

# Memorandum

November 25, 2020

To: David Palazzi, Washington State Department of Natural Resources  
From: Kyle List, PE, Anchor QEA, LLC, and Kathy Ketteridge, PE, PhD, Blue Coast Engineering  
cc: John Small, Anchor QEA, LLC

**Re: Whiteman Cove Project Hydraulic Assessment**

## Introduction

A team of consultants led by Anchor QEA has been retained by the Washington State Department of Natural Resources (DNR) to provide analysis, design, permitting, and outreach support for the Whiteman Cove Project (Project). The purpose of the Project is to re-establish anadromous fish passage between Whiteman Cove and Case Inlet in Puget Sound to meet the requirements of the 2013 federal court injunction for fish, which requires fish passage for “all species of salmon at all life stages at all flows where the fish would naturally seek passage” (*United States v. Washington*).

Whiteman Cove was historically a barrier lagoon located on the southwestern shoreline of the Key Peninsula in Pierce County, Washington. It is separated from Case Inlet by a natural spit formed by net littoral drift to the north and feeder bluffs to the south. The historical opening to the cove, located at the northern end of the spit, was closed in 1962 to create a perched brackish water lagoon that was intended for the rearing of juvenile salmon. The impounded lagoon is approximately 25 acres in size. Two control structures maintain water surface elevations in the lagoon at an average of 13 feet mean lower low water (MLLW) or 8.9 feet North American Vertical Datum of 1988 (NAVD88). Minimal water exchange occurs through the control structures between the perched lagoon and Case Inlet. Fish passage is almost completely blocked by the control structures. Freshwater input to the cove comes primarily from a small intermittent stream (Whiteman Creek) at the eastern end of the cove that drains the approximately 1.7-square-mile upland watershed.

Four options to provide fish passage to the cove were considered and evaluated as part of a screening-level feasibility study conducted by the Anchor QEA team as part of this Project (Anchor QEA 2020). The results of that analysis are documented in the Feasibility Report for the Project (Anchor QEA et al. 2020). The screening analysis provided information regarding fish passage, permitting, and site use challenges and opportunities for each of the proposed options. Following the screening analysis, all four options were moved forward into the feasibility study. This memorandum summarizes the results of the hydraulic analysis conducted for each proposed option described briefly below:

- Option 1: A new gated control structure at the current location of the DNR control structure

- Option 2: A new weir control structure at the historical opening to the north
- Option 3: An open channel at the historical opening of the cove with a bridge crossing
- Option 4: An open channel at the historical opening of the cove with road removal and rerouted access from the south

## **Purpose**

This memorandum summarizes the Whiteman Cove hydraulic model development and application, conducted by Anchor QEA and Blue Coast Engineering, to evaluate the four options listed above developed as part of the screening analysis. Options are discussed in detail below and in Section 3.2 of the Feasibility Report (Anchor QEA et al. 2020). A 1D hydrodynamic HEC-RAS model developed as part of previous work on the Project in 2014 and a 2D hydrodynamic HEC-RAS model developed as part of this work were used to evaluate changes to hydraulics within Whiteman Cove due to the proposed options. The results of this hydraulic assessment will be used to inform the habitat, coastal geomorphology, and transportation technical studies for the Project and to compare fish passage opportunities for each of the proposed options. At later phases of the Project, the hydraulic assessment will be used to help determine the preferred option for the site and final design of the preferred option.

## **Model Development**

The 1D HEC-RAS model developed in 2014 (Anchor QEA 2015) consisted of a series of elevation transects and was used to predict tidal exchange and water levels in Whiteman Cove based on several proposed options, including Option 1 (new gated control structure). The results of this modeling effort are used in this evaluation to assess hydraulics and fish passage at Whiteman Cove due to Option 1. Development of the 1D model is described in the Draft Preliminary Design Report for the Project (Anchor QEA 2015).

The 1D model was adapted and revised by converting the entire domain into a 2D model to capture the flow patterns in and out of the estuary for modeling Options 2 through 4. The 2D model consists of a variable resolution grid cell mesh with approximately 53,000 grid cells. The model grid cell sizes range from 8 to 16 feet in dimension. The model grid covers the entire Whiteman Cove and the Camp Colman access road, extends approximately 1,300 feet offshore into Case Inlet, and includes the Joemma Beach Park pier. The model uses a tidal boundary in Case Inlet to drive tidal flows and the small tributary (Whiteman Creek) is included for freshwater flow input to the model. Figure 1 shows the extents of the model grid and the boundary condition locations.

**Figure 1**  
**2D Model Domain**

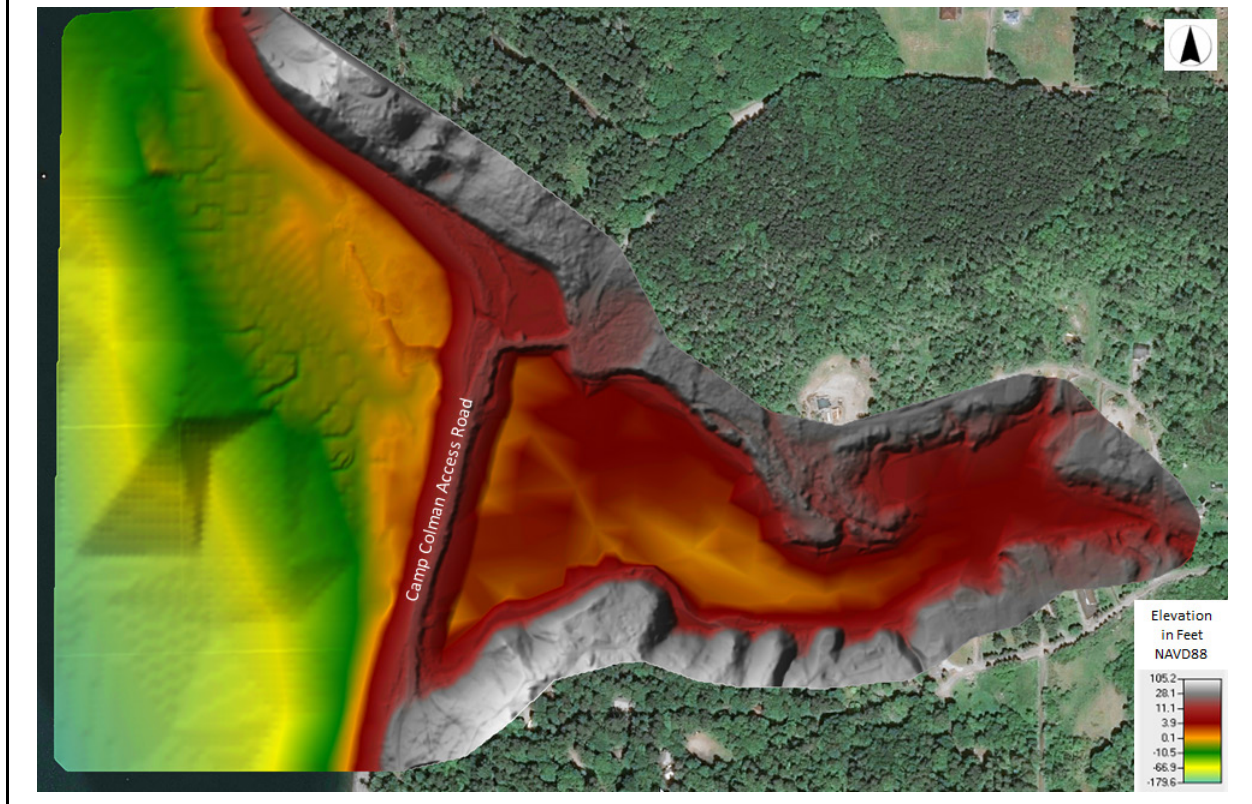


The 2D model geometry was based on a topo-bathymetric surface that was formed as the combination of the following data sources:

- Bathymetry measurements in Whiteman Cove (Anchor QEA 2015)
- Upland Topography Lidar Data (Pierce County Lidar Digital Terrain Model 2011)
- Case Inlet Bathymetry Data (Puget Sound DEM, Finlayson 2005)

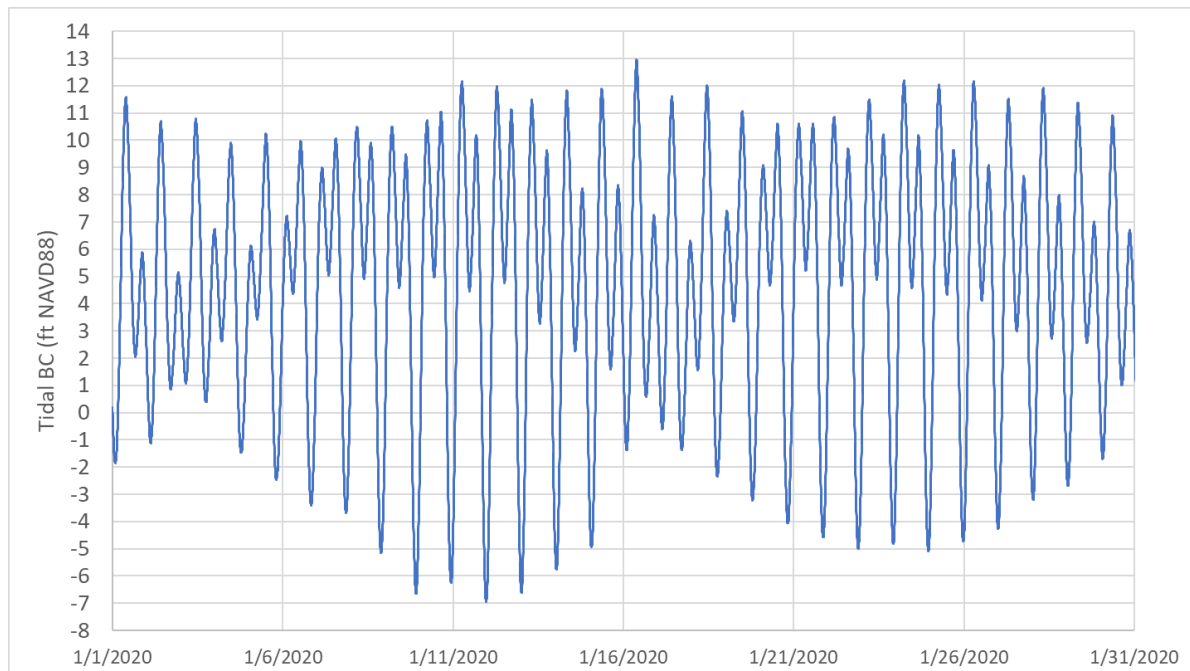
All datasets used in the model were converted to the model datum of feet NAVD88. A terrestrial-based survey was performed by Blue Coast Engineering at key locations on the Camp Colman access road, near the Camp Colman dock, and along the beach north of the road. These spot elevations were compared to the existing Pierce County Lidar data from 2011. There was minimal variation in elevations along the access road, with the greatest change in elevation from the 2011 LiDAR observed in the dynamic area north of the access road where coastal wave action and transport has likely caused changes in topography. No changes were made to the elevations in the model geometry based on the 2020 spot check survey. Figure 2 shows the existing model elevations prior to development of the two options.

