Wallacut River Confluence Restoration

Final Basis of Design Report

June 3, 2016

501 Portway Ave, Suite I01, Hood River, OR 97031 | 541-386-9003 | interfluve.com

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JUNE 3, 2016

SUBMITTED TO
Ian Sinks
Columbia Land Trust
1351 Officer's Row
Vancouver, WA 98661

PREPARED BY
Inter-Fluve, Inc.
501 Portway Ave, Suite 101
Hood River, OR 97031
(541) 386-9003

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1 Introduction

The Wallacut River flows into Baker Bay at Columbia River Mile (RM) 3, just upstream of Ilwaco, Washington (Figure 1). The Columbia Land Trust (CLT) acquired a 113 acre parcel of forested wetland bounded by the Columbia River to the south, the Wallacut River to the north and west, and Stringtown Road to the east. This marsh is hydrologically connected to the Wallacut River through two small culverts in a farm levee that runs parallel to the Wallacut. CLT is evaluating restoration actions at the site to improve fish habitat and wetland function by increasing the connectivity of the marsh to the mainstem Wallacut River while minimizing potential impacts to adjacent landowners.

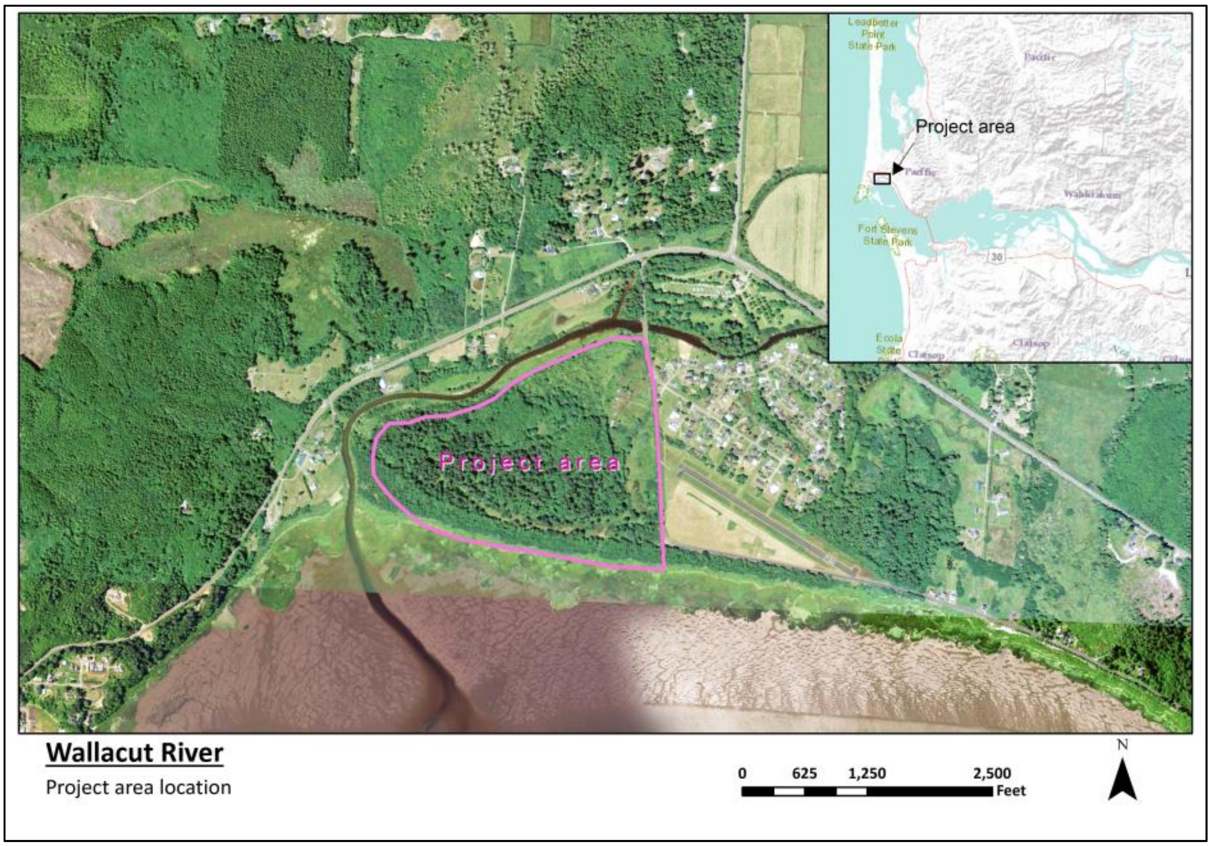

Figure 1. Wallacut River project area location.

The purpose of this project is to enhance marsh ecosystem function and rearing habitat for ESA-listed juvenile salmonids, including Lower Columbia River Chinook salmon (Oncorhynchus tshawytscha), Upper Willamette River spring-run Chinook salmon, Upper Columbia River spring-run Chinook salmon, Snake River spring/summer run Chinook salmon, Snake River fall-run Chinook salmon, Columbia River chum salmon (O. keta), Lower Columbia River coho salmon (O. kisutch), Snake River sockeye salmon, Lower Columbia River steelhead (O. mykiss), Upper Willamette River steelhead, Middle Columbia River steelhead, Upper Columbia River steelhead, and Snake River Basin steelhead. This project will seek to restore hydrologic connectivity between the Wallacut River and the marsh while addressing habitat and food web limiting factors for estuary habitat as listed in the 2011 Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead (Estuary Partnership and PC Trask 2011) and the Estuary Tributaries Subbasin Plan (LCFRB 2010). Limiting factors identified for juvenile salmonids in the Wallacut River include habitat connectivity, diversity, channel stability, riparian and floodplain function, stream flow, water quality, and substrate and sediment (LCFRB 2010).

Project Objectives

- Increase hydrologic connectivity between the marsh and the Wallacut River
- Increase habitat quality, quantity, and connectivity for native fish species including ESA-listed salmonids
- Restore diverse native vegetation communities and protect mature vegetation where practicable

Potential Constraints

The Columbia River Estuary (CRE) and the Wallacut River have experienced landscape changes which can impact the feasibility of successful ecosystem restoration. The following potential constraints were considered when considering project feasibility:

- Existing levee and tide gate infrastructure on the east side of the project area that limit natural hydrologic connectivity
- Hydro-regulation of the Columbia River
- Non-native species presence in the region
- Potential risk to adjacent property and infrastructure

Proposed project elements are listed below with BPA HIPIII activity categories in parentheses:

- Levee removal and borrow ditch filling (Activity category 2b)
- Marsh channel reconnection and excavation (Activity category 2a)
- Marsh floodplain wood addition (Activity category 2d)
- Revegetation (Activity category 9b)

Final Designs

Previous phases of design included a Preliminary (30%) Basis of Design report, Preliminary (30%) Design Drawings, 90% Basis of Design report, 90% Design Drawings, Updated 90% Design Drawings, and Updated 90% Basis of Design Report, and a bank stability analysis . This report and associated Design Drawings have been further refined based on comments received through reviews by Columbia Land Trust, BPA, Ecology and other project partners and agency staff.

The Final Design Drawings and bank stability analysis are included as appendices to this report. An Engineer's Opinion of Probable Cost and Technical Specifications are also being submitted with this report.

2 Site Investigation

Restoration opportunities were evaluated by reviewing existing data sets, on-site reconnaissance and survey, hydrodynamic modeling, and discussions with project sponsors and adjacent landowners. The site investigation and analysis is described below.

2.1 DATUMS

Tidal datums used in this report include:

- Highest measured tide (HMT) = 11.78 feet.
- Ordinary high water (OHW) = 8.02 feet. Assumed equal to MHHW, based on Ecology guidance.
- Mean higher high water (MHHW) = 8.02 feet.
- Mean lower low water (MLLW) = 0.11 feet.

Datums are taken from years of data defined by the current tidal epoch. MHHW refers to the mean of all the higher high tides. MHW refers to the mean of all the lower high tides. MLLW and MLW are similarly defined. All are referenced to the North American Vertical Datum of 1988 (NAVD88).

2.2 EXISTING DATA

Existing data sources for the project area include LiDAR, aerial photography, river gage records, historical vegetation and land use maps, a cultural resources investigation (Willis et al. 2013), and multiple primary literature resources.

LiDAR

A digital terrain model (DTM) of the lower Columbia River from RM 146.5 to RM 0 was developed for the US Army Corps of Engineers (USACE) in 2010. This DTM consists of bathymetric data collected between 1851 and 2010 and light distance and ranging (LIDAR) collected from 2009-2010 during low flow conditions (below 75% exceedance) (Dave Smith and Associates Inc, CC Patterson and Associates, and David Evans and Associates Inc, 2010).

Aerial photography and historical survey records

Historical and current aerial images are available for the site through United States Geological Survey (USGS). Imagery for years 1956, 1971, and 2014 were collected to evaluate historical land use and vegetation communities. Historical survey maps for the year 1859 were collected from the Bureau of Land Management General Land Office Records (BLM GLO) website.

Hydrologic data

National Oceanic and Atmospheric Administration (NOAA) water level gages are located on the Columbia River at Ilwaco, Washington (#9440597) and at Astoria, Oregon (#9439040). These data were compared to water sensor data collected on site to extrapolate historical tidal.

Historical land use

Historical land use data from T-sheets and historical land survey notes has been analyzed and summarized by the Estuary Partnership and researchers at the University of Washington (Burke 2010).

2.3 SITE SURVEY AND INVESTIGATION

Existing data was supplemented with onsite evaluations including site reconnaissance, topographic survey, water level monitoring, and bank stability analyses. Cultural resources assessment was completed by Willis et al (2013) and a wetlands assessment was completed by CLT.

Topographic and bathymetric survey

A 3-dimensional surface was prepared in AutoCAD combining the available LiDAR data with bathymetry and survey data collected on July 18 and August 22, 2014. Bathymetric data were collected using an echosounder and RTK GPS.

Water level monitoring

A three HOBO U-20 pressure sensors were deployed in the project area from May 1, 2014 through December 13, 2014 and January 28, 2015 through May 14, 2015. One sensor was placed in the Wallacut River, one in the marsh, and one in a tree to collect barometric pressure only. These data were used to calibrate the hydraulic model and establish baseline hydrologic conditions. These data were also compared to the nearby NOAA gages to extrapolate historical tidal data.

Bank stability

Bank stability was assessed in the field on March 14, 2016 to characterizing soil characteristics of the bank and classifying soils within these different layers. These data were used to populate a bank stability and toe erosion model (BSTEM).

Cultural resources assessment

A cultural resources assessment was completed by Historical Research Associates Inc. in 2013 (Willis et al. 2013).

Wetlands assessment

A wetlands assessment was completed by Columbia Land Trust in 2016 (CLT 2016).

3 Site Conditions and Baseline Analysis

3.1 LANDFORMS AND GEOMORPHOLOGY

Historical Floodplain Surfaces

The Lower CRE, which extends from the Pacific Ocean to Bonneville dam, has been shaped by a combination of physical processes and human alterations. Formation of pre-disturbance landforms within the project area was driven by a combination of tectonic processes, tidal hydrology, and marine processes. Marine processes, specifically maritime winter storm sequences, led to a substantial influx of sediment in the project area. This influx, mainly transported from wind and waves, built dunes and elevated floodplain surfaces (Canon 2015). Unlike in more upstream reaches of the Columbia, this sediment influx, combined with coast margin uplift, have allowed for the raising of the project area's surface to outpace corresponding coseismic subsidence (as well as contemporary levee-driven subsidence) (Canon 2015, Peterson 2013).

The Wallacut River enters the Columbia River in Baker Bay. Historical accounts describe the confluence of the Wallacut with Bakers Bay as a stream "40 yards wide" with "an open sandy bottom" (Topinka 2016). Baker Bay is characterized by a shallow intertidal embayment. The Bay is somewhat sheltered from high wave energy entering the mouth of the Columbia River due to its leeward position behind the Columbia's south spit. This sheltered position has allowed for relatively high sedimentation rates in the project vicinity (3 to 5 meters ka-1). This relatively rapid infilling and protected position led to the development of extensive tidal flats and marshes (3.2-6.5 feet), such as the surface the project area occupies, which have nearly infilled the tidal creek valleys that formed the embayment (Peterson 2013, Topinka 2016). These marshes historically supported conifers three and four feet in diameter, had extensive ponds, and vast amounts of drift wood and slash (Topinka 2016).

Historically, the migration of and deposition by the Wallacut River also likely had influence on the project area's surface. Scars visible on high-resolution LiDAR suggest that historically the Wallacut migrated across the southwestern portion of the project area, oscillating between erosional and depositional processes. Historically, larger floods from the Wallacut River and Columbia River, combined with ocean tides would have defined the shape of the Wallacut's mouth and associated fan.

Contemporary Floodplain Surfaces

The landforms visible at today's project area have been altered by a variety of anthropogenic impacts including flood control systems (dams and levees), infrastructure development, and vegetation change. The majority of the Wallacut River has been impacted by a levee and tide gate located at Stringtown Road. This tide gate significantly reduces upstream floodplain inundation from tides, which is presently classified as an isolated surge plain (Figure 2). Ditching and leveeing in the project area have reduced both magnitude and duration of the tidal cycle. This has impaired marsh processes that are dependent on inundation, including sediment deposition, tidal channel formation, nutrient cycling, and fish access.

The Wallacut River basin is primarily forested with residential and agricultural uses concentrated near the mouth of the river. The left bank of the Wallacut River in the project area includes a small farm levee and no habitable structures. The farm levee is connected with the marshplain via damaged culverts which allow flow into one tidal channel and a ditch system. This levee is deteriorating, and higher flows (above about 10.69 ft) overtop the levee. The project area includes a large portion of spruce forest with alder and willow along the riparian corridor. Native and non-native shrubs and herbaceous species are present within the study area, with species make-up dependent upon elevation. Elevations within the project area are mostly above the elevation of MHHW (8.02 ft). Some vegetation within the project area is likely present at an elevation lower than natural ranges given inundation protection from the levee. We do not suspect substantial contemporary marsh subsidence has occurred given the current elevations of the site and the partial connection to tidal hydrology in this area. The topographic survey at the site was used to ground truth the 2010 LiDAR no no systematic offsets in elevations that would indicate subsidence was found.

The right bank of the Wallacut River includes residential development and associated fences and lawns as well as native trees and shrubs. The existing homes and other buildings are located back from the river bank; however, a few fenced areas are close to the bank. A subdivision is located upstream of Stringtown Road to the east of the project area.

