence in the Elwha River intertidal zone is relatively low in the short term given the water surface gradient required for such a dramatic change in channel conveyance and orientation.

The geomorphology of the current lower Elwha River, including the western floodplain, formed in response to channel modifications, the Place Road Levee construction, and the influx of sediment from dam removal. The levee has influenced and continues to affect finer-scale topographic features within the western floodplain. The construction of the levee blocked tidal exchange between the Place Pond area and the remainder of the estuary, thereby reducing the daily tidal scouring that maintains tidal channels such as the WLRSC. The levee also encouraged the alignment of these channels in the western portion of the floodplain to parallel the levee. The presence of the levee continues to affect hydrodynamics, sediment processes, groundwater exchange in the vicinity of the levee. By blocking tidal exchange between the Place Pond area and the main estuary, the levee has made channels in the west floodplain less resilient to sedimentation by impairing the capacity of these channels to flush sediment. Dam removal increased the sediment load to the lower estuary. Because the Place Road Levee makes the WLRSC less able to flush incoming sediment, the channel has accumulated sediment since dam removal, resulting in reduction in habitat quality and quantity in the WLRSC and adjacent channels.

In the lower estuary, groundwater consists of a salty wedge that intrudes inland from Freshwater Bay, overlain by a brackish mixing layer, and topped with fresh groundwater. In general, the Elwha River loses water to the freshwater aquifer in the lower estuary, which then loses water to the Strait of Juan de Fuca. Near the river mainstem, groundwater flow from the river drives freshwater groundwater elevations. Along the shoreline of Freshwater Bay, tides force groundwater elevations up and down daily. Moving away from the mainstem of the river, the influence of the river stage on groundwater elevations decreases and tidal forcing becomes more dominant (**Figure 54**).



SOURCE: ESA 2021

Figure 54
Conceptual groundwater distribution

Water levels in Place Pond and West Pond are mainly driven by groundwater exchange. Wave overwash across the coastal berm and local drainage of precipitation also have a small influence on pond water levels. At Place Pond, groundwater elevations are influenced strongly by both the tides from Freshwater Bay and Elwha River stages. The Place Road Levee and the coastal berm are both permeable and allow for groundwater to pass through laterally into Place Pond. Evidence of fluvial suspended sediments in Place Pond has been observed following major river flow events, indicating that silty water from the east side of the levee has migrated through the relatively porous levee to the pond (**Figure 55**).

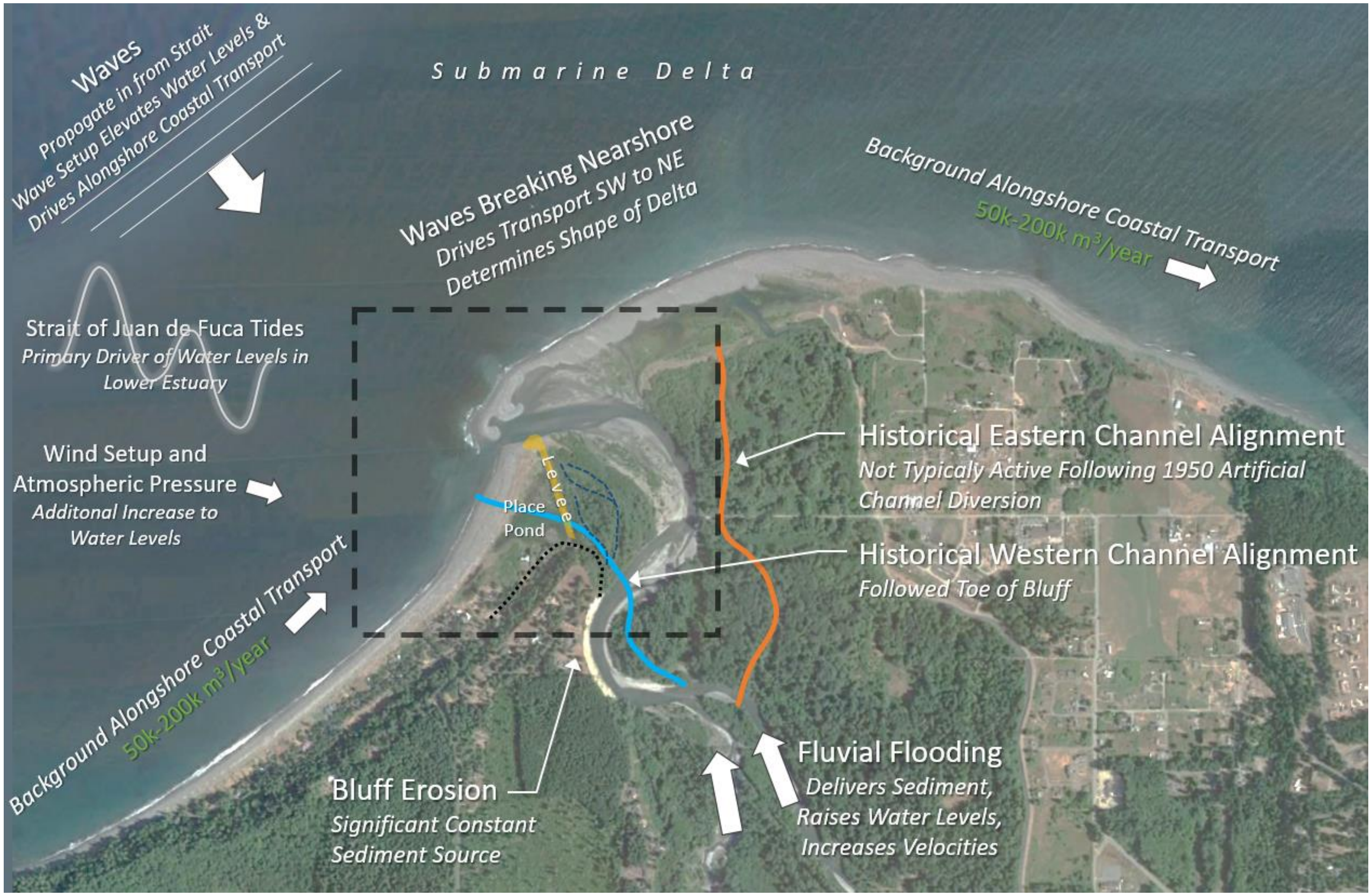
SOURCE: USACE 2011

Figure 55
Silt-laden water on the west side of the levee 2 days after peak flow event on January 10, 2002

The groundwater connection at Place Pond appears to be influenced by water levels farther upstream in the Elwha River. This implies that water from the Elwha River near Fox Point Bluff may be traveling through the West Floodplain and seeping through the levee near the south end, in addition to groundwater fluxes from Freshwater Bay. The overall conceptual direction of groundwater flow is from the Elwha River, through the West Floodplain, into Place Pond, and out through the coastal berm to Freshwater Bay. The direction of these pathways likely reverses under some conditions. No formal surface drainage pathways exist for Place Pond to drain out to the beach or to the estuary. Therefore, the primary way that pond water levels decrease is via groundwater flow out to the bay. The Place Road Levee blocks potential surface drainage pathways that could distribute surface water into the lower river outlet.

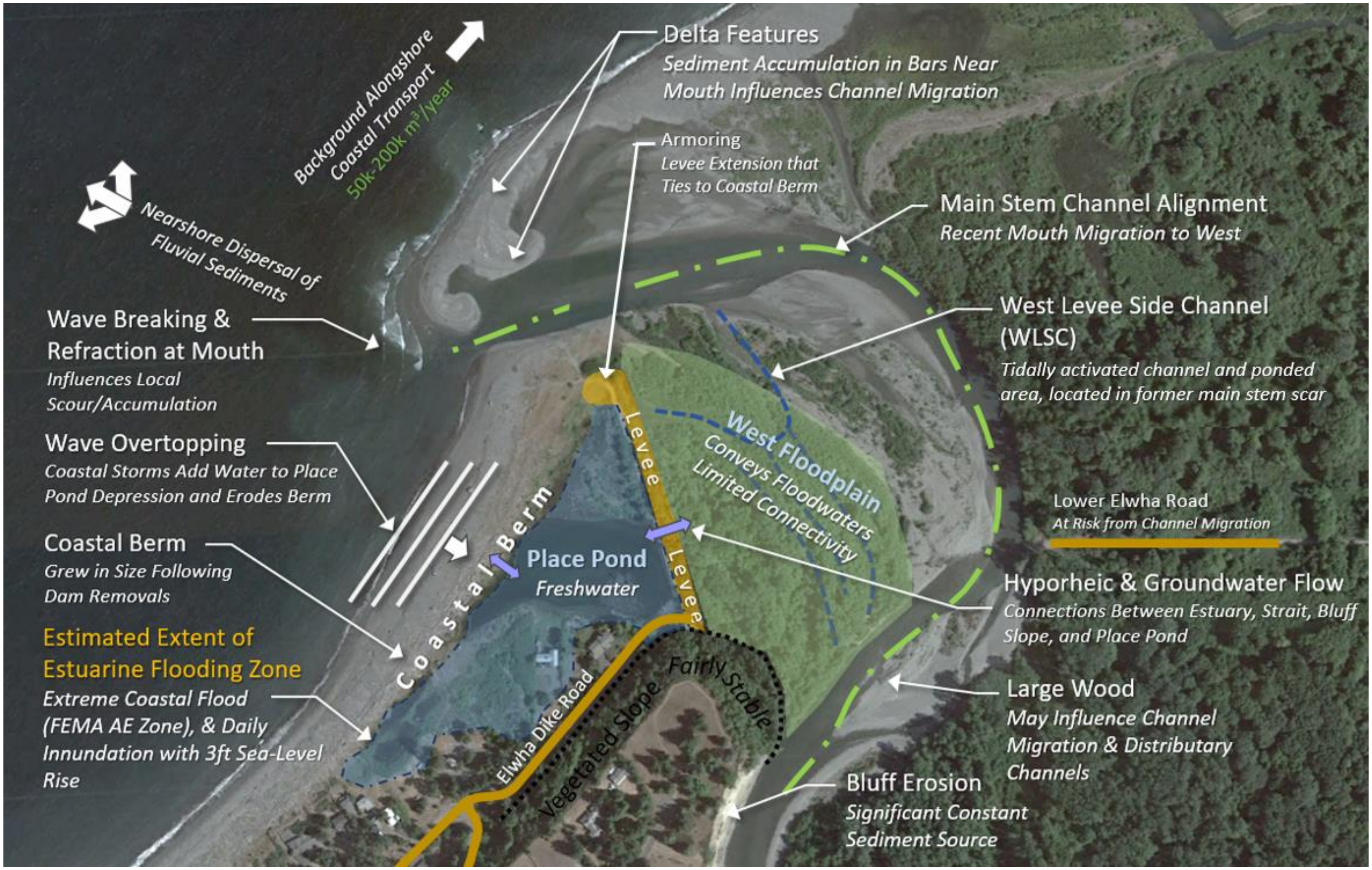
Under existing conditions, Place Pond is protected from high surface water levels in the Elwha River by the Place Road Levee. The levee is able to contain the existing 100-year fluvial flow with a 90% confidence (USACE 2011). However, the levee does not protect the pond from coastal flooding that overtops the coastal berm from the Strait of Juan de Fuca. This coastal flood hazard may inundate areas in the Place Road Community regardless of the presence of the Place Road Levee. This conclusion was reached by USACE in 2011, and is also reflected in the recent 2019 FEMA FIRM maps for the area. Table 4 in Section 3 indicates that out of the 12 parcels nearest to the levee, seven lots have structures within the existing FEMA 100-year flood zone. Furthermore, groundwater flow through the levee and the coastal berm causes elevated water levels in Place Pond that approach flood levels. Details on existing and future flood hazards for the Place Road Community are detailed in Section 7.2.

Figures 56 and 57 present a summary of the important physical processes that affect conditions in the historic west estuary.



SOURCE: ESA 2021

Figure 56
Lower Valley Conceptual Model



SOURCE: ESA 2021

Figure 57
West Estuary Processes

7.1.1 Conceptual Understanding of Levee Modifications

Full removal of the levee, truncation of the levee, or a smaller opening in the levee will create a surface water connection from the river, via the WLRSC, to Place Pond. Flow will primarily be conveyed in and out of the WLRSC channel, which is a localized low area and already has periodic surface water connection to the outlet of the river. Most of the flow into and out of Place Pond will be channelized through the WLRSC, regardless of the length of opening of the breach. Modeling conducted for this study showed that under Alternative 1, Alternative 2, and Alternative 3, most flows were confined to the WLRSC despite the fact that each alternative has substantially different levee removal lengths. This results in nearly identical water levels among the three alternatives.

Sedimentation Trends in the WLRSC with Modification

Over time, the WLRSC channel will adjust to channel dimensions that are appropriate to convey the full tidal prism of Place Pond under these alternatives. Since the current channel is a blind channel with no surface connection to Place Pond, the increase in tidal prism with restoration is anticipated to enlarge the channel. Follow the dam removals, the WLRSC has aggraded in recent years from a bottom elevation of around 4 feet NAVD88 in 2002 to a current bottom elevation of approximate 5.5 feet NAVD88 (Shaffer et al 2009). This sedimentation trend, as described elsewhere in this report, is attributed to increased sediment supply following the dam removals, the main stem channel migration eastward, and a limited tidal prism within the blind tidal channel.

Were the WLRSC to be connected to Place Pond via a full or partial removal of the levee, water would be conveyed into and out of the pond with every tide cycle through the WLRSC. The potential tidal prism of the Place Pond basin is approximately 40 acre-feet of water. Conveying such a volume of water would scour the WLRSC until reaching a geomorphically appropriate condition. The mature size of this channel can be estimated using relationships developed as part of the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) (PSNERP 2011). The PSNERP tidal channel sizing relationship for the Port Angeles area indicates that a tidal prism of 40 acre-ft and an anticipated tidal marsh acreage of 16 acres would encourage the WLRSC to develop into a tidal channel with a depth of 6.5 to 9 feet below MHHW (approx. -2.5 to 0 ft NAVD88) and a top width of between 35 and 80 feet. These dimensions are larger in width and depth than under the current dimensions of the WLRSC (approximately 1 to 1.5 feet in depth below MHHW and 15 to 20 feet in width), and would thereby provide additional intertidal habitat for juvenile salmonids. The increased flushing through the channel would improve water quality in the WLRSC, counteracting the detrimental trends in temperature and dissolved oxygen observed in the WLRSC since dam removal (Shaffer et al 2009).

The tidal exchange of the considerably larger flows than existing conditions would generate scouring forces to counteract the aggrading trends observed in the channel in recent decades. A lagoon connected by a persistent tidal channel has been present in this area in many documented conditions of the lower estuary prior to the construction of Place Road Levee (see Figure 3, 4, and

5), even when the main stem of the river is located on the eastern side of the valley. This indicates that removing the levee to allow tidal exchange would likely maintain a tidal channel regardless of the main channel outlet location. The increased depth and velocities through the WLRSC is also likely to encourage tidal exchange and sediment scouring within the north-south oriented channels within the West Floodplain. In the long term, the orientation, shape, and location of a primary tidal channel connected to the Place Pond area will likely change in response to main stem channel migration.

As part of the restoration effort, mechanically excavating the channel to the size predicted from the PSNERP channel sizing relationship is recommended to accelerate habitat enhancement. While the channel would eventually self-adjust to the appropriate size, this process can take considerable time, depending on annual hydrology and soil conditions. It is important to distinguish this one-time mechanical excavation associated with project implementation from ongoing maintenance dredging in the WLRSC. Maintenance dredging is sometimes proposed as a method to maintain open channels. However, dredging is disruptive to sensitive estuary environments, expensive, and likely to be contested by regulatory agencies. Without a connection to Place Pond tidal prism, the WLRSC and adjacent channels will likely continue to aggrade sediment. To offset this aggradation, maintenance dredging would need to be repeated to maintain the channel depths and width, particularly those channel dimensions observed pre-dam removal. If instead the restoration of tidal flows to and from Place Pond is implemented by removing the levee, then these tidal flows would naturally scour sediments in the WLRSC on a daily basis and not require maintenance dredging. Natural process restoration (i.e., the reconnection of tidal flows from a disconnected tidal lagoon) is a more effective, cost efficient, and sustainable way to achieve habitat outcomes when compared to repeated mechanical intervention.

Water Surface Elevations with Levee Modification

Following levee modification (full removal, truncation, or breach), average water levels in Place Pond will be lower than under existing conditions, but short duration high water level periods will occur during high tides and high river flows. Extreme river flows, and moderately high river flows in combination with high tides, will produce the highest water levels in the pond with the longest elevated water level durations. Water levels can rise very rapidly through the direct surface connection to the lower estuary during these peak events, in some cases up to 1.0 foot an hour. High water levels in the pond may occur multiple days in a row at each higher-high tide throughout the duration of a flood event on the Elwha River. Water levels can exceed ground elevations at the building at 1914 Elwha Dike Road and the tennis court at 1916 Elwha Dike Road. More information on these water levels relative to buildings and the tennis court is provided in Section 3.7.3. Under existing conditions, buildings on parcels farther to the west would not be impacted by surface water connection under the restoration alternatives, as the buildings are located at slightly higher ground elevations (above 13.2 feet NAVD88). However, with climate change, flood elevations in Place Pond will increase further. With 1 foot of sea-level rise, flood water levels will reach the building at 1916 Elwha Dike Road, and with 2.8 feet of sea-level rise (expected by year 2100), water levels would have reached the buildings at 1922 Place Road, had these building not recently been removed.

Adaptation and mitigation measures could be taken in combination with levee modification to limit the flood risk to the structures described above. These measures are described in 7.2.2. Landowners of at-risk parcels will have to be fully satisfied with potential flood protection mitigation measures, and/or at-risk parcels will need to be placed under conservation management in order to proceed with further planning for reconnection of historic west Elwha River estuary habitat.

Regardless of the open surface water connection, groundwater flow to and from the mainstem and Freshwater Bay will continue to exchange water into and out of Place Pond. However, these groundwater flows will be dwarfed by the volume of flow exchanged via the surface water connection and have a negligible effect on Place Pond water levels. Similarly, wave overtopping will still contribute water to the pond during periods of high wave runup, but these flows will not have a significant effect on water levels in Place Pond given that the surface water connection will quickly equalize any small water level differences.

The surface water connection to Place Pond will allow fish passage during most conditions, although velocities in the WLRSC may exceed fish passage guidance during peak events. Inside the pond, velocities will be mostly quiescent, providing suitable rearing habitat for juvenile salmonids and other species.

Channel Migration with Levee Modification

In its current alignment, Place Road Levee does not directly influence the main channel alignment of the lower Elwha River. Its hydraulic connection to the Elwha River flow is limited to floods when water overtops the West Floodplain and drains through the WLRSC to the estuary. The WLRSC is prone to sedimentation under existing conditions, as described previously. Assuming that recent erosion rates (2011–2020) at the upstream head of the western lateral bar continue, the mainstem channel could potentially reach Place Road Levee in 40–90 years. This trend underscores the relatively low likelihood of full-scale channel avulsion through a constructed opening or northern truncation of the Place Road Levee in the short term (the next 5–10 years).

Under the scenario of a full removal of the Place Road Levee, the Elwha River will eventually retake its historical channel outlet or form a tidal lagoon west of the current levee, in a form similar to the upper left panel of Figure 5. The primary surface water connection will initiate at the WLRSC. A full-scale channel avulsion and formation of a new outlet in the short term will require an extreme fluvial flood with low estuarine energy to create sufficient water level gradient to the Strait of Juan de Fuca. A truncation of the Place Road Levee will ultimately have the same long-term outlook as the complete removal: an outlet forming through the historical western channel alignment, although a higher rate of local erosion in the WLRSC could occur compared to the complete removal scenario. A smaller breach of the Place Road Levee would likely preclude the outlet from shifting west of the levee.

7.2 Hazard Evaluation for Community

The community west of the Place Road Levee is subject to flooding under several types of hydrologic and geomorphic events at the present-day and into the future. Low-lying properties closest to the Place Road Levee are the most vulnerable given their low elevations relative to estuarine water levels and proximity to the existing river outlet. This section evaluates the vulnerability of the community under events including major fluvial flooding, major coastal flooding, combined estuarine flood event, tsunami, and three mainstem realignments. Additionally, changes in the frequency and severity of each hazard with climate change are described.

This analysis focuses on hazards in the western portion of the estuary and Freshwater Bay shoreline. The risk to the Lower Elwha Klallam community along the eastern side of the estuary has not been evaluated in this study.

Major Fluvial Flood

Description: Extreme high flows on the Elwha River inundate the lower estuary, including the West Floodplain.

Existing Likelihood of Occurrence: Will occur infrequently to rarely (once in every 20 to 100 years). Increase in severity and frequency with climate change as peak flow rates on the Elwha River increase 35% by the end of the century.

Role of Place Road Levee: Levee prevents floodwaters from directly inundating low-lying infrastructure south and east of the levee. Groundwater flow through the levee may gradually increase water levels in Place Pond and threaten low-lying surrounding infrastructure under extreme events (>100-year flood).

If the levee is removed or breached, elevated floodwaters from the Elwha River will directly reach Place Pond and surrounding infrastructure. Water levels will likely exceed ground elevations near buildings on the lowest parcels around Place Pond at the peak of the flood. Note that overtopping of the levee is possible under an extreme fluvial, coastal, or combined event. The Elwha River will eventually form a distributary channel and outlet at the western delta, as has been documented under pre-dam conditions (1872) and as recently as 1939 if unimpeded by the levee.

Role of WLRSC and West Floodplain: The West Floodplain is currently inundated on an annual basis, receiving shallow and relatively slow-moving water compared to the mainstem channel. This area is a depositional zone for fine sediment and is not currently at high risk of channel avulsion in the short term. Surface waters flow into the WLRSC due to its local topographic elevations and provide the primary surface water connection between the West Floodplain and the Elwha River.

If the levee is removed or breached, the increased flow will likely cause erosion and enlargement of the WLRSC. Formation of another channel through the West Floodplain and Place Pond depends on an event-driven hydraulic gradient (tides and river stage), although this area is prone to sedimentation in the short term.

Details: Flooding in the Place Road Community could occur during a major river flood event. Water levels in the pond may become elevated as a result of direct overtopping of the levee, levee failure, and/or heavy seepage through the levee into Place Pond. The 100-year river flood event was modeled as **Scenario 4** in the hydrodynamic modeling. A similar 100-year event was analyzed by FEMA and by USACE. **Table 9** reports the 100-year water surface elevations at stations along the levee, where station 0+00 is the southern-most end of the levee, and station 9+00 is the downstream end of the levee. Under all three studies, the levee is expected to have adequate freeboard under the 100-year fluvial event and no overtopping is anticipated. With sea-level rise and climate-driven changes in peak streamflows, the freeboard will decrease, especially at the downstream end of the levee. This could result in direct overtopping by the latter half of the 21st century or early 22nd century. Additionally, with high water levels adjacent to the levee, seepage will likely be higher and could result in elevated water levels in Place Pond regardless of the available freeboard. Scenario 4 predicts that pond levels could reach approximately 9 feet NAVD88 under existing conditions. With around 1 foot of sea-level rise, a similar event could result in flooding of the lowest parcels around Place Pond.

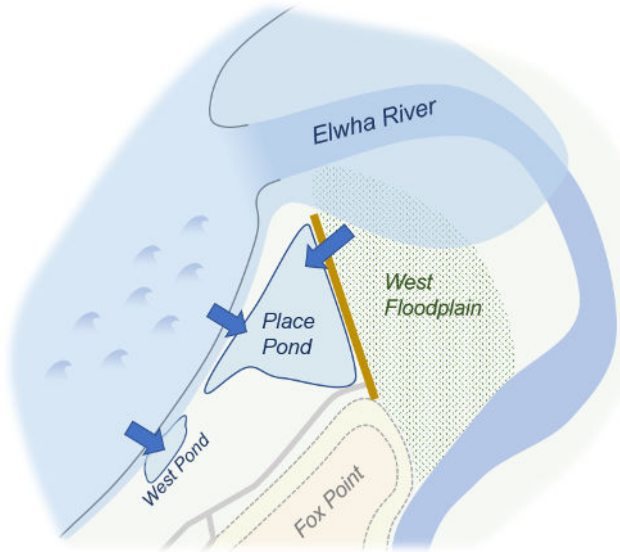
TABLE 9
100-YEAR FLOW WATER SURFACE ELEVATIONS EAST OF THE PLACE ROAD LEVEE

Levee Station	2009 Constructed Crest Elevation (ft NAVD88)	100-Year River Flood (USACE 2011) (ft NAVD88)[4]	2019 FEMA 100-Year Flood * (ft NAVD88)	2021 ESA 100-Year Flow Scenario 4 (ft NAVD88)
8+05 (near north end)	14.4	10.3	12.0	11.0
4+25 (middle)	14.9	11.8	12.0	11.3
1+35 (near south end)	16.5	15.5	12.0	11.8

* The FEMA 100-year flood considers both coastal and fluvial flooding

[4] The USACE model used an estimated post-dam removal bed morphology applied to bathymetry and topography from 2002-2009.

Major Coastal Flood



Description: Extreme high astronomic tides, in combination with low-pressure storm systems and/or coastal swell waves, flood the lower estuary and Freshwater Bay. Wave overtopping of the coastal berm causes localized flooding landward of the beach.

Existing Likelihood of Occurrence: Will occur infrequently to rarely (once in every 20 to 100 years). Increase in severity and frequency with climate change as sea-levels rise and storms become stronger and more common.

Role of Place Road Levee: Levee prevents elevated floodwaters from directly inundating Place Pond from the east. Levee has no effect on runup and overtopping of the coastal berm. Levee may limit drainage pathways for receding floodwaters generated by coastal berm overtopping and limits the potential for a distributary channel to form from the Elwha River.

If the levee were removed or breached, elevated floodwaters may enter Place Pond from the east via the WLRSC. Deposition is expected during the receding limb of the tidal cycle, whereby channels to the Elwha River could form along preferential drainage pathways that are influenced by sediment deposits. Removal of the levee will not impact overtopping of the coastal berm.

Role of WLRSC and West Floodplain: The WLRSC and the West Floodplain play a minor role during major coastal flooding. A major coastal flood would likely cause minor scour of these channels due to low velocity tidal exchange and could eventually form into more prominent channels.

If the levee were removed or truncated, the increased tidal prism exchanged via the WLRSC would likely cause scour to enlarge the WLRSC. The West Floodplain in its current form will act as a buffer for the hydraulic head gradient between Place Pond and the Elwha River. Formation of a tidal lagoon would be expected in the short term, and development of a larger distributary channel through the West Floodplain expected in the long term.

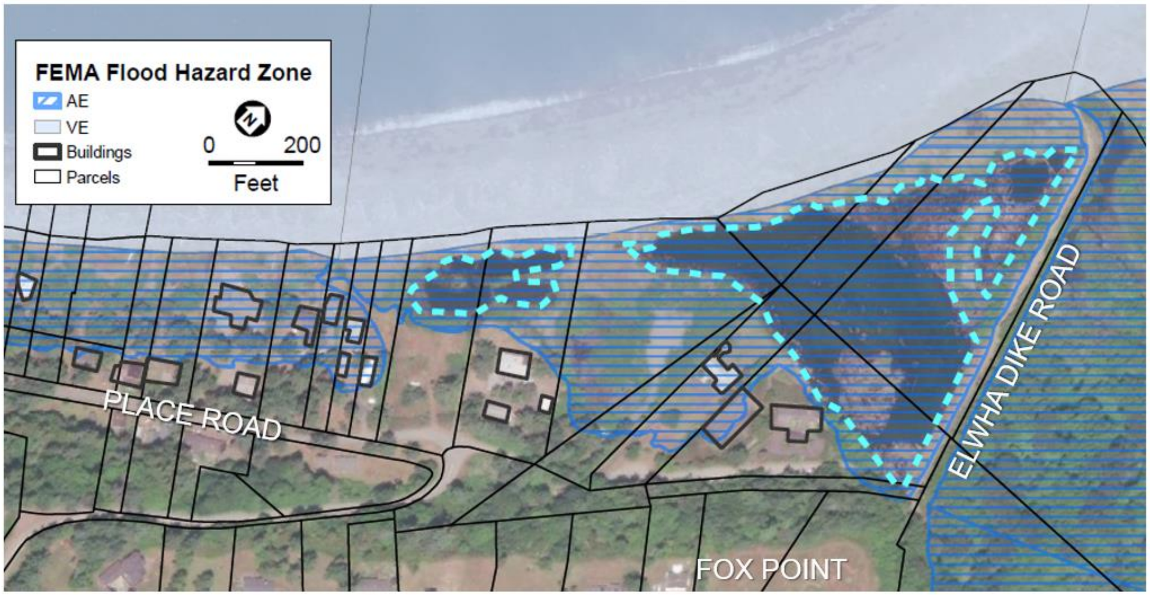
Details: Coastal flooding of the Place Road Community can occur during high total water levels in Freshwater Bay, generated as a result of high astronomical tides, low atmospheric pressure, wind and wave setup, and wave runup. There are two primary mechanisms by which flood waters may enter the low-lying Place Road Community: wave overtopping (and, with sea-level rise, still water overtopping), and increased groundwater elevations. The Elwha River delta is exposed to both northerly and westerly wind waves, and to Pacific Ocean swell waves traveling east along the Strait of Juan de Fuca that can overtop the coastal berm separating Place Pond and West Pond from Freshwater Bay. Overtopping events have been documented in the 1970s, and evidence of gravel overwash fans (**Figure 58**) is visible on the landward side of the coastal berm. CGS (2009) provides additional detail on overtopping of the coastal berm into Place Pond. Under extreme coastal water levels, groundwater flow through the coastal berm into Place Pond and West Pond can increase pond water surface elevations. Groundwater flow may also enter from the northern end of the Place Road Levee, as high coastal water levels back up into the lower reaches of the river.