**Figure 2**  
**Existing Conditions Model Elevations**



The boundary conditions used in the model were based on the tidal predictions for the Ballow, Washington, National Oceanic and Atmospheric Administration (NOAA) station (No. 9446583) occurring in January 2020. These include spring tides occurring near January 10, 2020. Because there are no longer verified tidal measurements at the Ballow NOAA gage located approximately 3 miles northwest of Whiteman Cove, the measured and validated tidal levels from the Seattle NOAA gage (No. 9447130) were transformed to the Ballow NOAA station using the provided scaling factors and temporal offsets. Figure 3 shows the tidal time series of water surface elevations used in the model simulations.

**Figure 3**  
**Tidal Boundary Conditions: January 2020**



For freshwater flow inputs, a negligible flow rate (0.01 cubic feet per second [cfs]) to provide model stability was used for the baseline (tide-only) conditions simulations for existing conditions and each option. The 200-year flow rate (approximately 160 cfs) established for the Whiteman Cove drainage basin was used in an additional simulation to evaluate the effects of high flows on the hydrodynamics for each of the options. The flow rate was estimated using U.S. Geological Survey regression equations (StreamStats) with an estimated basin size of 1.9 square miles (Mastin et al. 2016). The 200-year flow rate was used instead of the 100-year flow rate to be conservative and to take into account potential increases in rainfall intensity in the future due to predicted climate change.

The spatially varying roughness coefficients for the model were assigned with the Manning's  $n$  bed roughness coefficient with values based on observations of the bed composition from previous site visits and standard guidance from Chow (1959). The Manning's  $n$  roughness coefficient in the inlet and inlet side slopes for each option was set to a value of 0.02.

## Options

The two options selected for hydraulic evaluation were determined as part of the screening-level feasibility study (Anchor QEA 2020). They include the open channel with single span bridge design (Option 3) and an open channel design without a bridge requiring a new access route to Camp Colman (Option 4). The inlet opening for each option was developed in CAD software and applied to

the same model grid cell mesh geometry. The model is not a sediment transport or morphological model, and therefore the model does not compute changes to topography to the inlet channels and surrounding beaches that are expected to occur over time. The following sections describe each option and show the final model geometry of each.

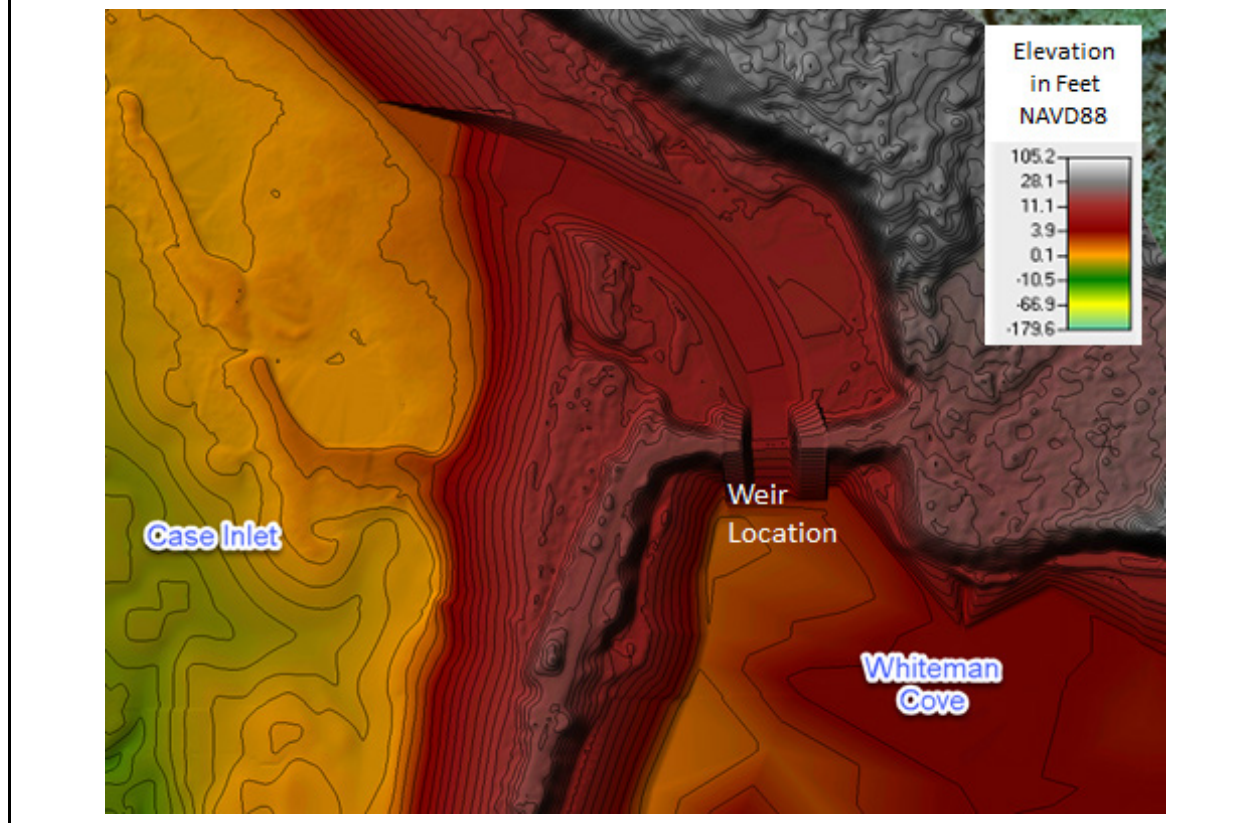
### *Option 1: New Gated Control Structure*

Option 1 consists of a single or series of large culverts between Whiteman Cove and Case Inlet that are regulated by a hydraulic gate. The structure would be built in the current location of the DNR control structure. The gate would open to allow tidal exchange at higher tidal elevations, and close at lower tidal elevations to maintain a specific water surface elevation in the lagoon. This structure would also be able to close automatically or manually at extreme higher water levels to prevent flooding of infrastructure in the lagoon (if any is found to occur). No bridge structure is required for this option because the tide gate control structure can be designed to support vehicular access.

### *Option 2: Weir Opening*

Option 2 consists of a 40-foot box culvert or series of smaller box culverts with a non-erodible bottom (i.e., armor rock or concrete sill) at the approximate location of the historical opening to the north. The non-erodible bottom of the opening would act as a weir that would maintain the water level at a set elevation in the lagoon and provide grade control for the outlet channel. The elevation of the weir would be established at +9.0 feet NAVD88, which is expected to maintain the minimum water depths in the cove at current levels. The opening would allow some passage of sand and gravels through the opening depending on tidal elevations and flows and nearshore sediment supply. The box culverts would be capable of maintaining vehicle access to Camp Colman along the exiting roadway. The 2D hydraulic model for Option 2 does not include the culvert features other than the non-erodible bottom weir structure. The top of the culverts will be designed with a freeboard above extreme water levels and therefore the culvert structure is not expected to constrict hydraulics of the inlet during tidal conditions above the weir crest. A 40-foot wide inlet channel with thalweg with elevations ranging from +8.0 feet NAVD88 at the toe of the weir structure to +3 feet NAVD88 on the beach is included as part of Option 2. Figure 4 shows the model geometry for Option 2. Additional information about the proposed culvert and weir design can be found in the Whiteman Cove Transportation Study (KPFF 2020).

**Figure 4**  
**Option 2 Model Geometry**

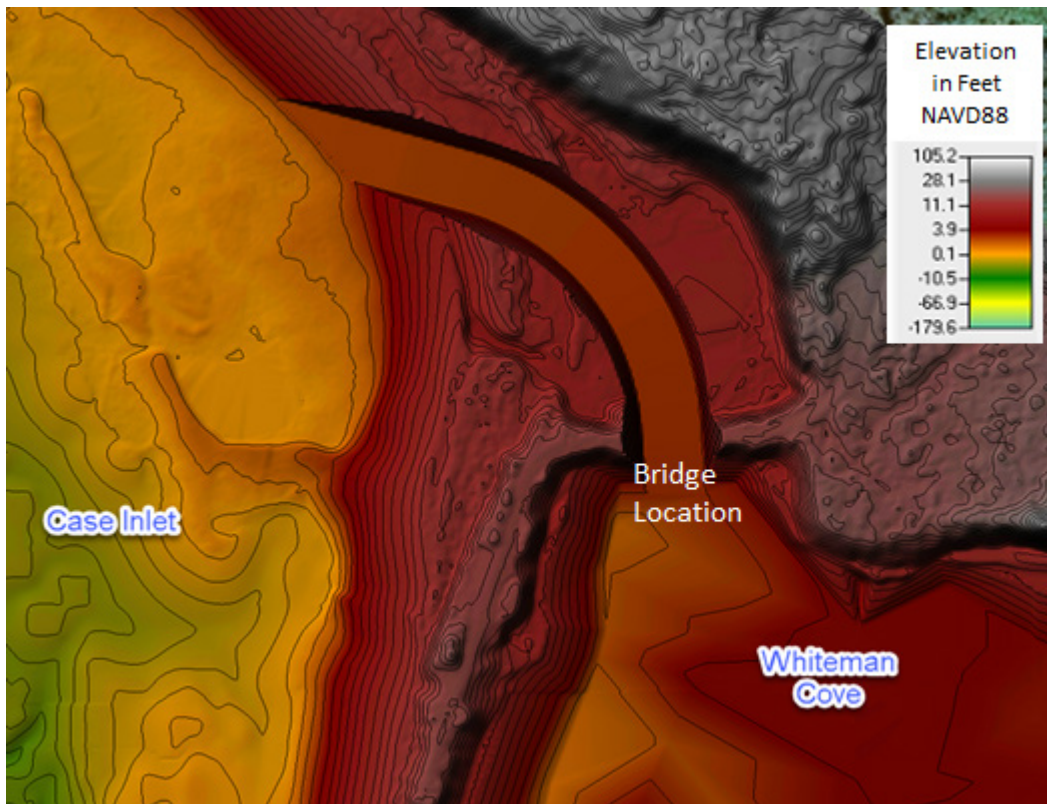


### *Option 3: Bridge Opening*

Option 3 consists of a broad, open channel inlet connection between Whiteman Cove and Case Inlet with a natural (sand and gravel) bottom. The channel alignment starts due north from Whiteman Cove at a bed elevation (thalweg<sup>1</sup>) of +3 feet NAVD88 (+7 feet MLLW) and gradually curls to the northwest and connects with Case Inlet at a bed elevation of approximately +2 feet NAVD88 (+6 feet MLLW). The inlet is approximately 550 feet long with a bed slope of 0.002. The channel is approximately 85 feet wide at the mean higher high water (MHHW) elevation (+10.4 feet NAVD88) and approximately 62 feet wide at the thalweg (+3 feet NAVD88). The channel side slopes were set to a slope of 1.5H (horizontal):1V (vertical). This option also includes a bridge and abutments along the existing alignment of the access road. The 2D hydraulic model does not include the bridge deck feature. The bridge design will be designed with a freeboard above extreme water levels and therefore the bridge deck is not expected to affect the hydraulics of the inlet. Figure 5 shows the model geometry for Option 3. Additional information about the proposed bridge design can be found in the Transportation Study (KPF 2020).