Hydroregulation has reduced flood magnitudes on the Columbia, while levees and tide gates have reduced flood magnitudes and tidal prism in the Wallacut River. These anthropogenic impacts have caused constriction of the Wallacut River channel and promoted deposition near the mouth , which has slowly been migrating south through the photo record

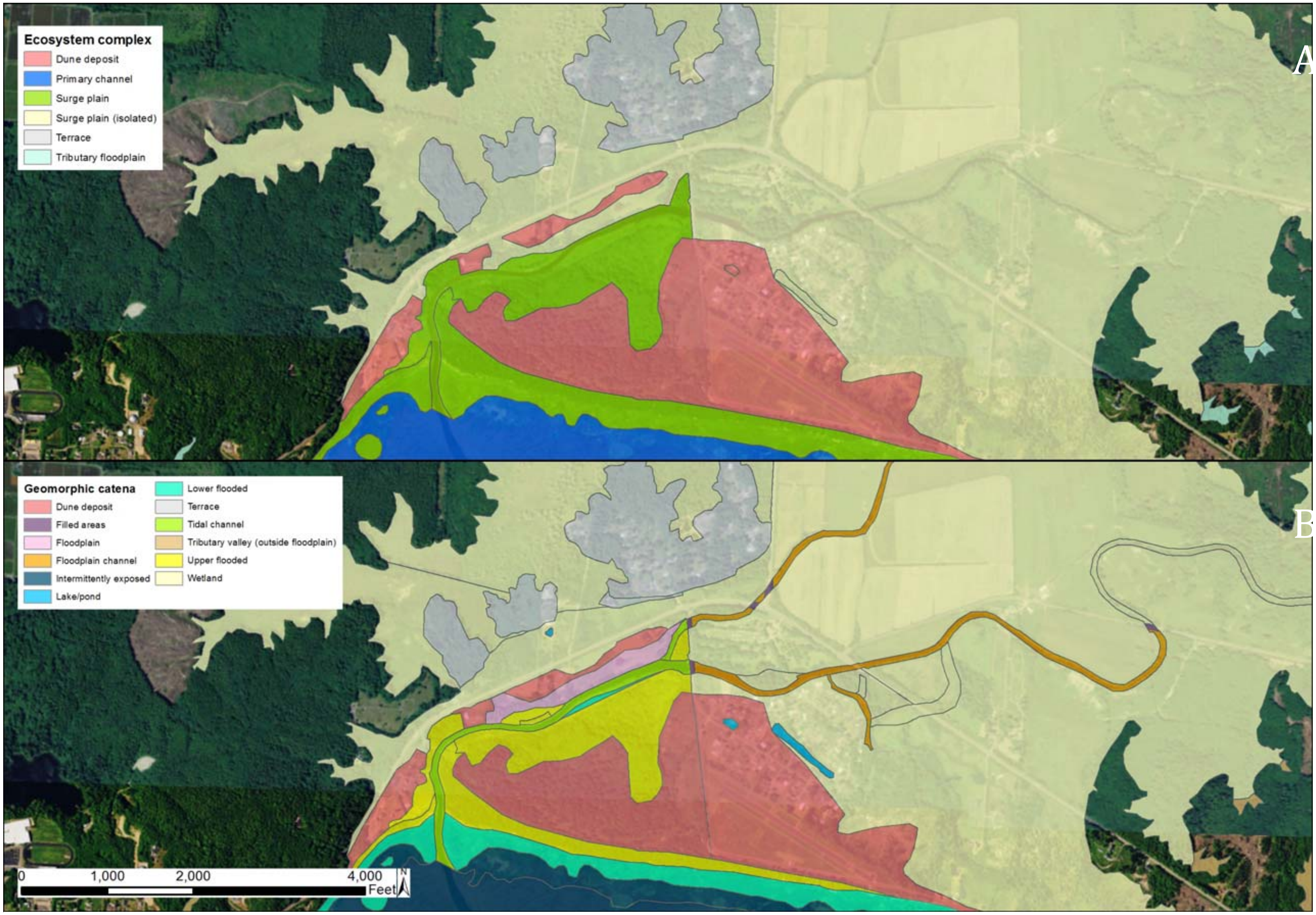

Figure* 2*. Ecosystem complexes and geomorphic catena of the Wallacut River mouth, data from Columbia River Estuary Ecosystem Classification (Cannon et al. 2012). (A) Displays ecosystem complex and (B) displays geomorphic catena.

3.2 HISTORICAL LAND USE

A cultural resources survey was completed for the Wallacut River Confluence project site and the report described historical land use in the area (Willis et al, 2013). The report's findings are summarized below; however more detail is available within the complete report.

Land use before European contact

The Chinook people historically occupied the Pacific coastline from Willapa Bay to Tillamook Head, and along the banks of the Columbia River from the mouth to the present day town of The Dalles, Oregon. The center of their territory was between Baker Bay and Willapa Bay. Most populations of Chinook people on the Pacific coast lived alongside bays, estuaries, and river mouths. They used these locations for fishing and shellfish harvested during late spring and summer. Gathering of plants and hunting supplemented their diet (Willis et al. 2013).

Land use after European contact

Euroamericans began trading with Lower Columbia Chinook peoples by the late 1700s. In 1795, the English ship Ruby docked in Baker Bay where its crewmen traded with Chinook peoples and began planting gardens on offshore islands. Following these occasional trips, Lewis and Clark's inland expedition arrived in the region for an extended stay in the Cape Disappointment-Baker Bay region of southwestern Washington from 1805 to 1811 (Willis et al. 2013).

Historical land surveys and aerial photography were collected from 1859 through 2014 from BLM GLO and USGS to evaluate historical land use at the project area (Figure 3). Historical survey maps from 1859 show the Wallacut River mouth wider and located farther north than it is today. The Wallacut River is shown with the Stringtown Road levee and tide gate in place by 1956, which was likely installed to control flooding and drain the land for agriculture. Much of the land has been cleared around the mouth of the river for agriculture with mature vegetation is only visible on the south half of the project area. The 1976 image shows a small settlement east of Stringtown Road. The farm fields in the project area have been reclaimed by vegetation by 2014, and more infrastructure is present north and east of the river.

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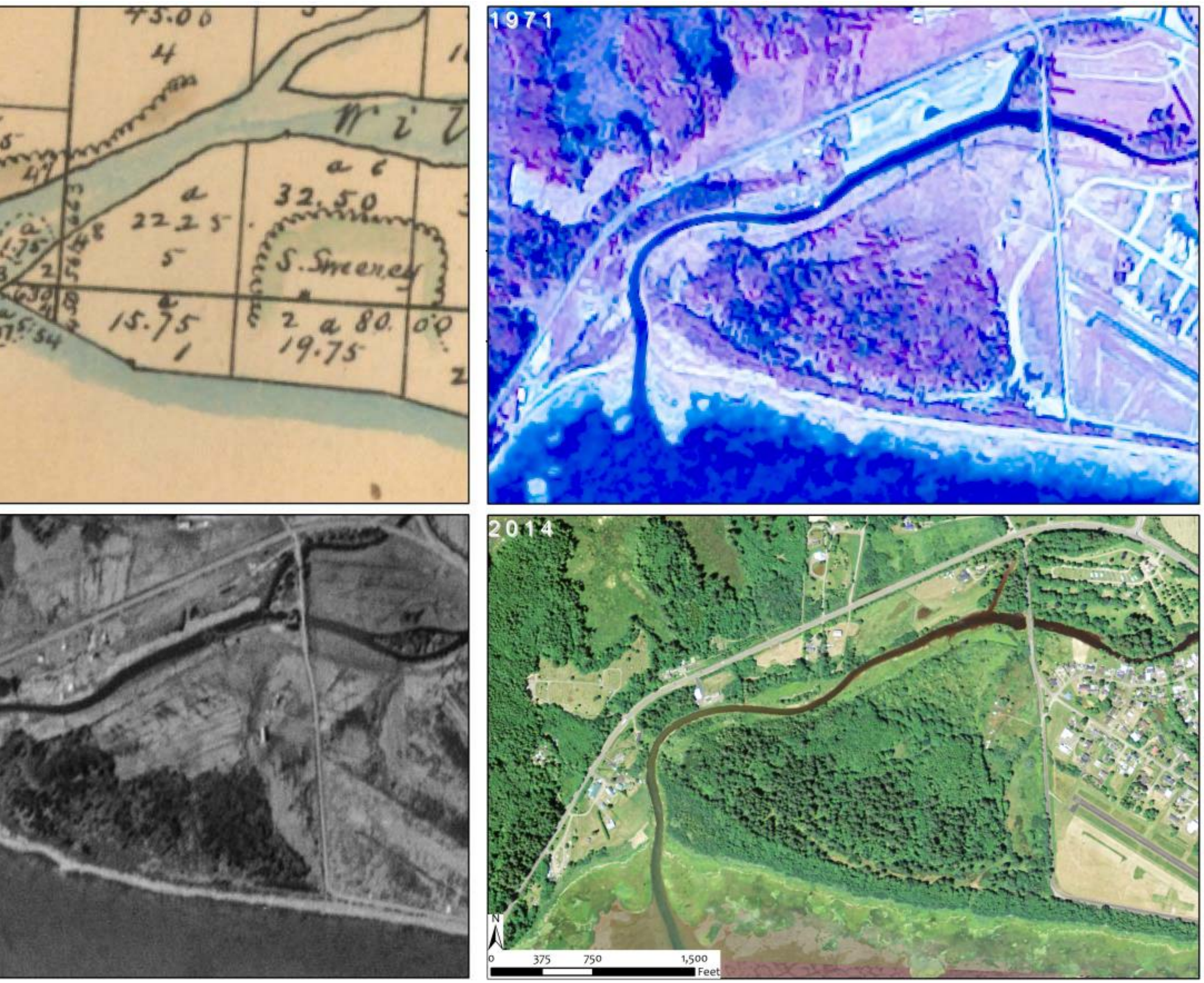
1971
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S. Sweeney
N
0
375
750
1,500
Feet

3.3 HYDROLOGY

The Wallacut River basin is approximately 5.5 square miles in area and varies from 0 to 390 feet in elevation. The watershed receives approximately 77 inches of precipitation annually (Franklin and Dryness 1988). Summers are typically cool and dry and winters are wet and mild (Figure 4).

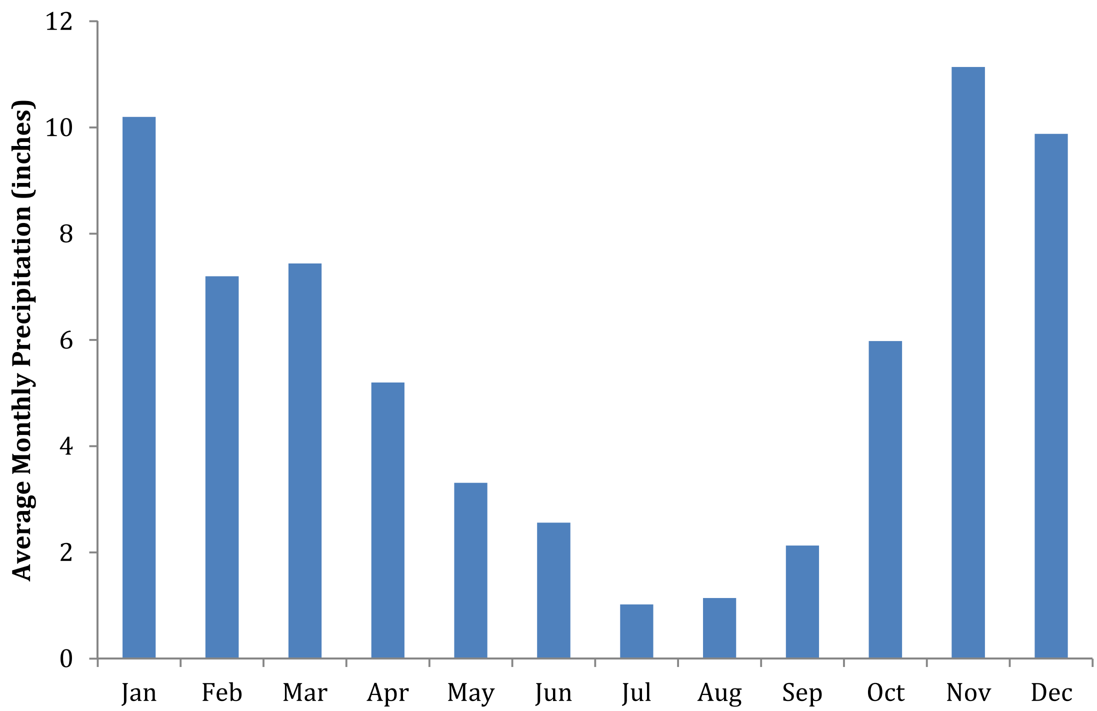

Figure 4. Average monthly precipitation at Astoria Oregon from 1981 - 2010 (usclimatedata.com).

The project area is bounded on the upstream side by a tide gate at Stringtown Road and on the downstream side by Baker Bay at RM 3 of the Columbia River. The tidal cycle is a driving hydrologic force year-round in the area, in particular during times of low flow from the Wallacut. Wallacut River return flows have been calculated using USGS Streamstats (Table 1). This calculation does not consider tidal influence on river stage but is useful for gaging the relative impacts of fluvial and tidal forces on geomorphology of the project area.

Table 1. Wallacut River peak flows estimated from regional regression equations

Peak Flow Event	Flow (cfs)	Standard Error (%)
2-year	333	47
10-year	552	46
25-year	666	46
50-year	758	47
100-year	853	48

Water level sensors were installed by CLT in May, 2014 to collect time series data on local water surface elevations (WSEs). These data were used to compare site hydrology with nearby tidal gaging stations and to calibrate hydraulic models (Figure 5). Elevations of the sensors were surveyed by CLT during installation.

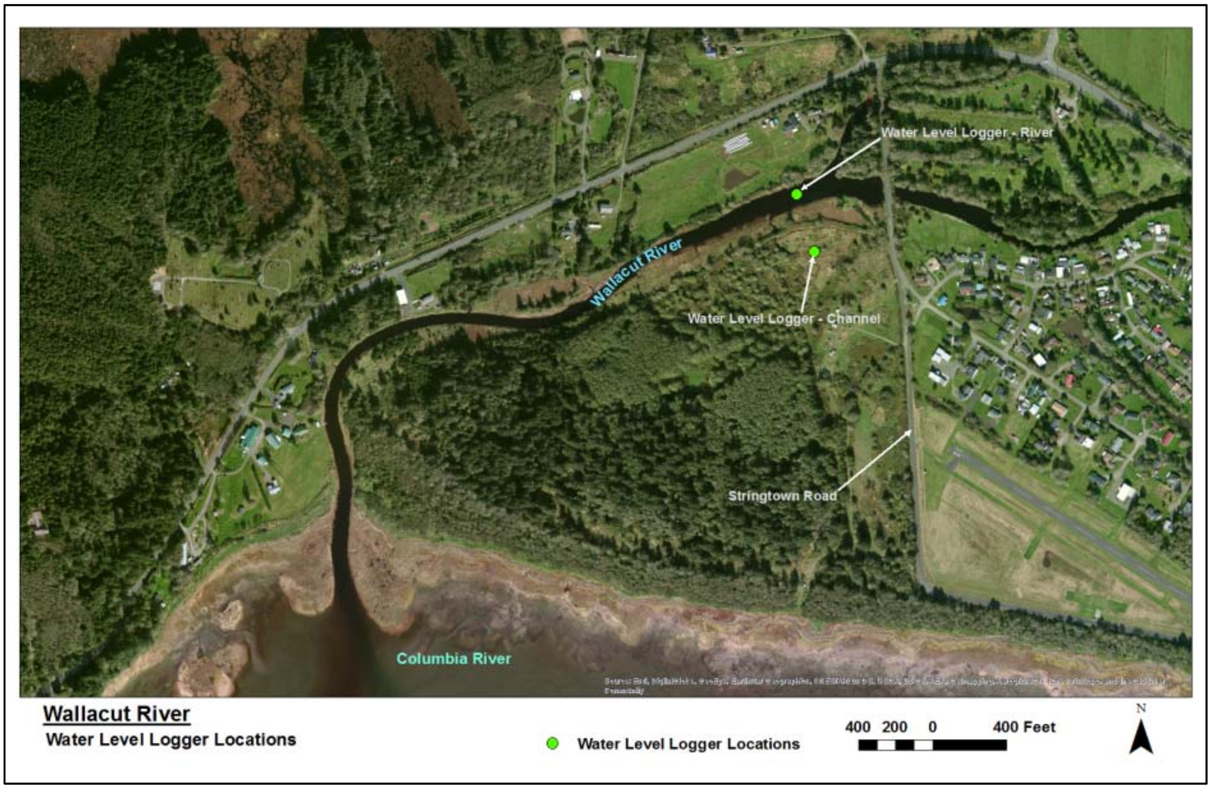

Figure 5. Onsite water level sensor locations. Sensors provide real time water surface elevations starting May 1, 2014.

The nearest tidal gage is located at Ilwaco, WA (#9440597). This gage is referenced to values recorded at the Astoria gage (#9439040) which has a longer term data set. The elevation offsets between Astoria and Ilwaco have been calculated by NOAA to be -0.8 ft at mean higher high water (MHHW) and -0.1 ft at mean lower low water (MLLW) (Table 2).

Table 2. Tidal reference elevations at NOAA gages at Astoria, OR and Ilwaco, WA (NAVD88).

	Astoria (ft)	Ilwaco (ft)
MHHW	8.81	8.01
MLLW	0.21	0.11

Figure 6 and Figure 7 show the stage relationship between the Astoria, OR stage data, Ilwaco, WA stage data, and the data recorded on the Wallacut River near Stringtown Road. The Wallacut River and Columbia River are synchronous above approximately 3 feet, with a slight lag likely due to conveyance time within the Wallacut River channel. Below 3 feet, the Wallacut River does not follow the pattern of the Columbia River. This is because the Columbia stage has dropped below the

Wallacut River stage, and the data represents only the Wallacut River flow during these low tide periods. The gradual decline of the Wallacut River from approximately 3.0 to 2.3 feet is due to a sediment deposit near the mouth that acts as a grade control, slowing outflow on the descending limb of the tidal cycle.