Flooding that occurs in the Place Road Community from Freshwater Bay is not mitigated by the Place Road Levee. During the 2011 modifications to the levee to improve flood resilience, the USACE noted that coastal flooding can still occur in Place Pond regardless of the levee improvements (USACE 2011). Coastal flooding is described in the recently updated FEMA maps (FEMA 2019), and is summarized in **Figure 59**. The blue-striped area in Figure 59 depicts the extent of the 100-year floodplain in the Place Road Community and overlays of structure footprints. Similarly, extreme coastal flooding is modeled under **Scenario 5** in the hydrodynamic model. Water levels in this event will exceed and inundate the low point at the east end of Elwha Dike Road, the residence at 1914 Elwha Dike Road, and the tennis court at 1916 Elwha Dike Road.

As sea levels rise, overtopping events will increase in frequency, and the volume overwashed during each event will increase. Elevated groundwater from high coastal water levels will cause even higher pond water levels than previously expected. While extreme coastal flooding rarely occurs today, in the future, an event with the same magnitude of inundation will occur on a more regular basis. Extreme events that today have a 1% annual chance to occur (i.e., a 100-year event) will become much more common as sea levels rise. With 0.8 foot of sea-level rise (anticipated by 2050), a 100-year event will occur with the frequency of a presentday 2- to 5-year event (20 to 50% annual chance to occur). **Figure 60** displays how these probabilities change over time for the 100-year total water level (USACE 2009).

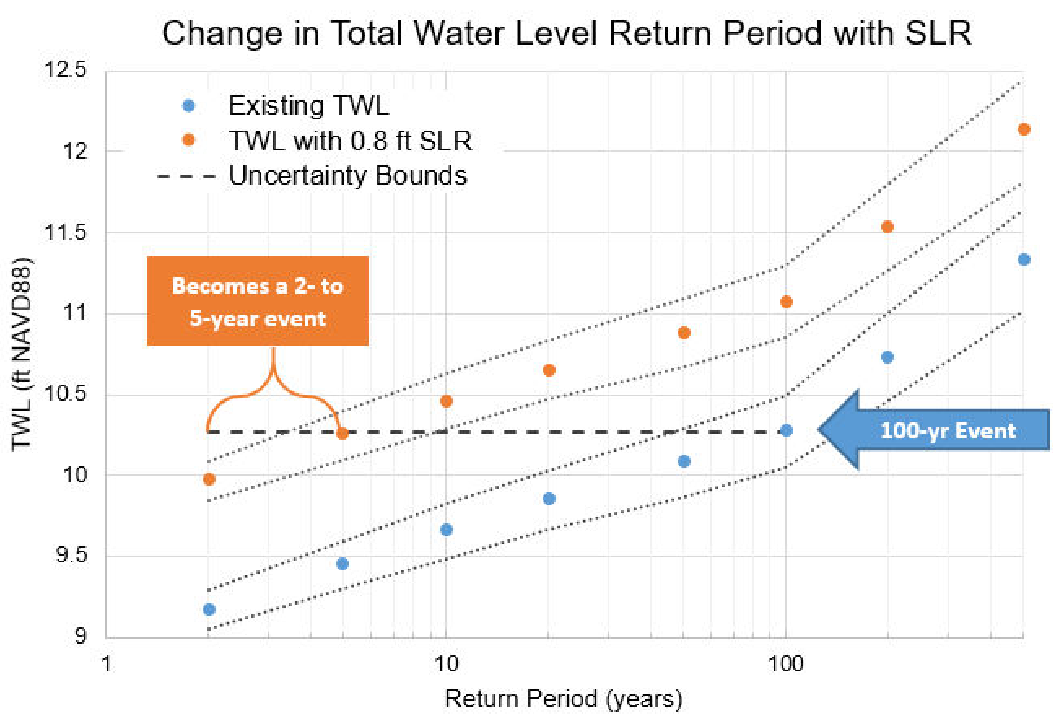
SOURCE: ESA 2020

Figure 58
Wave overwash gravel deposits along the landward side of the coastal berm fronting West Pond and Place Pond



SOURCE: FEMA 2019

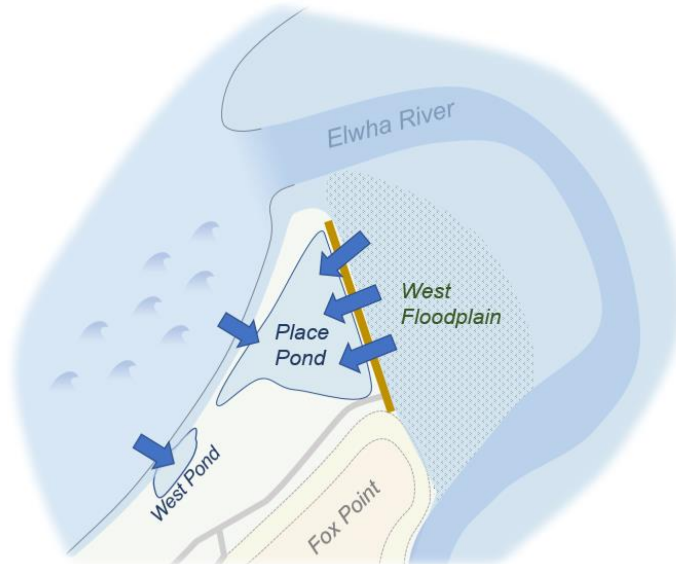
Figure 59
FEMA Coastal Flood Hazard Zone



SOURCE: USACE 2009, ESA 2021

Figure 60
Change in frequency of extreme events with 0.8 ft of sea-level rise

Combined Fluvial and Coastal Flood



Description: High flows on the Elwha River in combination with high coastal water levels and waves cause flooding in the lower estuary and along Freshwater Bay.

Existing Likelihood of Occurrence: Will occur infrequently to rarely. Flood event may be caused by two smaller coastal and fluvial events that occur simultaneously (e.g., a 20-year flood + a 20-year tide). Increase in severity and frequency with climate change.

Role of Place Road Levee: Levee prevents elevated floodwaters from directly inundating Place Pond from the east. Levee has no effect on runup and overtopping of the coastal berm. Groundwater flow through the levee gradually increases water levels in Place Pond and inundates low-lying surrounding infrastructure under some conditions. Levee may limit drainage pathways for receding floodwaters generated by overtopping in catastrophic events

If the levee is truncated or removed, elevated floodwaters from the Elwha River will directly reach Place Pond and surrounding infrastructure. Water levels in the Place Pond may already be elevated due to coastal flooding. Water levels will likely exceed ground elevations near buildings on the lowest parcels around Place Pond at the peak of the flood- as currently occurs.

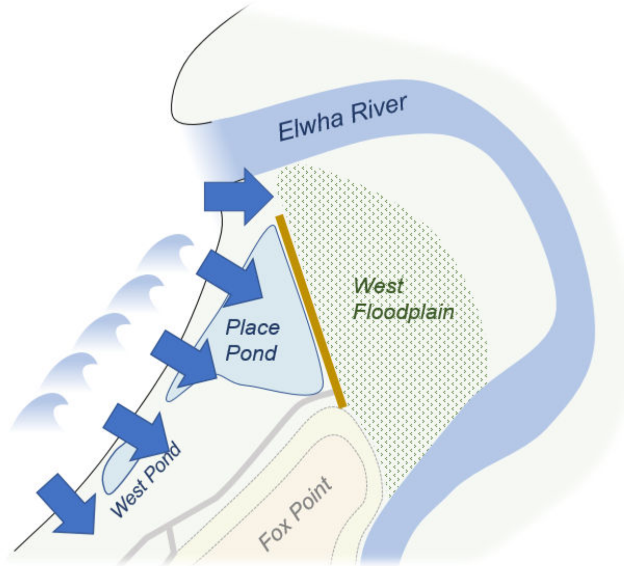
Role of WLRSC and West Floodplain: The WLRSC and West Floodplain do not directly influence planform adjustment of the lower Elwha River. This area is expected to aggrade, but smaller tidal channels may adjust through draining of flood waters. Formation of larger distributary channels through the West Floodplain is unlikely for existing conditions given that the levee limits head differential required to do so.

If the levee is truncated or removed, the area will equilibrate between coastal and Elwha River water levels. This scenario will produce the highest likelihood of planform adjustment due to the extent of inundated area. With relatively low-flow velocities on average, sediment transport capacity will correspondingly be low. When the tide recedes, the resulting sediment deposition patterns will drive the formation of drainage channels and a potentially larger channel with an outlet to the west delta as the Elwha River stage presumably remains elevated.

Details: A combined event consisting of a high flow on the Elwha River and high total water levels in Freshwater Bay could result in flooding of the Place Road Community under the current levee configuration. High river discharge in the Elwha River often occurs during periods of significant storm surge and elevated water levels in the Strait of Juan de Fuca (USACE 2009).

A small-to-moderate combined fluvial and coastal flood was simulated during the hydrodynamic modeling under **Scenario 1b** and **Scenario 2**. The modeled water level results indicate that, under existing conditions, a combined event with a relatively low return period (i.e., a 3- to 5-year event) can result in water levels in Place Pond that are nearly as high as under the 100-year Elwha River flood scenario. Flooding may be more extreme during a combined event of larger magnitude (e.g., a 10-year flow with a 10-year coastal water level). Sea-level rise and climate-induced increases in peak river flow will likely worsen flooding conditions for combined events.

Tsunami



Description: A tsunami caused by a major Cascadia Subduction Zone earthquake or an Aleutian Subduction Zone earthquake travels west through the Strait of Juan De Fuca and inundates the coastal floodplain. Destructive waves damage infrastructure and mobilize debris.

Existing Likelihood of Occurrence: A 10% to 40% chance to occur within the next 50 years (Randall et al. 2021; Butler et al. 2016; Stein et al. 2017; Oregon Emergency Management n.d.).

Role of Place Road Levee: Levee may confine tsunami pathways, potentially increasing water surface elevations in the coastal floodplain and limiting drainage pathways. If the levee were removed or breached, the flood hazard may be reduced slightly by allowing floodwaters to drain out toward the estuary and reducing wave reflection off of the levee.

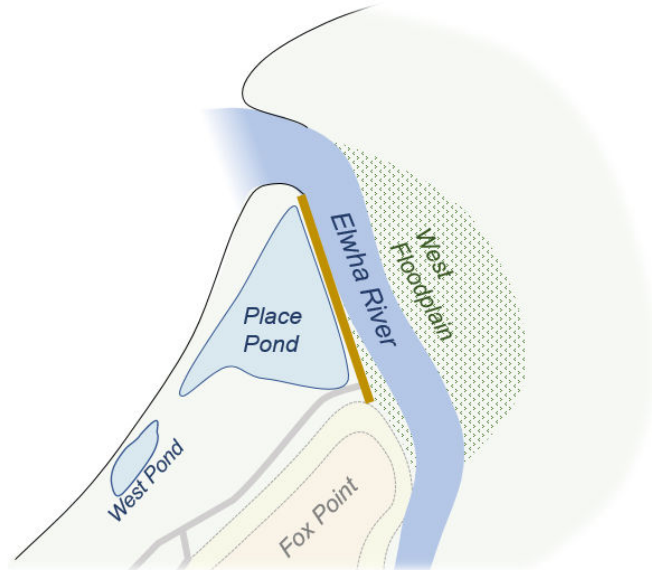
Role of WLRSC and West Floodplain: The WLRSC and West Floodplain have little to no influence on flooding during a tsunami, nor is significant geomorphic change expected in these areas as a result of a tsunami.

Details: A major tsunami (i.e., a Cascadia Subduction Zone earthquake event) would be extremely damaging to the community along Freshwater Bay. The entire coastal floodplain north of Fox Point may experience inundation exceeding 20 feet in depth and high-velocity currents. Place Road Levee offers no protection to the community in the case of such an event, and may exacerbate flooding impacts by limiting lateral pathways for floodwaters to disperse, and possibly causing wave reflection back toward the community. The levee may also block drainage pathways that naturally would drain to the lower estuary from the Place Pond and West Pond areas.

A major tsunami has not hit this region since the year 1700. Oral traditions from tribes and First Nations on both sides of the Strait of Juan de Fuca describe a devastating earthquake and tsunami that occurred around 1700.

This event was not modeled as part of this study, but additional details (including recent hydrodynamic model results conducted by others) on tsunamis at the Elwha River estuary are provided in Section 3.9.

Mainstem Avulsion Toward Levee



Description: Elwha River mainstem channel erodes a new channel parallel to the levee along all or part of the levee length. Erosion at the terminal end of the levee is possible. Water levels in Place Pond likely increase due to increased groundwater flow through the levee prism.

Existing Likelihood of Occurrence: Unlikely. Mainstem has meandered eastward over last 60 years. Elevations are relatively high in the south end of the West Floodplain, reducing likelihood of avulsion.

Role of Place Road Levee: Levee prevents river from avulsing farther west into Place Pond and surrounding area. Scenario assumes Place Road Levee maintains structural integrity under mainstem river flows moving along levee (1965 photo, **Figure 61**) or perpendicular to levee (1990 photo, Figure 61).

If the levee were removed or breached, it is possible that an avulsion may occur farther to the west, reaching Place Pond and the Place Road Community. A breach or limited removal of the levee may inhibit the ability of the channel to move farther west; however, floodwaters are likely to directly reach the pond with even a limited open breach, as shown in the Alternative 3 model results. This will subject the lowest-elevation parcels around Place Pond to flooding under river flood events and elevated coastal water levels. In the absence of the levee, it would be possible for the channel to reoccupy the 1964 alignment and pass through the existing Place Pond. This would subject low-lying parcels to significant erosion.

Role of WLRSC and West Floodplain: The east/riverside of the levee and West Floodplain are heavily vegetated as of 2021, with naturally recruited vegetation and continue to provide one of the most important side channel habitats along the Elwha River delta for fish (Quinn et al. 2013a, 2013b; Shaffer et al. 2009, 2017a, 2017b; Lincoln et al. 2018). If the Elwha River migrates or avulses parallel along the Place Road Levee, a portion of the West Floodplain would likely remain as a mid-channel bar (vegetated island) and possibly sustain an anabranching planform leading to the outlet. While the WLRSC would be converted to mainstem habitat, a new floodplain or off-channel habitat would be expected to form toward the eastern floodplain.

If the levee were removed or breached, the Elwha River will eventually form an outlet to the west delta. It is expected that additional distributary or blind tidal channels will develop from this new alignment. Abandonment of the current mainstem channel is unlikely in this scenario. The persistence of a multi-threaded planform would more effectively distribute stream power in the lower Elwha River and provide a greater range of habitat types and area across the estuary.

Details: If the lower reach of the Elwha River were to meander or avulse back to the western side of the floodplain, the main channel may come into contact with the levee along all or part of its length. This is similar to the configuration of the channel in 1965 following levee construction and in 1990 when a portion of the channel directly contacted the levee.

Although the levee is not a certified federal levee, the USACE analysis indicates that the levee should function as designed during the existing levels of a 100-year Elwha River flood with a 90% confidence. The exterior facing of the levee is armored with rock sizes ranging from 24 inches to 48 inches, which offers a degree of scour protection from mainstem river flows if the channel were to avulse as described in this scenario, but it would not remain structurally competent without regular maintenance. Riprap generally attracts flow and will encourage development of the channel thalweg along the levee toe. Without additional hydraulic roughness from wood or vegetation, habitat along the levee will be severely limited in quality and quantity.

River morphodynamics are difficult to predict. The lower mainstem channel is likely to continue migrating toward the east of the river valley for the foreseeable future, until a disturbance (natural or man-made) or extreme event (coastal, fluvial, or combined) initiates a sudden change in planform. A large fluvial event could cause a more rapid avulsion toward the west; however, this is less likely given the current elevations and vegetation density within the West Floodplain. It is possible that a meander cutoff upstream of the intertidal zone affects the channel alignment and outlet location, which is similarly event-based and difficult to forecast.

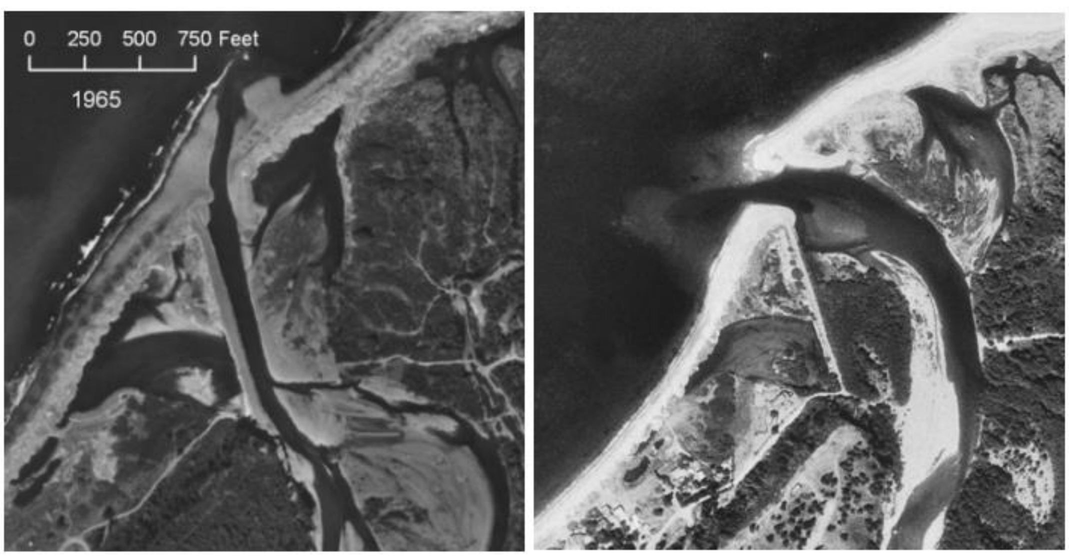


Figure 61
A 1965 (left panel) and 1990 (right panel) aerial image of the lower Elwha River estuary

Outflanking of North End of Levee

Description:
River continues to extend to the west and south as waves build the barrier sandbar in front of the outlet. River flow redirected by the bar eventually erodes the existing beach berm and reconnects Place Pond to the mainstem. Low-lying infrastructure around the pond becomes directly connected to tidal and lower estuary water levels.

Existing Likelihood of Occurrence:
Possible. Although the river may continue to extend toward the west as the bar builds, the flow is unlikely to be directed sufficiently far south to erode the existing beach berm (which is more than 150 feet wide) seaward of Place Pond. The more the river bends to the south, the longer it becomes and the less steep its water surface gradient becomes. If this path becomes longer, the river will likely seek a hydraulically shorter path directly through the barrier sandbar somewhere farther to the north. However, the river outlet has been moving closer to Place Pond over the last several years (see Figure 32), and the outlet of the river has historically been located in this region.

Role of Place Road Levee: Outflanking of the levee is possible, although unlikely in the short term at present levee alignment. Levee does not reduce flood hazards to low-lying infrastructure east of the levee under this event. If the levee were removed or breached, this condition may occur somewhat more readily. See *Mainstem Avulsion* description.

Role of WLRSC and West Floodplain: Evolution of the West Floodplain shape and extent is currently paired with the meander development at Fox Point Bluff. The current trend of the West Floodplain is an expansion of the gravel bar eastward and subsequent colonization by vegetation, which corresponds with a wider meander bend and increased likelihood of the Elwha River outflanking the northern end of the Place Road Levee. However, the downstream end is largely controlled by coastal processes and by beach topography downstream of the West Floodplain and the WLRSC. Outflanking of the levee assumes that the outlet remains in its current position or moves farther to the west.

Details: High-energy waves push sand up on the shore, which can form sandbars at the outlet of the estuary. These bars can redirect river flow parallel to the shoreline before the river eventually exits at the Strait of Juan de Fuca. Periodically, as this process causes the river to lengthen, the river will tend to seek a new, shorter path through the sandbars, forming a new outlet. Historic drawings of the lower Elwha River show wet lagoon areas on both sides of the outlet, indicating that the river outlet likely migrated parallel to shore throughout this region (Section 2).

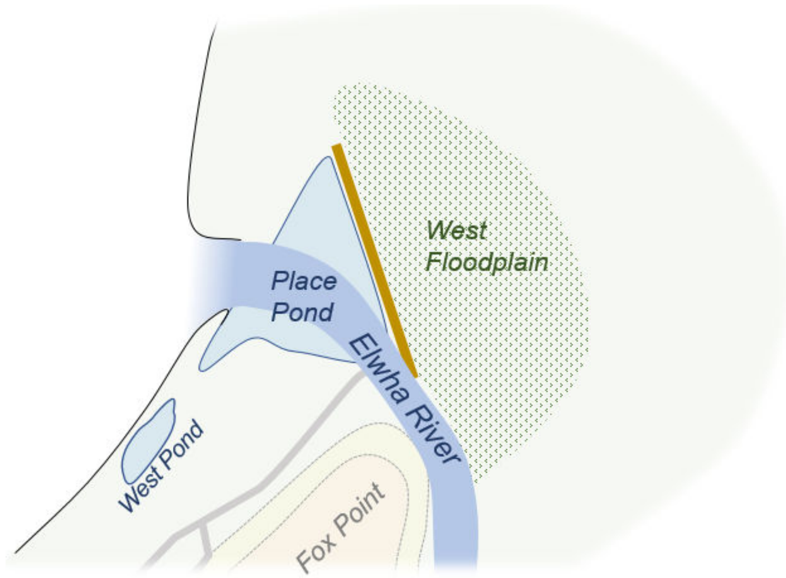
If the barrier bar that extends partially across the outlet as of late 2021 (**Figure 62**) continues to build to the southwest, the outlet may carve into the existing beach berm that fronts Place Pond. This would result in Place Pond and surrounding low-lying areas becoming directly connected to water surface elevations in the lower estuary, which may flood low-lying infrastructure under some scenarios. This event has not been evaluated as part of the hydrodynamic modeling. However, the conceptual model of the system suggests that elevations in Place Pond would be more similar to Port Angeles tide elevations than river stage elevations observed half a mile upstream at the lower Elwhay River gage. Increased salinities in Place Pond would likely become brackish or saline, which would impact adjacent septic systems.

SOURCE: Google Earth 2021

Figure 62
Barrier bar extending westward in July 2021

Fox Point Erosion and Outflanking of South End of Levee

Description: Erosion or bluff failure of Fox Point allows Elwha River to outflank south end of levee and avulse into Place Pond, following the 1964 mainstem pathway. Low-lying infrastructure around pond becomes directly connected to tidal and lower estuary water levels. Infrastructure in the mainstem pathway likely structurally damaged.



Existing Likelihood of Occurrence: Highly unlikely given existing rates of bluff erosion, levee armoring, and relatively high elevations in the West Floodplain, although possible to occur on long-term geomorphic timescale.

Role of Place Road Levee: Outflanking of the levee is possible, although highly unlikely in the short term. Levee would isolate the mainstem from the eastern estuary. If the levee were fully removed, this condition may occur somewhat more readily. See *Mainstem Avulsion* description.

Role of WLRSC and West Floodplain: A sudden change to the downstream hydraulic and geomorphic control would be necessary to route the Elwha River mainstem channel through the southern end of the Place Road Levee. The West Floodplain substrate is highly erodible material and subject to channel avulsion under a specific set of circumstances: a valley- or channel-spanning flow obstruction that prevents channel formation east of the West Floodplain, elevated stage in the Elwha River, and low estuarine energy. The WLRSC and West Floodplain would have an insignificant role under the aforementioned conditions.

Details: It is possible, although highly unlikely, that ongoing or sudden erosion at the base of Fox Point, in tandem with a major river avulsion could outflank the south end of the levee. Such an event is highly unlikely, given the modifications to the levee in 2009–2010 improved the southern tie-in at Fox Point, the relatively low rates of erosion at the end of Fox Point, and the vegetation in the West Floodplain. However, the slopes around Fox Point are identified as “unstable” in the Washington Coastal Atlas (WA Ecology 2004).

If such an event were to occur, the mainstem would pass through the west estuary via Place Pond before reaching the Strait of Juan de Fuca in a configuration similar to the 1964 channel alignment. Low-lying structures in the west estuary would be directly exposed to both fluvial and tidal flooding. Structures may be damaged as the river cuts a new channel through the historic west estuary. The east estuary may become disconnected from the mainstem of the river.

7.2.1 Levee Maintenance and Mitigation

Should the Place Road Levee remain in-place, it will likely require maintenance to ensure its structural integrity into the future. Repairs may include adding material, resetting riprap, resloping, and vegetation removal. Regular maintenance on the levee may need to be increased in the future as sea levels rise and floodwaters more frequently come into contact with the river-side of the levee.

In late 2020, NOAA NMFS issued a biological opinion that will require landowners to provide mitigation for both new projects and maintenance work on shoreline structures (NOAA and the Department of the Army's Civil Works 2020). NMFS concluded that repair and maintenance of existing structures will still constitute an incidental take of endangered Chinook salmon in Puget Sound. Therefore, future maintenance work on the Place Road Levee is likely to require mitigation. The extent and type of mitigation required will depend on the type of maintenance work and the anticipated lifespan of levee repairs. A copy of the memorandum between NMFS and the Department of the Army's Civil Works program describing the updated policy is included as **Appendix G**.

7.2.2 Adaptation Strategies

Considering the existing and future flood hazards to the Place Road Community, landowners may seek methods for managing these hazards. Several strategies could reduce the impacts of flooding as the frequency and magnitude of flood events increase into the future. These include improving the Place Pond Levee, construction of a setback dike or ring dike around low-lying properties, elevation of structures in-place, and relocation of structures.

A setback dike or ring dike could be constructed along the southwest edge of the pond to restore habitat function and reduce the hazard to adjacent parcels from coastal flooding from Freshwater Bay and high water levels in Place Pond. There has been extensive work looking at dike modifications prior to dam removals (USACE 2003, 2005). Another adaptation strategy previously considered by the USACE in 2003–2005 is the raising of structures in-place to elevations above anticipated flood levels. Raising building elevations could allow modifications to the levee for fish passage (i.e., Alternative 1, 2, or 3). Elsewhere in the Elwha River watershed, the National Park Service has assisted in raising the finished floor elevation of several at-risk homes in the floodplain on Hot Springs Road as a flood adaptation measure.

Moving the structures at 1914 Elwha Dike Road and 1916 Elwha Dike Road to higher ground is another adaptation option to reduce flood hazards and restore habitat function. A portion of the lot at 1916 Elwha Dike Road is higher in elevation and would be a location with less flood hazard. Options are limited for relocating the building at 1914 Elwha Dike Road within the lot, because most of the lot is low in elevation. It may be possible to move the building to a nearby lot with reduced hazards.