<sup>1</sup> The thalweg elevation is the lowest elevation in a channel along its alignment.

**Figure 5**  
**Option 3 Model Geometry**

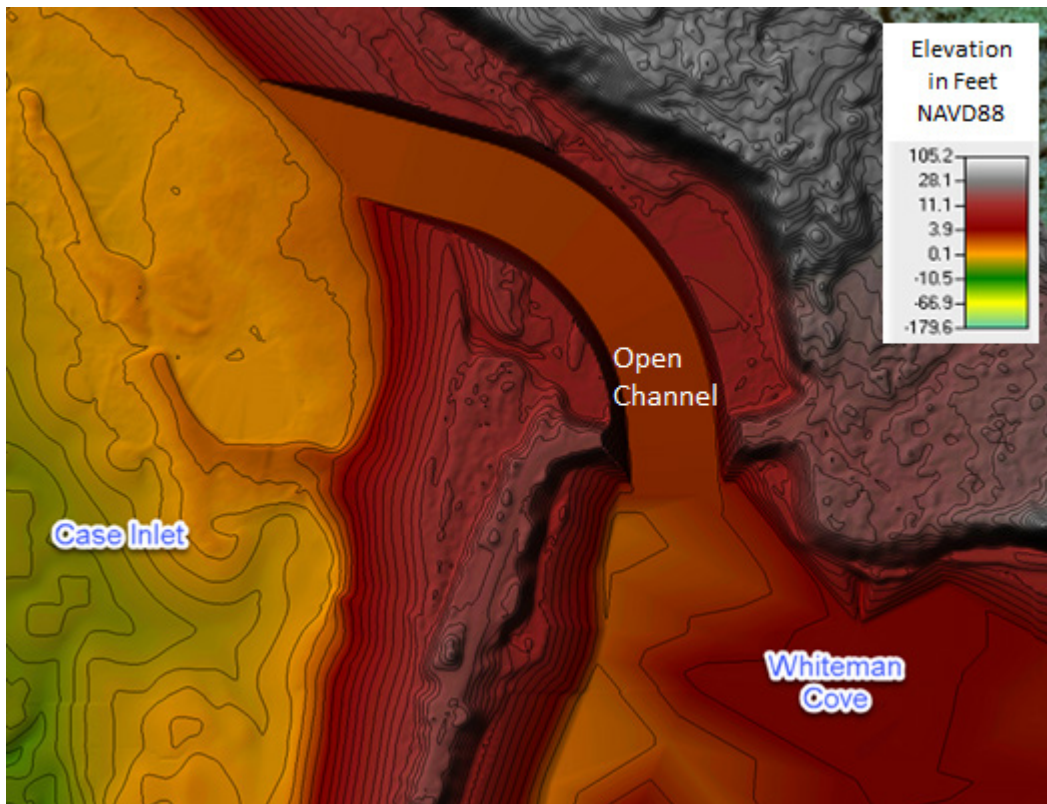


#### *Option 4: Open Channel*

Option 4 consists of an open channel slightly wider than the open channel designed for Option 3 with the same alignment, invert elevations, and gradients. The channel is approximately 120 feet wide at the MHHW elevation (+10.4 feet NAVD88) and approximately 85 feet wide at MHHW. The channel side slopes were set to a slope of 2H:1V. There are no bridge abutment features included in the Option 4 geometry. No bridge would be constructed over the opening and the access to YMCA Camp Colman from the north along the coastal spit would be removed within the footprint of the new open channel. A new access road would be constructed to access the YMCA camp along undeveloped Pierce County right-of-way from the south (KPFF 2020). Figure 6 shows the model geometry for Option 4.



**Figure 6**  
**Option 4 Model Geometry**



### 1D Model Simulations (Option 1)

The modeling effort conducted by Anchor QEA in 2014 included simulations for a functional gated control structure representative of Option 1. Two simulations were conducted, the first with a single 4-foot gate culvert and a second with two side-by-side 4-foot gated culverts. Tides used in the model were like those used in the 2D model simulations (discussed below) and freshwater flow into the cove was minimal to isolate tidal inundation processes. The invert elevation of the culverts was set to +5 feet NAVD88 (like the existing DNR structure) and the gate structure would allow exchange between the cove and Case Inlet at tidal elevations higher than +9 feet NAVD88. This would keep water elevations at or above the current water level in the cove (approximately +9 feet NAVD88). The gate structure would close off the culverts at elevations below +9 feet NAVD88.

Results of the modeling for Option 1 (one- and two-culvert options) are discussed in the Draft Preliminary Design Report (Anchor QEA 2015), and are summarized below:

- Some level of tidal exchange will be allowed between the cove and Case Inlet through the culverts at elevations above +9 feet NAVD88 (+13 feet MLLW), which occurs about 20% to 25% of the time over a typical year.

- Tidal flows into and out of the cove will be attenuated by the culverts. Tidal elevations at both the low end (+9 feet NAVD88/+13 feet MLLW) and the higher end (12.4 feet NAVD88/+16.5 feet MLLW) of allowed elevations in the cove by the control structure will lag behind the tide elevation in Case Inlet due to this attenuation.
- When exchange is occurring, current velocities in the culverts for both the one-culvert and two-culvert options will be high most of the time. Velocities are predicted to be higher than 2 feet per second (fps) more than 80% of the time over the model simulation. These velocities will be challenging from a fish passage perspective, where velocities higher than 2 fps are generally assumed to be unpassable by fish (Barnard et al. 2013).

## 2D Model Simulations (Options 2, 3, and 4)

A total of four model simulations were used to evaluate the changes to hydrodynamics of Whiteman Cove for each of the two options compared to existing conditions. The boundary conditions of each simulation are summarized in Table 1.

**Table 1**  
**Hydrodynamic Simulations**

Simulation	Model Geometry <sup>1</sup>	Tidal Boundary	Freshwater Flows <sup>4</sup>
1 – Existing Conditions Tides	Existing conditions	January 2020 tides	Nominal <sup>3</sup>
2 – Option 2 Tidal Exchange	40-foot-wide inlet with a bridge abutment and weir structure		
3 – Option 3 Tidal Exchange	85-foot-wide inlet with bridge abutments		
4 – Option 4 Tidal Exchange	120-foot-wide inlet <sup>2</sup>		
5 – Option 3 200-Year Flood Event (based on freshwater input)	85-foot-wide inlet with bridge abutments		200-year flood event <sup>4</sup> (160 cfs)

Notes:

1. The proposed bridge abutment dimensions were provided by KPFF and the reported channel width is based on the width at MHHW elevation.
2. The Option 4 inlet width refers to the width of the inlet at MHHW elevation.
3. Nominal flow (0.01 cfs) was used to establish the freshwater flow boundary condition for the simulation but limit effects on the tidal hydraulics of the system.
4. Estimated using U.S. Geological Survey regression equations based on estimated drainage basin for Whiteman Cove.

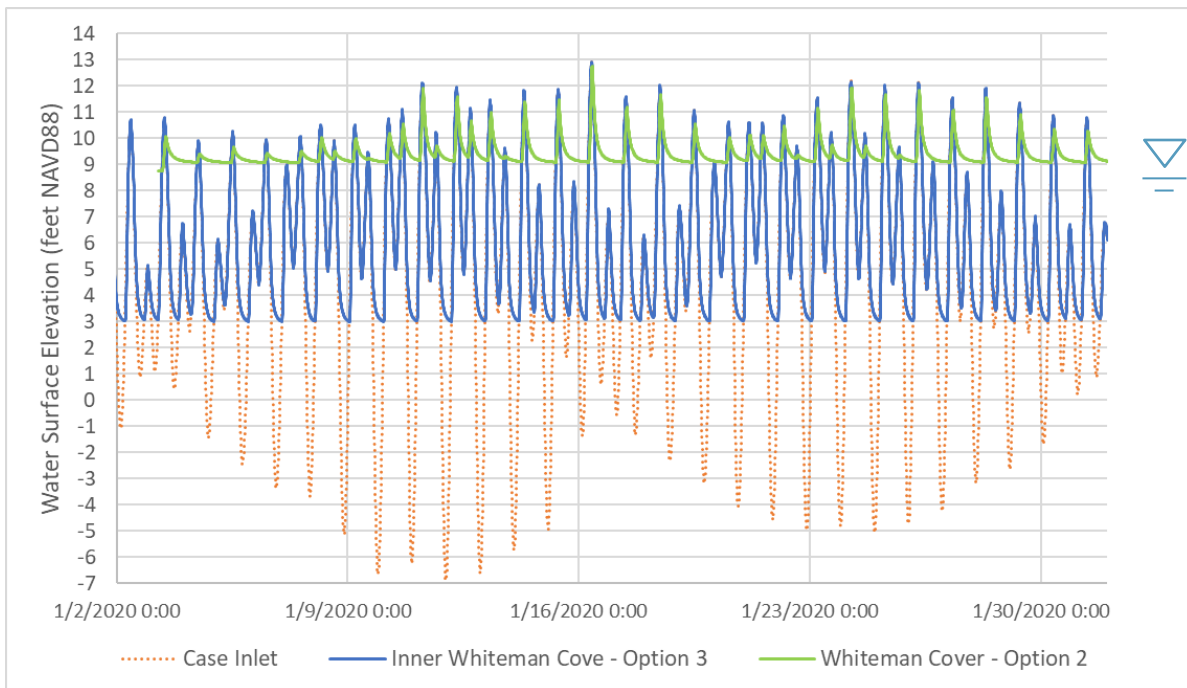
## Model Results

The hydrodynamic model simulations results were used to evaluate hydrodynamic conditions (i.e., water surface elevations and velocities) in the cove and tidal channels based on proposed Options 3 and 4.