Seasonal variation

Hydrologic patterns vary by season with tidal influence dominating during drier months, and river flows dominating during wetter months. No flow data is available for the Wallacut River upstream of Stringtown Road, so parsing and modeling these influences separately are not possible here. Inflow from the river upstream of Stringtown Road during summer is likely minimal based on the observed stage data collected downstream of the Stringtown Road tide gate.

Hydrology at the project area is complex, with tidal cycles controlling hydrology in summer months and Wallacut River flows contributing more significantly during winter months. Tidal influence during low flow summer conditions is dominant, and Wallacut River stage tracks very closely to the Columbia (Figure 6). The Wallacut River has more influence on site hydrology during wet winter months when the Wallacut River stage is higher than the Columbia River (Figure 7).

Understanding drivers of hydrology in the Wallacut River is important to assess how levee removal will impact hydrology. Fluvial processes are likely driving channel geometry during winter high flow periods, and we would therefore expect an increase in tidal prism driven by levee removal to have minimal impact on channel geometry during wet winter months.

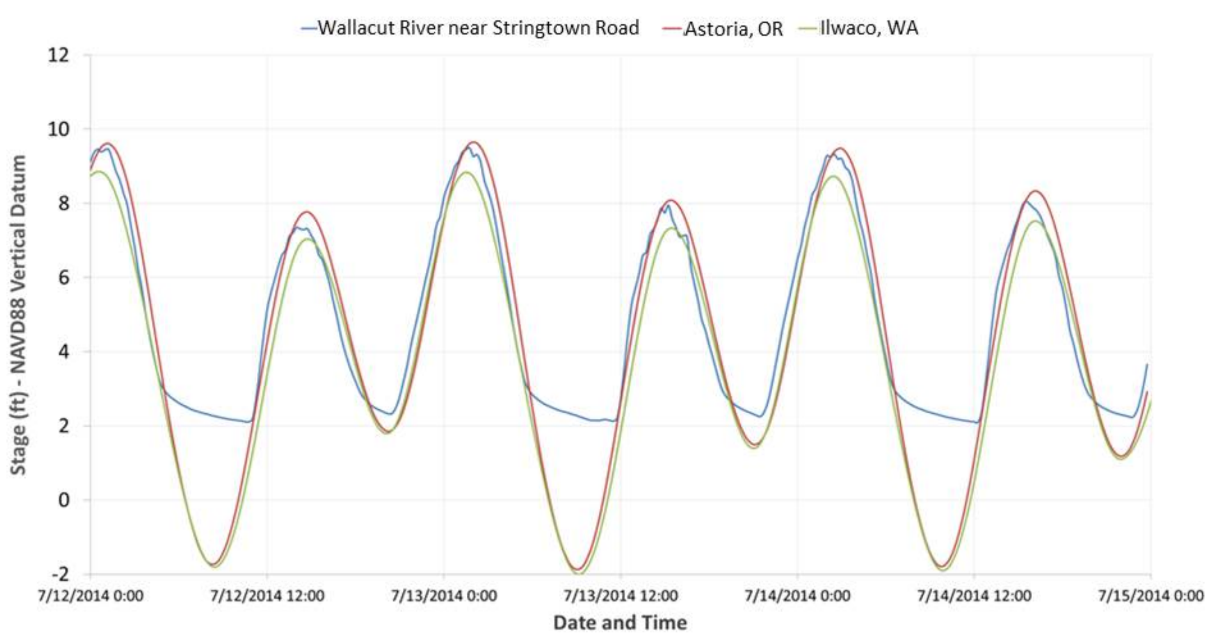

Figure 6. Astoria and Ilwaco gage data plotted with Wallacut River data collected in July 2014. Note that Columbia River and Wallacut River stages are very similar, indicating strong tidal influence on project area hydrology.

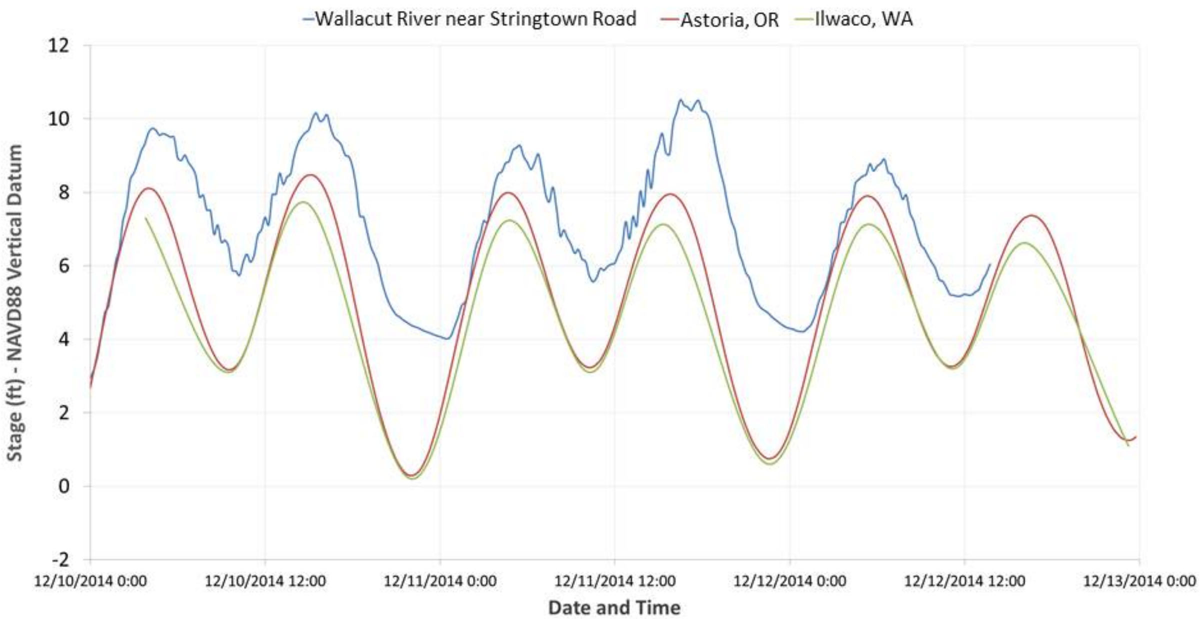

Figure 7. Astoria and Ilwaco gage data plotted with Wallacut River data collected in December 2014. Note that Wallacut River stage is higher than Columbia River stage, indicating strong riverine influence on project area hydrology

The published 99% and 10% annual exceedance probabilities of the Columbia River at the Astoria gage were related to the Ilwaco and Wallacut River stage heights. One-year and 10-year recurrence events at Astoria, OR and corresponding stage estimates for Ilwaco, WA and Wallacut River near Stringtown Road are reported in Table 3.

Table 3. Annual exceedance probabilities and corresponding stage heights (NAVD88). Estimates for Ilwaco, WA and the Wallacut River are referenced directly from the stage height recorded at Astoria. *Estimated Wallacut Stage does not include inflow from the Wallacut River.

Annual exceedance probability (at Astoria)	Recurrence interval (at Astoria)	Astoria Stage (ft)	Ilwaco Stage (ft)	Estimated Wallacut River stage based on downstream tidal influence (ft)*
99%	1-year	10.45	9.65	10.08
10%	10-year	12.25	11.45	11.94

3.4 SOILS

Soils data for the project are were obtained from the United States Department of Agriculture National Resource Conservation Service (USDA NRCS 2014) (Figure 8). Soils in the project area are composed of Ocosta silty clay loam in the lowlands, Westport fine sand in the uplands, and a small amount of Yaquina loamy fine sand to the east. The Ocosta series consist of deep, poorly drained soils located on floodplains and deltas. These soils formed from clayey alluvium deposited by coastal bays. Typically, drainage and inundation of these soils have been altered by ditching and pumping, and protected from frequent flooding with levees or dikes. These soils support native vegetation including grasses, sedges, red alder, Sitka spruce, and other conifers. The Westport fine sand is a deep, excessively drained soil formed in slightly weathered dune sand. It is typically used for home sites and has a higher erosion risk than the Ocosta soils. Established vegetation in these areas helps to prevent blowing soils, although it can be limited by a lack of nutrients and moisture. The Yaquina loamy fine sand is a deep, somewhat poorly drained soil that forms in mixed alluvium on terraces with slopes of 0-5% (USDA NRCS 2014).

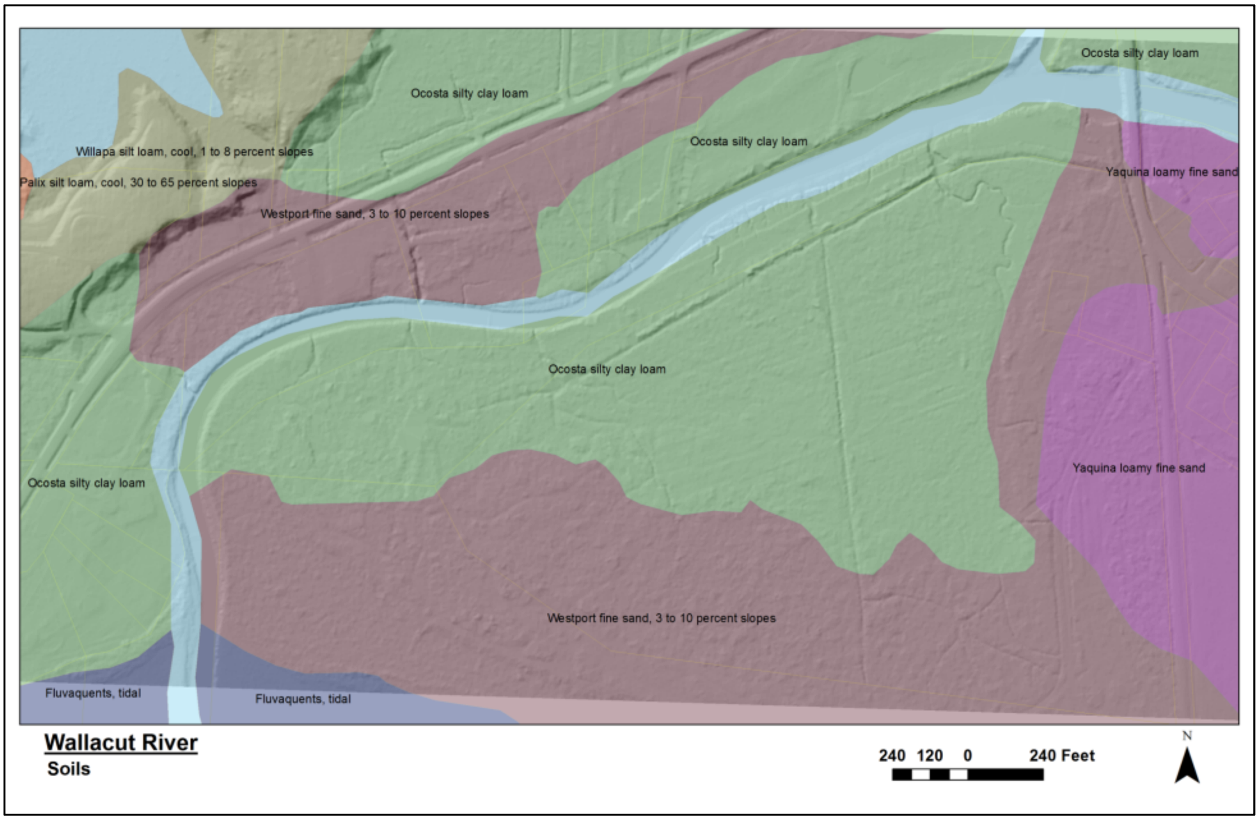

Figure 8. Soils data for the Wallacut River project area (USDA NRCS 2014).

3.5 VEGETATION

Historical land cover

The Wallacut River was historically surrounded by tidal sand and mudflats downstream of the present day Stringtown Road (Figure 9). An agricultural field was present in the project area by the late 1800s, with herbaceous non-wetlands and forested non-tidal lands in the center of the project area. Several scrub-shrub wetlands are located along the river farther upstream, abutting non-tidal forested areas in the uplands.

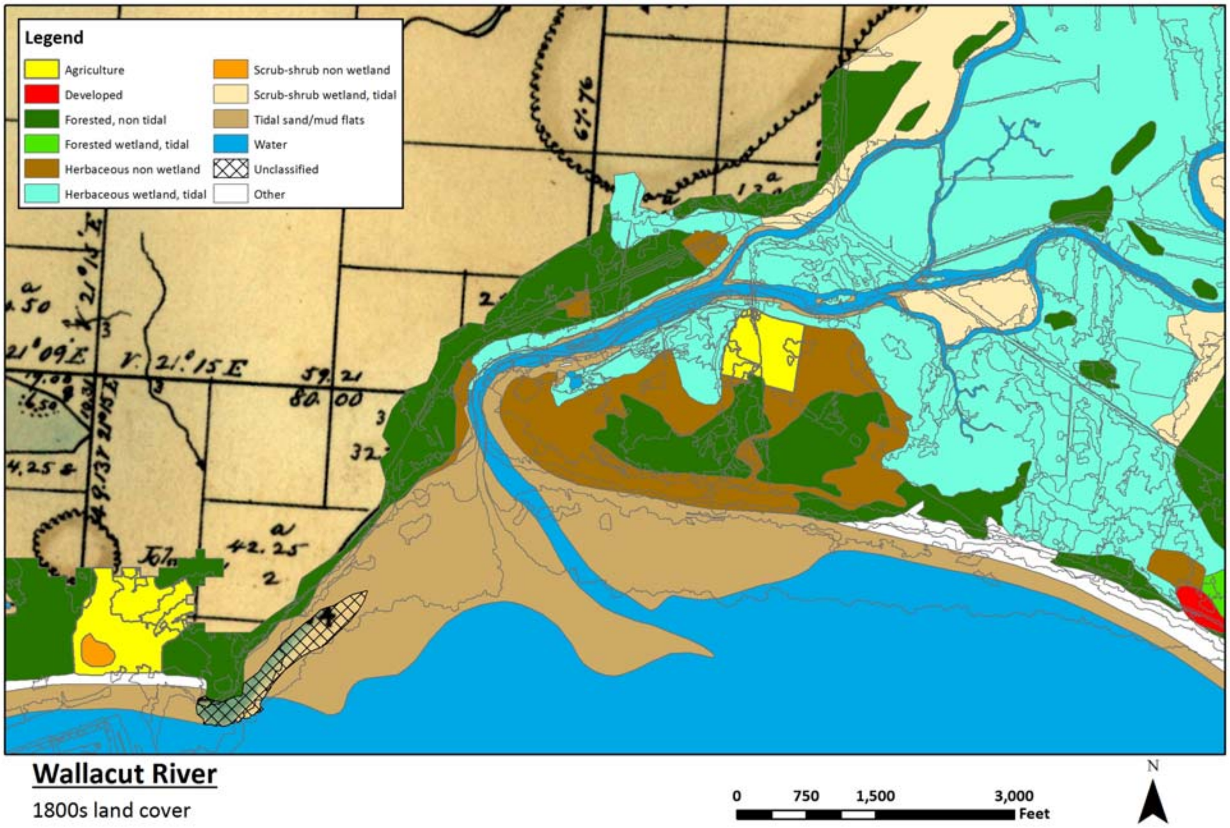

Figure 9. Historical land cover interpreted from 1800's T-sheets and plat maps (Burke 2010).

Current land cover

The project area vegetation corresponds to elevation gradients, soil type and past land use. In the higher, sandier areas closer to Baker Bay a second growth Sitka spruce forest predominates and this vegetative community is characterized as North Pacific Hypermaritime Sitka Spruce Forest (WA NHP, 2009). Plants found in this area include Sitka sprice, with an understory of salmon berry, swamp gooseberry, elderberry, Nootka rose, red alder, cascara, Pacific crabapple, sward fern, salal, Douglas spirea, red huckleberry and Oregon ash (CLT 2016).