Relocation of at-risk structures is a widely recognized risk reduction strategy for shoreline infrastructure that has fewer impacts to the natural environment than hard armoring or other defense strategies. Relocating structures within the floodplain moves development away from sensitive coastal and estuarine environments while reducing flood exposure for structures. The Washington State Marine Shoreline Design Guidelines (Johannessen et al. 2014) describes retreat or relocation examples in Washington State and provides guidance on how relocations for public and private infrastructure can be implemented. A recent Island County study also identifies a number of strategies for residential landowners adapt to sea level rise (Mulkern et al. 2020). Although targeted toward sea level rise exposure, the strategies are widely applicable to other types of increased coastal, estuarine, or fluvial flooding risk. Accommodation measures are intended to allow shoreline residents to live with increased flood risk and include damage reduction practices such as wet or dry floodproofing, building elevation, septic system improvements, water supply diversification, and utility consolidation. The Island County guidance also describes on-site and off-site managed retreat practices and highlights that managed retreat allows more room for habitat.

Structures farther west along Freshwater Bay are also within the 100-year FEMA flood zone due to coastal flooding. Their flood hazard will continue to increase with sea-level rise. However, these parcels appear to have limited vulnerability from fluvial or estuarine flooding from the Elwha River.

7.2.3 Conservation of Parcels for Restoration

Modifications to the levee to allow for fish passage into the historic west estuary area would increase the flood risk of eight parcels in the Place Road Community in the short term, and 10 parcels by year 2100 under climate change conditions. To enable full restoration of the west estuary, parcels at additional flood risk from restoration may be acquired and placed under conservation to accommodate potential inundation. This would allow for full or partial removal of the levee without significant change in flood hazard to parcels farther to the west. CWI has already acquired the 74302 parcel for conservation purposes.

Table 10 outlines which parcels would be affected by a major fluvial flood following levee modification.

TABLE 10
PARCELS AFFECTED BY RESTORATION ACTIONS

Parcel No.	Address	Ground Elevation Near Structures (ft NAVD88)[1]	Peak Water Level in 100-year River Flood After Restoration (ft NAVD88)	Increased 100-year River Flood Hazard After Restoration	Peak Water Level in 100-year River Flood with 2100 Climate Change, After Restoration (ft NAVD88)	Increased 100-year River Flood Hazard with 2100 Climate Change, After Restoration
74013	N/A	N/A	11.3	Already Open Water	11.9	Already Open Water
73967	N/A	N/A	11.3	Already Open Water	11.9	Already Open Water
73964	N/A	N/A	11.3	Already Open Water	11.9	Already Open Water
74515	1916 Elwha Dike Rd	12.0	11.3	Yes	11.9	Yes
74522	1914 Elwha Dike Rd	10.3	11.3	Yes	11.9	Yes
74523	N/A	N/A	11.3	Yes – No Structures Present	11.9	Yes – No Structures Present
74301	1912 Place Rd	N/A	11.3	Yes – No Structures Present	11.9	Yes – No Structures Present
74302	1922 Place Rd[2]	N/A	11.3	Yes – No Structures Present	11.9	Yes – No Structures Present
74296	1924 Place Rd	N/A	11.3	Yes – No Structures Present	11.9	Yes – No Structures Present
74303	1962 Place Rd	15.2	11.3	Yes – Flooding Away From Structures	11.9	Yes – Flooding Away From Structures
74304	1974 Place Rd	13.5	11.3	Yes – Flooding Away From Structures	11.9	Yes – Flooding Away From Structures
74305	1984 Place Rd	14.4	11.3	No	11.9	Yes
75306	2006 Place Rd	13.9	11.3	No	11.9	Yes – Flooding Away From Structures

1. Ground elevations from LiDAR near building pad – these elevations are not finished flood elevations and have not been surveyed by a professional land surveyor
2. Owned by CWI

7.3 Fish Habitat Benefits

The reconnection of the historic estuarine habitats west of the Place Road Levee would greatly expand the estuarine rearing habitats available to juvenile salmonids. The restored habitats would range between approximately 6.4 and 8.3 acres throughout a typical year. The restored historic estuarine habitats would be expected to provide high-quality rearing conditions for juvenile salmon. The connection between the restored habitats and the rest of the estuary is expected to result in similar water quality conditions in all parts of the estuary.

The restored historic estuary habitats are expected to be readily accessible to juvenile salmon regardless of which levee modification alternative is considered. Based on the elevation of the channel connection to the restored habitats, it is expected that the water direction will be into the restored habitats – and most favorable for juvenile salmon movement into the habitats – during approximately 30% of the tidal cycle.

Climate Change and Other Land Use Pressures

Reconnecting historic estuarine habitat in the west estuary would increase the resilience of the Elwha estuary to adapt to increasing climate change and land use pressures in the basin. Reconnection of the west estuary provides additional physical space for natural habitat adjustment with sea level rise, and additional refuge for off channel habitat under high riverine flows, which are anticipated to increase and become more frequent with climate change. Reconnection also increases the resilience of the system by providing a diversity of habitats with varying depths, vegetation cover, vegetation types, velocities, salinities, and substrates. This habitat diversity offers fish and other organisms options for refuge as stressors from climate change and other land use pressures, such as water diversions, increase.

7.4 Conclusions

- *What is the role of the Place Road Levee in lower river hydrodynamics including channel migration?*

  Place Road Levee acts to prevent direct connection of the Elwha River to the historic western estuary area. Under conditions up to the 100-year river flood, the levee offers flood protection to the Place Road Community. However, the levee provides little protection from coastal hazards, and partially blocks the flow of sediments to eastern Freshwater Bay shorelines, which helps maintain shorelines along much of the Place Road Community. The levee fully blocks fish passage into the historic west estuary.

  While the construction of the levee and other channel modifications have significantly influenced the lower Elwha River morphology in the past, the levee exerts little influence on sediment erosion, deposition, or lateral migration patterns of the mainstem channel post dam removal. Recent trends from aerial imagery (2011–2020) indicate that the West Floodplain/gravel bar has remained stable, although erosion at the downstream end of the first meander shows slow translation of the meander to the north. The area of greatest change, and likely short-term continued migration, is the increasing amplitude of the downstream meander to the east.

However, the levee continues to affect sediment, surface water, and groundwater processes in the WLRSC and other smaller channels in the vicinity of the levee. The levee blocks tidal flows from reaching Place Pond thus limiting the tidal exchange through the channel and the sediment flushing capacity of the channel. The presence of the levee makes the WLRSC less resilient to sedimentation. Following the increase in sediment loads after dam removal, the WLRSC has aggraded. This trend is anticipated to be mitigated or reversed were the tidal prism in the Place Pond area to be reconnected to the estuary.

- *What factors contribute to the hydrologic conditions of Place Pond and the low-lying area west of the Place Road Levee?*

  Water levels in Place Pond and the low-lying area west of the Place Road Levee are heavily influenced by groundwater exchange with the Strait of Juan de Fuca and the Elwha River. Under current conditions, the levee prevents surface water from directly overflowing from the river to the pond under extreme events. However, extreme coastal floodwaters are able to overtop the coastal berm and enter the pond area from the Strait of Juan de Fuca. Local precipitation is not considered a major contributor to hydrologic conditions in the pond area, since the pond's watershed area is so small. Groundwater is the primary driver for hydrologic conditions in Place Pond.

- *To what extent does the existing levee protect the Place Road Community from current and future flood hazards?*

  The levee does not provide flood protection against coastal hazards, including tsunamis and coastal flooding. FEMA maps the area around Place Pond as within the 100-year flood zone under existing conditions despite the presence of the Place Road Levee. Furthermore, the levee is permeable and conveys groundwater through and below the levee into the pond as evidenced by the hourly water level changes observed. Elevated water levels in Place Pond can occur under extreme conditions due to groundwater flow. However, the levee does provide protection for fluvial flooding at least up to the 100-year event by blocking direct overland flow across the levee alignment.

  Under the alternatives evaluated with partial or full removal of the levee, elevated floodwaters in the estuary would be conveyed via a surface connection into Place Pond. This would cause higher water levels than under current conditions for all alternatives, including under the limited 75-foot breach alternative. Flood waters conveyed via this connection would extend across eight parcels under extreme conditions (and ten parcels with climate change), although flood water would reach only the building at 1914 Elwha Dike Road and the tennis court at 1916 Elwha Dike Road under existing conditions. An opening in the levee may beneficially convey floodwaters from coastal overtopping (which is not limited or prevented by the presence of the levee) out of the Place Pond area, and thus reduce flood durations across nearby parcels already within the coastal flood zone.

  As climate change occurs, increased peak flood flows and elevated sea levels increase the hazard to the Place Road Community. Details on these hazards are described in the following section.

- *How does climate change effect future flood hazard to the community?*

  Climate change, including sea-level rise and peak river flow rate increases, are anticipated to further elevate the flood hazard in the Place Road Community. Increased sea levels will elevate groundwater in the study area, thereby increasing base water levels and peak water levels in Place Pond, and limiting the potential for the pond to drain to the ocean.

Elevated sea levels will also increase the frequency and severity of coastal overtopping of the coastal berm. With 0.8 foot of sea-level rise, which may occur as soon as 2050, water levels as extreme as present-day 100-year coastal flooding may occur every 2 to 5 years. Increases in peak river flow rates increase the likelihood of direct river overtopping of the Place Road Levee and increase groundwater flow into Place Pond.

Model Scenario 6 evaluated water levels in the pond with simulated climate change conditions in the year 2100 and found that peak pond water levels increased approximately 1 foot over present-day conditions via groundwater exchange, despite the presence of the levee. This is likely an underprediction of water level increases (see Section 5.7).

Under a partial or full removal of the levee, the extent of flooding during a peak event will increase with climate change. With 0.8 foot of sea-level rise (year 2050), floodwaters will reach the building at 1914 Elwha Dike Road, the tennis court at 1916 Elwha Dike Road, and the building at 1916 Elwha Dike Road. A total of 10 parcels will be at increased risk of flooding by year 2100.

- *Are there modifications that can be made to the levee to improve ecosystem function and allow functional fish access to the west estuary while still providing the current level of protection to the Place Road Community?*

  Modifications to the levee that would include a truncated levee or fully removed levee would subject low-lying properties around Place Pond to water levels in the lower estuary, which would exceed ground elevations near the homes at 1914 Elwha Dike Road and 1916 Elwha Dike Road and along portions of Elwha Dike Road itself during flood conditions.

  An alternative option would be to purchase the parcels immediately adjacent to Place Pond that have the highest degree of existing and future flood hazard. This would allow for full or partial removal of the levee without significant change in hazard to parcels farther to the west. A table of these parcels is provided in Table 10.

- *Are there other adaptation measures that the community could pursue that would increase flood resilience, and allow for habitat uplift?*

  There are adaptation measures that could be pursued by the Place Road Community that would not only increase the flood resilience of the homes that occupy the neighborhood, but also allow for habitat uplift in the west estuary. These include raising the built elevation of homes in-place, building relocation, and constructing a new setback levee. However, such adaptation measures may be costly, would not entirely eliminate flood risk to existing properties, and would require ongoing maintenance.

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Appendix A
Community Concerns

The following comments and questions were provided to CWI at the onset of this project.

We have heard anecdotal evidence for a lower river natural dam break flood during the era of the Place Rd levee. We are aware of a natural dam break flood in the Grand Canyon of the Elwha (>20 river miles upstream in 1967). Is there any history of a lower river landslide/natural dam break flood during that era as well?

The project team was unable to find evidence of such an event in the lower Elwha River. It is possible that a channel avulsion routed a large pulse of water, sediment, and debris to the lower river and estuary. The Hunt Road Side Channel, for example, has a history of cycling through phases of being the main channel or an anabranch, or being completely cutoff. When a floodplain channel is suddenly reoccupied, a torrent of wood and debris can be mobilized to form channel-spanning logjams or be transported downstream.

The Lower Elwha Klallam Tribe removed 4 levees from the east bank of the lower Elwha River in preparation for dam removal. Are there any other lower river levees or floodplain alterations that effect lower river process? If so, is there an interaction with the Place levee?

Infrastructure, particularly levees, have played a relatively minor role in driving channel planform evolution in the lower Elwha River.

Removal of eastern levees have opened up more floodplain area for the river to occupy during flood events. The Federal Levee is increasingly engaging with flow conveyed in the "Eastern Side Channel," which originates at RM 1.6 on the right bank of the Elwha River. The Federal Levee disconnects the historic floodplain surface to the east, but is not directly influencing lower river processes or planform.

The lower Elwha River is still responding to channel modifications from the 1950-1980s through meander development in the short term and re-establishment of an anabranching planform in the long term. Push-up, or sugar dikes, were constructed within the active river corridor and not all were documented. Some are still present in the floodplain today which influence flow patterns during floods (see Figure A.1).

The "Historic Anabranch" channel is a former river outlet, visible from 1939-1956 aerial photographs. These relict scars offer immediate opportunities as overflow channels and potential future mainstem alignments.

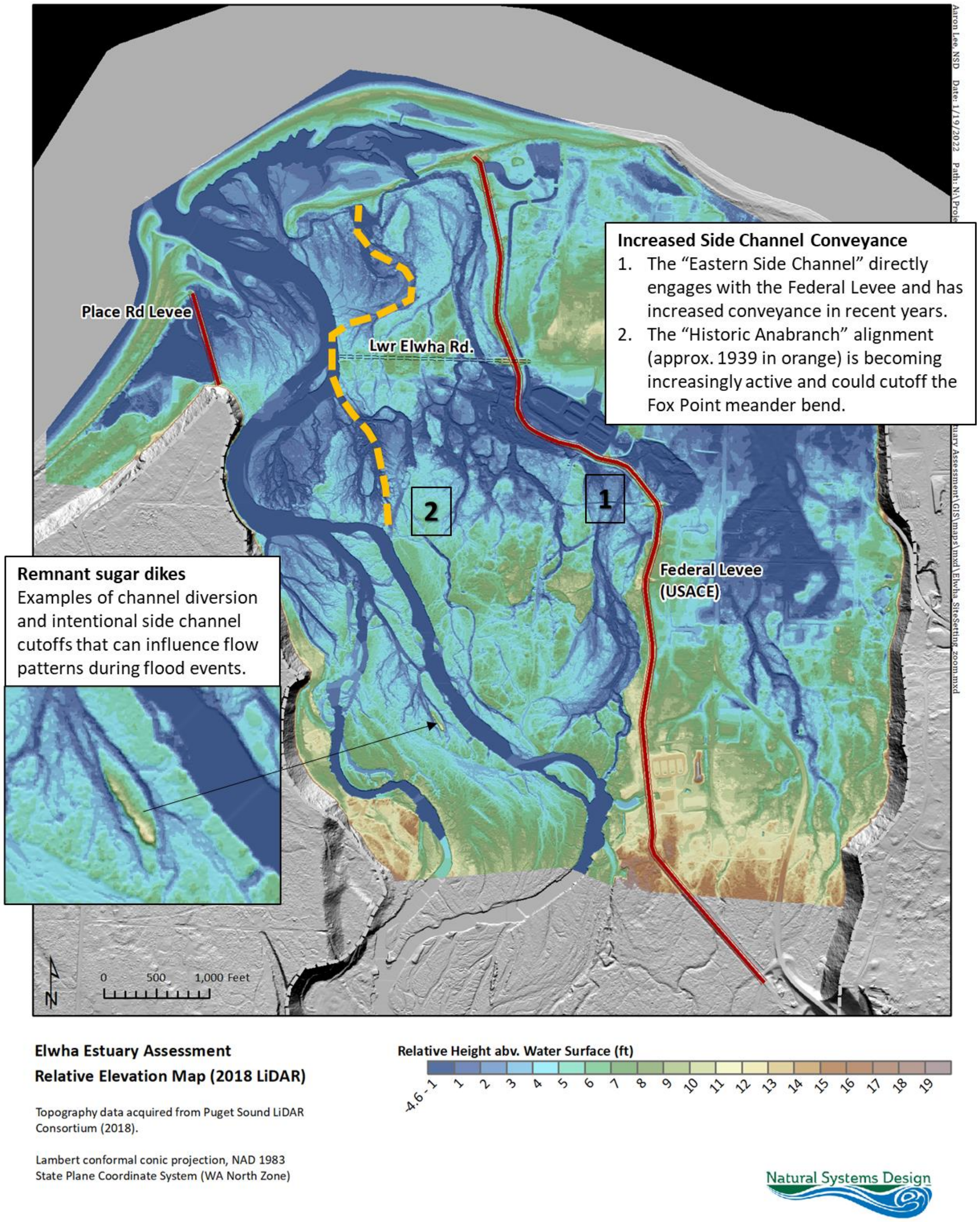

Figure A.1
Relative Elevation Map

Lower river and natural feeder bluff processes exacerbated by land clearing are actively eroding the Fox Point bluff, does the Place Levee provide flood protection from the continued erosion of this landform located immediately upstream of the levee?

A discussion of the interaction of the river, Place Road Levee, and Fox Point Bluff is provided in Section 6.2 ‘Fox Point Erosion and Outflanking’.

Long-time neighbors report playing around the WW II bunker on Fox Point. Our understanding is that the bunker slid down the hill due to river erosion in the late 50's/early 60's

The Elwha has been actively eroding Fox Point Bluff since at least 1936 as the meander moves westward. Over geologic history, the river has periodically engaged with and eroded the Fox Point Bluff landform.

We have pictures from the 1960's where the river was flowing through the gully between our home and the beach. The former owner of our property told us this was river flow and not tidal surge although the tide was probably high and the weather had been stormy.

The Place Road Levee was constructed in 1964. If the photos were before levee construction, the images likely showed elevated water levels in the western distributary channel that occupied the area which is now Place Pond. Water levels may have been elevated as a result of river flooding and coastal flooding. If the photos are from after the levee construction, the floodwaters in the photograph likely came from wave overtopping of the coastal berm into the low-lying Place Pond area. Without a specific date, it is difficult to identify the source of the floodwaters; however, the Place Road Community has always been and continues to be exposed to coastal flooding across the coastal berm.

Appendix B

Lower River Geomorphology and Channel Dynamics Memo

ESA

To: Hannah Snow, PE (Environmental Science Associates)

From: Aaron Lee, MS, EIT, Tim Abbe, PhD, PEG, PHG, Steve Winter PH, PWS
(Natural Systems Design)

Date: February 15, 2022

Re: Elwha Estuary Hydrodynamic Assessment – DRAFT Geomorphic Setting

INTRODUCTION

This assessment examines the Lower Elwha River immediately above its outlet into the Strait of Juan de Fuca. The focus is on the historical, current and future effects of the West (Place Road) levee on processes and habitat. This evaluation is based on our assessment of historic channel planform, channel migration trends, delta distributary channels and tidally influenced habitat.

The lower Elwha River is a meandering-anabranching channel within an alluvial valley. In the lower mile of the river its main channel has a bankfull width of 100 to 150 feet and an alluvial valley bottom (floodplain) width of 5,800 to 6,000 feet. Over recent geologic history (last several thousand years) up until the early twentieth century the river had active channels across much of the lower valley. Construction of the Federal Levee and Place Road Levee in the lower valley reduced the river's floodplain to less than half its natural width.

Channel planform and migration are influenced by a variety of factors: riparian vegetation, in-stream wood, flow, sediment supply and human actions. Disturbances to a river induced by natural processes (floods, landslides, earthquakes) or human activities (channel modification, levees, forest clearing, dams, floodplain development) can shift a system from one state to another. The Elwha River historically maintained multiple channel threads or distributaries at its outlet. This section describes the current geomorphic setting of the Elwha River, what past processes led to its contemporary state, and projections of future trends on the Place Road Levee and its surrounding features.

In this report, several time periods are distinguished by distinct events related to the former Elwha River dams. The years prior to dam construction (1913) are referred to as "historical" conditions. The Elwha River and Glines Canyon dams remained in place until their removals in 2011 and 2014, respectively. "Post dam-removal" is generally referred to the time after 2011. "Contemporary" refers to conditions that best represent the present conditions, which is in part based on availability of topographic data (2018-2020). Anticipated future conditions are generally referred by "short-term" and "long-term" outlooks. The former is within the time period of 0 to 5 years and the latter is in terms of multiple decades to centuries.

Contemporary Geomorphic Setting

The lowest 1.0 river mile (RM) segment of the Elwha River has a single meandering channel that is flanked by gravel bars and vegetated floodplain with an average gradient of 0.3 percent. The floodplain is heavily vegetated, though the underlying sediment is composed of alluvial material which is subject to erosion and reworking during high flow events. The Elwha River has a history of lateral channel mobility across the entire width of the valley floor, as evidenced by relict channel features and erosion along its valley walls shown in Figure 1. Following the removal of the Elwha (2011) and Glines Canyon (2014) Dams, the restored connectivity of sediment and wood transport from the upper basin has contributed to the re-establishment of an anabranching planform in the lower Elwha River.

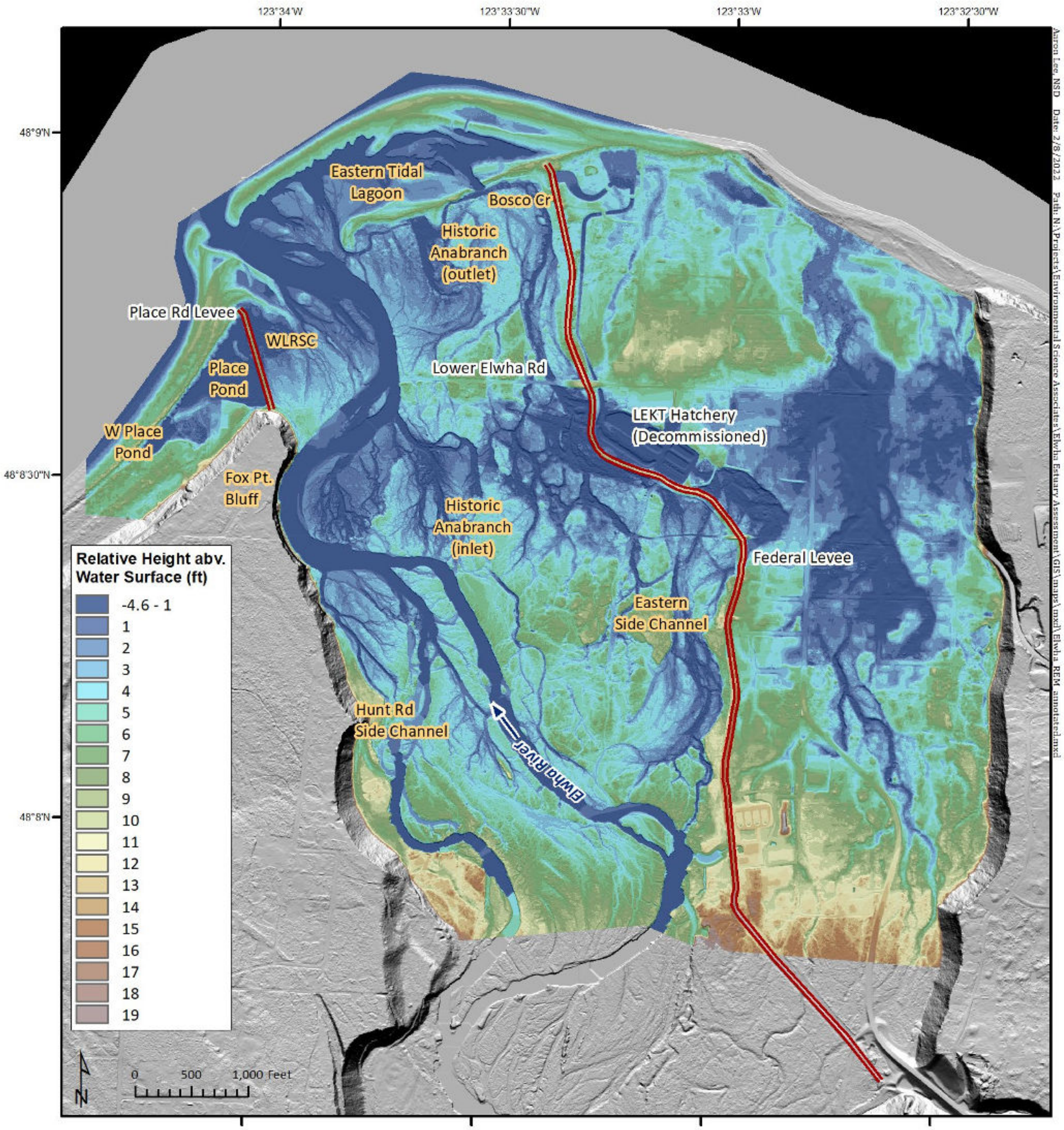

Figure 1. Relative elevation map based on a 2018 LiDAR-derived digital terrain model. The current alignment of Place Road Levee and the Federal Levee are shown in red. Western Lower River Side Channel is abbreviated as "WLRSC." The "Historic Anabranch" refers to the eastern channel of the Elwha River visible in the 1939 alignment. Its inlet is the former mainstem channel and bifurcation point and outlet is the former terminus to the Strait of Juan de Fuca.

Based on LiDAR-derived topography (QSI, 2019), the entire Elwha River valley bottom would be accessible to overflows from the main channel. However, the Federal Levee disconnects up to 60 percent of the valley bottom in the lower Elwha River, leaving 40 percent of its historical corridor accessible by the river. Place Road Levee extends from the northern tip of Fox Point Bluff approximately 900 feet to the northwest. Within the tidally-influenced zone (approximately to Fox Point Bluff in Figure 1), the active stream corridor is confined by Place Road Levee to the west and the Federal Levee to the east.

The western floodplain, in the vicinity of "western lower river side channel" (WLRSC) feature in Figure 1, includes low-lying terrain vegetated primarily with deciduous trees and a lateral bar composed of deposited sediment ranging from large cobble-sized material to sand and silt, indicating a relatively young and emergent feature on the geologic timescale. This bar has accumulated large wood and debris in recent years and is colonized by patches of vegetation. The western floodplain is inundated on an annual basis, but flows are typically shallow and broad across the vegetated area. Adjacent to the northern end of Place Road Levee on the streamward side is the WLRSC, which is a perennially inundated feature that is engaged both by flood flows from the Elwha River and fluctuations in tidal levels. This feature is located within an area occupied by one of the river's distributary channels in 1939 and is currently connected to the mainstem channel through a tidal channel when tidal elevations in the estuary are sufficiently high (Figure 2). The WLRSC is a drainage point for flood flows on the western floodplain but is not a flow-through channel.

Immediately upstream, the Elwha River meanders along the toe of Fox Point Bluff with a single channel thread. Erosion typically occurs along the outer meander bend where flow is concentrated, resulting in episodes of localized hillslope failure along the bluff. As flow exits the meander bend and overtops its left bank, sediment transport capacity is significantly diminished, and deposition of fine sediment occurs. Meander development at Fox Point Bluff has a direct impact on the formation and expansion of the western floodplain surface. A series of overflow channels through vegetated floodplain on the east side of the channel offer flow relief during floods. At this point, and approximately 4,000 feet upstream from the outlet, the influence of tides on water surface elevations in the Elwha River becomes muted. The planform in the reach segment upstream of the tidally-influenced reach is anabranching; two distinct channel threads split flow across a vegetated floodplain island, and while relatively stable at a decadal timescale, episodes of channel migration and avulsion can shift the direction and conveyance of primary flow paths.

Historical Context

The lower river and estuary have always been dynamic due to its low gradient and exposure to riverine and coastal processes. Historical maps from 1872 through 1919 document the presence of multiple outlets at the delta and an anabranching planform in the lower Elwha River, which a 1939 aerial photograph validates (Figure 2). The reduced sediment supply from the basin above the former dams to the Elwha River estuary, estimated between 2 to 10 percent of pre-dam yield (Magirl et al., 2014; Ritchie et al., 2018), resulted in a steeper bed gradient at the river outlet. Over the century (1913-2011) the dams were in place, the lack of sediment supply resulted in channel incision, a coarse boulder-bed dominated substrate, and erosion of the river's delta at the Strait of Juan de Fuca where the shoreline retreated over 500 ft (Warrick et al. 2019). This increased the river's gradient immediately upstream of its outlet. Compared with the 2018 delta configuration (post dam removal), the 2011 gradient (with Elwha River dams in place) at the outlet was approximately 25 percent steeper (0.0035 and 0.0027, respectively). A steeper profile was also a product of delta retreat during the dam era.