## Tidal Exchange

Based on the evaluation of tidal water levels in Case Inlet, the open channels proposed in Options 3 and 4 will allow for essentially full inundation and drying of Whiteman Cove over the tidal cycle. When water levels are below the thalweg of the proposed inlet channel (+7 feet MLLW, +3 feet NAVD88) most of the cove will be dry with some ponding in areas of the cove lower than the thalweg elevation. For Option 2, the cove will not be accessible to tidal inundation on a flood tide until the tide reaches or exceeds the weir elevation (+13 feet MLLW, +9 feet NAVD 88). When the ebb tide drops below the weir elevation, the flow out of the cove will experience a drop of 1 to several feet on the downstream side of the weir depending on the elevation of the tidal channel out on the beach. The water surface elevation in the cove will not drop below the weir elevation, which is approximately equivalent to the water level in the cove currently. A temporal comparison of the water surface elevations in Case Inlet and within the thalweg of the proposed inlet channel for both Options 2 and 3 is shown in Figure 7. The results show that with the new inlet channel, Whiteman Cove will experience the full upper tidal range for the area. When the tide drops below the upstream thalweg elevation of the proposed inlet channel (+7 feet MLLW, +3 feet NAVD88), the water in Whiteman Cove stops draining and elevations in the cove below the thalweg elevation will retain some ponded water. There were no significant differences between Option 3 and 4 in terms of tidal inundation; both options provide full tidal inundation to the cove.

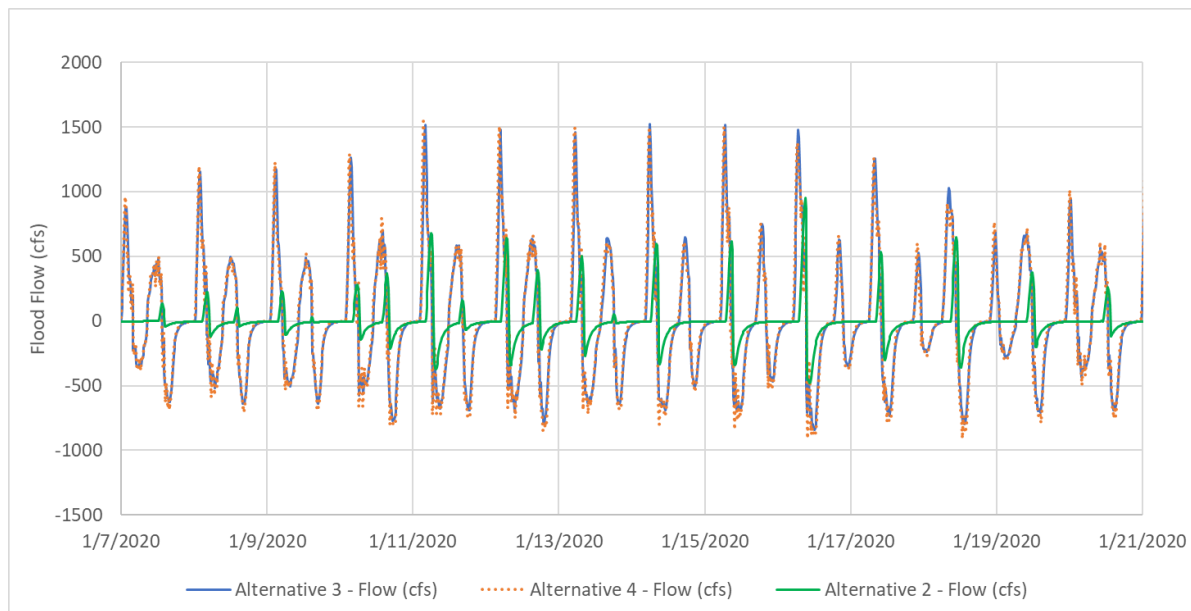
**Figure 7**  
**Predicted Water Surface Elevations in Whiteman Cove and Case Inlet**



Note: Results shown are for Options 2 and 3. No significant differences in water levels were observed for Option 4 compared to Option 3.

The tidal flow rate into and out of the Whiteman Cove estuary for Options 2, 3, and 4 was extracted from the model results. Figure 8 shows the flow rates for each option. Options 3 and 4 show very similar peak flow rates while the peak flow rates for Option 2 are significantly truncated. The mean tidal prism was estimated to be approximately 200 acre-feet (247,000 cubic meters) on the cumulative flow rate into and out of Whiteman Cove for Options 3 and 4, and only approximately 75 acre-feet (93,000 cubic meters) for Option 2. The predicted peak flow rates were up to 1,500 cfs for flood tide and 800 cfs during ebb tide. For Option 2, the predicted peak flow rates through the elevated weir structure were much lower at approximately 950 cfs for flood tide and 470 cfs during ebb tide.

**Figure 8**  
**Predicted Flow Rates through the Tidal Inlets**



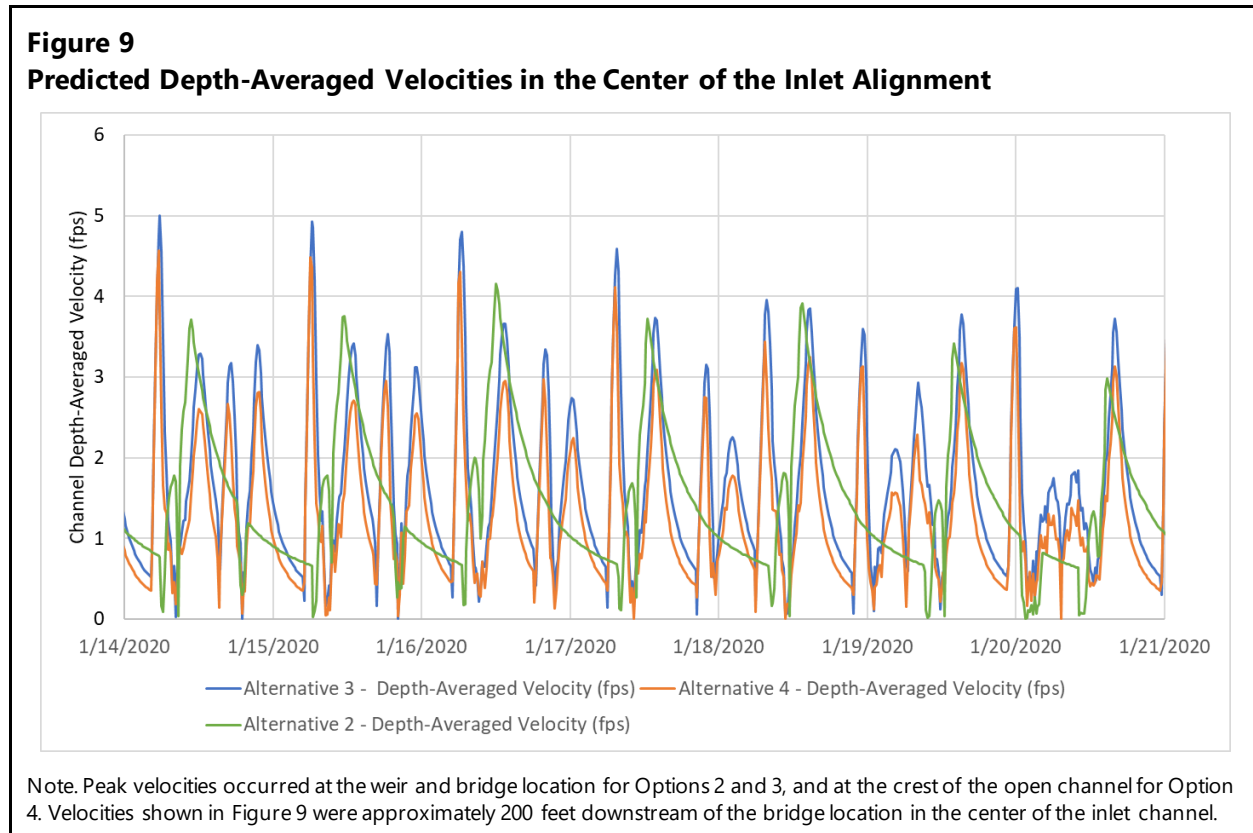
Note: Positive flow rates represent flood flow into Whiteman Cove and negative flows represent ebb flow out of Whiteman Cove.

## Current Velocities

Model results were used to develop predictions of current velocities in the proposed inlet channels for Options 3 and 4, within the cove, and in the vicinity of the shellfish beds owned by Seattle Shellfish adjacent to the cove along the shoreline of Case Inlet. Predicted velocities in the main body of the cove and in the nearshore area were nearly identical between Options 3 and 4. Velocity differences between Options 3 and 4 were predicted only within the inlet channel itself. Option 2 showed a very different velocity regime compared to Options 3 and 4 in the inlet channel due to the weir structure.

### Proposed Inlet Channels

Flow velocity through the inlet is important information for understanding fish passage. Figure 9 shows a time-series of predicted depth-averaged velocities over 7 days of the 31-day simulation for the center of the inlet for Options 2, 3, and 4 (simulations 2, 3, and 4). Table 2 summarizes the channel velocity at the center point location where the time-series results were evaluated for Figure 9.