The lower areas near the Wallacut River have more herbaceous and scrub-shrub wetland characteristics and are characterized as North Pacific Intertidal Freshwater Wetland (WA NHP, 2009). This characterization is the same for both sides of the farm levee that this project proposes to remove, however plant assemblages are different on either side of the levee in response to frequency of inundation and salinity. Plants in the area between the levee and the Wallacut River include include a brackish sedge, likely *Carex lyngbyei* and Pacific silverweed (*Potentilla anserine*) and native grasses that are representative of a high salt marsh plant community. Along the opposite bank willow and Sitka spruce are present at elevations above this bench. Within the leveed area in the lower marsh areas the plant community is dominated by red alder, salmonberry and elderberry. Herbaceous species present include slough sedge, sword fern and non-native grasses. Gorse and reed canarygrass are also present in this zone. When the levee is breached the plant community in this area is expected to change with increased salinity of the tidal water.

Finally, there are smaller portions of the site which have been used as a residential site and access roads. These areas appear to have been set on imported sand fill. The structures were removed in 2013 and the residential site area is dominated by a few ornamental plants and pasture grasses. The access road along the southern and eastern portion of the site is more occupied by woody plants The shrub layer, where present, consists mostly of salmonberry. Trees include red alder, Scouler's willow and Sitka spruce (CLT 2016).

3.6 FISH USE

The Wallacut River is part of the Columbia River estuary tributaries subbasin as defined by Lower Columbia Fish Recovery Board (LCFRB 2010). This basin provides important habitat for all juvenile anadromous salmonids of the Columbia River as they migrate to the ocean. Baker Bay has undergone severe loss of tidal swamp, tidal marsh, medium depth, and deep habitats while experiencing increases in shallows and flats (Johnson et al. 2003).

Estuary habitats produce large amounts of prey consumed by juvenile salmonids that migrate through the estuary. Outmigrating juveniles have relatively empty stomachs when they are passing through the John Day and Bonneville Dams on the Columbia River, indicating that only a small proportion of these fish are actively feeding. Juvenile fish in the CRE are actively feeding, and have high stomach fullness with significant amounts of insects associated with floodplain wetlands. Restored estuary habits are highly productive environments and export prey items (dipterans and amphipods) that are consumed by migrating juveniles in the mainstem Columbia River (Diefenderfer et al. 2012). Fish at restoration sites typically have high stomach fullness and are in better condition compared to those in unrestored areas (USACE and BPA 2013). Restoration of estuary habitats can have positive impacts for all juvenile salmonids that migrate through the CRE and not just ocean types that use these habitats directly.

The estuary tributaries basin provides important spawning and rearing habitat for ESA-listed species including threatened coho salmon (*Oncorhynchus kisutch*), Chinook salmon (*O. tshawytscha)* and chum salmon *(O. keta)* (NMFS 2013). This basin also provides important spawning and rearing habitat for other species of concern, including coastal cutthroat trout (*O. clarki ssp)* and Pacific lamprey (*Lampetra tridentata)*. Table 4 summarizes life-stage timing for these species in the basin.

Table 4. Life-cycle timing of species of concern in Columbia River estuary tributaries (LCFRB 2004).

Species	Life-stage	Timing
Fall Chinook	Adult Juvenile	mid-August - late October early April - June/July
Chum	Adult Juvenile	mid October - early December March-April
Coho	Adult Juvenile	mid-August - March rear in freshwater for a year, migrate in spring
Coastal Cutthroat	Adult - anadromous Juvenile Resident	late July - April rear in freshwater for two years live entire life-cycle in freshwater
Pacific lamprey	Adult Juvenile	spring and summer rear is freshwater for up to seven years

Limiting factors have been identified for juvenile salmonids in the Wallacut River in the Columbia Estuary Tributaries Subbasin Plan (LCFRB 2010) (Table 5). Project elements help address the limiting factors of habitat connectivity, diversity, channel stability, riparian function, and floodplain function. Levee removal and tidal channel excavation will provide fish access to tidal mudflat and marsh habitat at a wider range of flows while restoring full tidal hydrology to the marsh. This project is expected to provide rearing habitat for ocean-type juvenile fish such as fall Chinook while also increasing prey production for all juveniles migrating through the estuary.

Table 5. Limiting factors for juvenile salmon in the Wallacut River identified in Columbia Estuary Tributaries Subbasin Plan (LCFRB 2010).

Limiting factors for juvenile salmonids in the Wallacut River		Project elements			
Category	Limiting Factor	Levee removal and borrow ditch filling	Marsh channel reconnection and excavation	Marsh channel and floodplain wood addition	Revegetation
Habitat connectivity	Blockages to off-channel habitats	X	X		
	Blockages to stream habitats due to structures	X			
Habitat diversity	Lack of stable instream woody debris			X	X
	Altered habitat unit composition	X	X	X	
	Loss of off-channel or side-channel habitats	X	X		
Channel stability	Bed and bank erosion	X			X
Riparian function	Reduced stream canopy cover				X
	Reduced bank-soil stability				X
	Exotic and/or noxious species				X
	Reduced wood recruitment				X
Floodplain function	Altered nutrient exchange processes	X	X	X	X
	Reduced flood flow dampening	X	X	X	X
	Restricted channel migration (in marsh channels)	X	X		
	Disrupted hyporheic processes				
Stream flow	Altered magnitude, duration, or rate of change				
Water quality	Altered stream temperature regime	X	X	X	X
Substrate and sediment	Embedded substrates				
	Excessive fine sediments				X

4 Site analysis

A tidal prism analysis and hydraulic modeling exercise were performed to estimate possible changes to channel geometry with proposed levee removal.

4.1 TIDAL PRISM ANALYSIS

A tidal prism analysis was conducted to evaluate the erosion risk associated with levee breaches in the project area. The tidal prism is defined as the difference in water volume between MHH and MLL upstream of a tidal channel inlet, and is considered to be the channel shaping flow of a tidal system similar to a bankfull flow in a fluvial system (Williams et al. 2002). Tidal channels adapt to changes in tidal prism by expanding or contracting, with most significant changes observable at the inlet (Diefenderfer et al. 2008). Proposed levee removal will result in an incremental increase in tidal prism in the project area, and has the potential to affect the geometry of the channel as a new equilibrium is established. A tidal prism analysis was completed for the Wallacut River from the mouth to Stringtown Road.

Methodology

To evaluate tidal prism under existing and proposed conditions, the project area was divided into two adjacent sections: 1) the main channel and adjacent floodplain bench, and 2) the marsh immediately south of the ditch at the base of the levee (Figure 10).The demarcation was chosen to exclude the volume of the borrow ditch from the marsh volume estimates, given that it will be filled in the process of levee removal. Inundation volumes were analyzed for the two areas at MLLW, MHHW, and the estimated 99% exceedance tidal stage (hereafter – annual event) on the Wallacut River referenced to the Astoria gage (Table 3). A 3-dimensional surface was prepared in AutoCAD combining the available LiDAR data with bathymetry and survey data collected on July 18 2014, August 22, 2014, and June 23, 2015. This surface was compared with planar water surfaces at each of the three elevations in both the marsh and the Wallacut River. Inundation volumes within the mainstem were compared with inundation under proposed conditions to calculate the change in tidal prism and associated change in channel geometry.

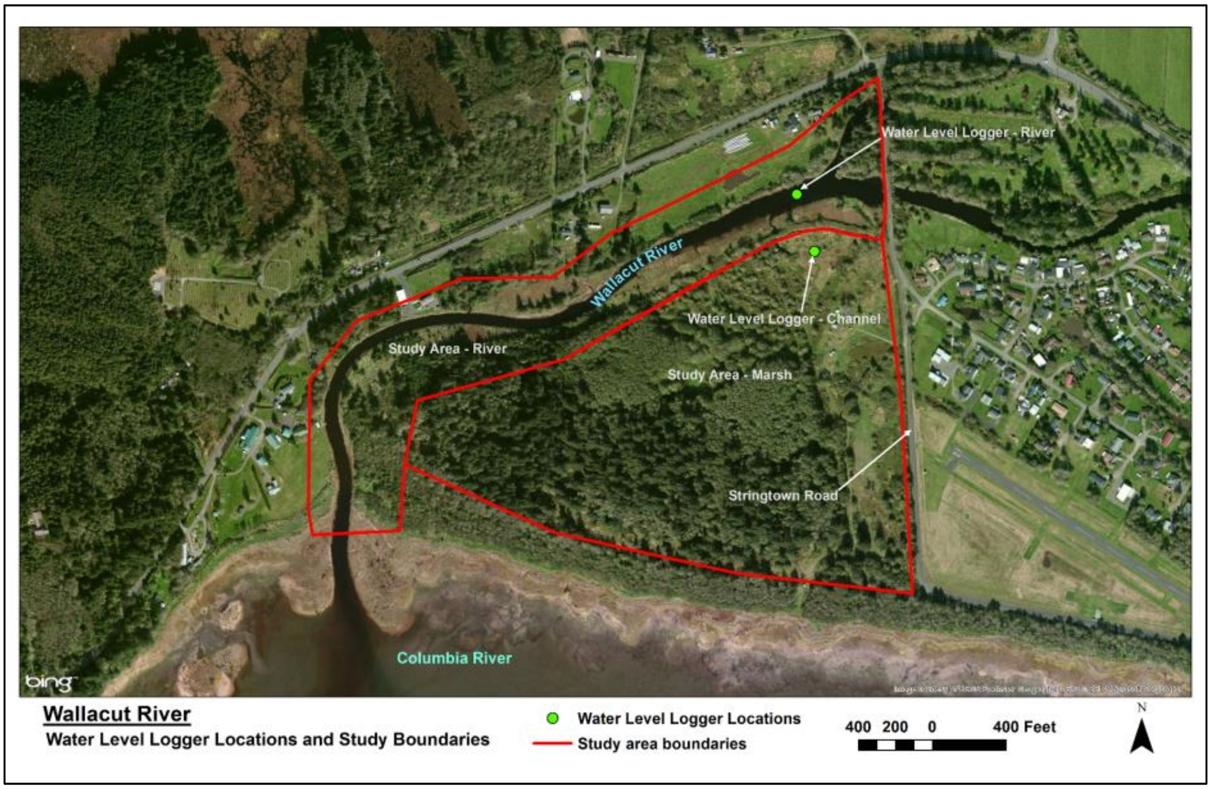

Figure 10. Tidal prism analysis extents.

The marsh is currently connected to the mainstem Wallacut River through two partially obstructed culverts. The partial obstruction slows the flow of water into the marsh as the tide is rising, and results in a water surface within the marsh that is lower than the mainstem. Water surface data collected in the marsh (Figure 10) was used to quantify existing marsh inundations based on mainstem flows. The average measured offset between the maximum water level in the mainstem channel and the maximum water level in the marsh was 0.76 feet. Under proposed conditions, it is assumed that the water surface elevation in the marsh will be in equilibrium with the water surface elevation in the mainstem.

Simplifications and Assumptions

Several simplifying assumptions were made during the analysis given the data available and hydrology of the site:

- Water currently entering the marsh is controlled by two culverts with varying degrees of connectivity through the levee. Only one of these connections is reflected in the existing condition analysis because only one marsh channel water sensor was present. The other two connection points, which by visual inspection convey less water than the one considered, were not included. This provides for a conservative (i.e. larger) estimation of project effects.
- The current analysis relies primarily on LiDAR in the marsh area. Detailed ground survey in the submerged areas within the marsh would likely slightly increase the marsh volume by more accurately representing submerged surfaces.

- Wallacut River channel geometry is most likely shaped by the tidal prism during summer months and a combination of tidal prism and riverine inputs during winter months. This analysis only considers tidal hydrology and does not consider fluvial inputs from the Wallacut River. The relationship between inlet cross section area and tidal prism volume in Equation 1 is useful for considering changes in channel geometry during lower summer flows.

Conclusions

This analysis predicts a 1.9% in the tidal prism volume at MHH with a 1.2% inlet expansion (Table 6). The increase in tidal prism is small because the majority of the marsh area is currently above the MHH elevation. Reconnecting the marsh will only increase inundation the tidal channels and localized areas of lower ground at all but the highest tides.

Table 6. Inundation volumes and percent increase in tidal prism at MHH.

	Inundation volume under existing conditions (yd^3)	Additional inundation volume under proposed conditions (yd^3)	Increase in inundation volume (%)
MHH (8.02 ft)	111,387	1,985	1.9

The relationship between tidal prism and channel cross sectional area has been investigated for tidal estuaries in the San Francisco Bay area (Williams et al. 2002):

$$A_{inlet} = 0.0284 * (V_{tidal\ prism})^{0.649} \qquad \textit{Equation 1}$$

Where A_{inlet} is equal to channel cross sectional area (square feet) at the inlet and $V_{tidal\ prism}$ is equal to the tidal prism volume (cubic feet). While San Francisco marshes have different tidal ranges, plant species, and substrate types compared to CRE marshes, this analysis is still useful for scaling expected changes in cross sectional area in relative terms. The tidal prism analysis shows that the tidal prism will increase by 1.9% under proposed conditions, which correlates to a 1.2% increase in cross sectional area at the inlet.

Inlet geometry in the Wallacut River is likely controlled by both fluvial and tidal hydrology. Diefenderfer et al (2008) found that marshes with a significant non-tidal component have geometry related to fluvial processes, and inlet geometry may not be completely governed by the tidal prism in these cases. At low tide when the water surface gradient and shear stress are at a maximum, additional overbank storage in the reconnected marsh could serve to attenuate streamflow's through the lower Wallacut River channel and reduce local velocity and shear stress. The estimated 1.2% increase in cross sectional area is conservative because it doesn't account for this potential decrease in fluvial erosion under proposed conditions.

4.2 HYDRAULIC MODELING

2D Description/ Methods

A two-dimensional (2D) hydraulic model was developed using TUFLOW to model existing and proposed conditions and aid in hydraulic analysis and design. The hydraulic model utilizes the Surface-water Modeling Solution (SMS) proprietary pre- and post-processing software and the TUFLOW proprietary hydrodynamic model. TUFLOW tends to be computationally stable and has been used extensively in tidal and estuarine environments.

This model calculates hydraulic parameters (mass and momentum transfer) within a grid. A grid cell size of 3ft was chosen for this analysis to balance model resolution and computational time. Hydraulic parameters are calculated by balancing conservation of momentum and conservation of mass through the boundaries of each element of the 2-D grid which is overlaid on site topography and bathymetry.

Hydraulic roughness is represented by materials characteristics assigned as polygons within the SMS software. Table 7 provides Manning's roughness values assigned for various materials characteristics used. These values were derived through model calibration.

Table 7. TUFLOW model calibrated roughness values

Material Type	Manning's Roughness Value
Channel	0.015
Floodplain Veg	0.07
Grass or Tidal Flats	0.03
Trees	0.1
Grass Bank	0.04
Marsh Inlet (existing conditions only)	0.2

Model Calibration

The TUFLOW 2D model calibration for Wallacut River was done in two steps. First, the model boundary condition was developed using tidal data from the nearby Ilwaco gage (Baker Bay, WA, Station 9440597) and Columbia Land Trust water depth probes (probe locations described in previous tech memo, Inter-Fluve 2015). Attempts were made to use in-channel roughness values to calibrate the marsh and channel water surfaces. However, at a variety of in-channel roughness values, the maximum water surface elevation in the Wallacut River tended to match that of the downstream boundary of the model. The elevated water surface measured in the channel (see Figure 12, Figure 14) was not able to be replicated by the model using the Ilwaco tidal data (which are derived from the data collected at Astoria, OR). There are physical processes that affect the channel water surface (wind, storm surges, etc.) which are not modeled explicitly and may partially explain this. A comparison of in-channel vs marsh water surface elevation was the most critical component of these analyses, thus, the measured maximums in both the July and December data were used to adjust the downstream boundary condition in the model to manipulate the water surface elevation and thus drive the tidal simulations.

The wetting of the marsh under existing conditions occurs via two small (<16”) culverts. Modeling these explicitly was not appropriate at the spatial scale of the model. In order to represent the wetting of the marsh, a small (1 grid cell wide) channel was developed in the model to allow flow to pass between the main Wallacut River channel, and the marsh. The Manning’s n roughness value through this inlet was manipulated to calibrate wetting and drying with hobo data.