During high flow events when water overtops its banks, the Elwha River occupies former channels within the floodplain or avulses into new flow paths. Over the 98-year life of the Elwha Dams, the principal source of sediment to the lower three miles of the river was from erosion of banks and bluffs (valley margins). Banks are composed of alluvium that ranges from silts to boulders. Bluffs are primarily composed of glacial outwash that typically ranges from silts to cobbles. These locally-derived sediment inputs along with in-stream wood were essential in driving channel migration and avulsions during the influence of the former Elwha and Glines Canyon Dams (Draut et al, 2011). The lower Elwha valley also experienced significant local impacts following European settlement. The entire valley was logged for its old growth timber; one Western Red Cedar in the lower Elwha Valley was 26.7 feet in diameter (Dodwell and Rixon 1902, p.16). During the mid-1900s local landowners confined the river with numerous "sugar" or "push-up" dikes composed of alluvium dug out the floodplain, which effectively concentrated flow and increased stream power in the main channel.

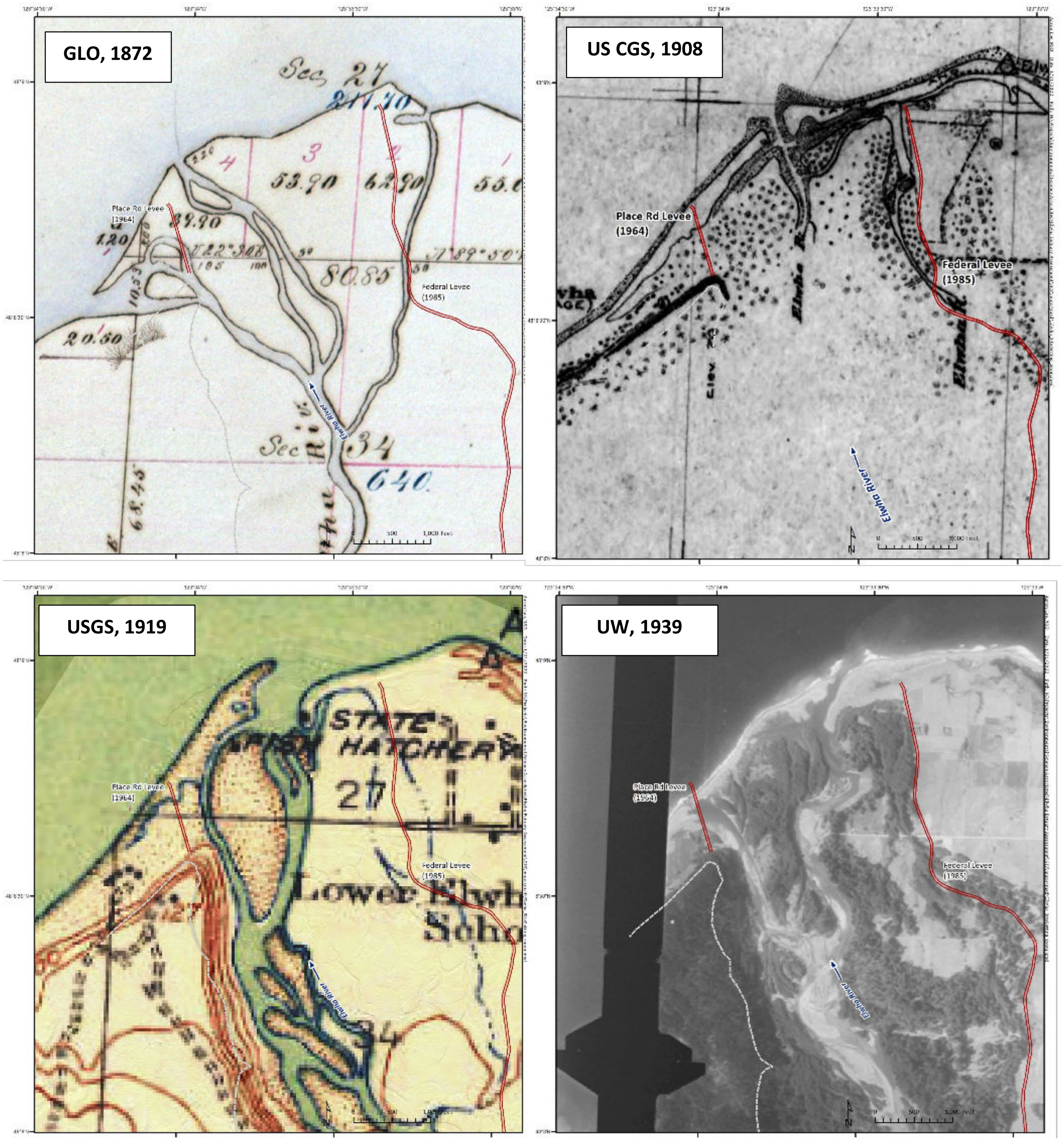

Figure 2. Historical maps and aerial photograph of the Elwha River outlet. Figures are ordered in chronological order from top-left to bottom-right (1872, 1908, 1919, and 1939). Note that all figures are referenced to the same coordinates. Place Rd Levee and the Federal Levee are shown in red.

Levees constructed on both sides of the lower river disconnected distributary channels and substantial areas of floodplain. The levees also limit future channel migration. The Place Road Levee was constructed in 1964. The levee cut-off the mainstem outlet of the river which flowed due west just north of Fox Point Bluff, a similar alignment to the western distributary channel mapped in 1872 (Figure 2). Place Pond is situated in the former location of the western distributary channel. The Federal Levee on the east side of the lower extends 1.8 miles from the pre-dam shoreline at the Strait up to the State rearing channel. The Federal Levee, a U.S. Army Corps of Engineers-certified structure built in 1985, cut-off a distributary channel in the delta and confined the alignment of Bosco Creek to the estuary, thereby reducing the available habitat area and confining flood flows to a narrower floodplain corridor (Figure 1, Figure 2). Prior to dam removal the Federal Levee was raised, and rock revetment added to prevent channel migration from eroding the levee.

Channelization and straightening of the mainstem Elwha River sponsored by Clallam County, including dike construction that intentionally cut-off of the eastern distributary channel (“Historic Anabranch” in Figure 1; and “Disconnected Eastern Distributary Channel” in Figure 3), occurred in the 1950s to 1980s (Pohl, 1999; Warrick et al., 2011). These actions further concentrated stream power in the lower Elwha River and directed flow along the toe of Fox Point Bluff. The mainstem channel responded primarily through lateral channel migration and meander amplification. There is a definitive trend of westward channel migration based on the aerial photograph record from 1939 and 2006 from Fox Point Bluff to the outlet (Draut et al., 2008). As the Elwha River eroded into Fox Point Bluff, a pair of meander bends established and continued to amplify over time. A large sediment deposit formed immediately downstream in conjunction with the meander pairs and was subsequently colonized by vegetation. Aerial photographs indicate that around 1990 the river flowed directly along the northern end of Place Road Levee. The WLRSC is likely a remnant scour feature from the former mainstem Elwha River and exists today as a floodplain pond connected by smaller tidal channels. Construction of Place Road Levee and other channel modification activities are responsible in part for the formation and persistence of the western floodplain.

Construction of engineered logjams in the lower river (1999-2016) was successful in restoring some anabranching planform and in improving sediment retention. Dam removal (2011-2014) released sediment that had been stored for a century. Restoration of the river’s sediment supply aggraded the river channel, improved floodplain connectivity, and contributed to restoration of anabranching and distributary channels.

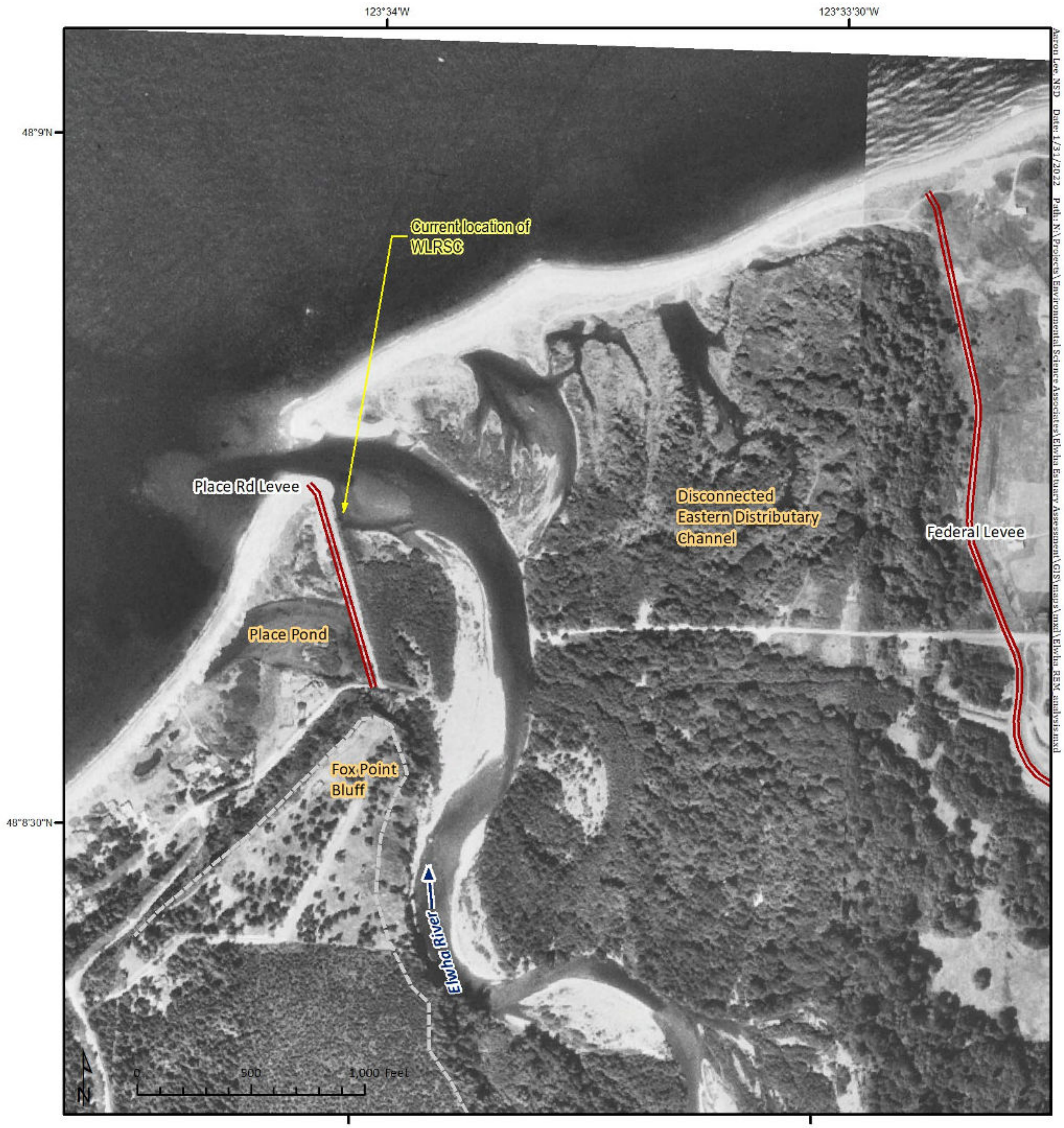

Figure 3. Aerial photograph (1990) of the lower Elwha River. Annotated with pertinent infrastructure and geomorphic features. Approximate levee alignments are shown in red.

Anticipated Channel Evolution

The short-term response from dam removal has been well documented in previous studies (Ritchie et al., 2018; East et al., 2014, Draut et al., 2008). Dispersion of the sediment pulse from released reservoir sediments has led to aggradation and enlargement of gravel bars downstream, decrease in gradient at the Elwha River outlet, and an increase in sinuosity and braiding index (Draut et al., 2008). The lower Elwha River is anticipated to continue to respond through increased lateral mobility as the system trends toward an anabranching planform.

Stable large wood partitions shear stress along the river, helping to retain gravels and fine sediment, can aggrade the river system, and shift planform types under certain conditions. An example of this transition is construction of engineered logjams on the lower Elwha River, as shown in Figure 4 (USBR and ERDC, 2016).

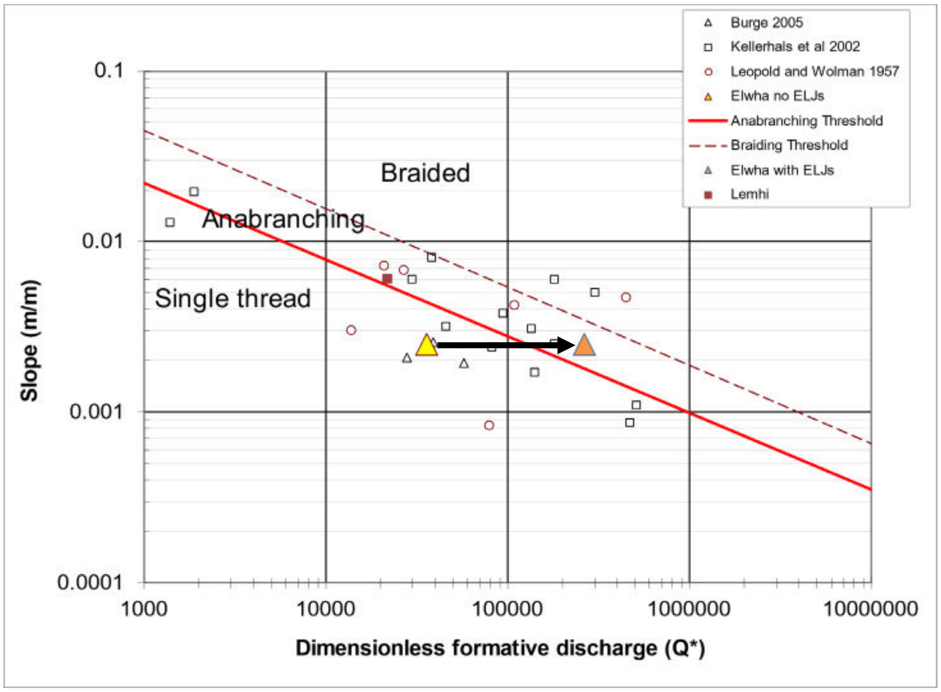

Figure 4. Plot of stream channel planform types based on a dimensionless anabranching threshold, adapted from Eaton et al., 2010. Orange and yellow triangle represents the lower Elwha River with and without engineered logjams, respectively. Logjams increase retention of gravels and effectively reduce the median grain-size, which can shift planform type from single-thread to anabranching. Data from Tim Abbe, 2016.

Over the long-term, it is expected that development of multiple channel threads and mid-channel vegetated bars are likely to occur given the relative increase in sediment and wood supply resulting from dam removal. At some point in the future, the main channel will directly engage with the Place Road and Federal levees, as the Elwha River has historically migrated across its wide floodplain. The probability of these scenarios or channel avulsion in the lower reach is not considered high in the short-term (0 to 5 years).

Under the existing meandering planform of the lower Elwha River, Place Road Levee engages with flood flows on an annual or semi-annual basis but the structure itself is not a primary driver of the western floodplain bar evolution. Place Road Levee is positioned across a historic distributary channel and outlet to the western delta, which currently controls the western extent of the Elwha River floodplain and estuary. Field observations suggest that flow drains toward the WLRSC and along northern extent of Place Road Levee during floods. The hydraulic head generated by small to moderate flood events is insufficient to initiate channel avulsion through the western floodplain, though still possible with an extreme, low-frequency event (e.g. high fluvial energy and low estuarine energy). Aggradation of the western floodplain surface through yearly fine sediment deposits will likely continue in the short- to medium-term with further development of the meander pair. The western floodplain lateral bar will likely experience erosion at the upstream end and enlargement downstream of the bar apex due to down-valley translation of the meander pairs (Figure 5). Using lateral channel migration rates from aerial imagery for the period of 2011-2020, the Elwha River could reach Place Road Levee in 40-90 years. Within this 90-year timespan it is possible that meander cutoff or formation of a more substantial side channel though the western floodplain could reach Place Road Levee.

The most likely outcome is a re-establishment of an anabranching planform or distributary channel through the western floodplain that meets Place Road Levee. Note that adjustments to the orientation and conveyance of channels upstream may influence the timing and degree of evolution at the western floodplain. Place Road Levee will continue to restrict sediment and nutrient transport, and subsequent habitat formation west of the levee. The structure will ultimately be subjected to direct engagement with a distributary channel or flipping of the mainstem in the long term. The WLRSC is a preferential location for the lower Elwha River to interact with Place Road Levee. Erosion and undermining of the levee toe are expected with prolonged exposure to down-valley flow along the structure. The annotations in Figure 5 describe recent channel changes (2011-2020) overlaid on 2018 LiDAR hillshade.

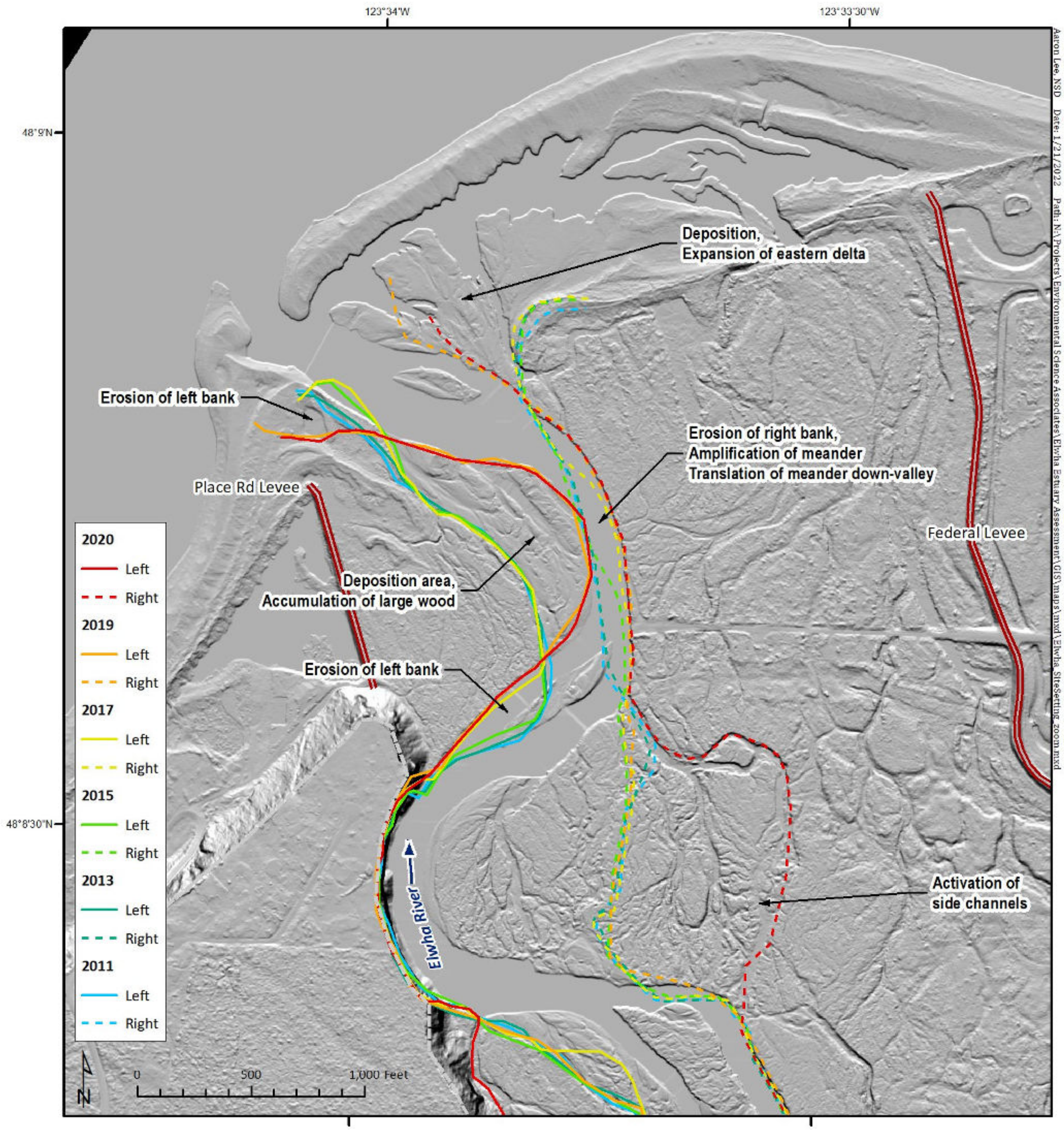

Figure 5. Channel traces of left (solid line) and right (dashed line) bank alignments from 2011 to 2020 aerial photographs. Note that dam removal initiated in 2011 and was completed in 2014. Bank lines are delineated at the streamward edge of unvegetated floodplain and represent conditions at the time of image collection. The text labels describe changes that have occurred between 2011 and 2020. The 2020 channel trace includes the extent of a known side channel, "Activation of side channels," which was engaged during this time period.

The primary findings from the geomorphic assessment on the impacts of and to Place Road Levee are listed below:

1. **The current planform of the lower Elwha River has been adjusting to man-made channel modifications.** Establishment of a single-threaded meandering channel can be traced back to construction of Place Road Levee and other man-made channel modifications. Localized erosion and expansion of the western floodplain surface is tied to evolution of the meander pair in the lower Elwha River, which has also been influenced by dam removal (2011-2014).

2. **Place Road Levee currently has a minor influence on channel planform and habitat formation.** While the construction of the levee and other channel modifications have certainly influenced the lower Elwha River morphology in the past, the structure itself has a limited effect on sediment erosion, deposition, or lateral migration patterns of the current mainstem channel. Recent trends from aerial imagery (2011-2020) indicate that west floodplain/gravel bar has remained stable, though erosion at the downstream end of the first meander shows slow translation of the meander pair to the north. The area of greatest change, and likely short-term continued migration, is amplitude of the second (downstream) meander to the east.

3. **Place Road Levee precludes formation of channel or lagoon to the west.** The levee was constructed to limit the western extent of channel migration and it continues to preclude formation of a channel or lagoon to the west. Historical maps dating to 1872 (Figure 2), and as recently as the 1960s, indicate that an active distributary channel and river outlet flowed through the current alignment of Place Road Levee. If unimpeded by the current levee, the Elwha River will eventually form a channel or lagoon to the western delta through Place Pond.

4. **Place Road levee will have long-term impacts on channel planform and habitat formation.** The topographic disconnect between the current western floodplain and Place Pond (former lagoon and Elwha River channel) limits the available habitat and restricts potential sediment and nutrient delivery to the western estuary. The hypothetical scenario of complete removal of Place Road Levee would result in increased sediment delivery to Freshwater Bay, including Place Pond, and associated expansion of habitat but would result in increased flood and erosion risk for the easternmost 2 to 3 residences adjacent to the levee.

5. **Habitat features in the estuary are spatially transient**. The lower Elwha River will re-occupy former channels and abandon current ones. Distributary and tidal channels will also change over time as the primary mainstem channels shift position or orientation. The WLRSC is projected to experience sedimentation as the main channel is currently migrating to the east. There is currently an expansion of inter-tidal habitat in the eastern tidal lagoon that extends from the river's outlet past the north end of the Federal Levee. Side channels originating from the Elwha River near RM 1.6 ("historic anabranch (inlet)" in Figure 1 have been conveying more flow into the eastern tidal lagoon along side of the Federal Levee.

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Appendix C

Place Flood Control Zone District Letter

ESA

5a
11-12-86

BEFORE THE BOARD OF CLALLAM COUNTY COMMISSIONERS, STATE OF WASHINGTON

In the matter of:	)	
	)	
Forming "The Place" Flood Control Zone District	)	CR RESOLUTION NO. 67, 1986
	)	

THE BOARD OF CLALLAM COUNTY COMMISSIONERS finds as follows:

I. Chapter 86.15 R.C.W. provides for the formation of flood control zone districts for flood control purposes.

II. Citizens in "The Place" area have requested flood control assistance.

III. That a public hearing was held on November 12, 1986, at 10:00 a.m., in the Commissioners' Meeting Room, to take public testimony regarding the formation of "The Place" Flood Control Zone District.

NOW, THEREFORE, BE IT RESOLVED by the Board of Clallam County Commissioners in consideration of the above findings of fact:

1. That "The Place" Flood Control Zone District is hereby formed.
2. That the boundaries of the Flood Control Zone District shall generally be all those parcels commonly known as "The Place". (A list of Assessor's parcels numbers identifying the legal boundaries of the Flood Control Zone District is attached.)

PASSED AND ADOPTED THIS 12 DAY OF November, 1986.

BOARD OF CLALLAM COUNTY COMMISSIONERS

Evan Jones, Chairman

Lawrence Gaydeski

Dorothy Duncan

ATTEST:

Karen Flores
Clerk of the Board

PLEASE PUBLISH: November 16, 1986

PLEASE BILL: Clallam Co. Public Works
223 East 4th Street
Port Angeles, WA 98362

cc: newspaper
Public Works
minutes

CR RESOLUTION NO. 67, 1986

The boundary of the Flood Control Zone District is generally described as all those parcels between the west end of the Place Road and the Elwha River, and the lower bluff line and the Strait of Juan de Fuca, containing the following parcels:

Parcel Numbers:

07 31 27 320000	07 31 33 130300	07 31 33 140175
320050	130325	140200
07 31 33 110000	130335	140225
110025	130350	140250
110050	130400	140375
110075	130425	140440
110100	130450	140450
110125	130500	140500
110150	130550	07 31 33 220000
110200	130575	220050
110225	130600	220100
110250	130650	220125
110275	130700	220150
110300	130725	07 31 33 310100
110325	130750	310200
110350	130800	310225
110375	130850	07 31 34 220025
110400	130875	220100
130000	130900	
130050	130925	
130100	130950	
130125	130975	
130150	131000	
130200	131025	
130320	131050	
130250	131100	

Block 1 Lots 1-14, Block 2 Lots 1-17 Plat of the Place

Appendix D
Prior Water Level Records

ESA

The USGS collected water level data in the lower estuary during a limited deployment from May 2009 to April 2010 (Duda et al. 2011). Figure D.1 displays the locations of loggers installed in Place Pond and in the WLRSC (referred to as West Estuary Channel WESC). Like the 2020 sensor deployment conducted for this study, a muted tidal signal was seen in the Place Pond water levels. A lag was observed between the recorded muted tidal signal in Place Pond and the water levels from Port Angles, suggesting that groundwater exchange rather than a surface water connection is primarily responsible for changes in water levels in Place Pond. Throughout most of the deployment, Place Pond was warmer than other sensor sites within the east estuary, which implies that limited surface water exchange occurs. In the WESC site (corresponds to this study's WLRSC site), rapid increases in salinity and changes in temperature were observed, implying a higher degree of connectivity and mixing occurs in WESC relative to Place Pond.

The study concluded that some degree of connectivity exists between Place Pond and the lower Elwha through groundwater exchange, although the extent of the connectivity is limited, and that the pond is not connected to the Strait by a surface water connection except during wave overwash events. These findings are consistent with the water surface elevation data collected as part of this study, indicating that dam removals have not had a significant effect on connectivity thru groundwater exchange.