**Table 2**  
**Depth-Averaged Velocity Statistics in the Center of the Proposed Inlet Channels**

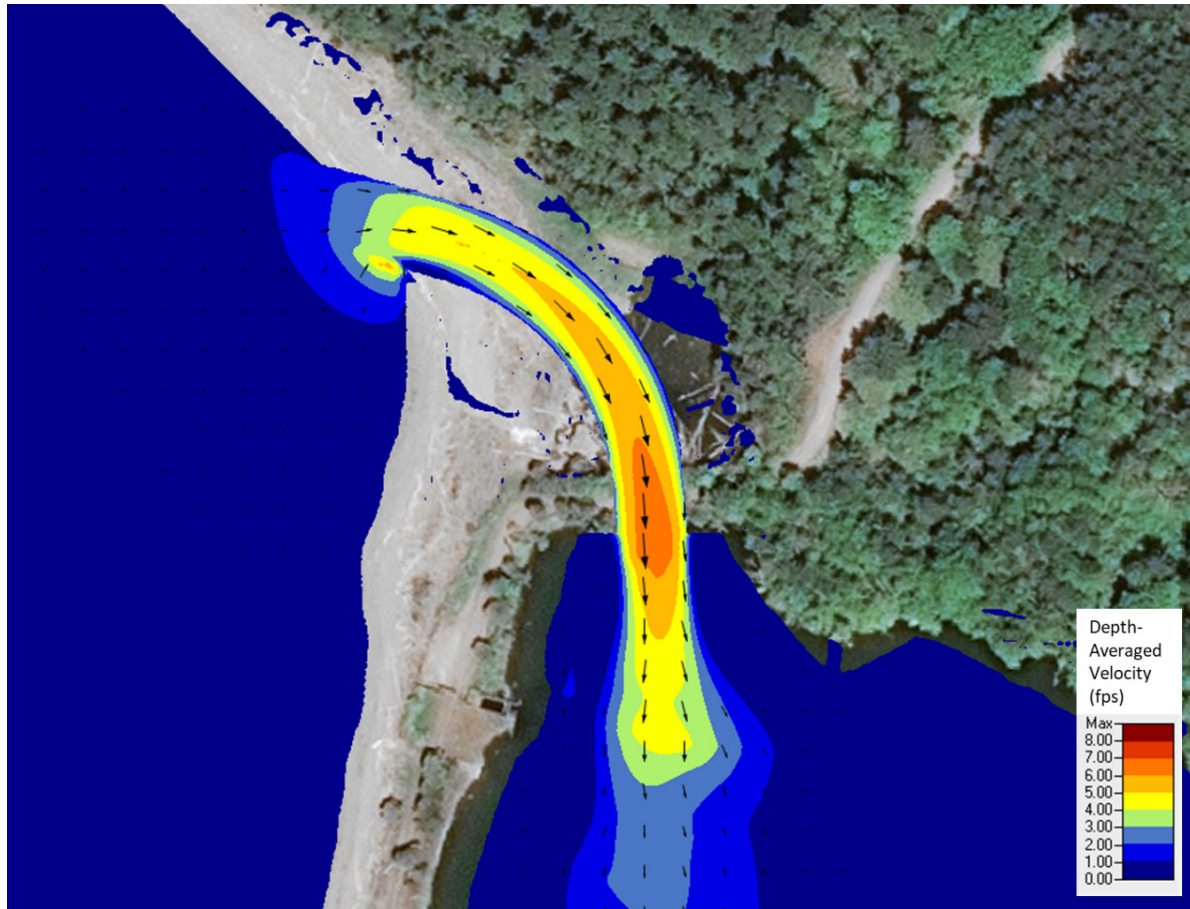
Value	Depth-Averaged Velocity (fps)		
	Option 2	Option 3	Option 4
Mean	1.3	1.6	1.2
Median <sup>1</sup>	1.2	1.4	1.0
Maximum <sup>2</sup>	4.2	4.9	4.5
Value	Percent of Predicted Velocities (%)		
Velocity less than 2.0 fps	62	67	84

Notes:

1. Median velocity represents the 50th percentile (e.g., 50% of the time velocities were predicted to be less than 1 fps for Option 4).
2. Maximum velocity refers to the maximum velocity in the center of the inlet alignments over the month-long tidal simulation without freshwater input (Simulations 2 and 3).

The average and median channel velocities were generally low, below 2 fps in the center of the inlet channel. When velocities in the channel are above 2 fps, there are typically areas of the inlet channel fringes with velocities lower than 2 fps for each alternative. It should be noted that the inlet channel will be returned to a natural state and allowed to migrate and form smaller low flow channels, thus changing the velocities in the inlet at various tidal stages. The mean velocity through the narrower Option 3 channel with the bridge abutments had the highest average predicted depth-averaged velocity (1.6 fps) in the inlet, occurring during flood tide. The highest velocities predicted in the inlet channels for each alternative occur in the location of the current road alignment. The predicted peak velocity in the inlet at this location is 9.2 fps for Option 2, 6.7 fps (shown in Figure 10) for Option 3, and 5.5 fps for Option 4. The maximum velocities in the channel are expected to decrease over time as the channel bed erodes and changes due to tidal flows following implementation of either Option 3 or 4. However, peak velocities will remain high through the armored weir opening for Option 2. The model does not predict bed changes over time or the subsequent expected changes in maximum channel velocities. A geomorphology analysis summarizing expected changes to the channel over the long term, based on Options 2, 3 and 4, is provided in the Coastal Processes Assessment memorandum (Blue Coast Engineering 2020).

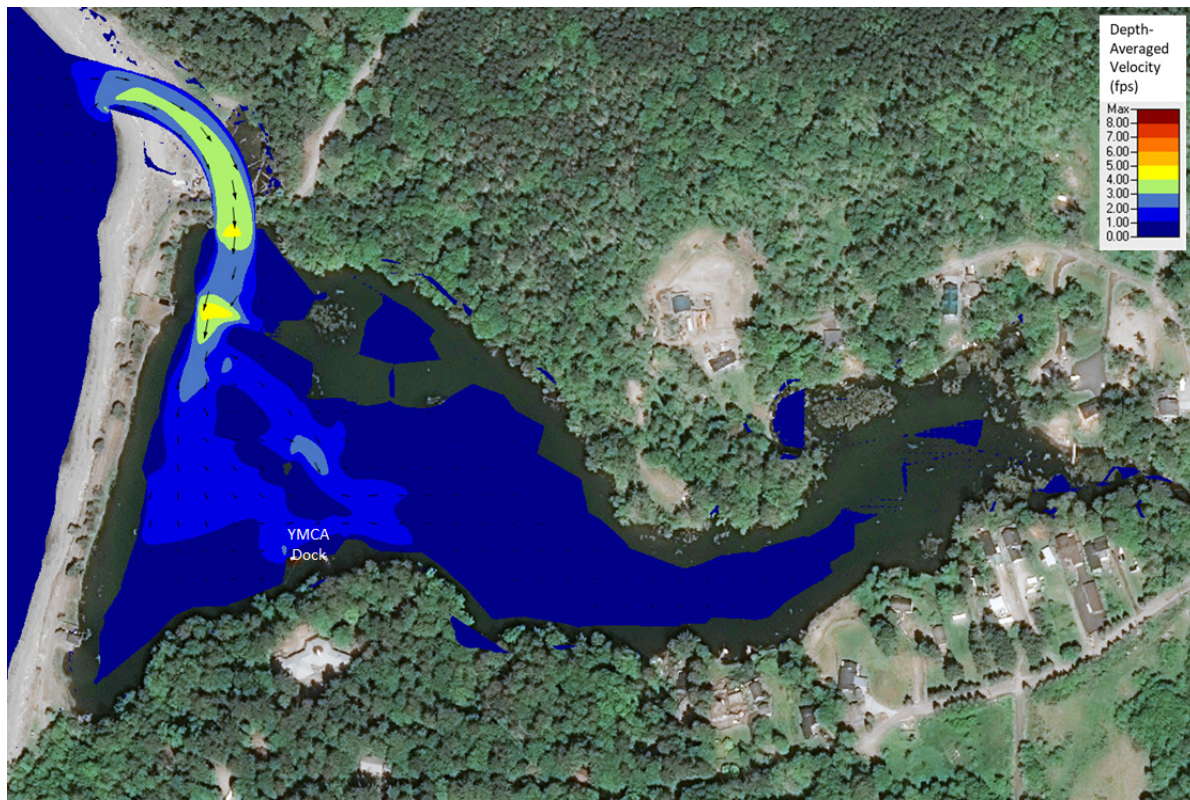
**Figure 10**  
**Plan View of Initial Maximum Velocity in the Tidal Inlet for Option 3**



### *Whiteman Cove*

Hydrodynamic model results were used to evaluate changes to current velocities in the cove near the YMCA docks and eastern end of the cove due to the proposed options. The existing conditions in the cove do not have tidal velocities that propagate further than a few feet from each of the existing culvert connections to Case Inlet. With the full tidal connection achieved with Options 3 and 4, the tidal velocities within the cove increase but remain fairly low in areas not adjacent to the new inlet channel. For Option 2, velocities are highest through the weir structure but significantly lower in Whiteman Cove due to the reduced tidal prism compared to Options 3 and 4. For Options 3 and 4 where full tidal inundation occurs, the highest velocities in the cove were predicted to occur when the cove is starting to fill during flood tide. Figure 11 shows the maximum predicted depth-averaged velocities in the cove in the vicinity of the YMCA dock during flood tide.

**Figure 11**  
**Initial Maximum Tidal Depth Averaged Velocity in Whiteman Cove near the YMCA docks**

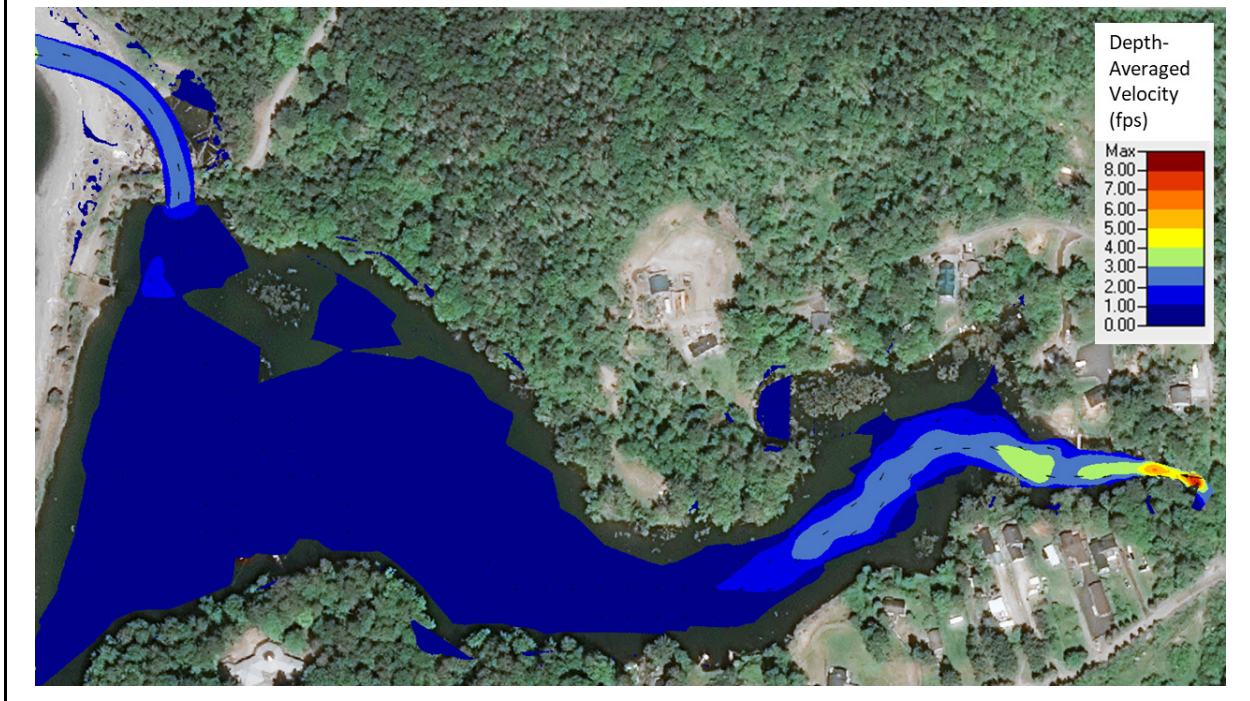


The maximum depth-averaged velocity near the YMCA dock is approximately 2.1 fps, with an average velocity of 1.5 fps in the area. The maximum predicted depth-averaged velocity in the back of the cove (east side of the cove) was approximately 0.8 fps during flood tide.