As shown below in Figure 11 and Figure 12, the marsh remains at an elevation of 5.8’, similar to the hobo data, and becomes wet once the channel water surface elevation passes 7’. This is similar to the observed hobo data, but is insensitive to relatively small changes in water surface elevation (WSE) between 6’ and 7’. Despite the insensitivity of small tidal fluxes, the modeled marsh data shows good results for higher tides, as shown in the peak tide for July 11th, 2014 with the modeled water surface 8.67’ and the observed at 8.55’. The modeled channel water surfaces and Ilwaco data are nearly perfectly aligned with the exception that the channel WSE does not drop below 2.4’, which is comparable to the channel hobo data that does not drop below 2.7’. The channel peaks of both the model and observed hobo are a comparable 10.23’ and 10.25’, respectively.

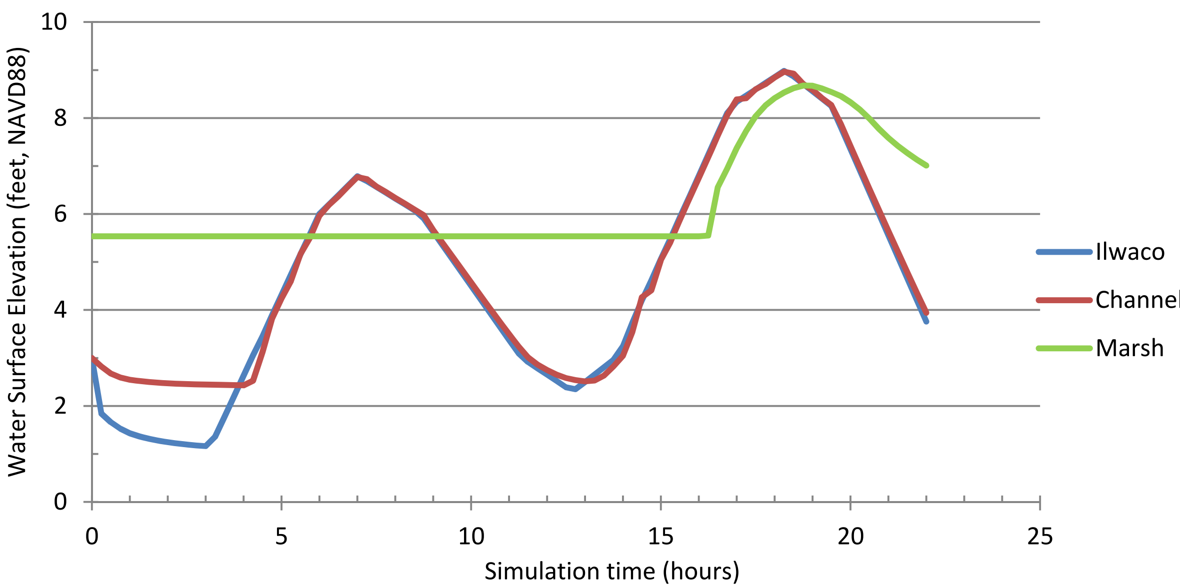

Figure 11. Model simulation result for tidal data for July 11th, 2014.

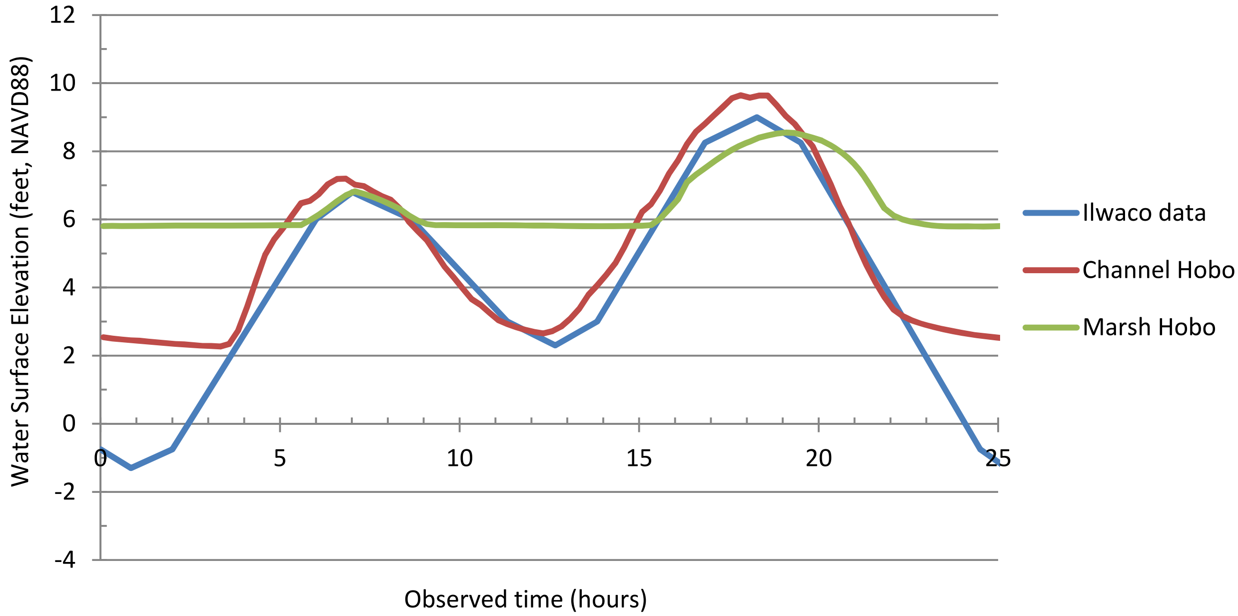

Figure 12. Observed tidal data for Ilwaco and Channel and Marsh hobos for July 11th, 2014.

The second model calibration used the December 5th, 2014 'king tide'. Manning's n values were adjusted from 0.2 to 0.25 for the marsh inlet so that tidal peaks in the channel for both modeled and observed data are comparable (10.23' and 10.25', respectively).

The modeled marsh water surface shows a time lag and muted peak compared to the channel, which matches the observed relationship from the hobo data. The modeled marsh stage does not drop as quickly as the observed hobo data, and the modeled marsh WSE is higher (9.6' and 8.7', respectively) (Figure 13, Figure 14). These model results are considered a reasonable representation of the observed data, and the inaccuracies noted provide a greater inundation than observed, resulting in a conservative estimate for total inundation.

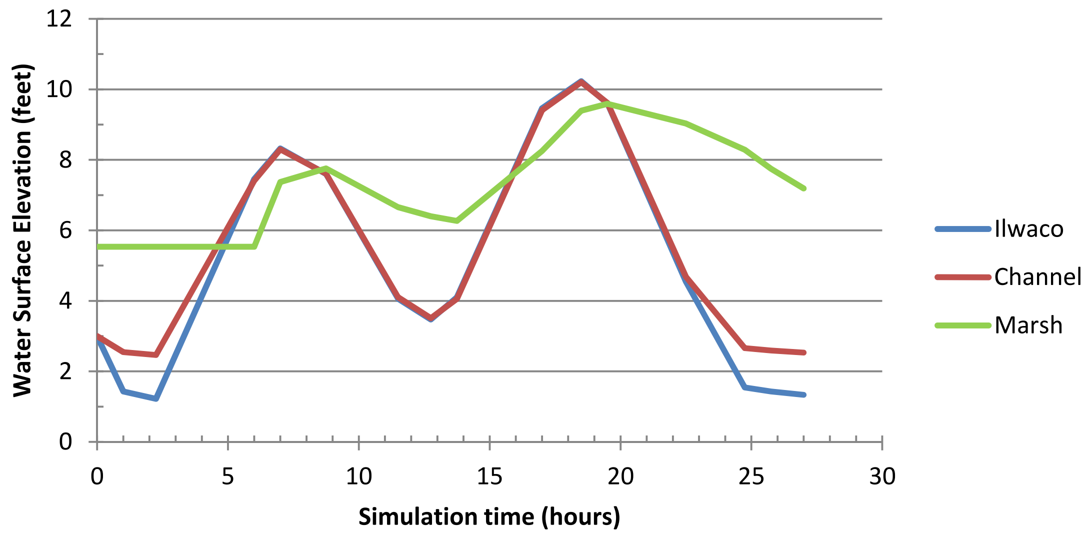

Figure 13. Model simulation result for December 5th, 2015 king tides.

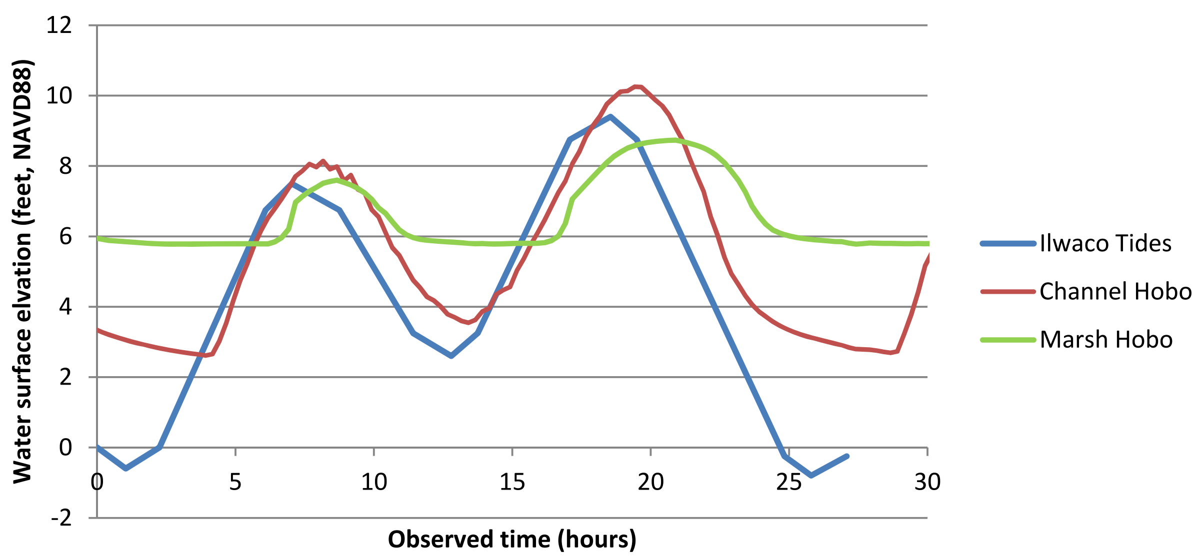

Figure 14. Observed tidal data for Ilwaco and Channel and Marsh hobos for king tides of December 5th, 2014.

Existing vs Proposed Conditions Outputs

The model was run using a 27 hour time series based on a high tide event in the observed data on the Wallacut River on December 5th, 2014. This time span includes water surface elevations over 2.25 feet above MHHW. For the purposes of this memorandum, modeled results are shown at 4 discrete simulation time steps, which were selected because they illustrate the tidal extremes as well as points of highest modeled velocity (Figure 15):

- 7 hours – This point represents maximum inundation during the smaller of the two tidal cycles modeled. The peak water surface at the boundary during this cycle (8.35 ft) is slightly above MHHW.

- 17 hours 10 minutes – This point on the flood tide is where velocity is at a maximum in many locations throughout the Wallacut River, due to the high water surface gradient between the inlet and upstream boundaries.

- 19 hours – This point is the slack tide during the larger of the two tidal cycles modeled, when water surface elevations are at a maximum. This event was chose to represent a "King Tide", which is a larger than average tidal event..

- 22 hours, 30 minutes – This is the point on the ebb tide where many points in the channel experience velocity maximums.

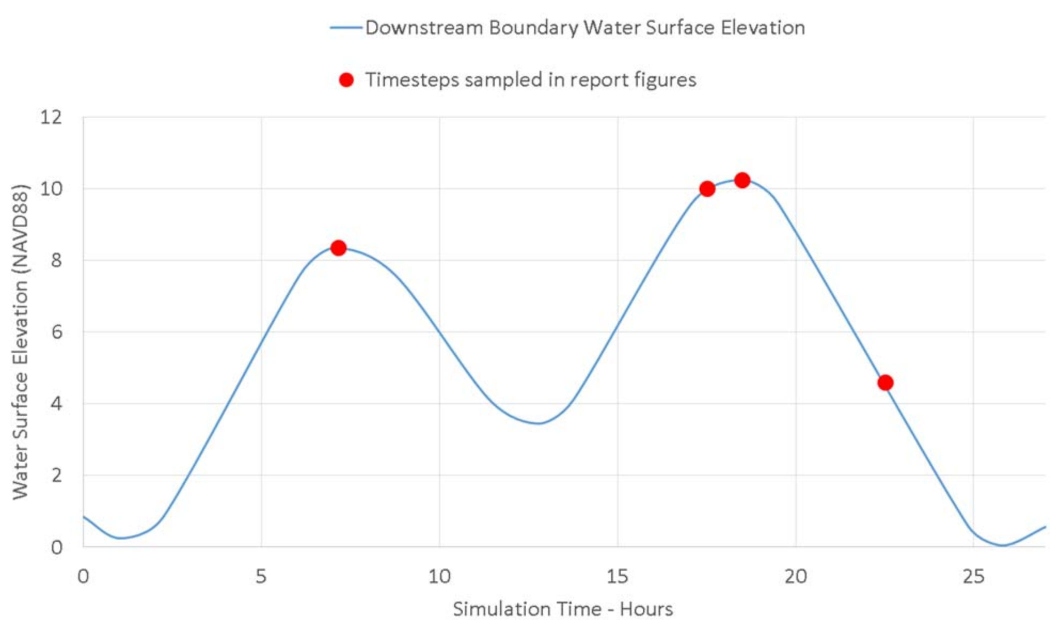

Figure 15. Modeled water surface elevation at the downstream boundary and model sample locations for figures displayed in this report.

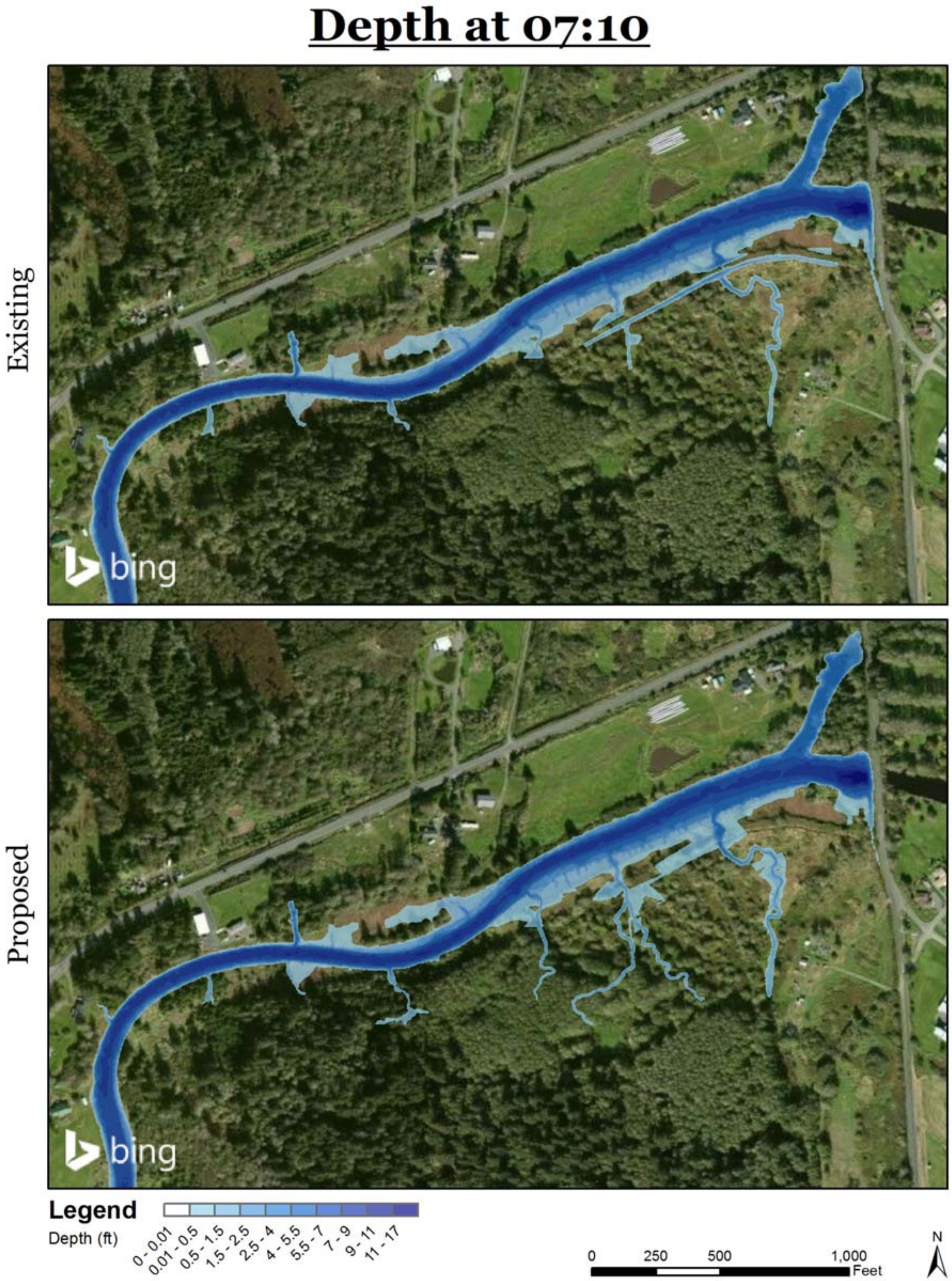

Figure 16. Existing vs proposed water depth at simulation time 7 hours and 10 minutes.