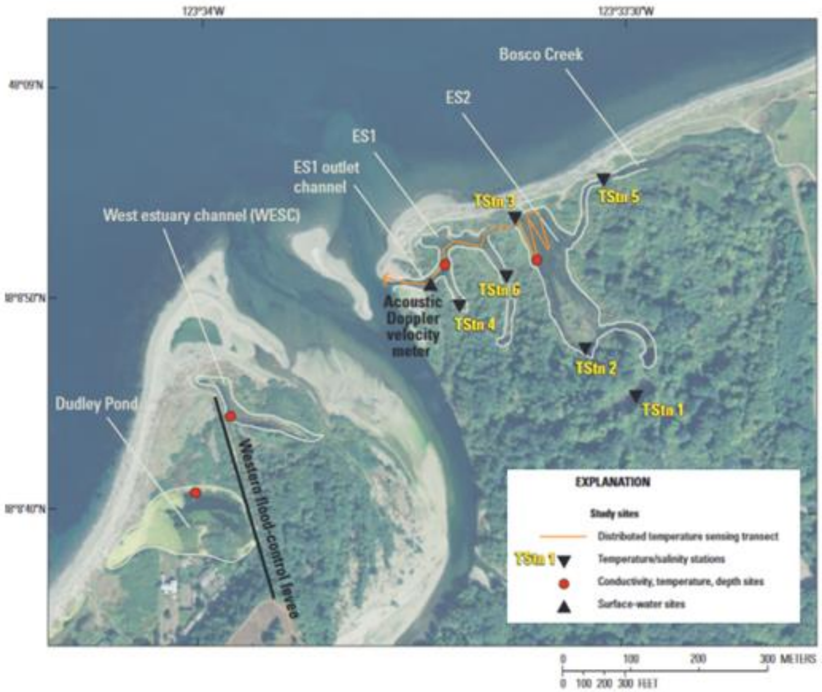


Figure 4.2 Locations of data collection sites near the Elwha River, Washington, September 2009

SOURCE: USGS 2009

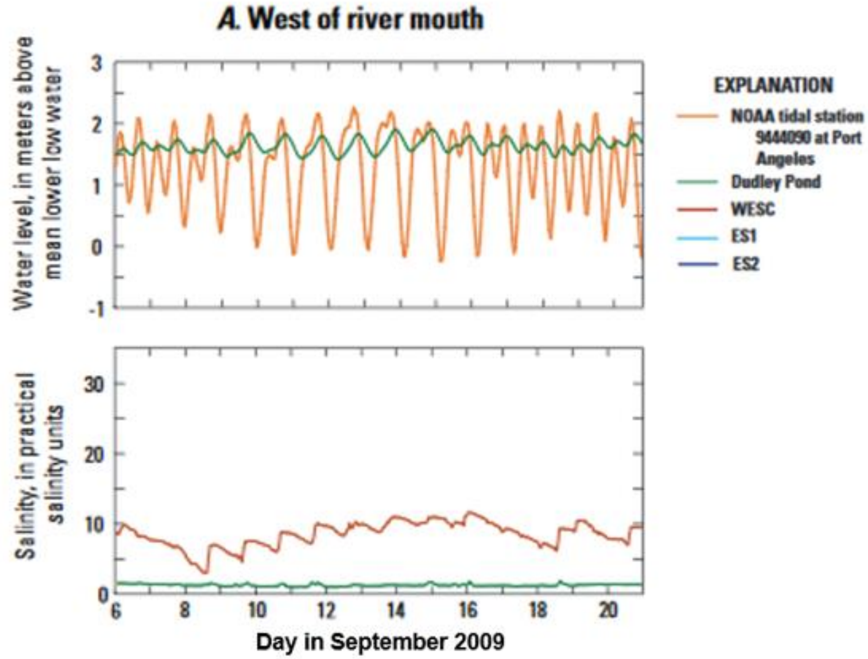
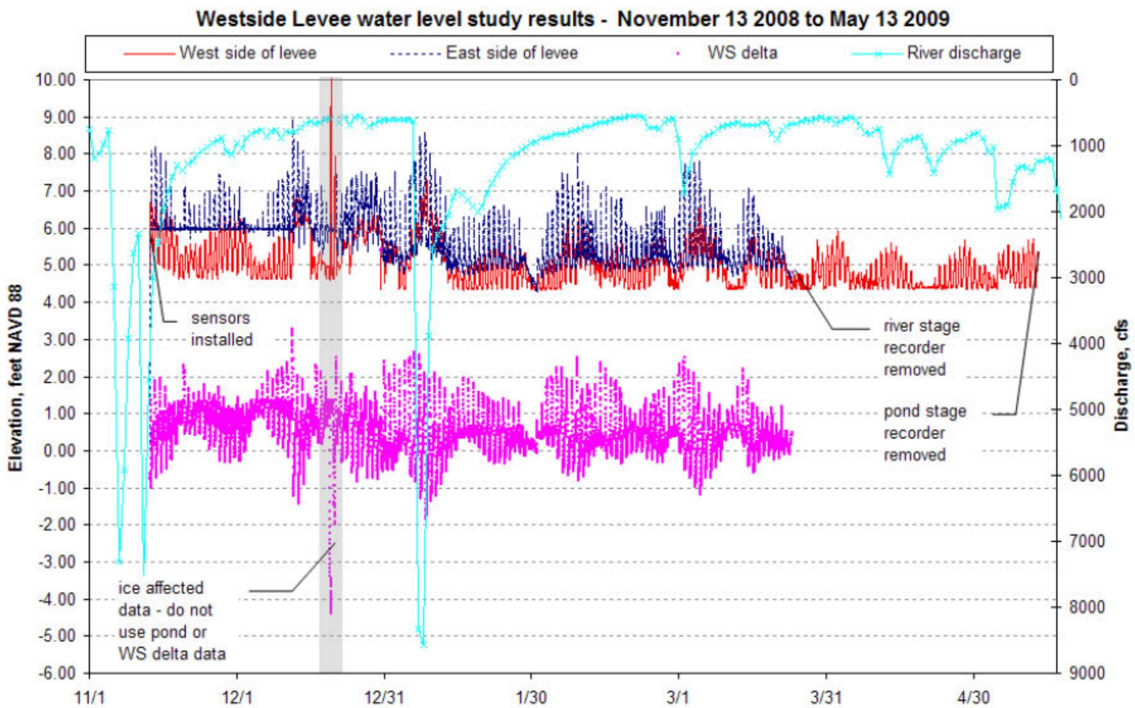


Figure 4.16 Surface-water levels and salinity over a 2-week (spring-neap) tidal cycle during low flow for (A) Dudley Pond and WESC in the west estuary of the Elwha River, Washington, September 2009

Figure D.1
Data collected in Place Pond during 2009 USGS study.
Figures reproduced from USGS 2009

USACE also deployed water level loggers in the river and in Place Pond during the winter of 2008-2009 to support the design of the levee modifications. Data collected during this deployment is shown in Figure D.2. The 2011 document does not specify where loggers were installed within the delta, pond, and river. Like the USGS investigation, USACE found that daily tidal fluctuations were observed on both sides of the levee. Instantaneous differences in water surface elevations on either side of the levee ranged between -1.8 feet to 2.6 feet, with the east side of the levee generally reporting higher water levels. The USACE reports that while the river outlet exhibits semidiurnal tides, the pond water levels are diurnal and lag behind the river water level peaks by up to 10 hours, which is similar to the lag seen in the USACE and CWI water level records in Place Pond.



SOURCE: USACE 2011

Figure D.2
Water surface elevation records collected by USACE around Place Road Levee

Appendix E
Wave Data

ESA

NDBC 46087 Neah Bay

The Neah Bay buoy operated by the National Data Buoy Center (NDBC) has been operating since 2004 at the entrance to the Strait of Juan de Fuca, although continuous measurements are not available until 2015. While not providing local measurements at the Elwha estuary, the buoy captures swell waves entering the Strait that propagate to the delta, as shown in Figure D.3. Peak annual wave heights at the station exceed 20 feet with periods longer than 20 seconds. In November 2020, the buoy drifted from the station and was not reinstalled as of this draft. Because of this, the buoy data was unable to provide hydrodynamic model runs during the fall and winter of 2020/2021.

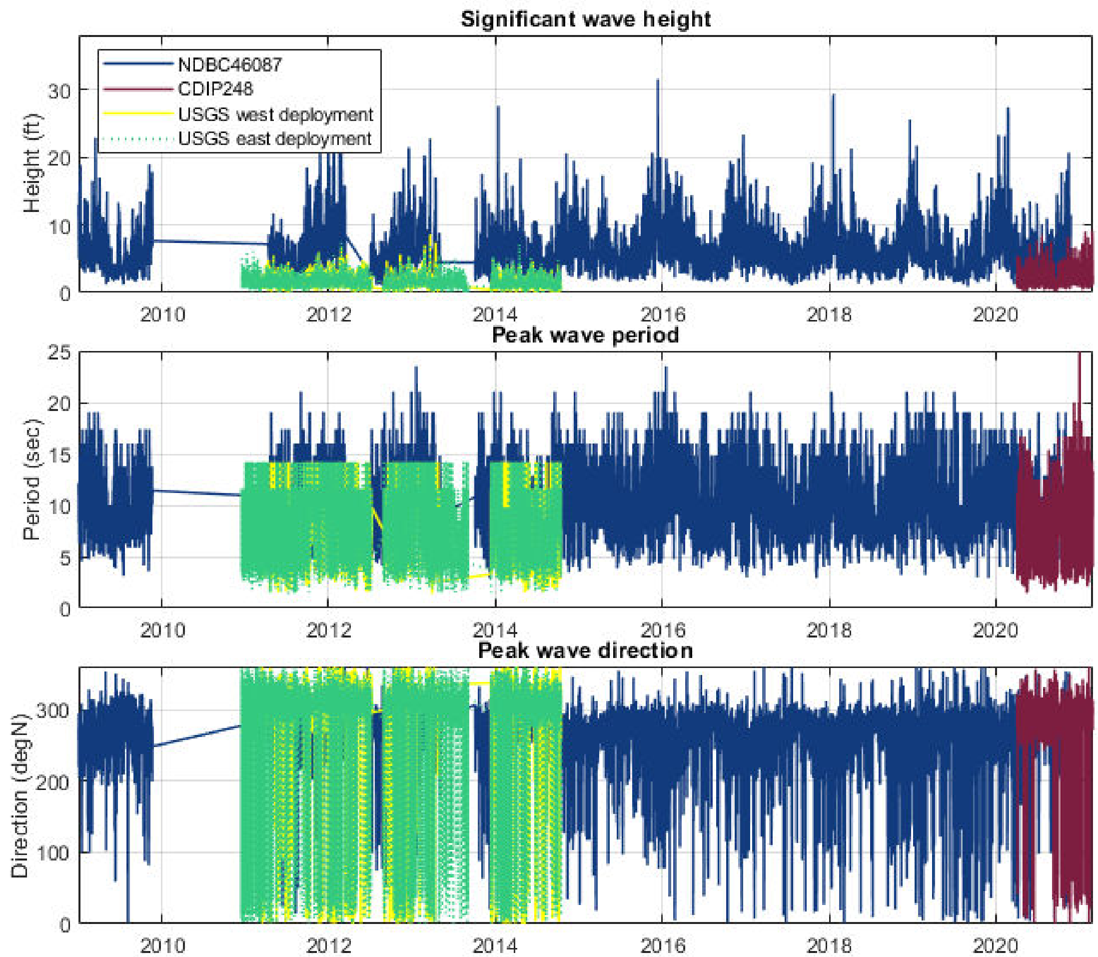
CDIP Buoy 248

A recently installed buoy managed jointly by NDBC and the Coastal Data Information Program (CDIP) is located in Freshwater Bay, approximately 2.5 miles from the river entrance. The location of the buoy is shown in Figure 14 of the main report, and data from the buoy are presented in Figure D.3. The buoy captures swell and wind waves offshore of the study area. Since the buoy is offshore of the delta, the data represents waves that have not refracted across the substantial subtidal delta. Peak significant wave heights reach 10 feet with wave periods around 15 seconds.

USGS Tripods and Moorings

As part of the research campaign for the Elwha and Glines Canyon dam removals, the USGS installed a series of wave tripods and moored wave buoys around the delta. The locations of the sensors are shown in Figure 14 of the main report, and the collected data in shown in Figure D.3. Peak significant wave heights in the nearshore reach 6–7 feet in height. The wave height and direction of these measurements vary from the other wave data primarily because these sensors were installed in the nearshore on the delta, where wave refraction has already occurred.

Although the data captured by these sensors is more representative of nearshore wave conditions than the CDIP or NDBC buoys, the delta bathymetry has changed substantially since dam removals and nearshore wave conditions have likely changed somewhat. This data represents the only nearshore or intertidal wave data available in the region.

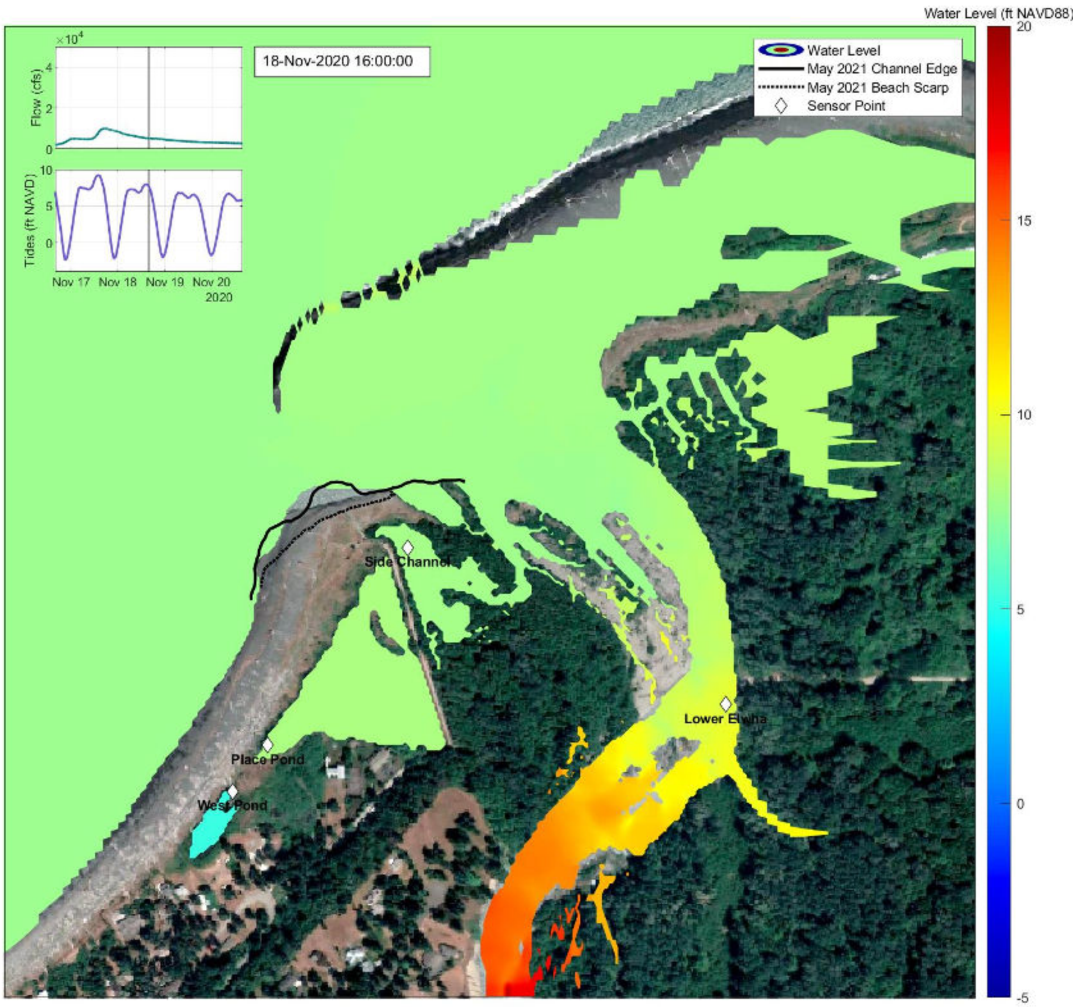


SOURCE: ESA & NSD 2020

Figure D.3
Wave height, period, and direction from NDBC Neah Bay Buoy, CDIP Freshwater Bay Buoy, and USGS Elwha River Delta deployments.