Simulation 4 was used to evaluate the potential effects of the predicted 200-year return interval freshwater flood on the hydraulics and sediment transport (Blue Coast Engineering 2020) within Whiteman Cove with the Option 3 bridge and inlet channel. Velocities in the cove based on the same creek flow for Option 4 were nearly identical to those shown for Option 3. The 200-year return interval flow rate (161 cfs) was developed with StreamStats software (Anchor QEA 2015). A synthetic hydrograph was developed with the peak 200-year flow rate aligning with low tide (approximately elevation 0.0 feet NAVD88). The predicted depth-averaged velocity results, shown in Figure 12, show that currents during the 200-year freshwater flood event quickly taper off from the 2 to 8 fps predicted near the creek mouth. Predicted depth-averaged velocities in the rest of the cove remain generally below 1 fps. The results show that at low tide, the inlets can easily convey the 200-year flood. Flow rates through the channel during normal tidal exchange without any freshwater inflow are up to 10 times larger than the 200-year flood.



**Figure 12**  
**Predicted Initial Depth-Averaged Velocity for the 200-Year Flood Event**



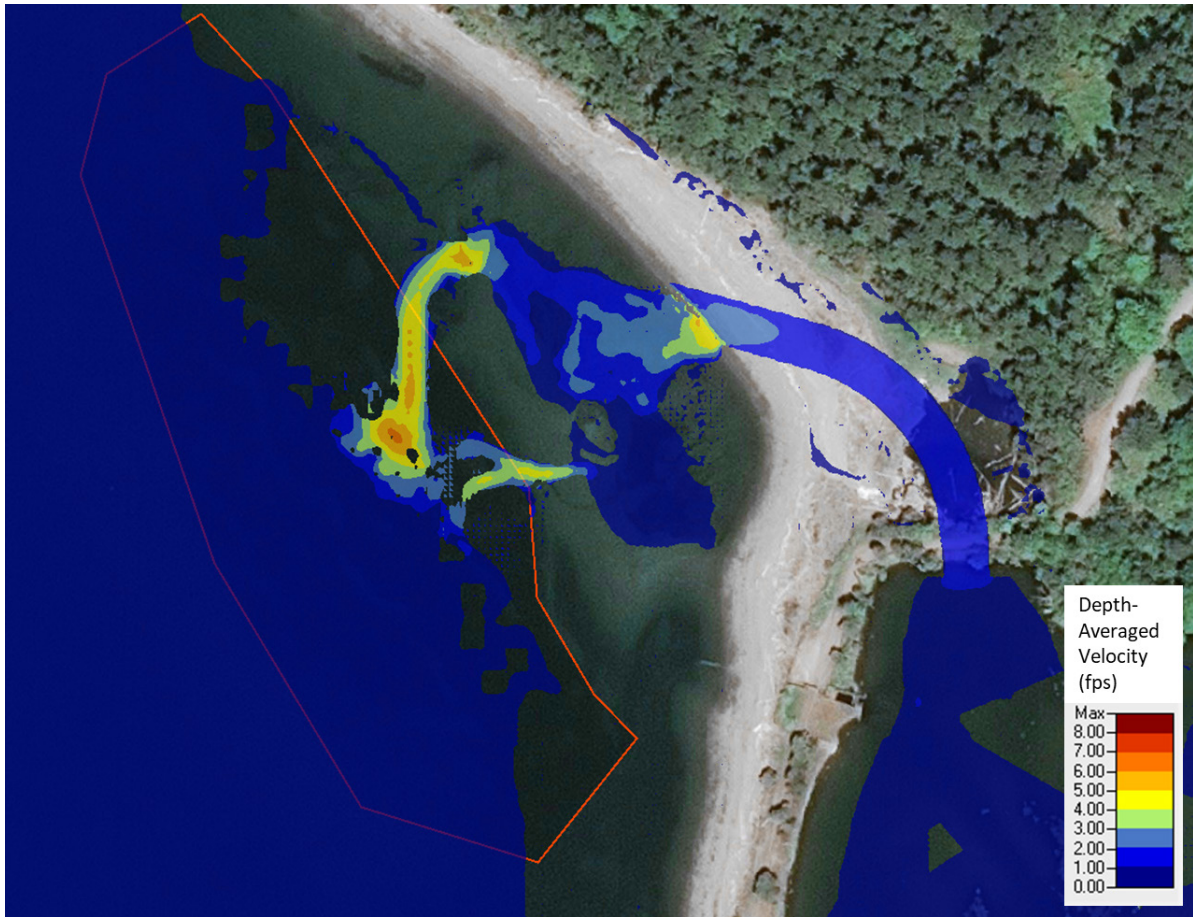
### *Shellfish Beds*

Hydrodynamic model results were also used to assess current velocities near or over the shellfish beds located in the lower tidelflat outside of Whiteman Cove due to the proposed options. Figure 13 shows the approximate locations of the current shellfish farming area where shellfish are either currently being farmed or have the potential to be farmed in the future. Figure 14 shows the peak flow velocity during ebb tide over the shellfish beds for Option 3. Predicted velocities from the model for Option 4 over the beach and shellfish bed area are nearly identical to Option 3. Option 2 shows a reduction in flow over the shellfish bed area due to the smaller tidal prism resulting in less flow through the inlet channel and less flow passing through the shellfish bed area (Figure 15).

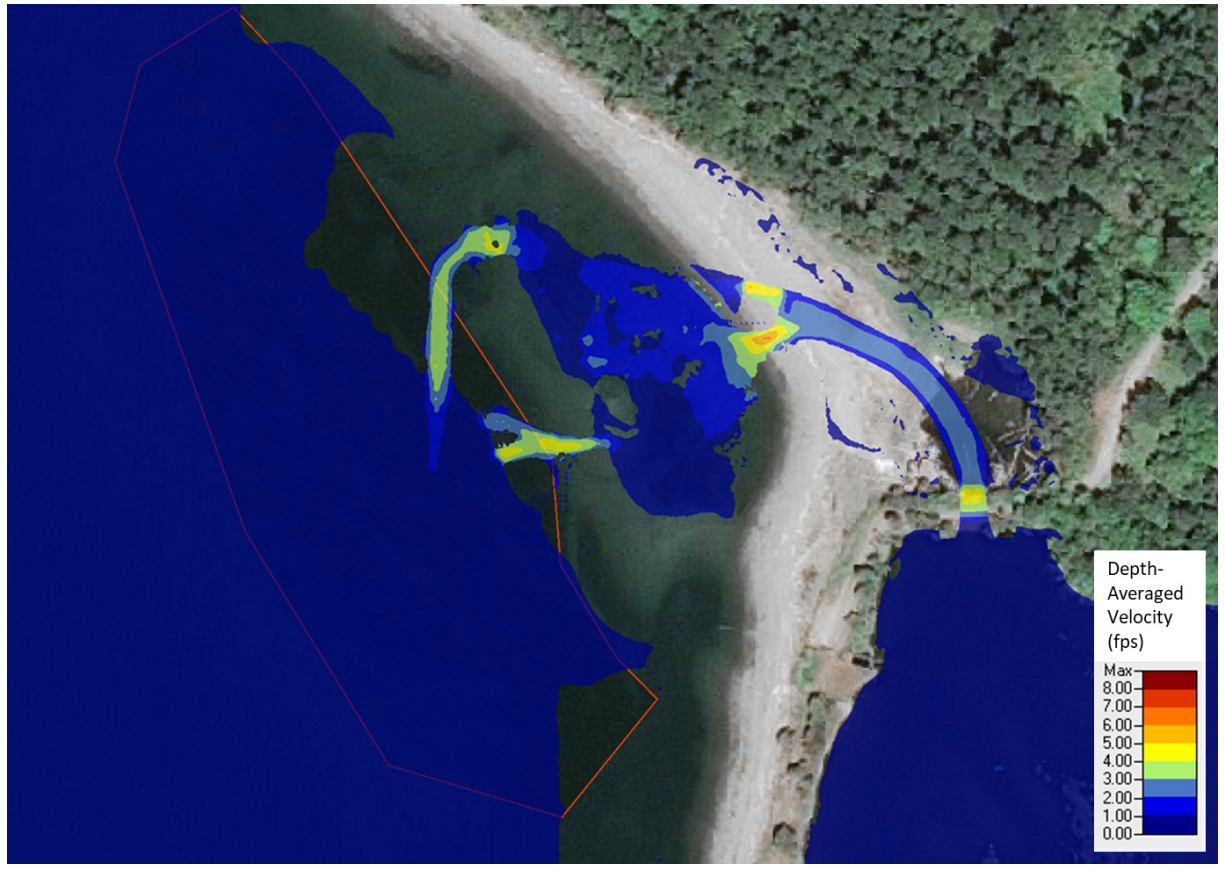
**Figure 13**  
**Approximate Shellfish Bed Location**



**Figure 14**  
**Predicted Initial Maximum Depth-Averaged Velocity During Ebb Tide for Option 3**



**Figure 15**  
**Predicted Initial Maximum Depth-Averaged Velocity During Ebb Tide for Option 2**



The model results suggest that because of the proposed tidal inlet that would be constructed as part of Options 2, 3, and 4, additional flows will pass through a relatively small area of the shellfish bed area during ebb tides compared to the existing conditions. Initial velocities immediately following construction will be relatively high, with an average velocity of approximately 4 fps with some small areas potentially seeing depth-averaged velocities as high as 6.5 fps. These higher velocities are located in remnant channels within the shellfish beds at low tide and will occur over a short duration over the tidal cycle. Predicted depth-averaged velocities for Option 2 are significantly lower (3 to 4 fps). Velocities are lower for Option 2 due to the weir structure limiting the volume of ebb tidal flow from the cove. Figure 15 also shows the water levels in the cove remaining constant during low tide compared to Options 3 and 4.