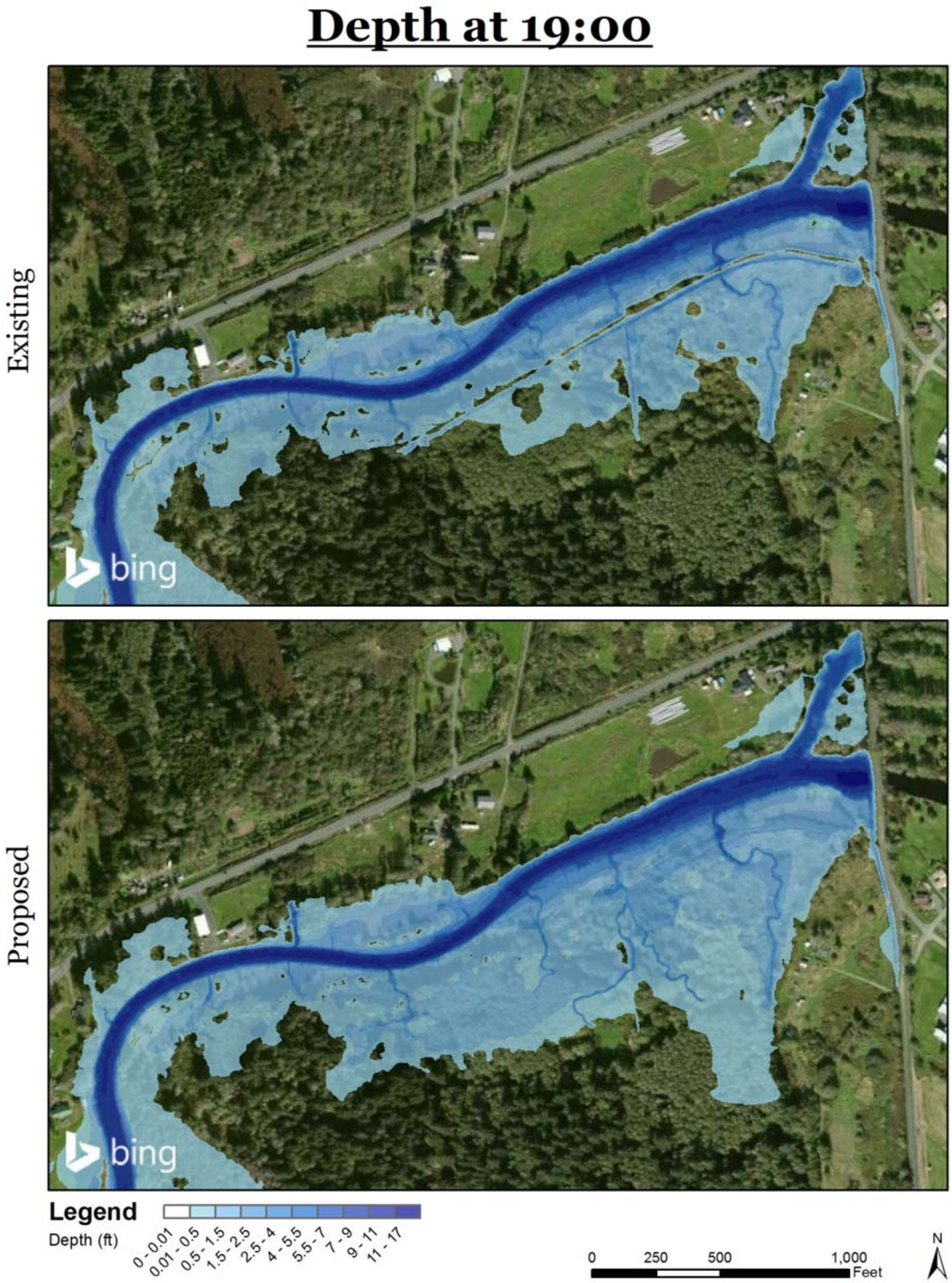

Figure 17. Existing vs proposed water depth at simulation time 19 hours.

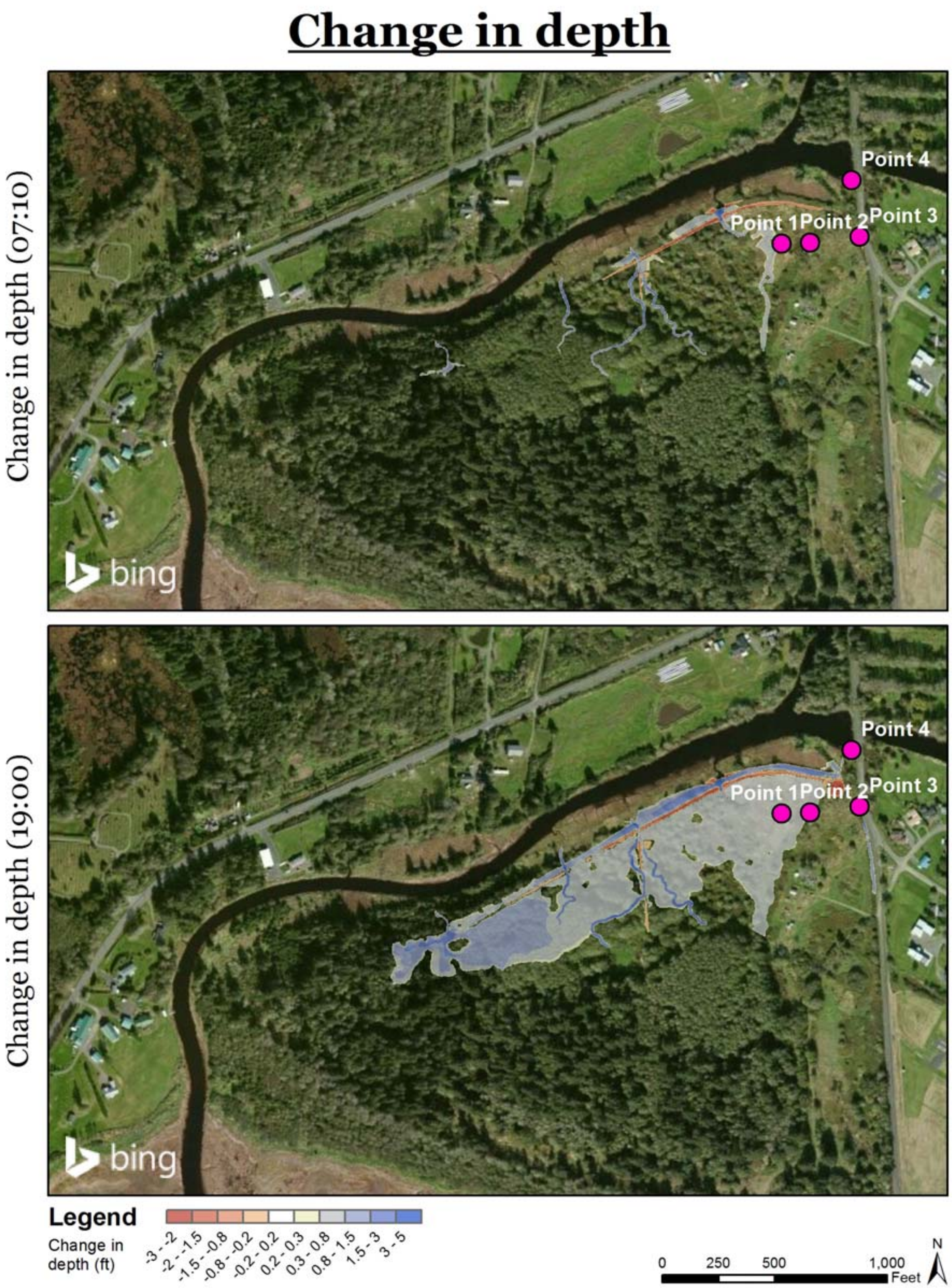

Figure 18. Change in depth (proposed minus existing). Points 1-3 correspond to inundation depth time series data shown in (Figure 19).

Inundation at 7 hours and 10 minutes (Figure 16), which is very close to MHHW at the site, shows a slight increase in wetted area along constructed channel segments and near channel areas, as well as along the margins of the levee that will be removed during the project. The majority of the site is not inundated at MHHW. Water depth in the main channel does not change (Figure 18).

Inundation at 19 hours extends beyond the levee under existing as well as proposed conditions. In addition to the culvert connection at Marsh Channel A, the levee overtops in several locations when the water surface elevation in the main channel exceeds 9.4 ft. With enhanced connectivity under proposed conditions, water is allowed to more fully inundate the site. The depth of newly inundated areas around the margins of the site is low (under 0.5 ft) in many locations.

Inundation duration changes were examined at 4 points near the existing marsh channel (point 1), near the inundation extent (point 2), in the main channel at the entrance to the existing ditch (point 3), and in the ditch itself (point 4) (Figure 19). Inundation depth increases under proposed condition in the reconnected marsh. The duration of inundation decreases because marsh draining is limited by the culverts under existing conditions, and will be free draining under proposed conditions. The main channel at the entrance to the ditch shows no change under proposed conditions, with the exception of a very slight decrease in the water surface at low tide under proposed conditions.

The ditch along Stringtown road (on the right side of the inundation images) is shown to wet up under both existing and proposed conditions. The ditch is currently connected by a very small (< 1ft diameter) culvert with an approximate length of 20 ft. There is currently no tide gate in place on this culvert. The topography used to model the site left this area as an open ditch, therefore inundation in the ditch is likely overestimated by the model. Modeled depth is not increasing in the main channel or in the ditch as a result of the project (Figure 18), and therefore no adverse impact related to additional surface water in this location is expected as a result of the project.

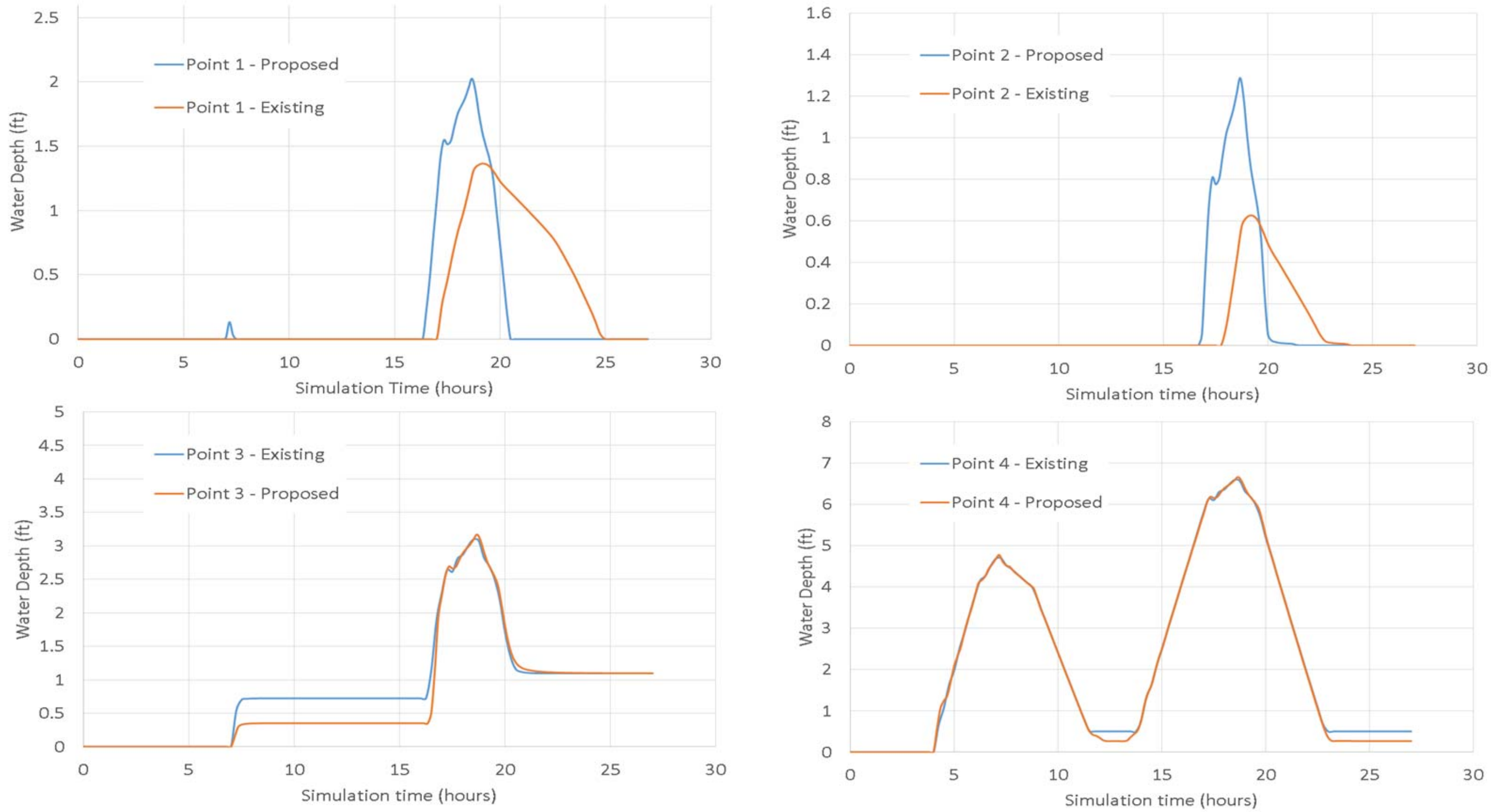

Figure 19. Depth/duration curves for 4 sample points (depicted in Figure 18)

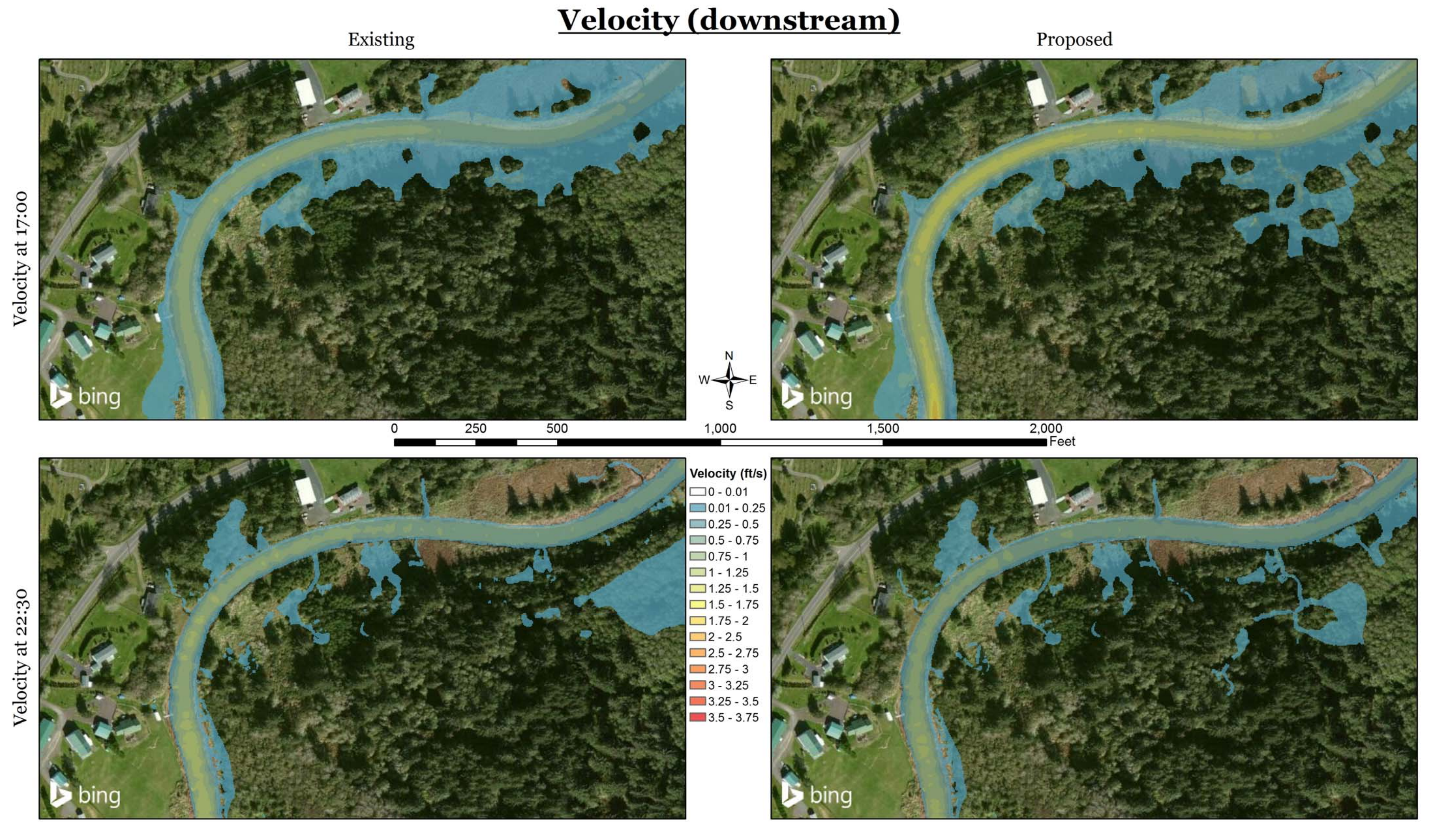

Figure 20. Modeled velocities under existing (left) and proposed (right) conditions during high velocity periods on both flood (top) and ebb (bottom) tides at the Downstream Bend.