Appendix F
2D Model Results

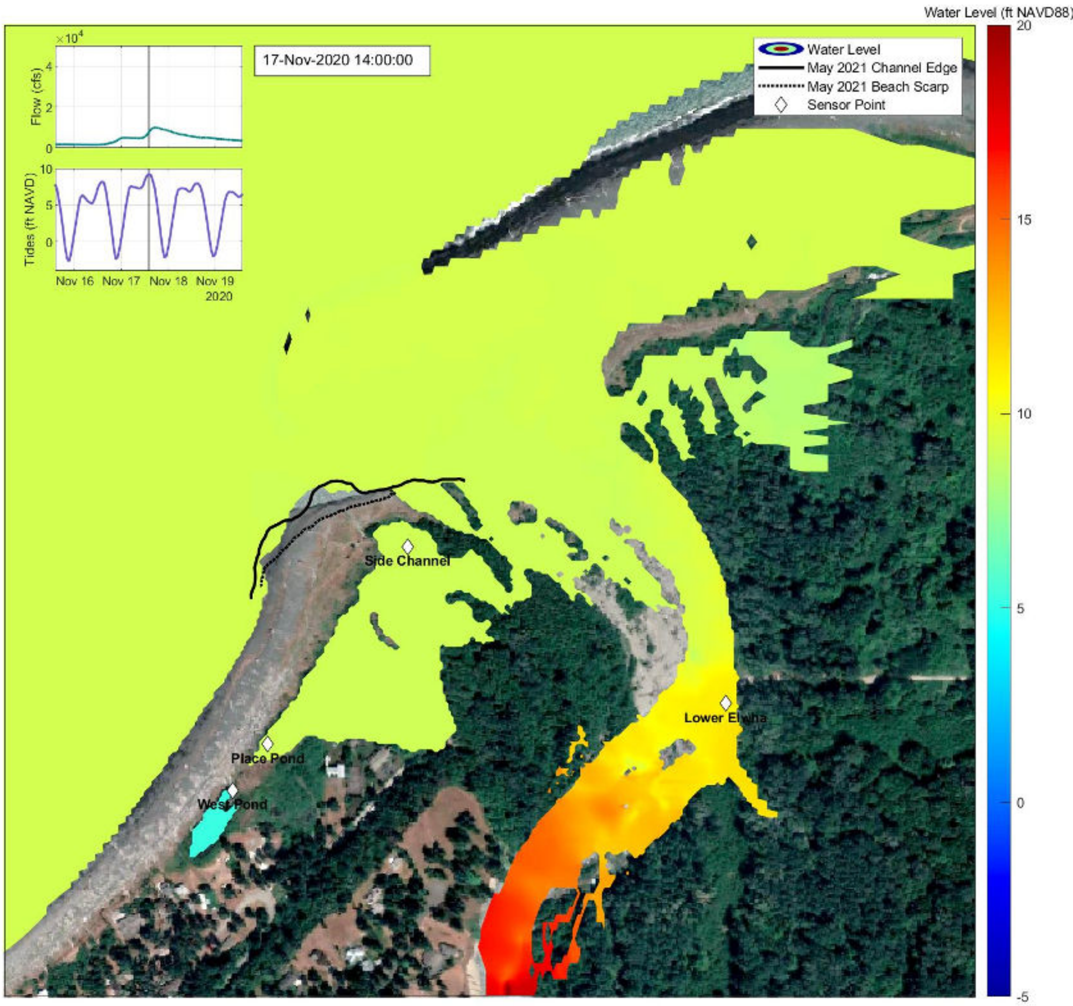
ESA



Scenario 1a - Calibration

Existing Conditions

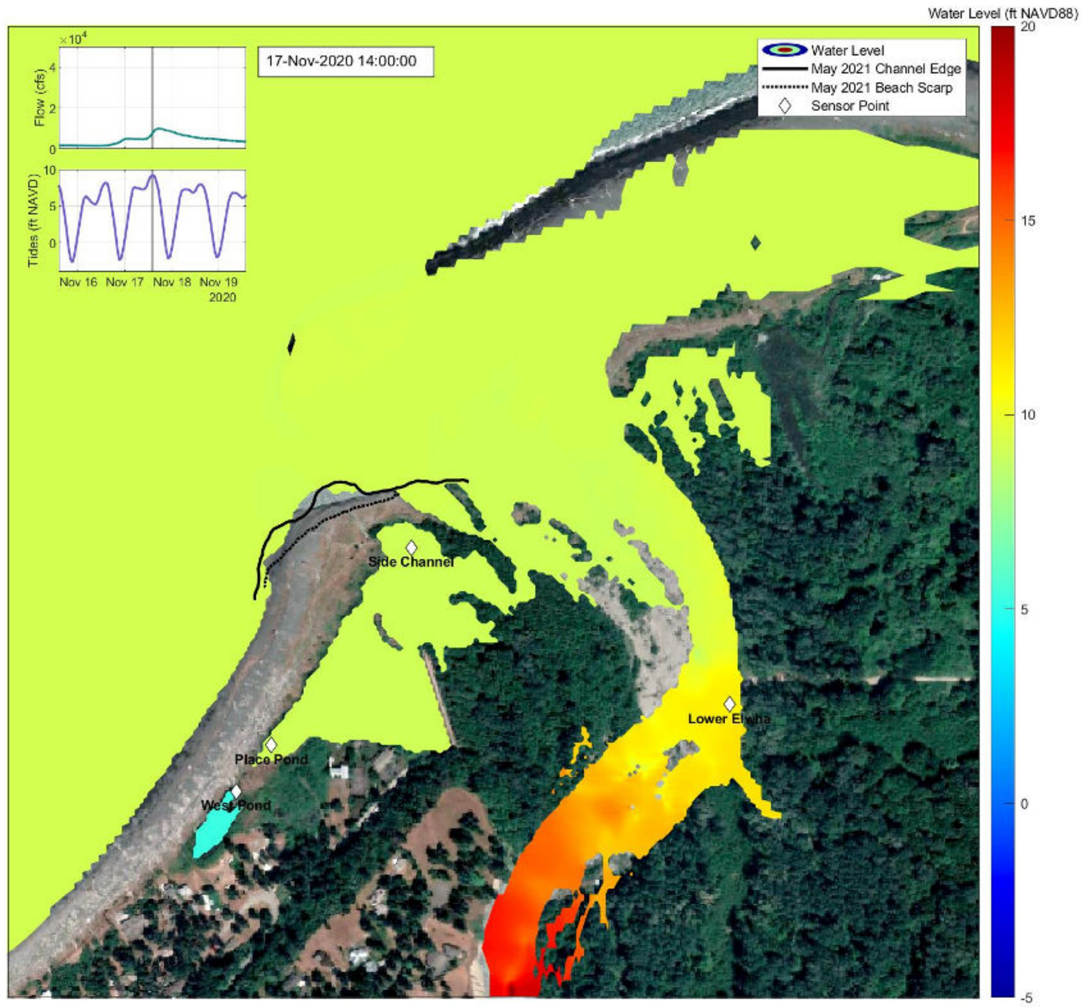
Peak flood timestep



<u>Scenario 1a - Calibration</u>

Alternative 1

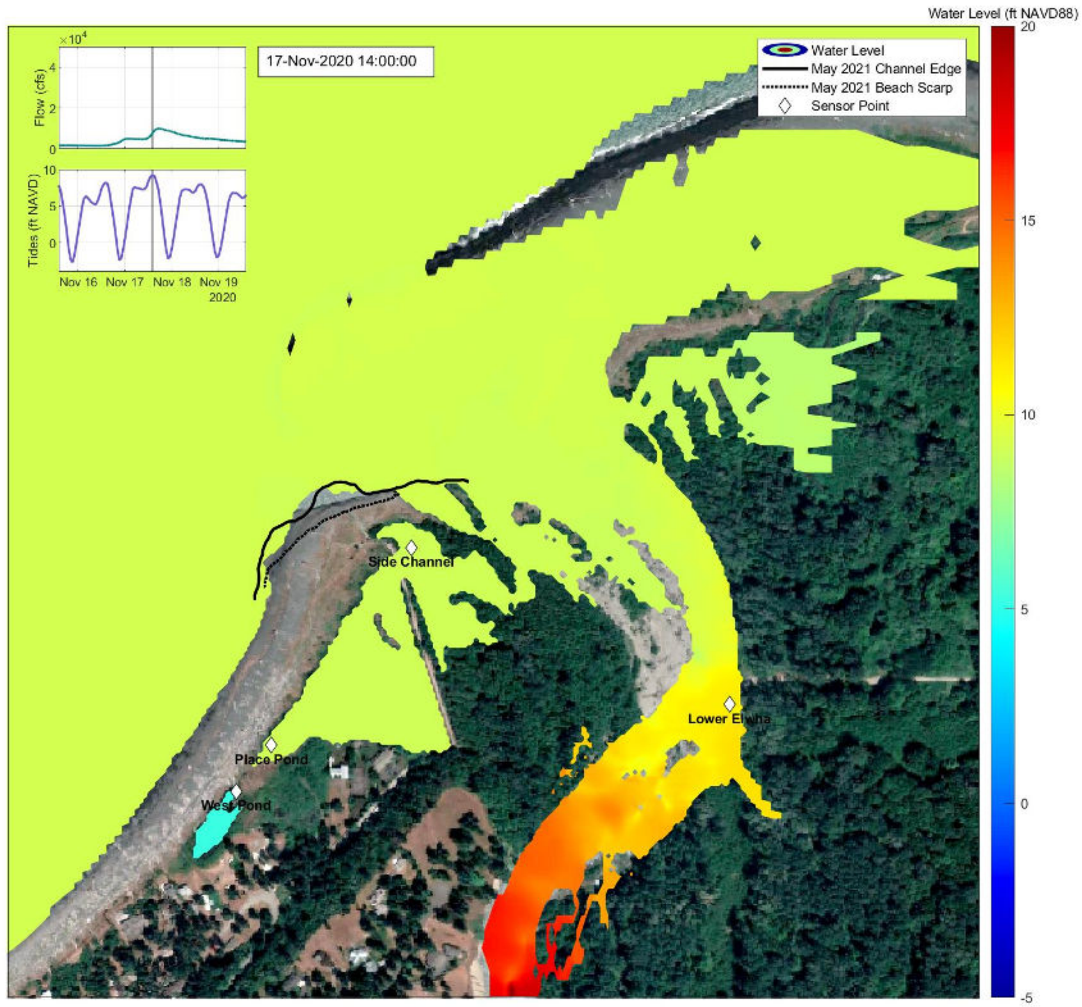
Peak flood timestep



Scenario 1a - Calibration

Alternative 2

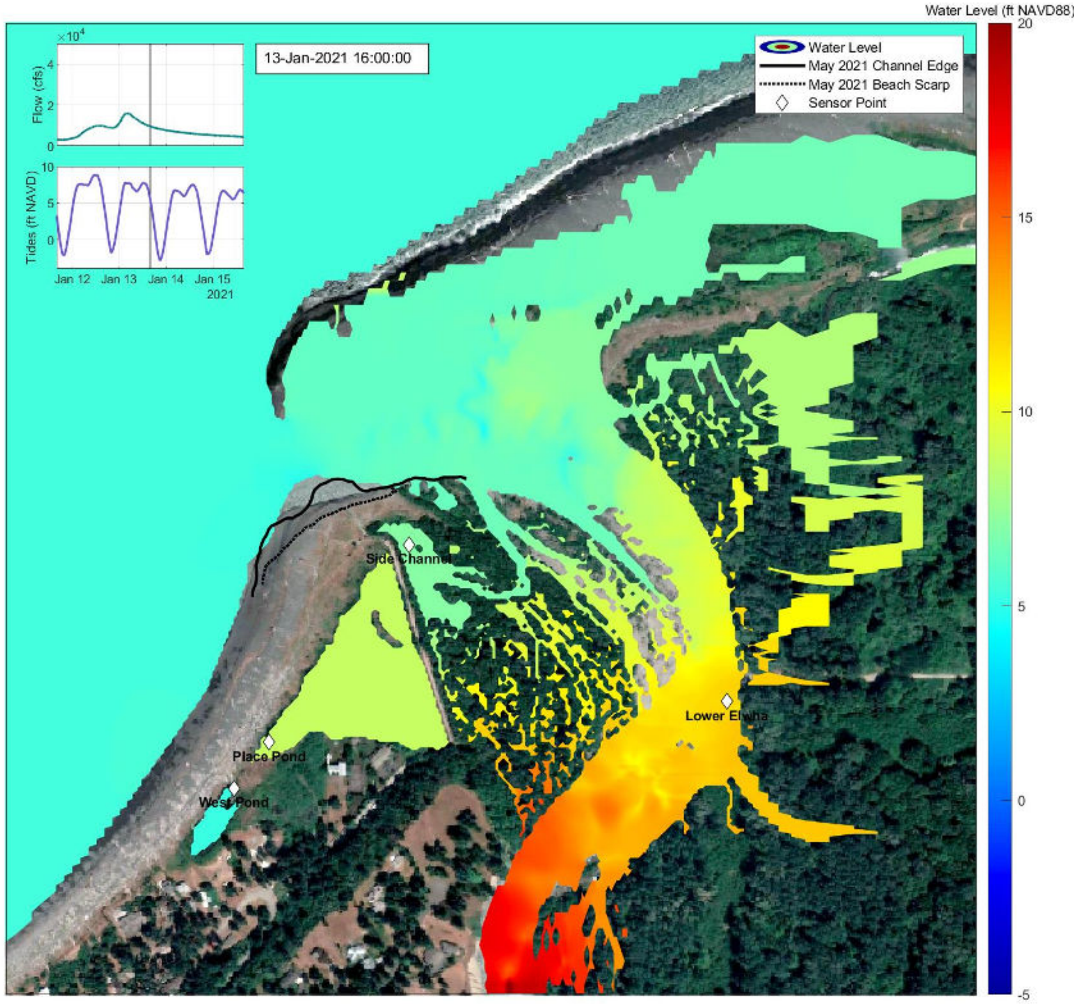
Peak flood timestep



Scenario 1a - Calibration

Alternative 3

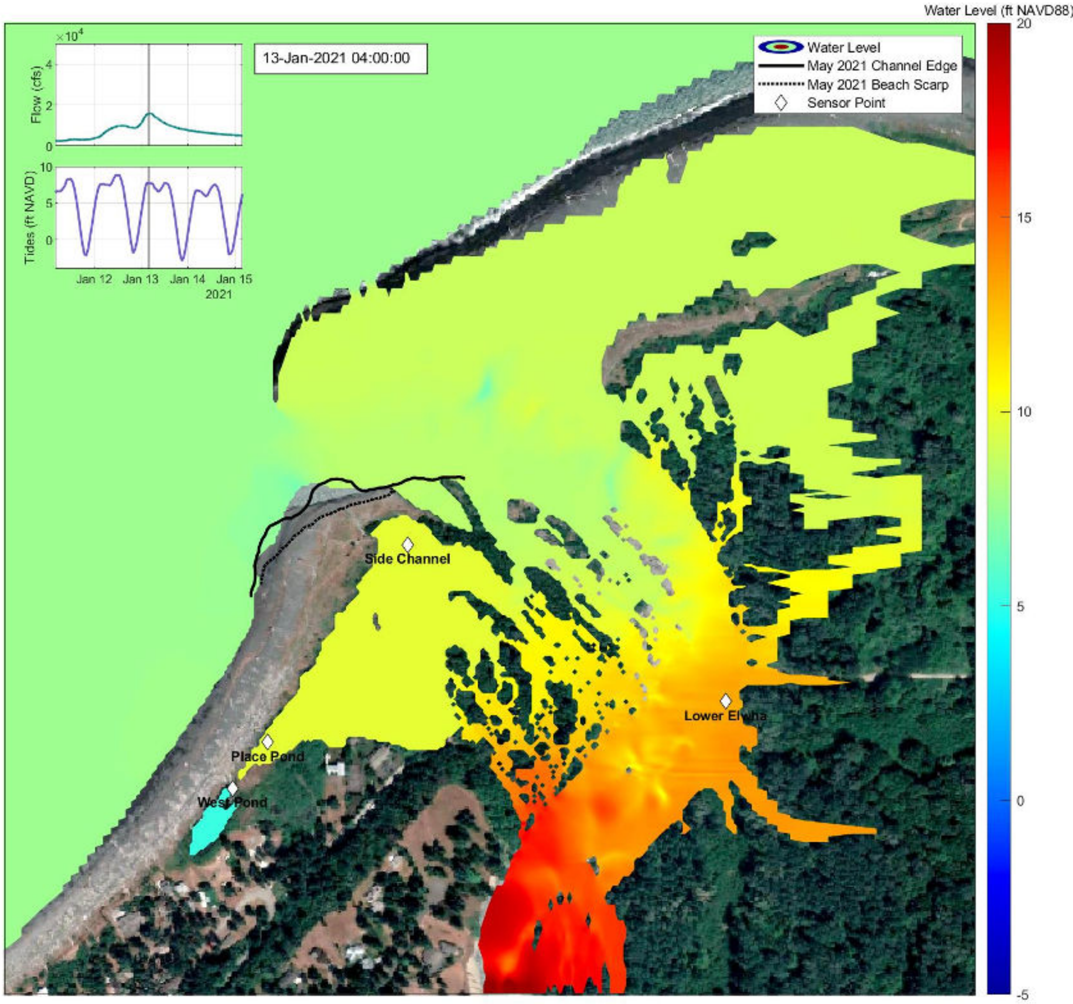
Peak flood timestep



Scenario 1b - Calibration

Existing Conditions

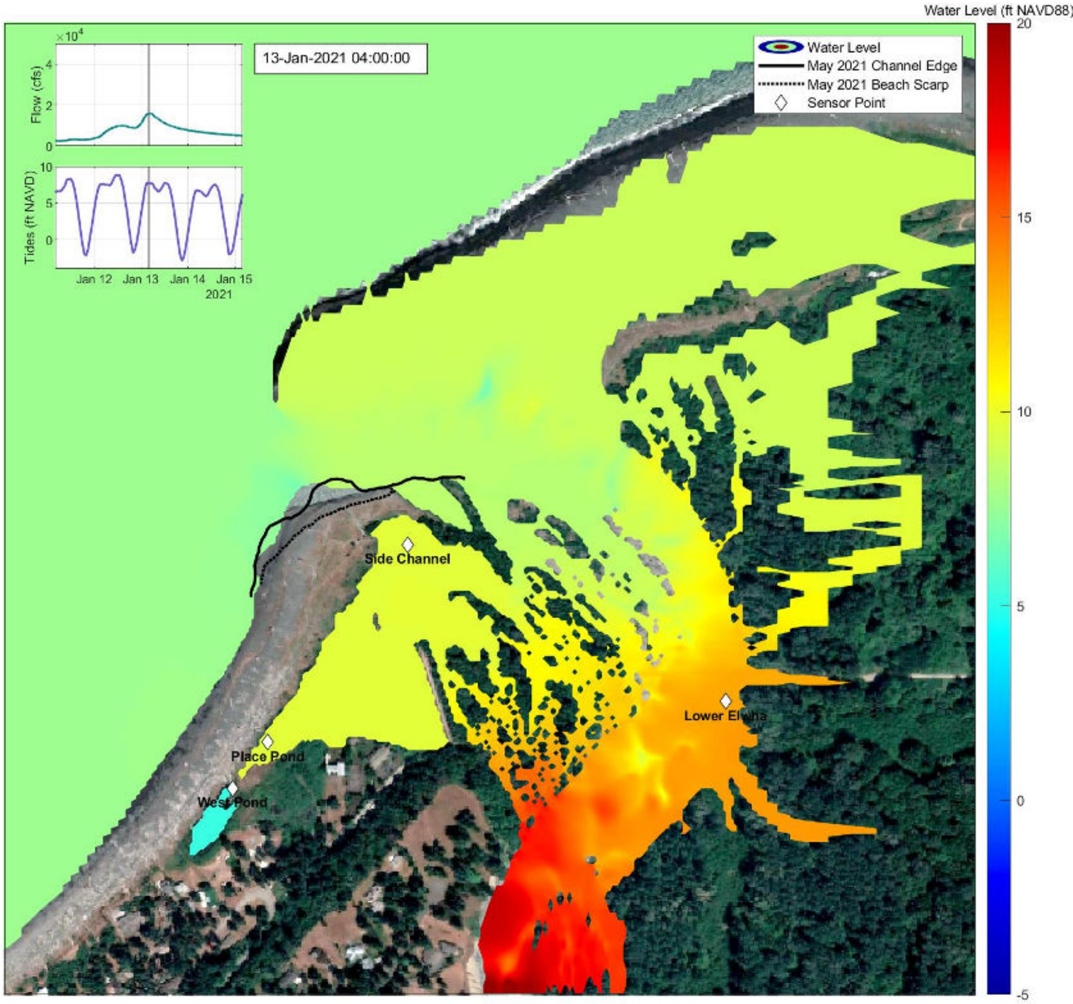
Peak flood timestep



Scenario 1b - Calibration

Alternative 1

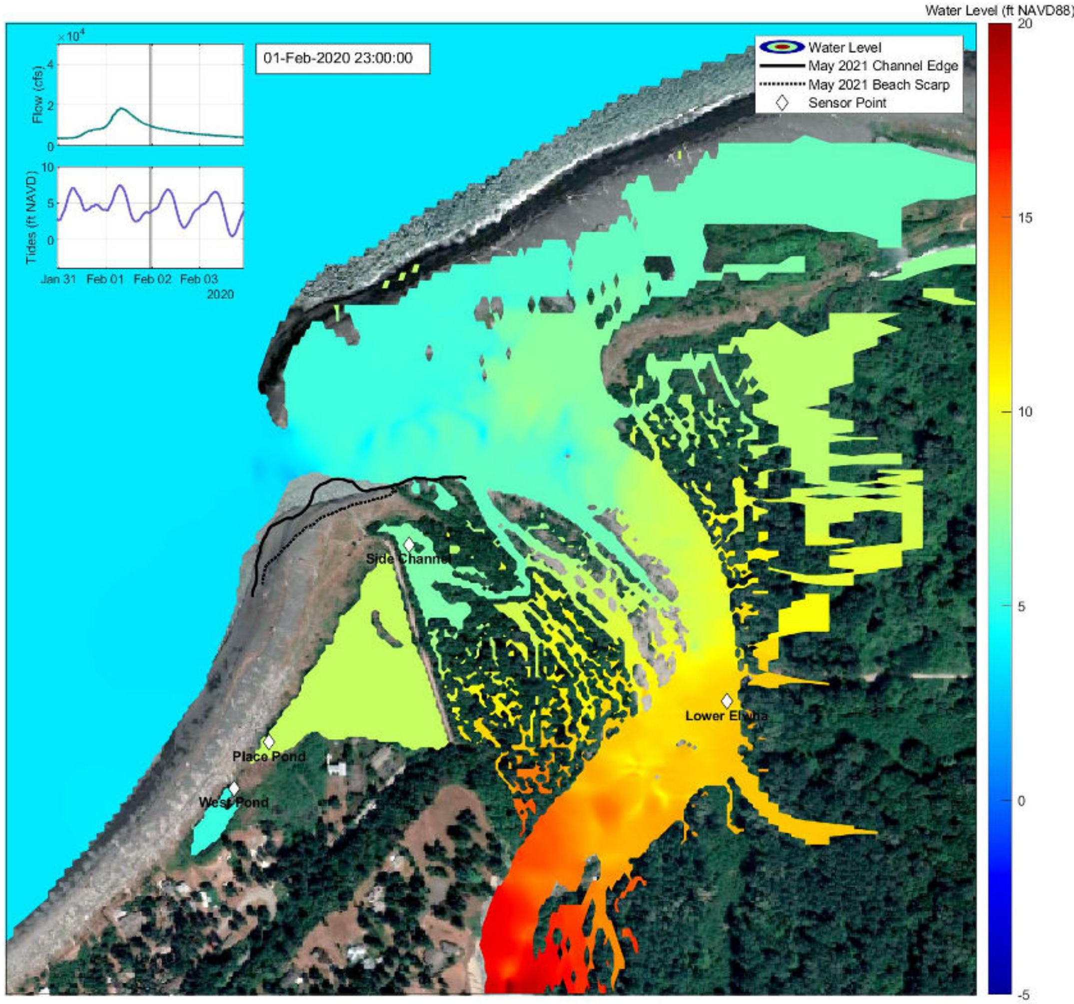
Peak flood timestep



Scenario 1b - Calibration

Alternative 2

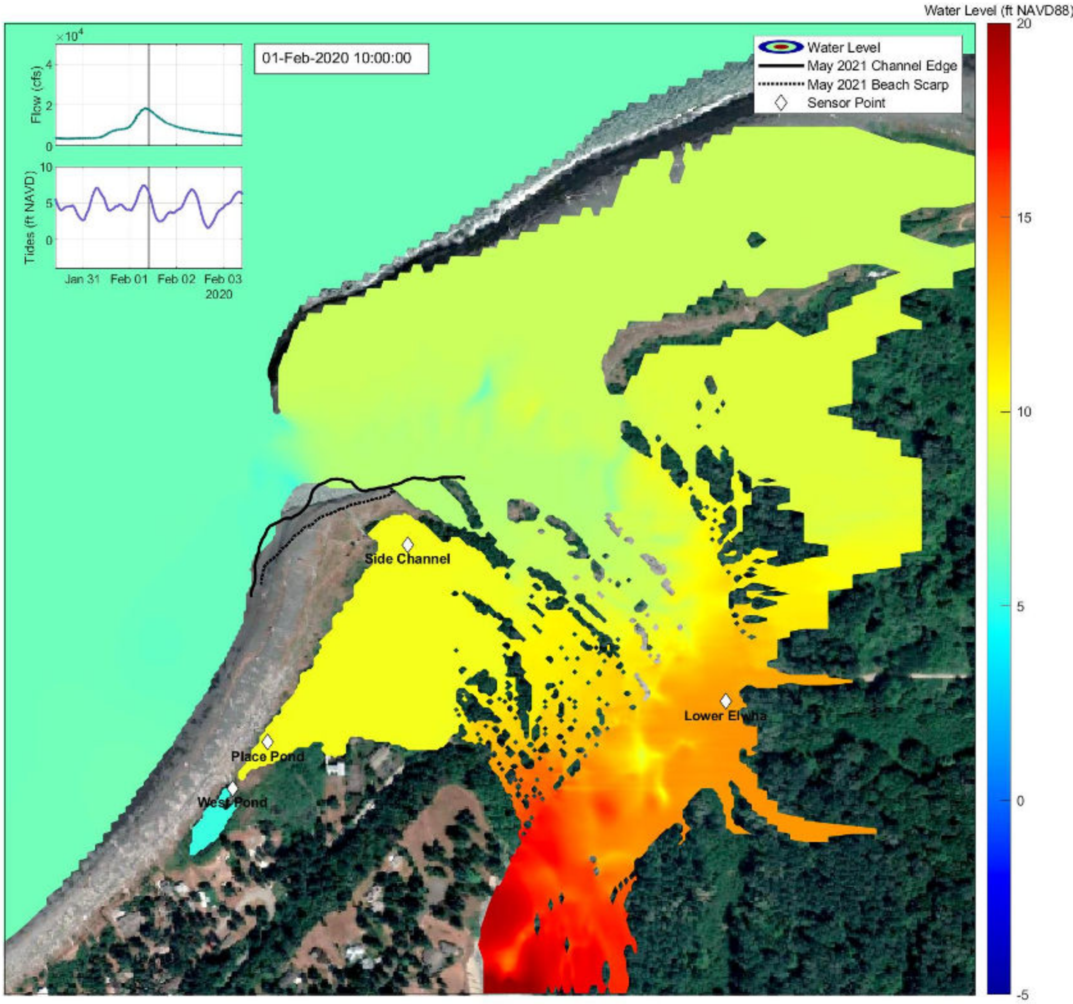
Peak flood timestep



Scenario 2 – High Estuarine Event

Existing Conditions

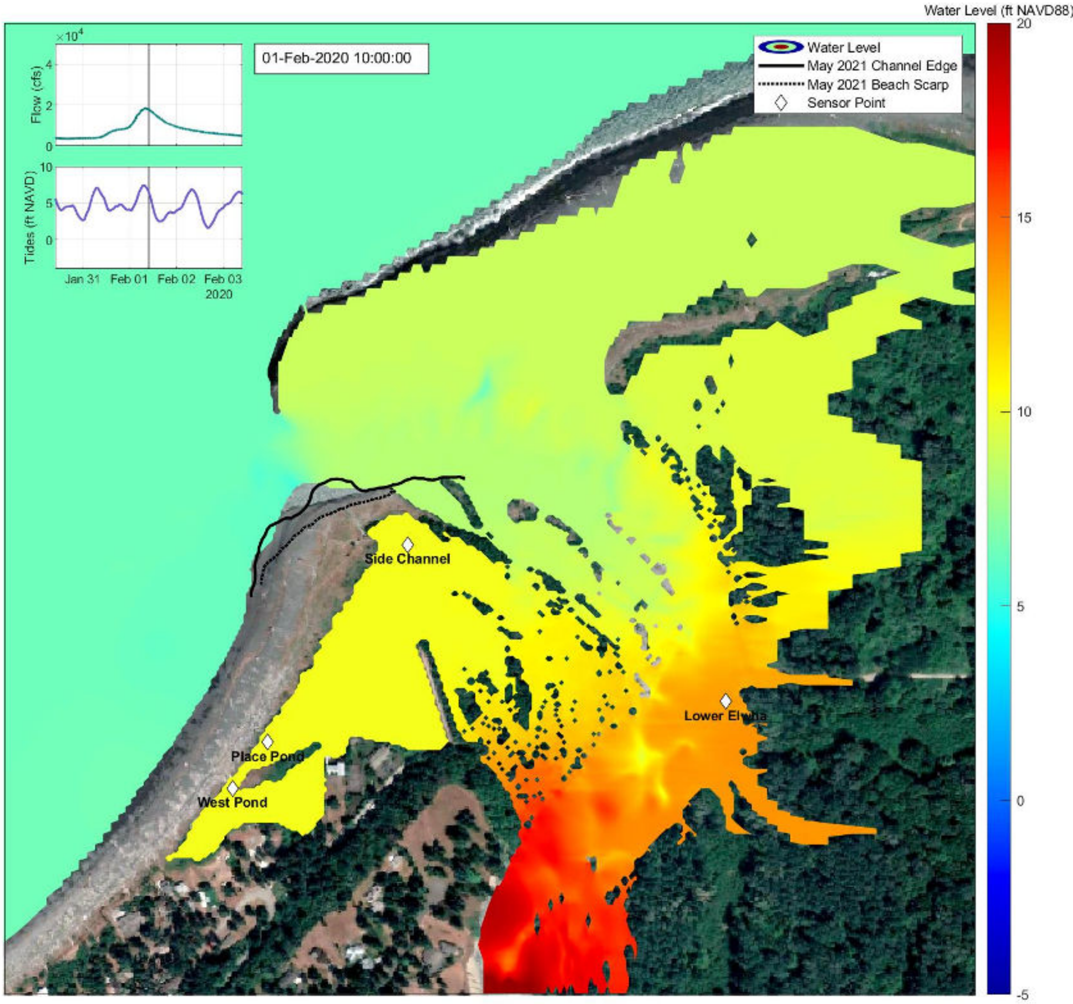
Peak flood timestep



Scenario 2 – High Estuarine Event

Alternative 1

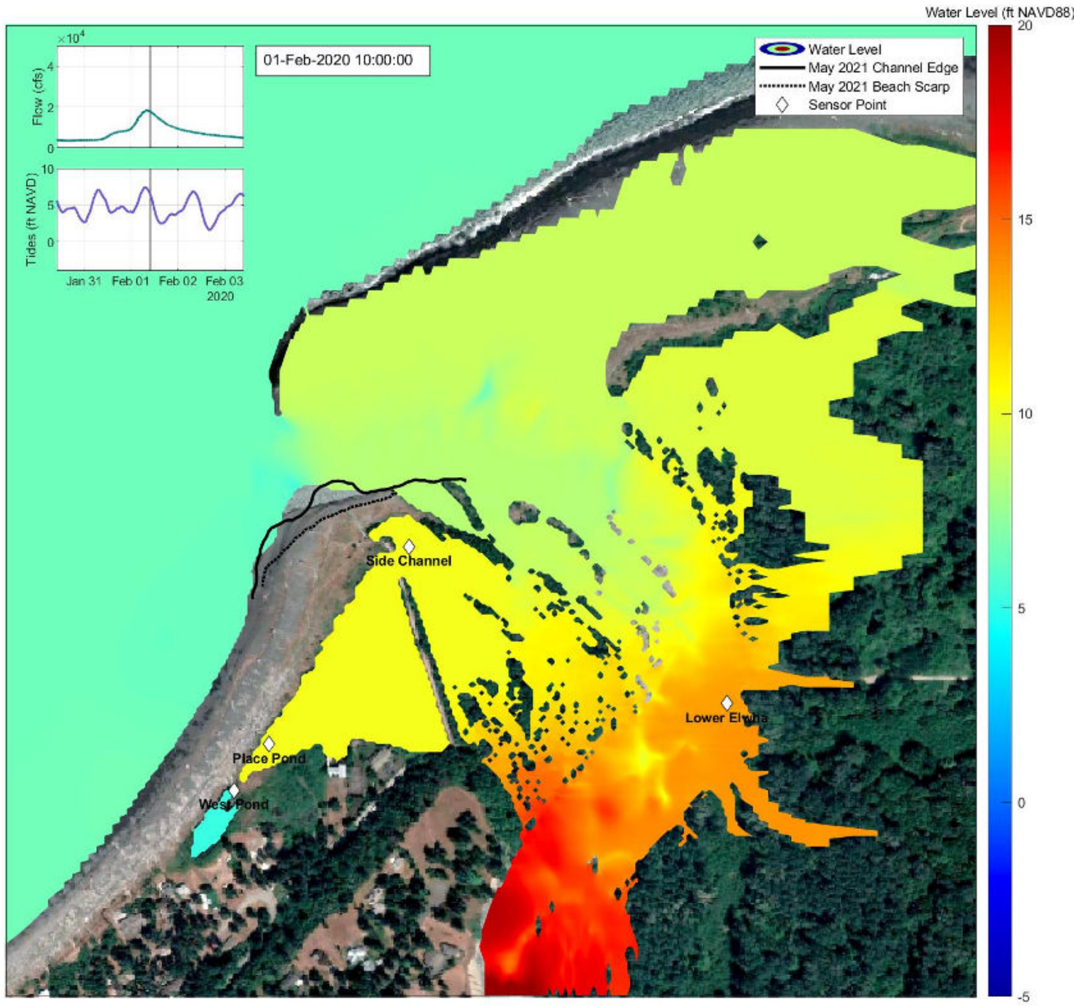
Peak flood timestep



Scenario 2 – High Estuarine Event

Alternative 2

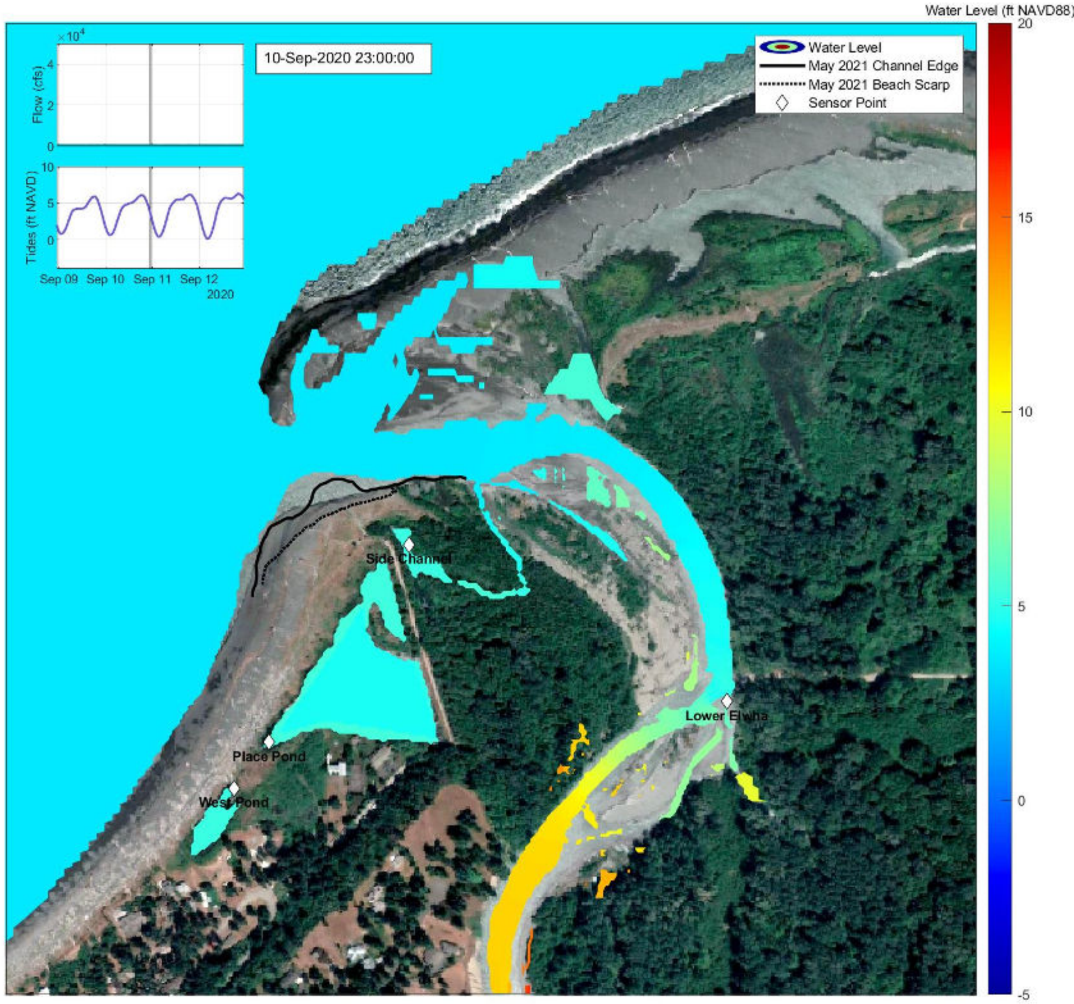
Peak flood timestep



Scenario 2 – High Estuarine Event

Alternative 3

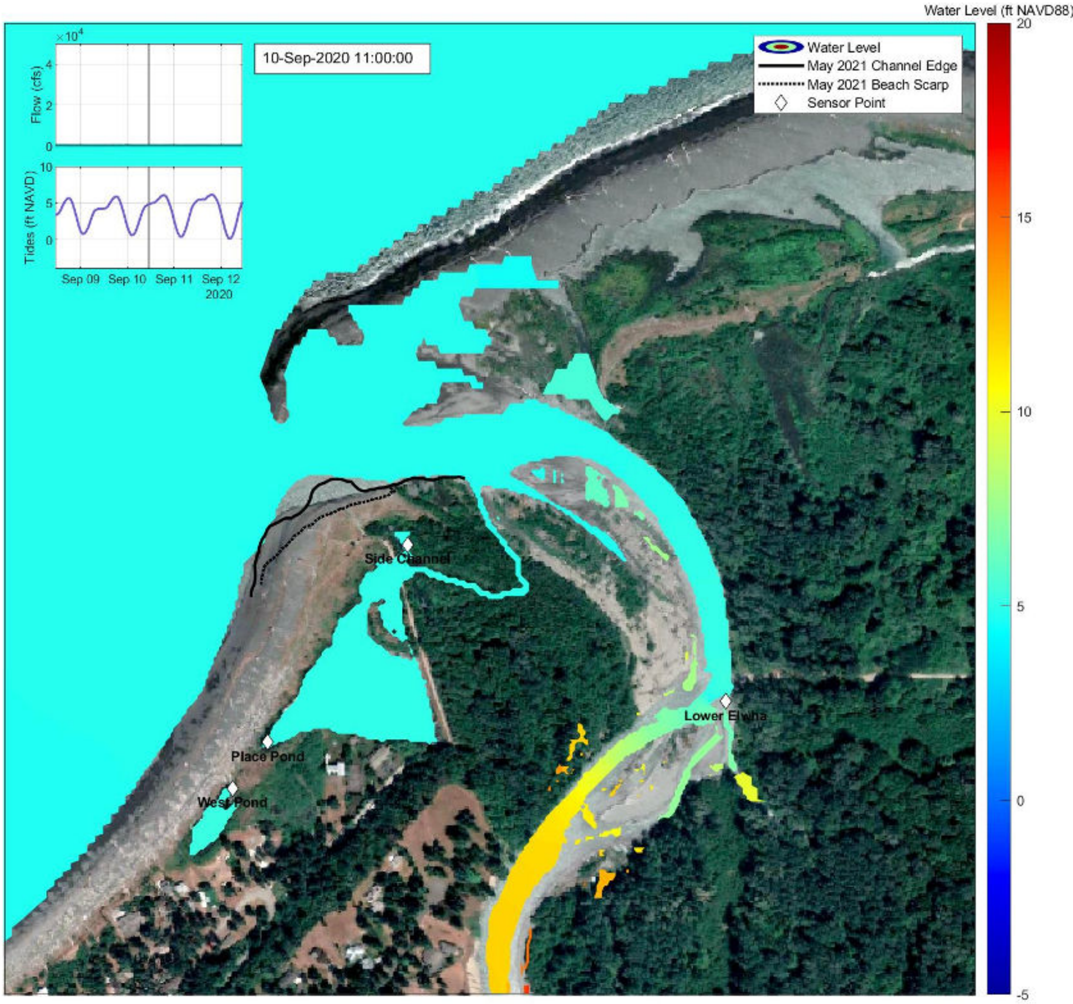
Peak flood timestep



Scenario 3 – Low Estuarine Event

Existing Conditions

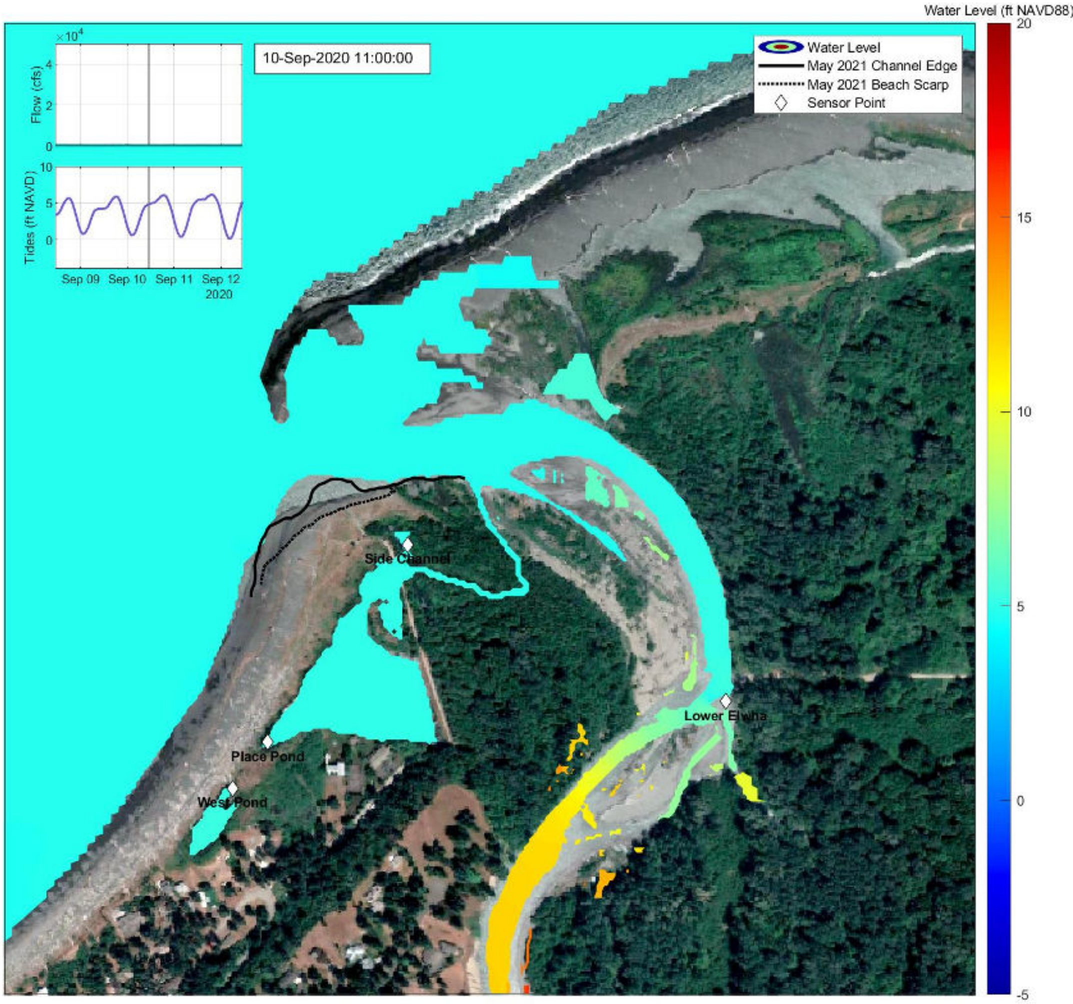
Peak flood timestep



Scenario 3 – Low Estuarine Event

Alternative 1

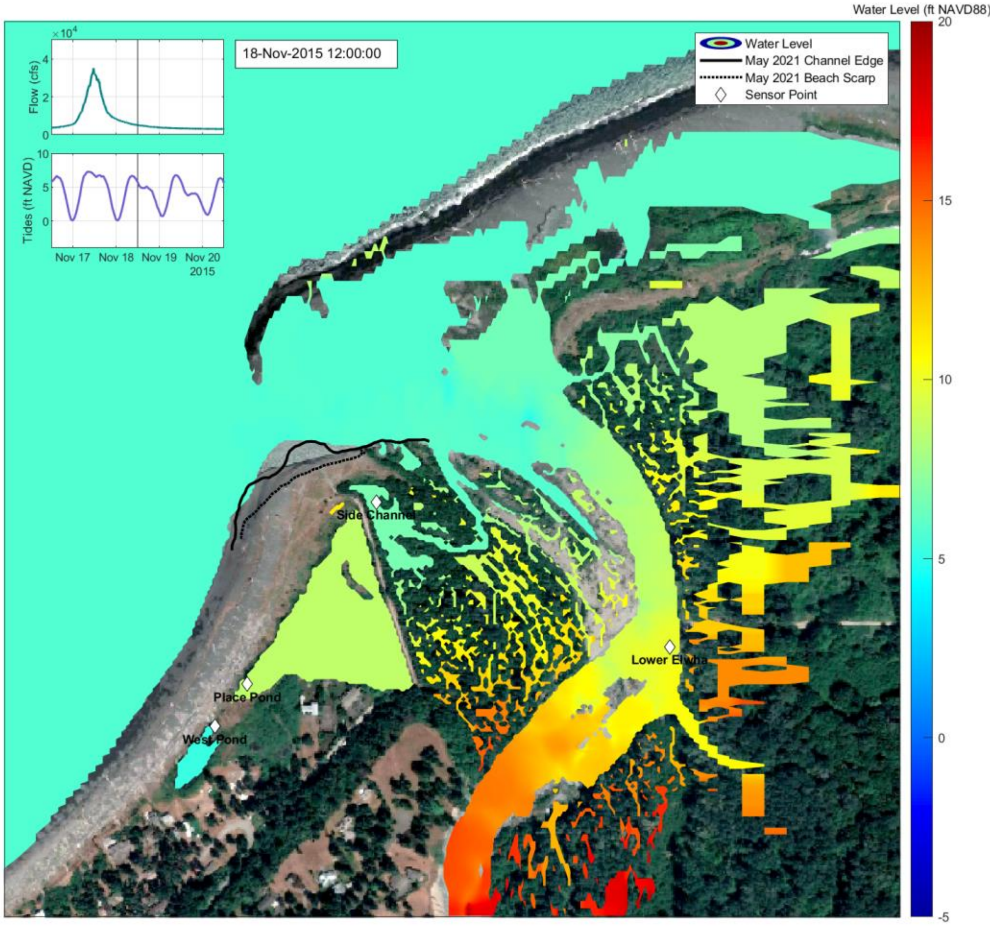
Peak flood timestep



Scenario 3 – Low Estuarine Event

Alternative 2

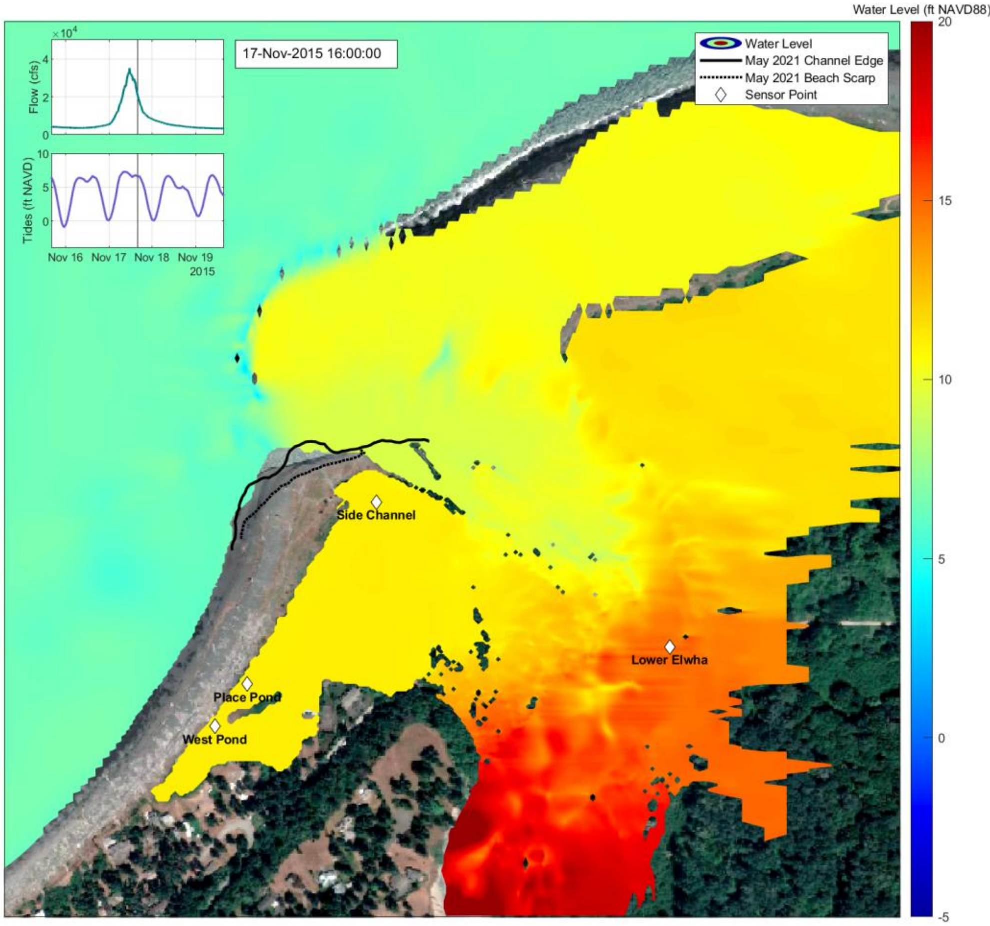
Peak flood timestep



Scenario 4 – 100-year Flow

Existing Conditions

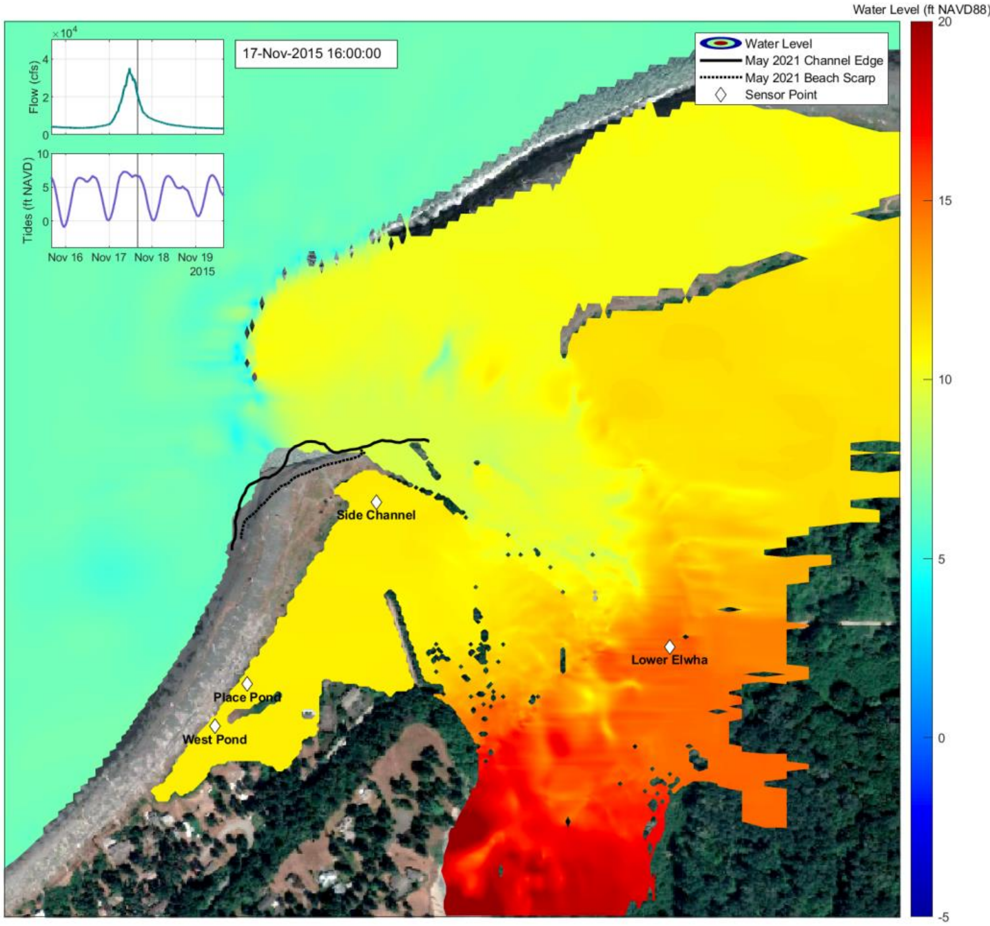
Peak flood timestep



Scenario 4 – 100-year Flow

Alternative 1

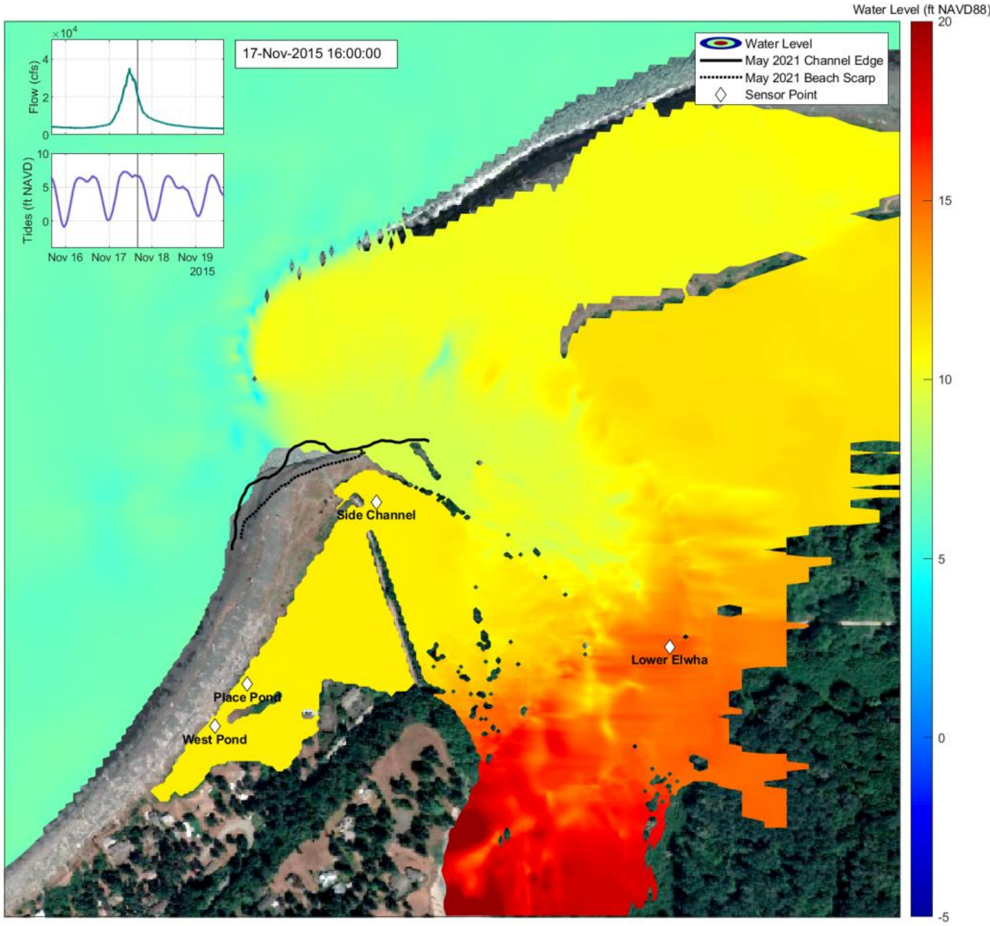
Peak flood timestep



Scenario 4 – 100-year Flow

Alternative 2

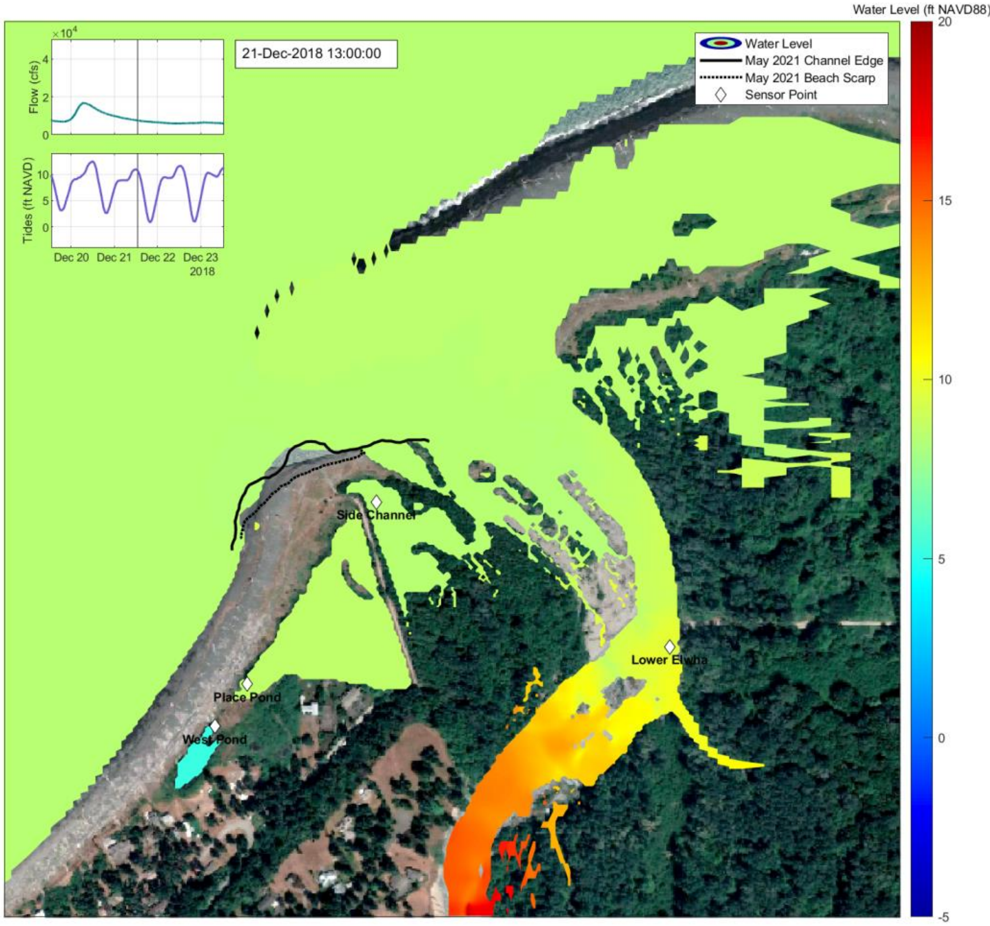
Peak flood timestep



Scenario 4 – 100-year Flow

Alternative 3

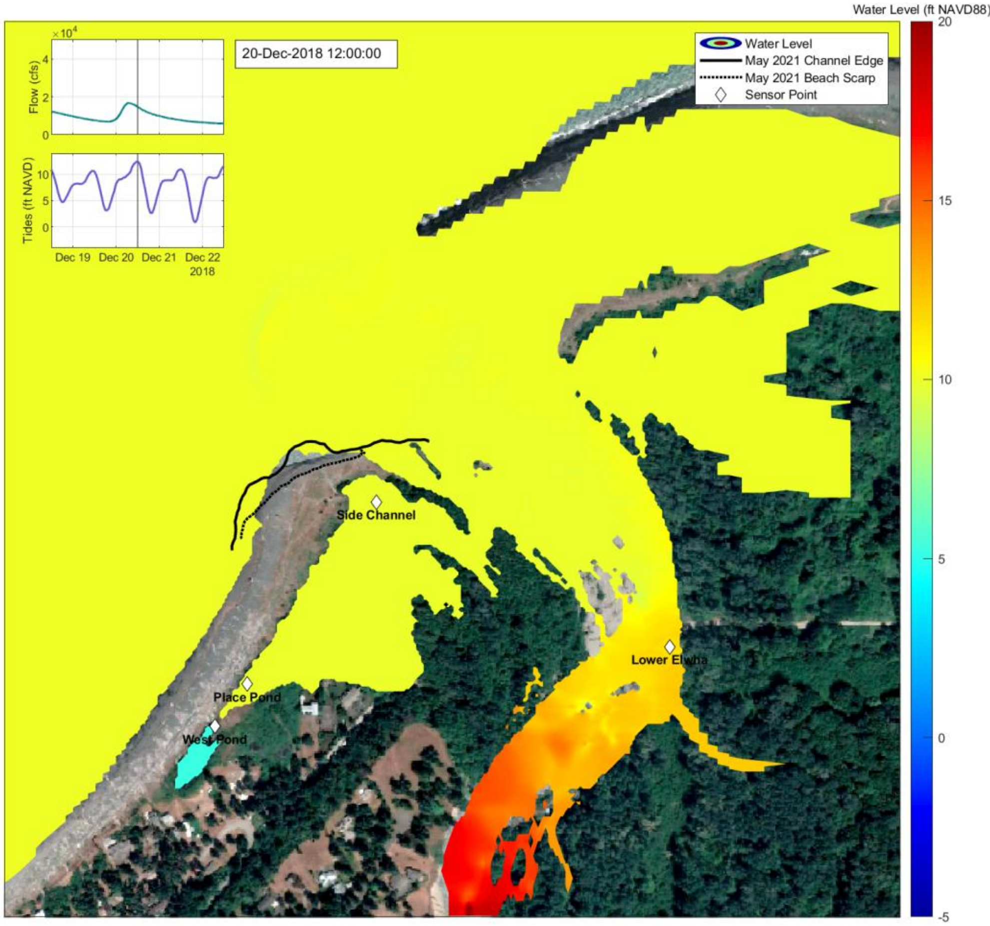
Peak flood timestep



Scenario 5 – 100-year Tide

Existing Conditions

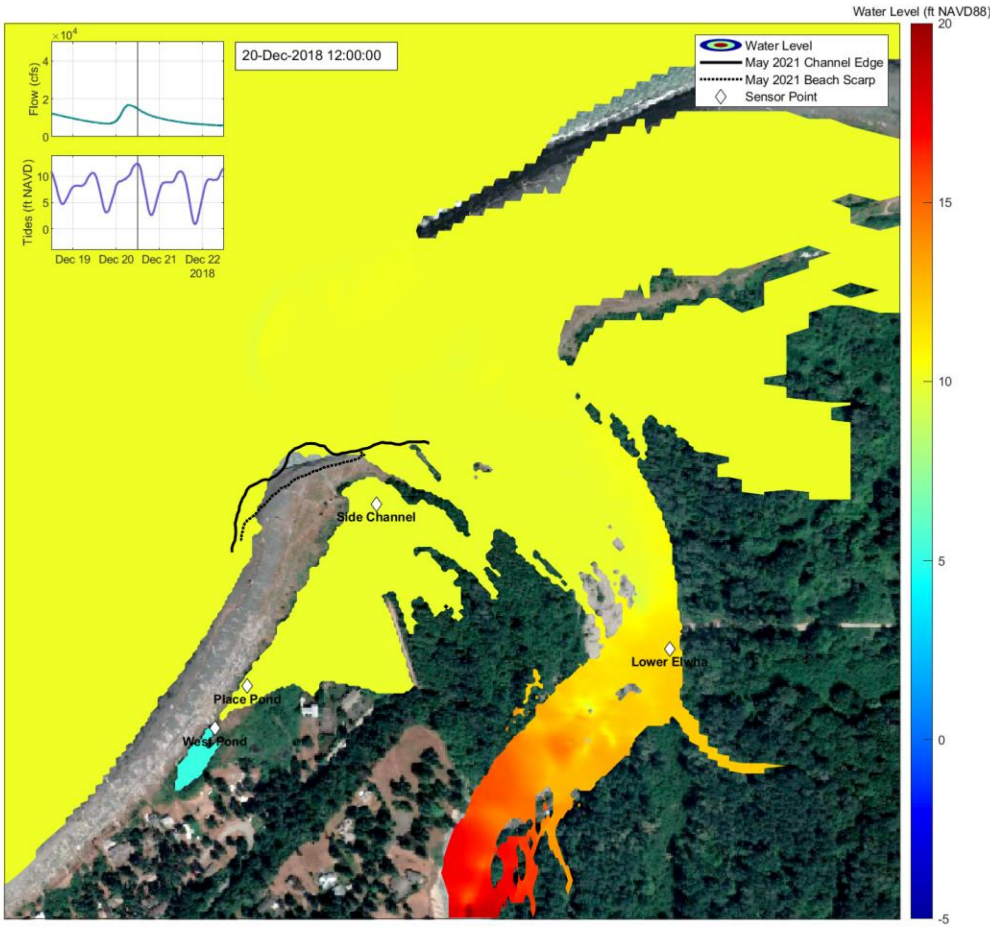
Peak flood timestep



Scenario 5 – 100-year Tide

Alternative 1

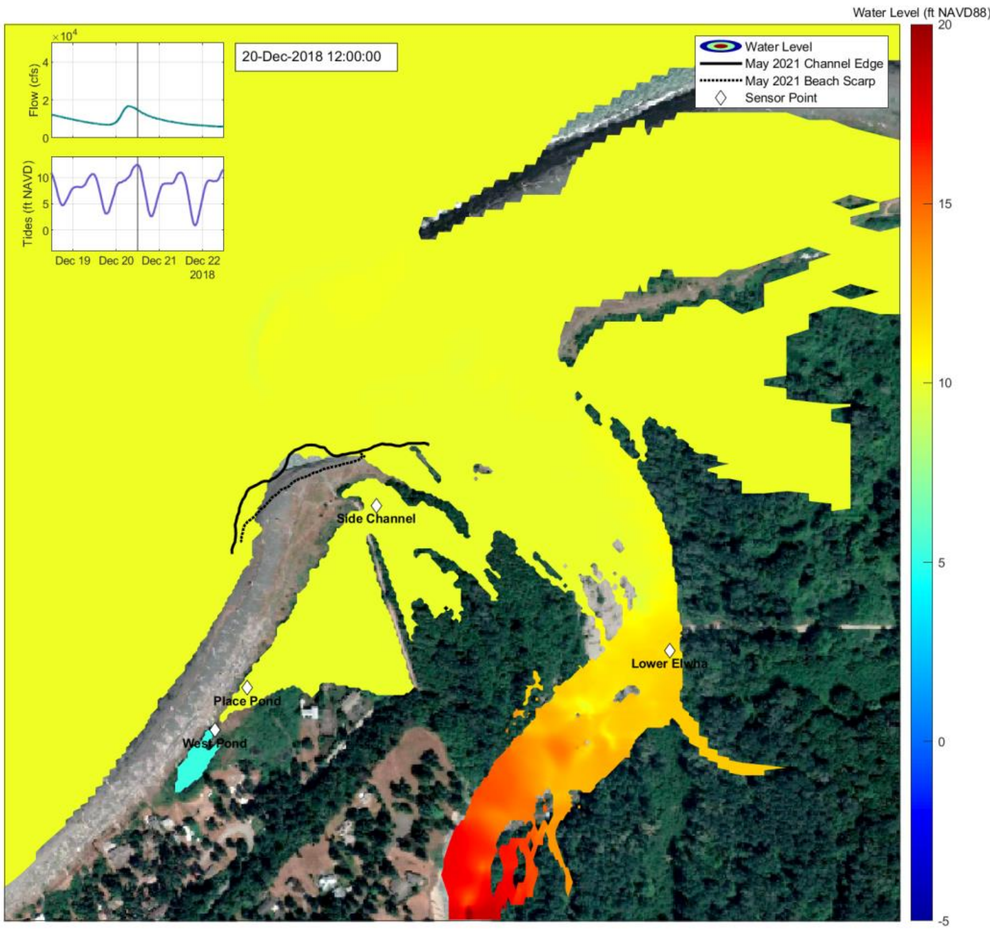
Peak flood timestep



Scenario 5 – 100-year Tide

Alternative 2

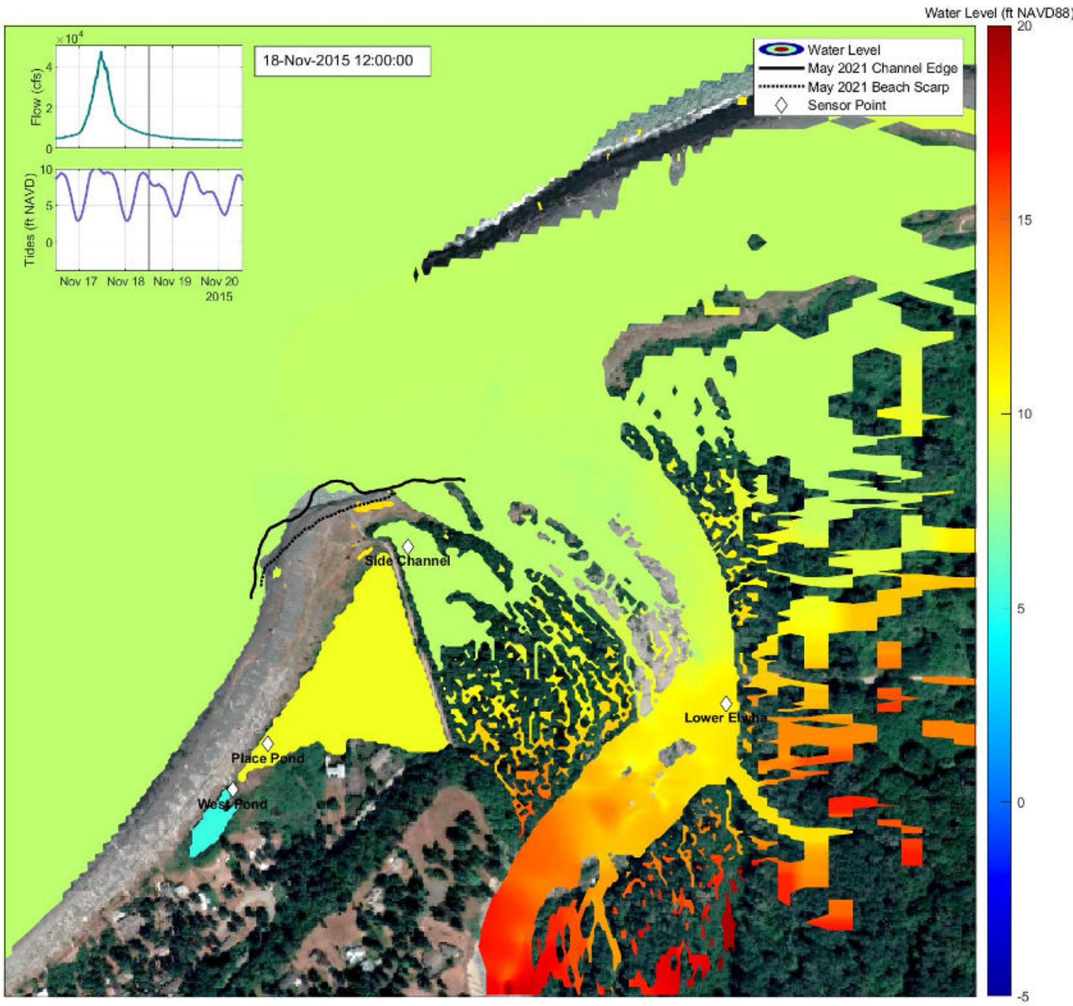
Peak flood timestep



Scenario 5 – 100-year Tide

Alternative 3

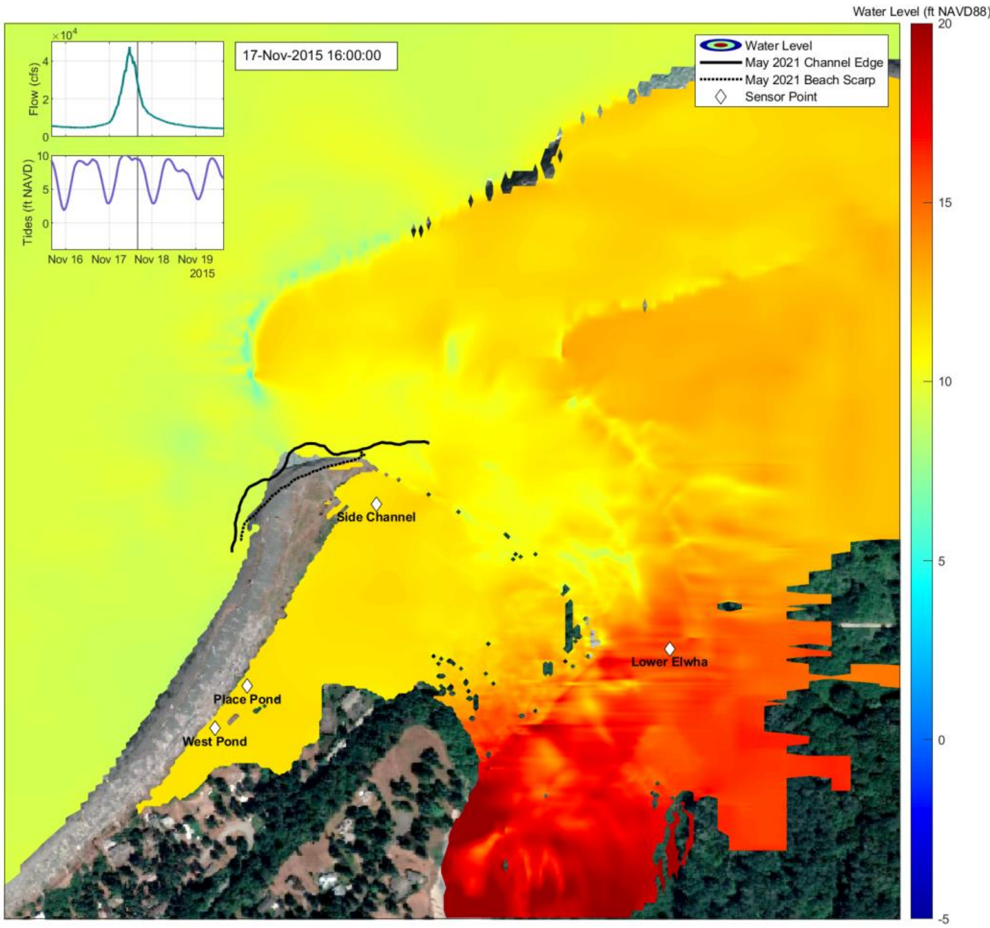
Peak flood timestep



Scenario 6 – Year 2100

Existing Conditions

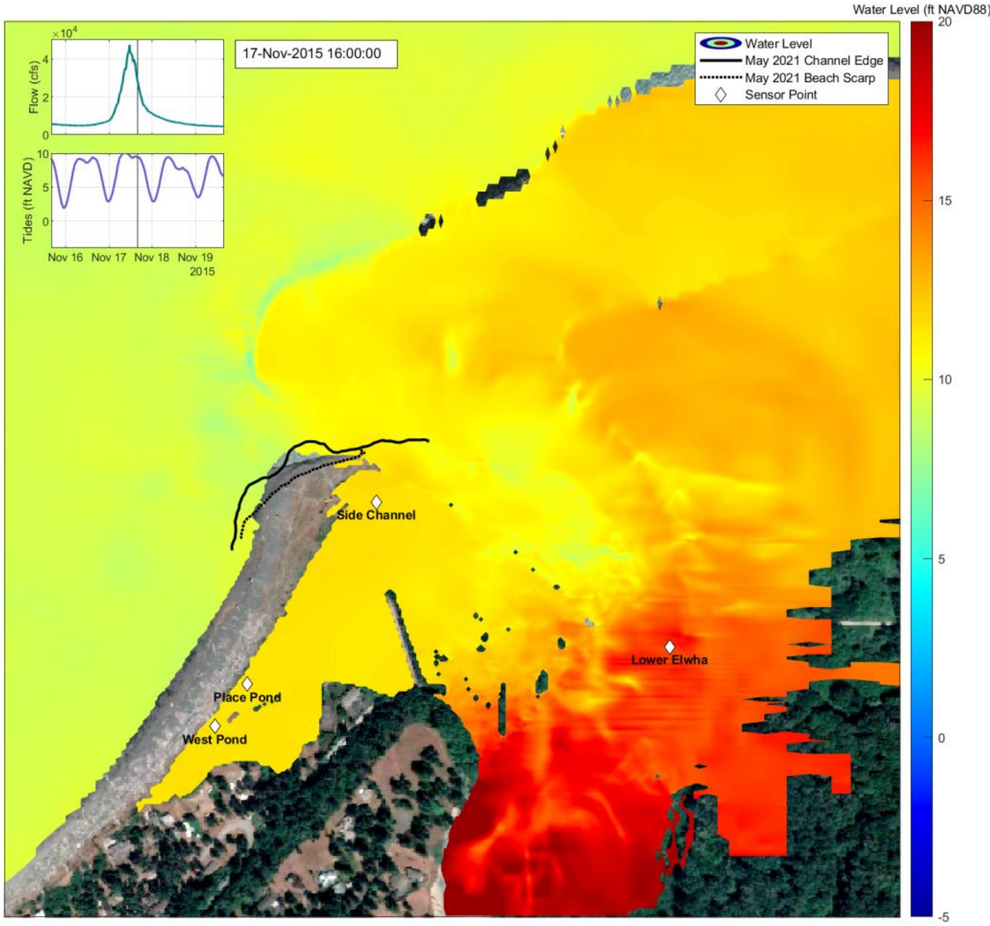
Peak flood timestep



Scenario 6 – Year 2100

Alternative 1

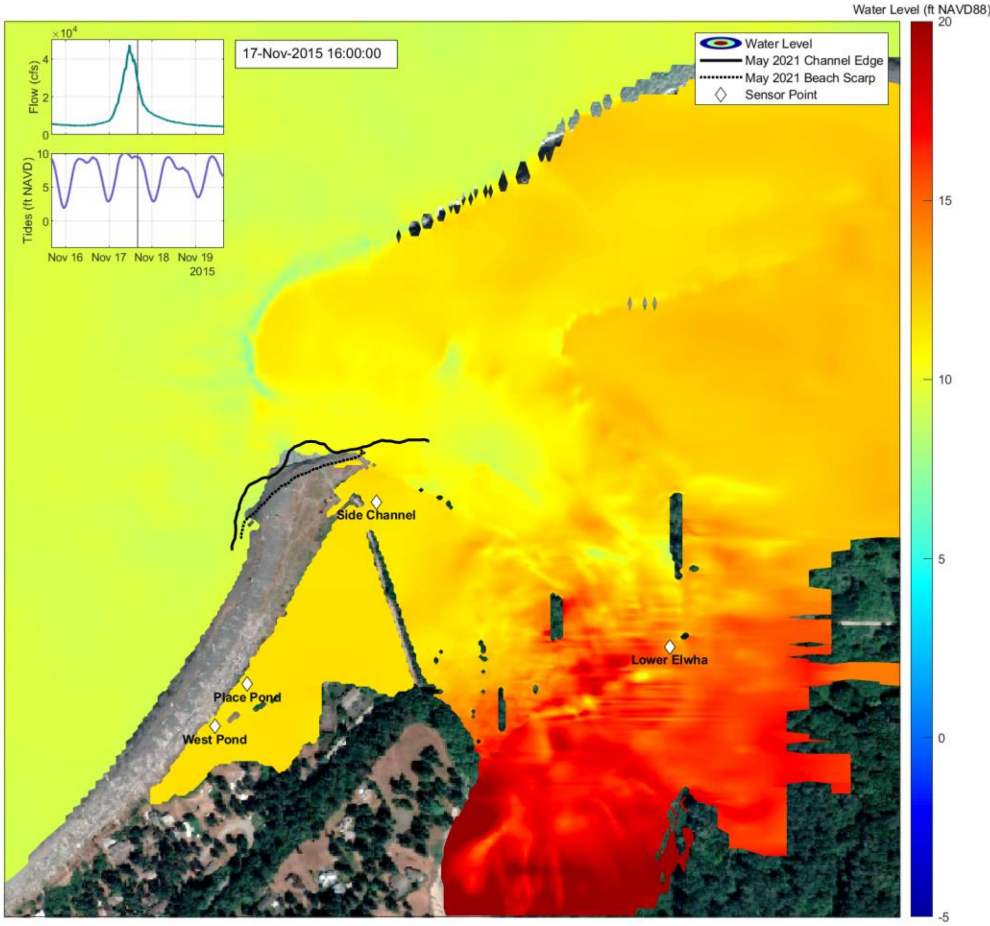
Peak flood timestep



Scenario 6 – Year 2100

Alternative 2

Peak flood timestep



Scenario 6 – Year 2100

Alternative 3

Peak flood timestep

Appendix G

NMFS Evaluation of Existing Structures

ESA

MEMORANDUM BETWEEN THE DEPARTMENT OF THE ARMY (CIVIL WORKS) AND THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

1. Purpose. This memorandum resolves for the Department of the Army's Civil Works program and the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) (the agencies) how the agencies evaluate the effects of projects involving existing structures on listed species and designated critical habitat in Endangered Species Act Section 7 consultations.

2. Background. The issue of how to evaluate the impacts of projects that involve existing structures under section 7 of the Endangered Species Act (ESA) implicates work on both existing U.S. Army Corps of Engineers (Corps) Civil Works projects as well as the Corps' Regulatory Program review of a project proponent's request for discharges or work associated with existing structures.

On May 17, 2021, the Corps submitted a notification to the NMFS West Coast Region (WCR) to initiate an elevation of Policy Issues Regarding National Marine Fisheries Service West Coast Region's Guidance for Assessing the Effects of Structures in Endangered Species Act Section 7 Consultation under the Clean Water Act 404(q) joint agency memorandum. On July 9, 2021, NMFS WCR responded to this request explaining, among other things, that NMFS did not believe the 404(q) elevation process was the appropriate tool to resolve the issues raised.

On September 1, 2021, both agencies and the Council on Environmental Quality (CEQ) received a request from the House Subcommittee on Commerce, Justice, Science, and Related Agencies and the Committee on Appropriations asking the agencies and CEQ to resolve the dispute.

Recent discussions between NMFS and the Office of the Assistant Secretary of the Army (Civil Works) have resulted in the mutual understanding of the legal and policy issues as documented within this memorandum.[1]

[1] This document is not a rule, regulation, or policy guidance. The discussion it contains may not apply to a particular situation based upon the individual facts and circumstances. It does not change or substitute for any law, regulation, or any other legally binding requirement and is not legally enforceable. It does not impose any new or additional requirements on action agencies, applicants, or NMFS and does not alter the existing requirements relative to ESA section 7(a)(2) consultations.

3. Legal Considerations.

a. In April 2018, NMFS WCR issued internal Guidance (Guidance) that laid out principles for making determinations about effects under section 7 of the ESA involving existing structures. The internal, non-binding Guidance was intended to enhance consistency across the West Coast Region in applying the section 7 regulations[2] and help NMFS section 7 biologists determine when the future impacts of a structure are to be considered "effects of the action" in an ESA section 7 consultation. The Guidance did not undergo Office of Management and Budget or Office of Information and Regulatory Affairs (OIRA) or formal public review.[3]

b. In August of 2019, the Services published a final rule updating the ESA section 7 implementing regulations. 84 Fed. Reg. 44976 (August 27, 2019). Among other things, the regulations modified the definition of the term "effects of the action" and added a stand-alone definition of "environmental baseline." *See* 50 C.F.R. § 402.02. The rule clarified various aspects of how agencies and the Services evaluate effects associated with existing agency facilities—including how the issue of agency discretion and authority may, or may not, impact such analyses. Although the discussions included in this memorandum cite to the 2019 ESA regulations and preamble language, the substance and outcome of this memorandum would be the same under the previous version of the ESA regulations as well.[4]

The 2019 regulations include a "but for" and "reasonably certain to occur" two-part test to determine the effects, or "consequences" of an action. "A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to

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[2] In October 2020, NMFS issued a Report to Congress on The National Marine Fisheries Service's Consistent Application of Endangered Species Act Regulations and Implementation of Guidance For Conducting Effects Analyses on Existing Structures that reviewed the 2018 Guidance, along with similar guidance around the country. That review concluded that the WCR 2018 Guidance was consistent with NMFS's national ESA approach (both before and after the 2019 ESA regulations).

[3] In issuing the Guidance in April 2018, NMFS evaluated whether such review was necessary and determined that such process was not required. Following the issuance on October 9, 2018, of Executive Order (EO) 13891, Promoting the Rule of Law Through Improved Agency Guidance Documents, NMFS re-evaluated the Guidance and again determined that the Guidance did not meet the definition of a significant guidance document and therefore took no further action with respect to the already issued Guidance.