These velocities through the shellfish bed area will quickly mobilize sand and gravel within the ebb tidal delta and form a localized braided network of small channels, similar to what existed at the site historically (Blue Coast Engineering 2020). As these channels form, flow velocities will decrease until they are too low to continue to erode the small channel and channel formation will slow and likely

reach an equilibrium condition. Note that the 2D HEC-RAS model does not compute morphological change (forming of a channel) and therefore does not predict the formation of the nearshore channel that would be expected to form after tidal exchange is established. Geomorphology of the channel and nearshore area, including analysis of future changes based on Options 2, 3, and 4, is provided in the Coastal Processes Assessment completed for this Project (Blue Coast Engineering 2020).

For the existing conditions simulation, tidal velocities in the shellfish bed areas were lower, with a maximum velocity of less than 0.2 fps. It is unclear if this change to hydrodynamic conditions in the nearshore will have an effect on shellfish (primarily geoduck) farming operations. Additional coordination with the shellfish bed stakeholders and evaluation of the predicted hydrodynamic conditions should be further evaluated as part of the Project design.

## Water Levels and Flooding

The following sections describe the tidal water level conditions at the site currently and how the water levels in the cove would be affected by each option under current conditions as well as for sea level rise (SLR) conditions.

### Tidal Datums

Tidal datums for Case Inlet, adjacent to Whiteman Cove, are taken from the NOAA tide station at Budd Inlet and are shown in Table 3.

**Table 3**  
**Tidal Elevations (NOAA Station No. 9446807, Budd Inlet, South of Gull Harbor)**

Tidal Datum	Elevation Relative to MLLW (feet)	Elevation NAVD88 (feet) <sup>1</sup>
HAT	16.5	12.4
MHHW	14.5	10.4
MHW	13.5	9.4
MTL	8.3	4.2
MSL	8.3	4.2
MLW	3.0	-1.0
MLLW	0	-4.1

Notes:

1. Conversion from MLLW to NAVD88 is -4.1 feet.

HAT: Highest Astronomical Tide

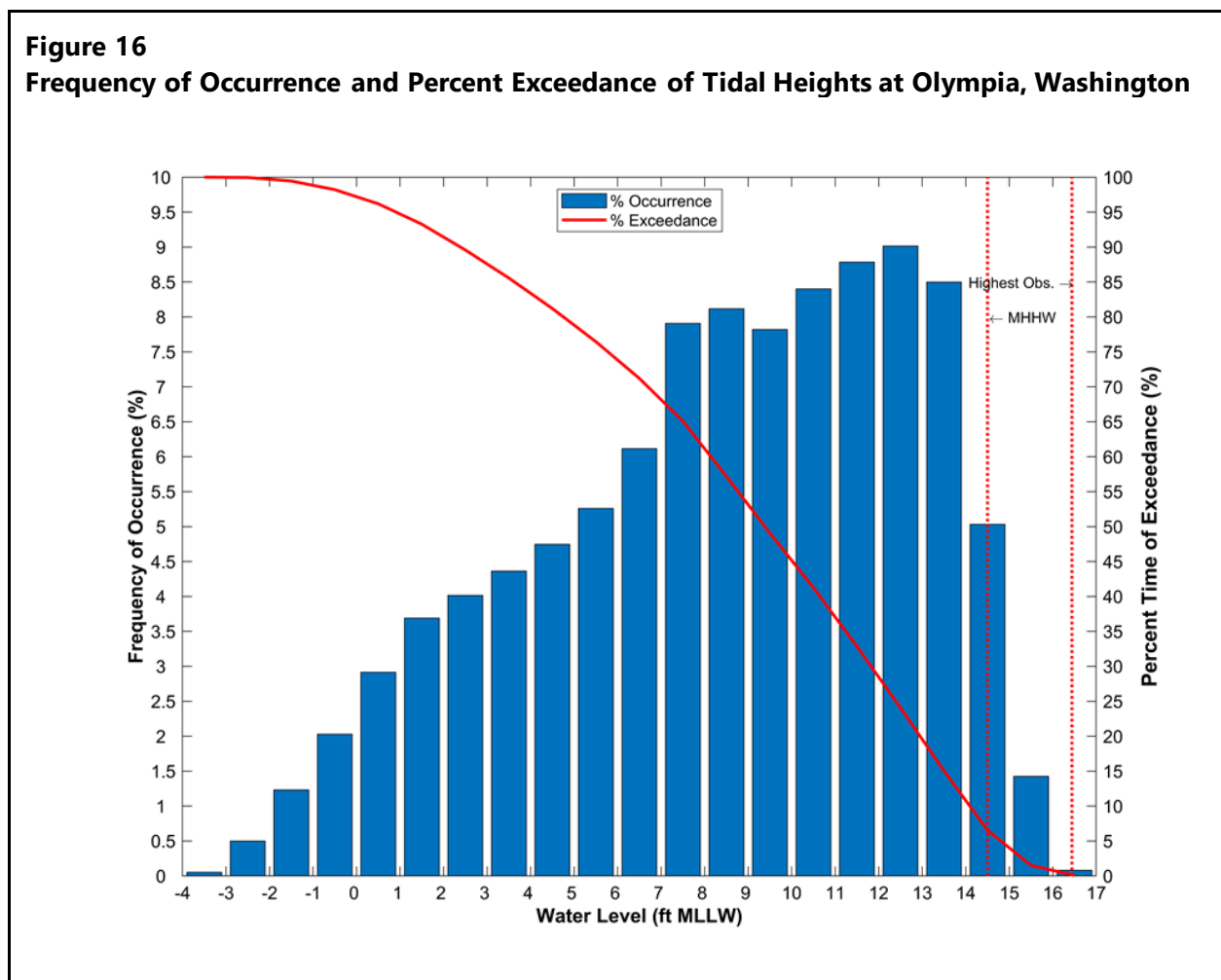
MHW: mean high water

MSL: mean sea level

MTL: mean tide level

## Current Water Levels in Whiteman Cove

The water surface elevation in Whiteman Cove is currently controlled by the constructed roadway berm and north and south control structures. No time series data for water levels in the cove are available, so the precise fluctuations of water levels in the cove are unknown. However, based on comparisons of water surface elevations taken from LiDAR data and measurements taken as part of this Project, the water surface elevation likely ranges from 9 feet NAVD88 (13 feet MLLW) to 10.5 feet NAVD88 (14.5 feet MLLW). Based on tidal datums in Case Inlet, the water surface elevation in the cove ranges from mean high water to mean higher-high water. Based on analysis of tide data at Olympia, Washington (Figure 16), water levels in Case Inlet are expected to be higher than the current water level in the lagoon between 5% and 20% of the time over the course of a year.

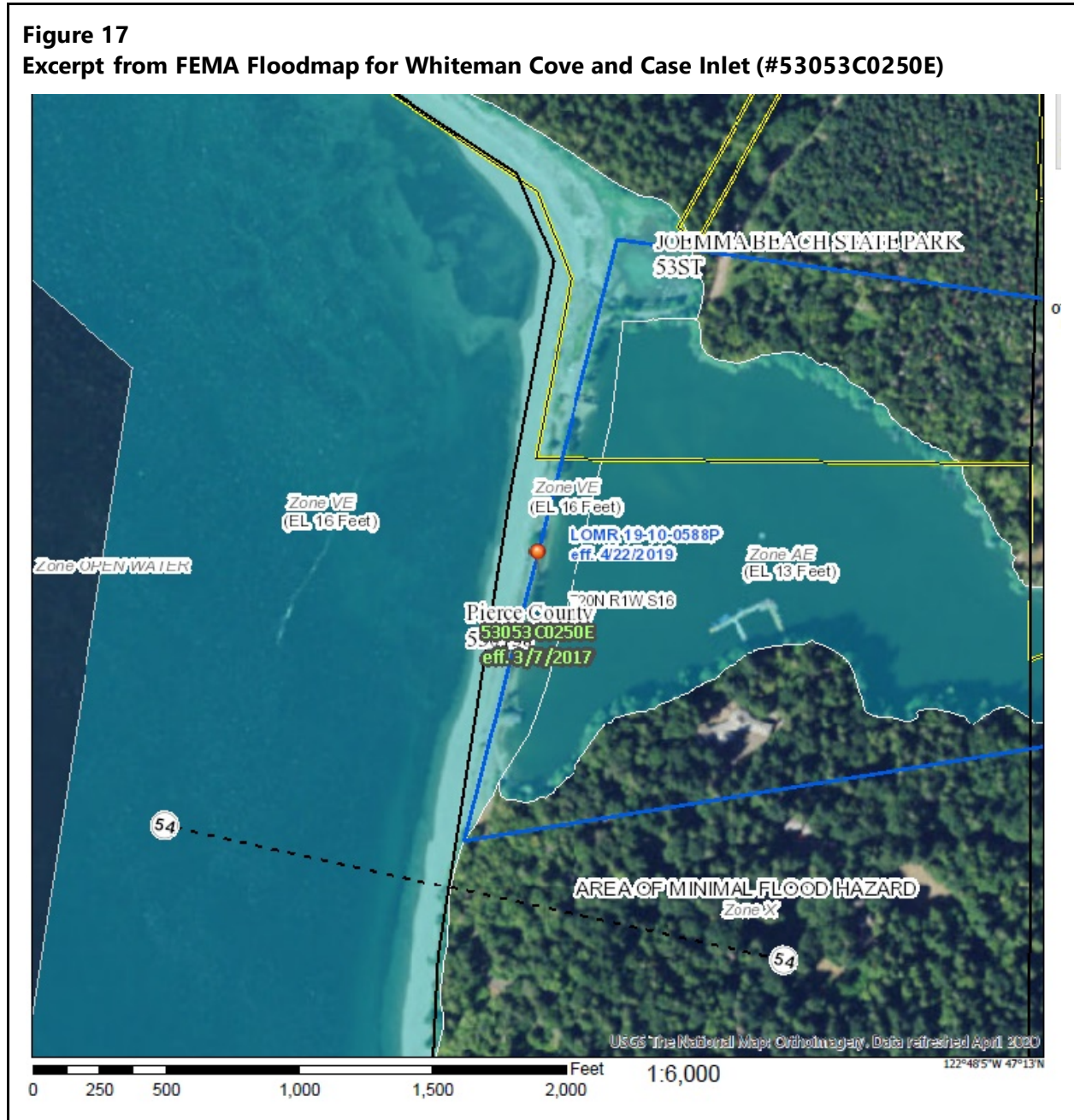


## Federal Emergency Management Agency 100-Year Flood Elevations

The effective 100-year Federal Emergency Management Agency (FEMA) flood elevation in Whiteman Cove, as shown in Figure 17, is currently 13 feet NAVD88 (17 feet MLLW) (FEMA Map#53053C0250E,

3/7/2017). The 100-year FEMA flood elevation in Case Inlet adjacent to the cove is 16 feet NAVD88 (20 feet MLLW). The flood elevation in Case Inlet includes the influence of wave and wave run-up, which would will not impact flooding in the cove itself if it were connected to Case Inlet through an open channel (as shown in Options 3 and 4). The 100-year FEMA flood elevation in Case Inlet without including impacts of wave and wave run-up is 13.2 feet NAVD88 (17.2 feet MLLW) (FEMA 2017). Based on this information, the FEMA 100-year flood elevation in the cove is not expected to change significantly due to implementation of any of the Options.