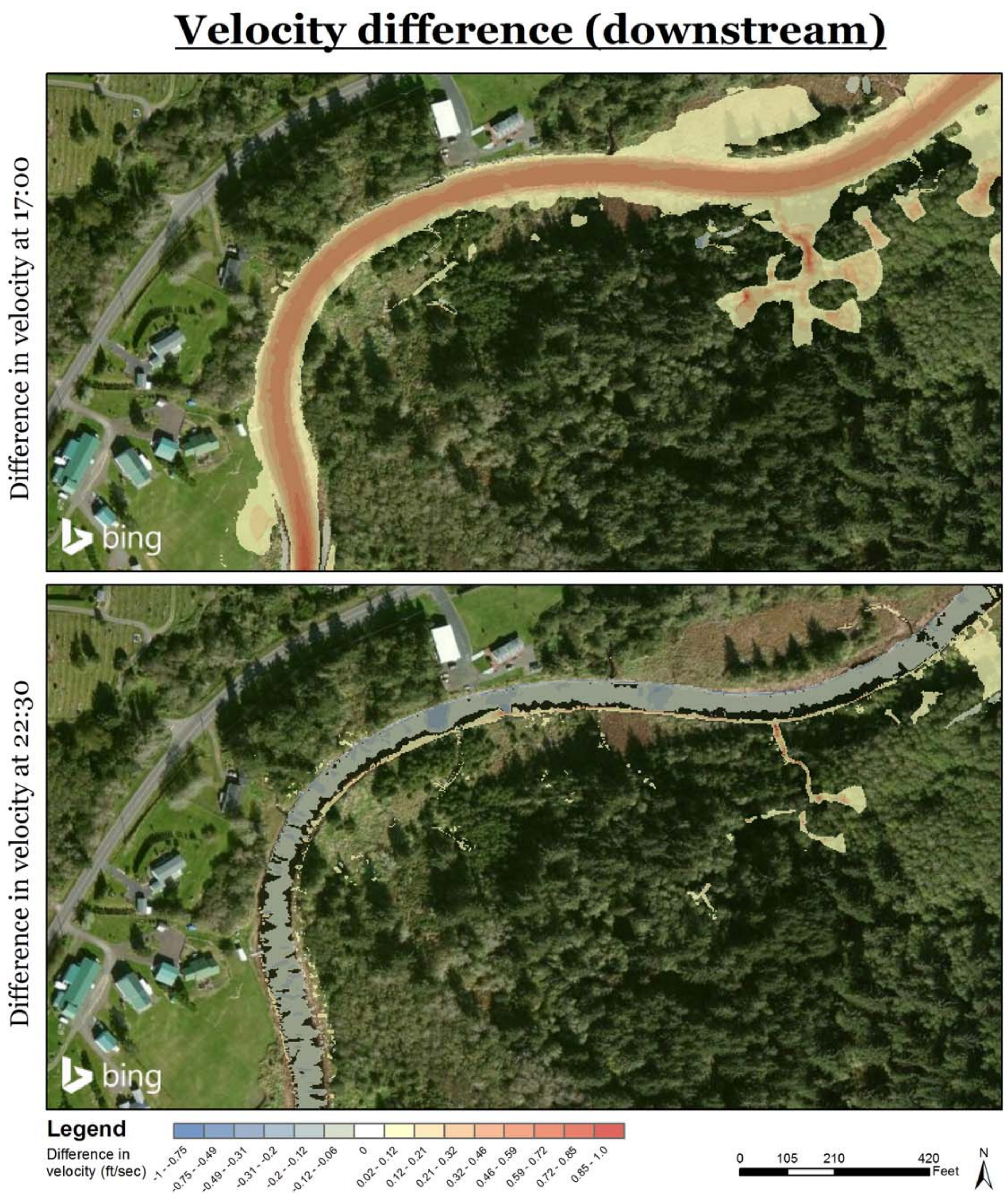

Figure 21. Differences in modeled velocities (proposed minus existing) near the Downstream Bend (the first bend upstream of the mouth of Westport Slough). Red areas represent a velocity increase under proposed conditions while blue areas represent zones of velocity decrease. Results are shown during high velocity periods on both flood (above) and ebb (below) tides.

The differences in velocity between existing and proposed conditions in the downstream portion of the project show velocity increase on the flood tide and a slight decrease on the ebb tide. Higher velocities are not concentrated, but consistently greater throughout the downstream portion. These increased velocities occur at a moment when the downstream water surface is increasing but the upstream water surface remains lower as higher portions of the marsh fill, steepening the gradient driving water velocity. Because most of the marsh elevations are well above MHHW, this phenomenon will occur infrequently, becoming more pronounced at very high tides. Velocity increase modeled for this condition in the mid-channel areas throughout the bend is consistently between 0.4 and 0.6 ft/s.

The absolute values of velocities on both the flood tide and the ebb tide are low under both existing and proposed conditions (see Figure 20 - generally between 1.0 and 1.5 ft/s in the mid-channel areas, with values less than 1.0 ft/s along the banks). These velocities are generally within a range that would generally be considered too low to exceed the threshold for movement of even non-cohesive bank substrates (Fischenich 2001). Additionally, it should be reiterated that the velocity increases depicted in Figure 21 are observed over a small time period (10 to 20 minutes) during a high flow event.

Elevated velocity at the far downstream edge of the model is assumed to be a model boundary affect, and not representative of actual site hydraulics. Note also that during more extreme events in this location, wind and storm surge are factors in both inundation extents and the forces banks are subjected to. Neither of these phenomena were incorporated into the current modeling effort, but will affect the system similarly under both existing and proposed conditions.

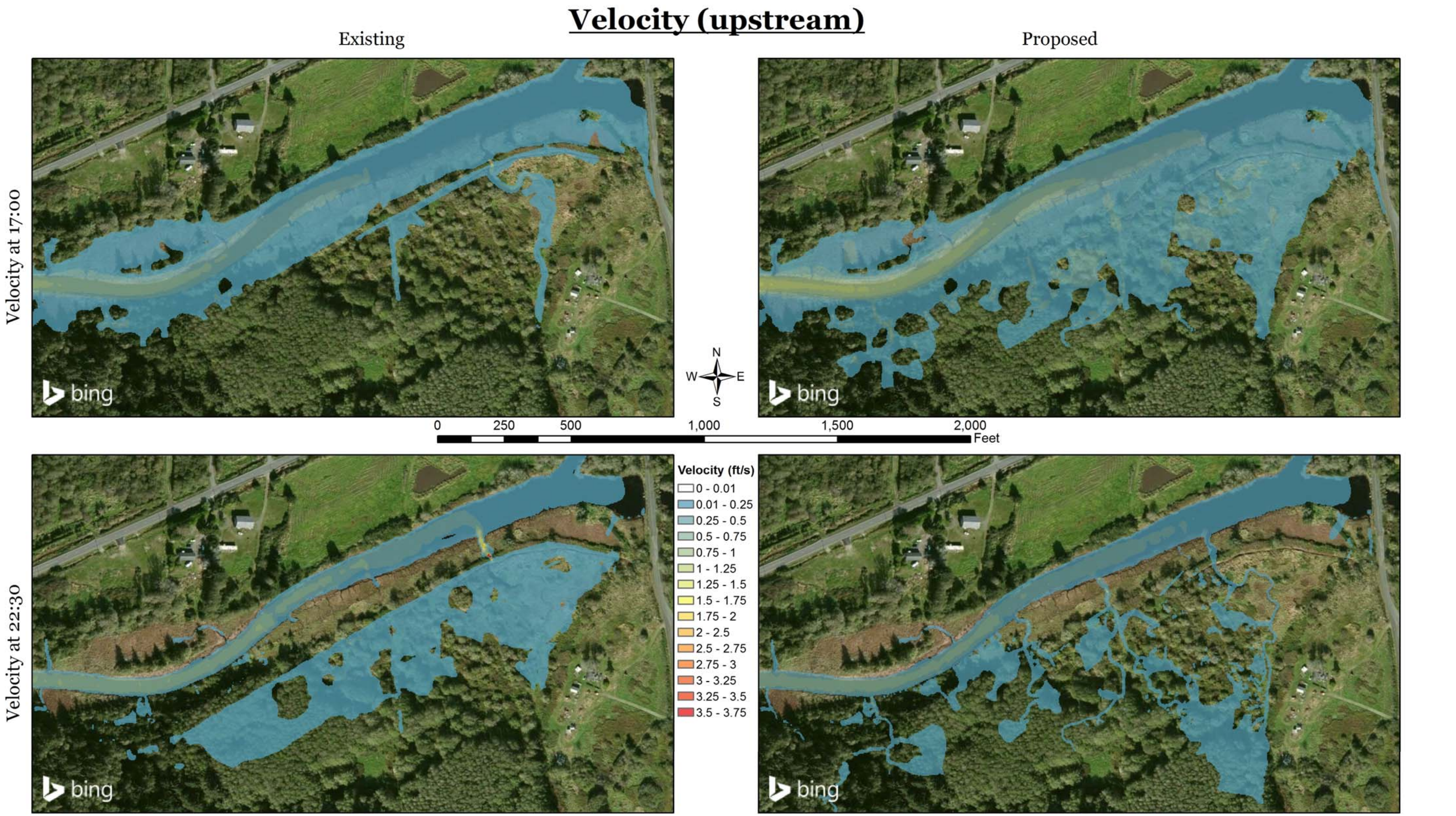

Figure 22. Modeled velocities under existing (left) and proposed (right) conditions during high velocity periods on both flood (top) and ebb (bottom) tides at the upstream end of the project area.

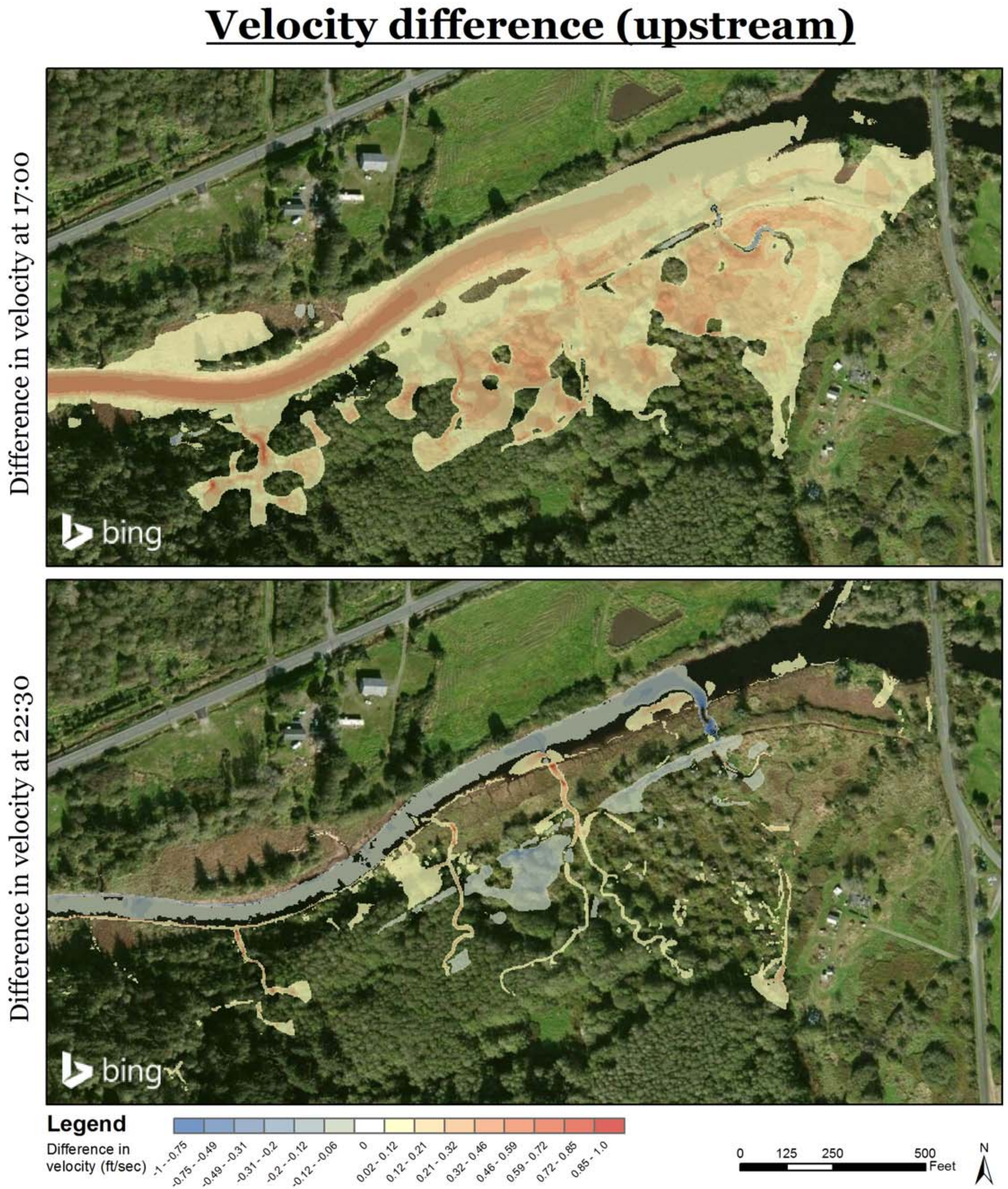

Figure 23. Differences in modeled velocities (proposed minus existing) near the upstream end of the project area. Red areas represent a velocity increase under proposed conditions while blue areas represent zones of velocity decrease. Results are shown during high velocity periods on both flood (above) and ebb (below) tides.

The differences in velocity between existing and proposed conditions in the upstream portion of the project show velocity increase on the flood tide and zones of both velocity increase and decrease on the ebb tide. Many of the areas with higher velocity under proposed conditions are those that were not inundated under existing conditions. Velocity increases are generally less than 0.4 ft/s, but slightly higher in the mid-channel areas toward the downstream edge (left) of Figure 23. Elevated velocity in the main channel is reduced as the water spreads out over the marshplain to the south of the channel at this high water surface elevation.