[4] The 2019 amendments were intended to clarify, not change, the scope of an effects analysis. *See*, *e.g.*, 84 Fed. Reg. 44976-78 ("The Services do not intend for these regulatory changes to alter how we analyze the effects of a proposed action."); 44989 ("As discussed throughout this rule and in the proposed rule, the Service's overall approach to "effects of the action" has been retained."); 44990 (explaining the "but for" "approach is, in application, consistent with the prior regulatory definition, and the Services accordingly anticipate the scope of their effects analyses will stay the same"); 44991-92 ("With the revisions we are making in this final rule and as discussed elsewhere in this rule, there will not be a shift in the scope of the effects we consider under our new definition of "effects of the action.").

occur." *See* 84 Fed. Reg. 44976, 45016, 45018 (Aug. 27, 2019); 50 C.F.R. § 402.02;[5] 50 C.F.R. § 402.17.[6]

The 2019 regulation defined "environmental baseline" as "the condition of the listed species or its designated critical habitat in the action area, without the consequences to the listed species or designated critical habitat caused by the proposed action. The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process. The consequences to listed species or designated critical habitat from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are part of the environmental baseline." 84 Fed. Reg. 45016, 50 C.F.R § 402.02.

The preamble to the 2019 rule discusses the definition of environmental baseline and how the extent of an agency's discretion should be used to determine whether consequences are part of the environmental baseline or caused by the action (84 Fed. Reg. 44978-79):

> [W]e added a sentence [to the environmental baseline definition] to clarify that the consequences of ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are included in the environmental baseline. [That] sentence is specifically intended to help clarify environmental baseline issues that

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[5] 50 C.F.R. § 402.02 defines "effects of the action" as "all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action. A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action. (*See* § 402.17)."

[6] 50 C.F.R. § 402.17. Other Provisions: (a) *Activities that are reasonably certain to occur.* A conclusion of reasonably certain to occur must be based on clear and substantial information, using the best scientific and commercial data available. Factors to consider when evaluating whether activities caused by the proposed action (but not part of the proposed action) or activities reviewed under cumulative effects are reasonably certain to occur include, but are not limited to:

> (1) Past experiences with activities that have resulted from actions that are similar in scope, nature, and magnitude to the proposed action;
> (2) Existing plans for the activity; and
> (3) Any remaining economic, administrative, and legal requirements necessary for the activity to go forward.

(b) Consequences caused by the proposed action. To be considered an effect of a proposed action, a consequence must be caused by the proposed action (*i.e.*, the consequence would not occur but for the proposed action and is reasonably certain to occur). A conclusion of reasonably certain to occur must be based on clear and substantial information, using the best scientific and commercial data available. Considerations for determining that a consequence to the species or critical habitat is not caused by the proposed action include, but are not limited to:

> (1) The consequence is so remote in time from the action under consultation that it is not reasonably certain to occur; or
> (2) The consequence is so geographically remote from the immediate area involved in the action that it is not reasonably certain to occur; or
> (3) The consequence is only reached through a lengthy causal chain that involves so many steps as to make the consequence not reasonably certain to occur.

> have caused confusion in the past, particularly with regard to impacts from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify.
>
> We added this third sentence because we concluded that it was necessary to explicitly answer the question as to whether ongoing consequences of past or ongoing activities or facilities should be attributed to the environmental baseline or to the effects of the action under consultation when the agency has no discretion to modify either those activities or facilities. The Courts and the Services have concluded that, in general, ongoing consequences attributable to ongoing activities and the existence of agency facilities are part of the environmental baseline when the action agency has no discretion to modify them. With respect to existing facilities, such as a dam, courts have recognized that effects from the existence of the dam can properly be considered a past and present impact included in the environmental baseline, particularly when the Federal agency lacks discretion to modify the dam. *See*, *e.g.*, *Friends of River v. Nat'l Marine Fisheries Serv.*, 293 F. Supp. 3d 1151, 1166 (E.D. Cal. 2018).

With respect to agency authority in the context of a discretionary agency action, the preamble to the 2019 rule clarified that, consistent with the statutory purpose of the ESA, the effects of the discretionary action are not limited to those effects or activities over which a federal agency exerts legal authority or control: "The Services decline to limit the 'effects of the action' to only those effects or activities over which the Federal agency exerts legal authority or control. Once in consultation, all consequences caused by the proposed action, including the consequences of activities caused by the proposed action, must be considered…provided those activities would not occur but for the proposed action under consultation, and both the activities and the consequences to the listed species or designated critical habitat are reasonably certain to occur. Where this causation standard is met, the action agency has a substantive duty under the statute to ensure the effects of its discretionary action are not likely to jeopardize a listed species or destroy or adversely modify its critical habitat." 84 Fed. Reg. 44990 (https://www.federalregister.gov/d/2019-17517/p-145).

c. The Corps interprets its project authorities to require that constructed Civil Works projects be operated and maintained in such a manner that the projects continue to serve their Congressionally authorized purposes, subject to appropriations and budgeting principles. Only Congressional action to change the authorization or de-authorize an existing Civil Works project can alter or terminate this responsibility. However, the manner in which operation, maintenance, repair, replacement, and rehabilitation is performed is often discretionary and subject to ESA section 7 consultation. Examples of discretionary actions include, for example, changing the timing and frequency of how the Corps operates a fish passage facility and adjusting the timing of in-water construction to comply with an in-water work window to reduce impacts on ESA-listed species.