Again, the absolute values of velocities on both the flood tide and the ebb tide (Figure 22) are low under existing and proposed conditions (generally between 0.75 and 1.25 ft/s in the mid-channel areas, with values less than 1.0 ft/s along the banks). Similarly to the downstream portion of the project area, velocities are within a range that would be considered too low to exceed the threshold for movement of even non-cohesive bank substrates (Fischenich 2001).

This project will increase marsh inundation inside the project area. While the depth of inundation in the project site increases in many locations, the duration of inundation is reduced due to improved drainage on the ebb tide. Maximum water surface elevations (WSE) in the Wallacut River are expected to remain unchanged as a result of the project (Figure 18). Water velocity on the incoming tide (Figure 21 and Figure 23) is expected to increase under proposed conditions. Previous model runs have looked at adding a side channel to the meander bend near the mouth of the Wallacut, however this element has been eliminated from the current project proposal.

4.3 POTENTIAL IMPACTS ON ADJACENT PROPERTIES

Surface water

The Stringtown Road levee and tide gate will remain in place and function as they currently do. The farm levee within the project area is currently overtopped by tides over 9.42 feet and provides no additional flood protection for properties behind the larger Stringtown Road levee. Descriptions from residents as well as the FEMA FIRM illustrates that the neighborhood east of Stringtown Road is currently at risk to flooding (Figure 24). Flood risk for properties east of the Stringtown Road levee will not be changed by the proposed project.

No impact to water surface elevations is expected at Stringtown road as a result of the project. This statement is supported by modeled time series data in this location, showing no change in maximum modeled water surface at either Point 3 or Point 4 (Figure 19), as well a similar modeled extents of inundation (Figure 17).

The Stringtown Road levee has a minimum elevation of 10.69 feet, is likely overtopped at tides exceeding 10.69 feet, and will likely continue to be overtopped at 10.69 feet following project completion. The proposed project will furthermore have no effect on flooding or stormwater conveyance in the Wallacut River upstream of the Stringtown Road levee and tidegate. The inundation depth and patterns on adjacent propertis during larger floods than those modeled are not expected to change under proposed conditions based on several lines of evidence:

1. The farm levee under existing conditions would have become less and less significant of a barrier as flows exceed 9.4 feet
2. The mapped 100 year flood zone does not extend into the high ground on the eastern edge of the site (Figure 24). No cut to this high ground is proposed as part of the project, and no additional flowpath for floodwater is expected from the south and east sides of the existing marsh.
3. No change in modeled maximum water surface elevation in the mainstem Wallacut (existing vs proposed) was seen at either MHHW or higher (King) tides (Figure 18).

Groundwater

A basic groundwater calculation was performed to assess potential impacts of the proposed project on groundwater table elevations. In general, water travels orders of magnitude more quickly over the surface than through the ground and water transport through soil is a function of the hydraulic gradient (i, unitless) and hydraulic conductivity (k, ft/day) as described by Darcy's Law. Hydraulic gradient is calculated according to the following equation:

$$i = \frac{\Delta h}{l}$$

Where Δh (ft) is the difference in head and l is the horizontal distance.

Specific discharge is the velocity of water as it is transported through soil driven by a given hydraulic gradient, and is calculated according to the following equation:

$$q' = k * i$$

Where q' is specific discharge (ft/day), k is hydraulic conductivity (ft/day) and *i* is the hydraulic gradient (ft/ft).

A calculation was performed to evaluate how much further groundwater is likely to travel through the substrate during the "king tide" event under existing and proposed conditions. Hydraulic conductivity for sands/loamy sands was used in this calculation, and is reported by the USDA NCRS as 12 – 40 feet per day (USDA-NRCS, Saturated Hydraulic Conductivity). Hydraulic gradient was calculated conservatively by assuming the groundwater elevation is equal to MLL at 0.11 feet. Surface water elevations of the Wallacut River were set to 10.25 feet under proposed conditions and 9.45 feet under existing conditions according to model results. The length for the hydraulic gradient calculation was set to 246 feet to represent the measured distance from the marsh edge sample point in Figure 19 to the center of Stringtown Road. This location is short of the homes and provides a conservative estimate of horizontal distance in the calculation of hydraulic gradient.

Specific discharge under existing conditions was calculated as 0.46 – 1.55 ft/day, while specific discharge under proposed conditions was 0.49– 1.64 ft/day. This represents an increase in groundwater velocity of 0.03 – 0.09 feet/day under proposed conditions and a king tide scenario. These king tides typically only last a few hours, and given this brief period of inundation, transport of groundwater through the substrate is likely less than 0.09 feet. This is far short of the distance to adjacent properties east of Stringtown Road. This preliminary calculation suggests that the proposed project will not significantly impact groundwater table elevations behind the Stringtown Road levee and that a more detailed groundwater analysis is not warranted.

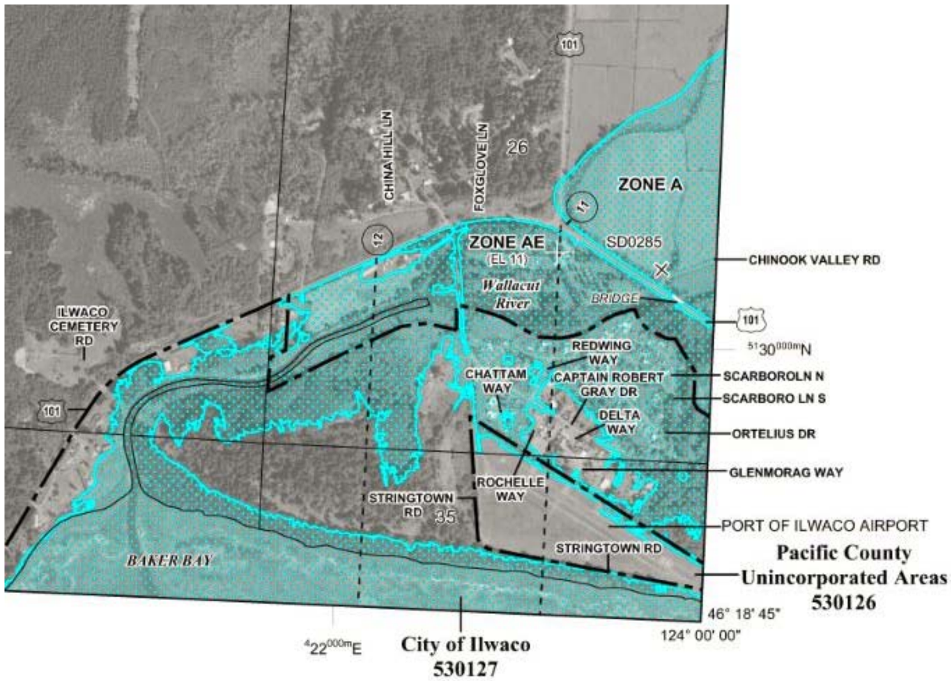

Figure 24. FEMA Flood Insurance Rate Map clipped to show the project area located in southeast corner of the map. Blue hatch indicates the 100-year flood boundary. Map number 53049C0710D. Effective Date May 18, 2015.

Bank stability analysis

A rapid site assessment and bank stability and toe erosion model (BSTEM) were utilized to evaluate the potential of the project to exacerbate bank erosion under proposed conditions. Results of the BSTEM indicate that bed erosion is likely to be the dominant form of erosion under proposed conditions. See Appendix for a full discussion of bank erosion modeling.

Modeling results and bank stability assessments suggest that the erosion risk on the outside bank downstream of the project is fairly low. Fischenich (2001) described threshold values for "permissible velocity" of soil lined channels. Maximum mid channel velocities in the Wallacut River channel are generally sufficient to mobilize fine sand and silts (1.5 to 2 ft/s). Modeled velocities along the banks were typically less than 1.5 ft/s, which is below the reported "permissible velocities" for bare soil. These values are reported before vegetation is accounted for, and in general the bank of the Wallacut River are well vegetated. This means that vegetated banks can likely withstand higher threshold velocities before erosion will take place.

Summary of risk to adajcent properties

Model results and preliminary groundwater calculations suggest that the effects of the project with respect to both surface and groundwater will be very minimal to residences east of Stringtown Road. Bank stability modeling results, tidal prism analysis and modeled velocities provide multiple lines of evidence that adjustments to the banks downstream of the project are likely to be minor under proposed conditions.

5 Project Elements

5.1 LEVEE REMOVAL, BORROW DITCH FILL, AND TOPOGRAPHIC COMPLEXITY MOUND PLACEMENT

Description

Currently a 1950 foot long levee and associated borrow ditch separate a large section of the Wallacut River from its left bank floodplain. The levee will be removed and the borrow ditch filled to increase hydrologic connectivity and daily inundation of the adjacent wetland. The restoration action will support a more natural hydrologic regime and increase the quality and size of the wetland. It will also allow for the reconnection of existing and constructed marsh channels between the wetland and Wallacut River. The largest of these channels are referred to in the design plans as Marsh Channels A, B and C. Marsh Channel A is currently connected through the levee by two small culverts. These culverts limit inflow during the flood tide and delay the draining of the marsh during the ebb tide. These culverts will be removed and Marsh Channel A will be reconnected. Marsh Channels B and C are currently disconnected from the mainstem Wallacut River by the existing levee, although they likely receive some water at high tide via the borrow ditch connecting them to Marsh Channel A. The direct hydraulic connection between these channels and the mainstem Wallacut River will be restored by levee removal. The levee and ditch area will be seeded and planted with native woody riparian vegetation.

Some portions of the levee where existing mature trees are growing will be retained. An estimated 3,350 cubic yards of material will be removed from the levee, with 2,400 cubic yards of this material used to fill the existing borrow ditch. The remainder of this material will be used to form topographic complexity mounds in the project area to support diverse vegetation communities. These mounds will provide topographic complexity and locations where spruce and other species adapted to higher marsh elevations can be planted.

Benefits

Removing the levee and filling the borrow ditch will increase hydrologic connectivity during the tidal cycle and increase the spatial extent of inundation in the wetland. The restoration of a more natural tidal cycle will help restore ecosystem function by supporting a diverse native plant community, improving nutrient cycling, and increasing quantity and quality of off-channel habitat for aquatic species.

Design Criteria/ Considerations

This project element will be consistent with conservation measures of BPA HIPIII activity category 2b, set-back or removal of existing berms, dikes, and levees (BPA 2014). The levee will be graded to match the existing topography both at the toe of the levee on the riverward side and on the opposite side of the borrow ditch. Connections of the marsh channels through the levee will be made at elevations that match existing tidal channel elevations. The borrow ditch is currently filled with thick vegetation and woody debris. Removal of this material will be necessary during construction to facilitate filling with adjacent levee material. Spoils will be placed within the marsh to simulate marsh microtopography. Compacted soil beneath the levee overburden will be loosened by disking or scarification with excavator teeth prior to replanting.

5.2 MARSH CHANNEL RECONNECTION & EXCAVATION

Description

Marsh Channels A, B, C and D are existing features within the left bank floodplain and labeled in the plans. Marsh Channel A will not include any earthwork other than the levee/culvert removal described above. The geometry of the inset channel through the levee/ditch area will match that on either side of the existing channel.

The current alignment of Marsh Channel B is an approximately 1,400 foot long, straight ditch running north-south across the project area. Portions of the current alignment on the south side of the levee will be filled and a meandering alignment will be created. The new alignment follows existing topographic depressions and will provide more complex flow paths and additional edge habitat to support juvenile salmonid rearing. A net volume of 1180 cubic yards of material will be removed from this channel.

Marsh Channel C currently terminates at the existing levee. A new section of this channel will be excavated to the south of the levee in order to introduce consistent tidal fluctuations into lower elevation areas south of the levee. A net volume of 280 cubic yards of material will be removed to create 430 linear feet of new marsh channel.

Marsh Channel D (which consists of two adjacent channels that converge near the location of the levee) is currently disconnected from the mainstem Wallacut River. The levee in this area will be removed, but the channels will not be excavated farther than the levee because the existing meandering channels appear sufficient in length and alignment to provide the desired level of connectivity.

Benefits

The new alignments of Marsh Channel B and C and the reconnection of Marsh Channel D will create over 2000 feet of additional tidal channel while improving the quality of the existing habitat. All of the marsh channels will be more accessible to salmonids, providing high-flow refugia and rearing habitat.

Restoring tidal hydrology and tidal channels will reverse the existing marsh developmental trajectory from degradation to restoration over time. Increasing connectivity with levee removal and tidal channel enhancement will increase sediment supply to the marsh plain, increase nutrient cycling, and allow the marsh to export organic material to support a macrodetrital food web in the Wallacut River and Baker Bay.

Design Criteria/ Considerations

This project element will be consistent with BPA HIPIII conservation measures of activity 2a, improve secondary channel and wetland habitats (BPA 2014). Several lines of evidence were used to determine the hydraulic dimensions of the newly excavated marsh channels. Initially, Marsh Channels B and C were sized based on the dimensions (width to depth ratio and top width) of Marsh Channel A, which is currently functioning (although not fully connected). Secondly, the contributing area to each channel was estimated, the volume of the tidal prism above it was calculated. The tidal prism volume was then compared to the relationship developed by Williams et al (2002) described in equation 1.

$$A_{inlet} = 0.0284 * (V_{tidal\ prism})^{0.649} \qquad \textit{Equation 1}$$

Designed channel dimensions were, in general, slightly larger than that which would be predicted by the contributing tidal prism at Mean Higher High Water (MHHW). This suggests that the trajectory of channel change toward equilibrium in the marsh channels will generally be depositional, although adjustments due to both erosion and deposition should be expected as the channels mature. All constructed marsh channels are designed to slope downward into the Wallacut River to promote draining and limit fish stranding. Spoils will be placed within the marsh adjacent to channel areas to simulate marsh microtopography. Areas of mature native vegetation will be avoided.

5.3 MARSH FLOODPLAIN WOOD PLACEMENTS

Description

Wood placements are planned at strategic locations within Marsh Channels A, B and C. These will consist of grouping of 2 to 3 pieces of large wood, ballasted by buried vertical snags and arranged to mimic natural accumulations of floodplain wood.

Benefits

Wood in these locations will provide hydraulic roughness to slow ebb and flood tide flows, accumulate driftwood, and provide cover and habitat for fish utilizing the tidal channels. These placements may also provide seed structures for beaver activity, and while not specifically designed for this purpose, this use would further support overall habitat complexity within the marshes.

Design Criteria/ Considerations

This project element will be consistent with BPA HIPIII conservation measures of activity 2d, install habitat-forming natural material instream structures (BPA 2014). Wood will be secured to vertical snags using threaded rod pins in order to resist buoyant forces at full submersion. The ends of the wood pieces will be notched into the existing ground and partially buried in some locations where channel dimensions warrant. Large wood placements are designed and placed to mimic natural accumulations of wood to the maximum extent practicable while providing the necessary stability. These structures are not expected to create fish stranding issues. They are not large enough to back up water behind them on an outgoing tide, and tidal hydrology is expected to transport sediments fine floodplain sediments through the structures.

5.4 REVEGETATION

Description

Revegetation will include seeding and installing woody plantings (bare roots and cuttings) following construction. A seed mix will be applied to all distrurbed areas following construction by the contractor. Wetland seed mix will be applied in wetland areas and upland soil stabilization seed mix will be applied in upland area. Woody plantings will be planted by CLT according to sheet 22 of the plans, which shows zones for scrub shrub and forest species. Scrub shrub revegetation will cover approximately 19.9 acres, while forested revegetation will cover 6.6 acres.

Benefits

Site revegetation is expected to support a diverse native plant community, decrease erosion following site reconnection, increase long-term large wood recruitment on site, and reduce the spread of invasive species. Revegetation will support marsh recovery and provide habitat and food for insects, fish, and other organisms in the marsh and larger estuary.

Design Criteria/ Considerations

The revegetation plan was developed using reference communities found on site and in nearby areas. Vegetation in tidal marsh environments establishes at distinct elevation bands in relation to the tidal cycle, and suitable elevations have been listed for each species and will be used to guide revegetation.

The project area currently contains forests and wetlands that attract a variety of wildlife. The proposed project is not likely to significantly increase bird densities or attract birds that are not already present in the project area. The revegetation plan has been designed to accommodate air traffic safety for the nearby airport by limiting large trees within runway approaches. The project is not expected to have a negative impact on air safety.

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