d. Corps regulatory permits authorizing the construction of structures, including fill, typically authorize the permitted structures to exist indefinitely with no expiration date cited. 33 C.F.R § 325.6. Pursuant to general condition 2 at 33 C.F.R. Part 325, Appendix A, and Nationwide Permit General Condition Number 14, permittees are required to maintain the authorized structure or fill in "good condition." If the work required to maintain the structure in good condition involves a new discharge or new structure or work that affects navigable waters, the entity responsible for the structure is required to obtain a separate permit authorization for the discharge, structure, or work that facilitates the maintenance work.[7] "Maintenance" in and of itself is not an activity subject to regulation under Corps regulatory authority. A decision on the permit application for the discharge, structure, or work that facilitates maintenance would not affect an underlying, prior permit that authorized the existence of the structure for an indefinite duration. The decision on the permit facilitating maintenance is not a decision on whether the structure should continue to exist, but a decision on whether to authorize the specific work proposed. The authorization of the existence of the structure can only be changed through a separate process to modify or revoke that prior permit. 33 C.F.R § 325.7. If the Corps were to deny a permit application for the discharge associated with the work to facilitate the maintenance of an existing, permitted structure, such a denial would not revoke or otherwise affect a prior authorization for the structure to exist, nor would the denial modify the requirement to maintain the structure in good condition.

4. Resolution. The Corps recognizes that it has an obligation to request ESA consultation on discretionary federal actions it undertakes or authorizes involving the repair, replacement, maintenance, or modification of existing structures if the activities it proposes to undertake or permit may affect listed species or designated critical habitat.

a. Corps Civil Works Projects. In the case of existing Civil Works projects, the Corps typically lacks the discretion to cease to maintain or operate these Congressionally authorized agency projects or facilities. Only Congressional action can alter or terminate this responsibility. Within each consultation initiation package, the Corps will clearly define the action, describe the Congressional authorization providing for the construction of the project and requiring its continued operation, and specifically set forth the limits to its discretion over the continued existence of the project. NMFS will individually defer to the Corps' case-specific and supported interpretation of any limits to its discretion on a project-by-project basis.

When the Corps lacks the discretion to modify (or cease to operate and maintain) a previously authorized structure, the effects stemming from the existence of that structure into the future would be considered part of the environmental baseline. However, generally any short-term effects of the action (e.g., construction impacts), as well as any other parts of the action over which the Corps retains discretion (e.g., manner and timing of maintenance or operations) would be evaluated and included in the effects of the action analysis. *See* 84 Fed. Reg. 44979 (explaining that consultations will evaluate the future effects of all discretionary operations, even those operations that the federal agency proposes to keep the same).

b. Corps Regulatory Program. By contrast, the Corps acknowledges, consistent with Section 3.d above, that it has the discretion to decide whether to issue (or deny) a regulatory permit to replace, repair, maintain, or otherwise modify existing structures, and that in deciding whether to grant such a permit, it will consider the impacts of its decision on ESA-listed species and critical habitat. *See*, *e.g.*, 33 C.F.R. § 325.2(b)(5) (review of permit applications pursuant to section 7 of the ESA); 40 C.F.R. Part 230.10(b)(3) (Corps 404(b)(1) Guidelines requiring that permits for dredge or fill may not be issued if it would jeopardize the continued existence of species listed as endangered or threatened or result in the likelihood of the destruction or

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[7] Under section 10 of the Rivers and Harbors Act of 1899, the Corps has authority to regulate "structures and/or work in or affecting navigable waters of the United States. 33 C.F.R § 322.3(a). Under section 404 of the Clean Water Act, the Corps has authority to regulate "discharges of dredged or fill material." 33 C.F.R § 323.3(a). If there is a structure or work in or affecting the navigable waters or a discharge of dredged or fill material that serves the purpose of facilitating maintenance work, the Corps will evaluate the effects of the maintenance work when making a permit decision.

adverse modification of a habitat designated as critical); and 33 C.F.R. § 320.4 (Corps public interest review applies to all applications for Department of the Army permits and requires an evaluation of the proposed activity to determine whether issuance of the permit is contrary to the public interest where expected benefits are balanced against reasonably foreseeable detriments. One such factor of consideration is 'Fish and Wildlife.').

Because the Corps has discretion to issue regulatory permits, future effects stemming from the existing structure are not always considered part of the environmental baseline. Instead, the agencies will evaluate, as an effect of the action, what consequences would not occur but for the action and are reasonably certain to occur.

To evaluate whether the future effects from an existing structure should be considered a consequence of the action, the agencies will consider whether the maintenance, repair, replacement, or modification activity may cause effects that occur later in time or outside of the immediate area involved in the action, and whether the action may extend the impacts of the existing structure into the future. In reaching this determination, the agencies will consider various factors, including the current condition of the structure, how long it would likely exist irrespective of the action, and how much of it is being replaced, repaired, or strengthened, as well as whether a prior consultation has addressed the effects of the structure (and, if so, for what time period). The agencies acknowledge that not all maintenance-type activities would result in the structure having future effects that would be considered a consequence of the maintenance-type action.

If the applicant seeking a Corps' regulatory permit is another federal agency, and that federal agency lacks the discretion to modify or cease to maintain or operate an existing agency structure or facility, then the extent of the federal agency applicant's discretion should be used to define the action. Similar to Corps' Civil Works projects, the federal agency applicant should clearly define the action, describe the Congressional authorization providing for the construction of the project and requiring its continued operation, and specifically set forth the limits to the federal agency applicant's discretion over the continued existence of the project. This information should be included in the consultation initiation package. NMFS will individually defer to the federal agency applicant's case-specific and supported interpretation of any limits to its discretion on a project-by-project basis.

The agencies agree that provisions of a reasonable and prudent alternative (RPA) or reasonable and prudent measures and terms and conditions in an incidental take statement (ITS) that address activities that are completely outside the Corps' authority should be assigned solely to applicants. *See, e.g.,* 84 Fed. Reg. 44990 ("When the Services write an incidental take statement for a biological opinion, under section 7(b)(4)(iv) of the Act they can assign responsibility of specific terms and conditions of the incidental take statement to the federal agency, the applicant, or both."). The Corps will include as a condition of the Corps permit the ITS or RPA when required under a Section 7 consultation.

5. Expiration Date. This memorandum is effective immediately and will remain in effect until it is amended, superseded, or revoked, whichever occurs first, upon written agreement from both agencies.

____________________________ 1/05/22

Michael L. Connor
Assistant Secretary of the Army (Civil Works)
Department of the Army

____________________________ 1/05/22

Richard W. Spinrad, Ph.D.
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