**Figure 17**  
**Excerpt from FEMA Floodmap for Whiteman Cove and Case Inlet (#53053C0250E)**



## Predicted Sea Level Rise

SLR predictions for Case Inlet are discussed in the Coastal Processes Assessment completed for the Project (Blue Coast Engineering 2020). They range from 0.7 foot by 2050 to up to 2.2 feet by 2100.

## Flooding Potential

Options 2, 3, and 4 all propose to construct an open channel between the cove and Case Inlet. While the FEMA 100-year flood elevation is not expected to be changed due to this action, more common water levels in the cove will increase compared to current conditions due to tides. As discussed above, the cove will experience water levels up to 2 feet higher than the current range of water levels about 35% of the time over an average year. This is based on our current understanding of the range of water levels in the cove at present.<sup>2</sup>

Figures were developed to evaluate potential for flooding of properties adjacent to Whiteman Cove based on Options 3 and 4 due to increase in water levels in the cove at current high tides and due to predicted SLR. A list of mapped water levels is provided in Table 4.

**Table 4**  
**Water Levels Used to Evaluate Flooding Potential in Whiteman Cove**

Water Level	Elevation Relative to MLLW (feet)	Elevation NAVD88 (feet) <sup>3</sup>
Current water level in Whiteman Cove <sup>1</sup>	14.1	10
Mean higher high water	14.5	10.4
MHHW + low range of SLR by 2100 (+1.7 feet) <sup>2</sup>	16.2	12.1
HAT	16.5	12.4
MHHW + high range of SLR by 2100 (+2.2 feet) <sup>2</sup>	16.7	12.6
FEMA 100-Year Elevation in Case Inlet (without wave run-up)	17.3	13.2
HAT + low range of SLR by 2100 (+1.7 feet) <sup>2</sup>	18.2	14.1
MHHW + high range of SLR by 2100 (+2.2 feet) <sup>2</sup>	18.7	14.6

Notes:

1. Time series of water levels in the cove are not available. Value is average of information from discrete measurements of the cove water level.
2. See Blue Coast Engineering (2020) for discussion of SLR scenarios.
3. Conversion from MLLW to NAVD88 shown in Table 3.

HAT: Highest Astronomical Tide

<sup>2</sup> Time series data for water level elevations in the cove are not available. Water levels in the cove are expected to range between 9 and 10.5 feet NAVD88 based on available data sources.



Figures showing the extent of potential flooding based on water levels provided in Table 4 are shown in Figure 18 for the western side of the cove and Figure 19 for the eastern side of the cove. From review of these figures, and based on existing LiDAR, flooding of homes or structures will not occur. Portions of properties along the shoreline will be inundated during high tide, with impacts to shoreline areas more pronounced in the far western end of the cove where elevations along the shoreline area lower.

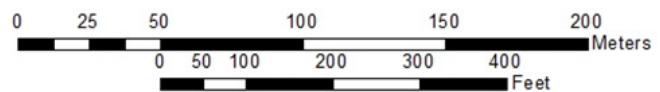
Elevations of existing private docks along the shoreline of the cove are not available. However, it is likely that these structures will need to be modified to function over range of water levels (both low and high) that would occur in the cove based on Options 3 and 4.

**Figure 18**  
**Flooding Potential, West End of Cove**



**Flood Levels at Various Elevations**

- |                                  |                                  |
|----------------------------------|----------------------------------|
| — 10 ft NAVD88 - Current         | — 12.6 ft NAVD88 - MHHW + SLR8.5 |
| — 10.4 ft NAVD88 - MHHW          | — 13.2 ft NAVD88 - FEMA          |
| — 12.1 ft NAVD88 - MHHW + SLR4.5 | — 14.1 ft NAVD88 - HAT + SLR4.5  |
| — 12.4 ft NAVD88 - HAT           | — 14.6 ft NAVD88 - HAT + SLR8.5  |



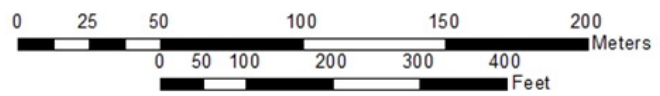
**Figure 19**  
**Flooding Potential, East End of Cove**



Document Path: P:\BlueCoast\GIS\Anchor\_0117\Whitman Cove\MXD\WMC\_FloodingLines\_East.mxd

**Flood Levels at Various Elevations**

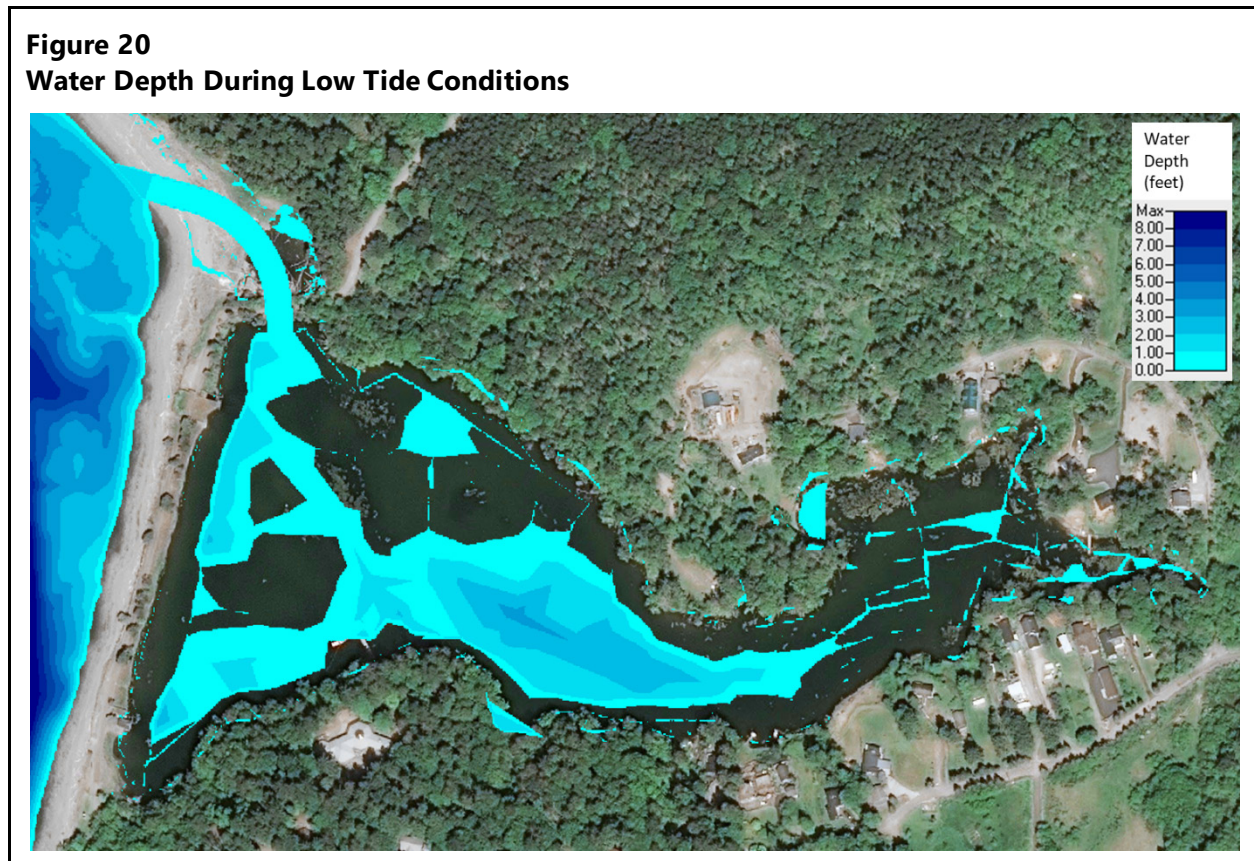
- 10 ft NAVD88 - Current
- 10.4 ft NAVD88 - MHHW
- 12.1 ft NAVD88 - MHHW + SLR4.5
- 12.4 ft NAVD88 - HAT
- 12.6 ft NAVD88 - MHHW + SLR8.5
- 13.2 ft NAVD88 - FEMA
- 14.1 ft NAVD88 - HAT + SLR4.5
- 14.6 ft NAVD88 - HAT + SLR8.5



## Low Water Levels in the Cove

In addition to higher water levels in the cove, Options 3 and 4 will also result in lower water levels in the cove than the current water level. Over the tidal cycle, the water level in the cove will fall to the elevation of the entrance channel proposed in Options 3 and 4. At this time, that elevation of the channel has been set at 3 feet NAVD88 (7 feet MLLW), which is approximately mean tide level in Case Inlet. Figure 20 shows the expected extent of water remaining in the cove at low tides as predicted by the model. Water levels are expected to be lower than 7 feet MLLW about 35% of the time over a typical year (see Figure 16).

**Figure 20**  
**Water Depth During Low Tide Conditions**



## Salinity

Based on the results of the hydrodynamic modeling, Whiteman Cove estuary will flush most of the volume of the cove with each full tidal cycle. Only a small volume of water in the cove (below elevation +3 feet NAVD88) will remain after every lower low tide. Salinity will generally match the salinity in Case Inlet, even during high freshwater flow events in the creek.

## Conclusions

The hydraulic study was used to provide predictions of hydraulics in Whiteman Cove based on proposed options to establish fish passage to the cove (Options 2, 3, and 4). The model was used to predict water surface elevations and flow velocities in the cove and to examine the extent of tidal inundation into the cove both spatially and temporally.

The model was used to show that the natural extents and timing of tidal inundation will occur in the cove for both Options 3 and 4. For Options 1 and 2, the modeling shows that only a fraction of the natural tidal extent will occur in the cove because the elevation at which tidal exchange is allowed in Option 1 or the elevation of the channel opening in Option 2 is higher than the channel elevation in Options 3 and 4 (+ 9 feet NAVD88/13 feet MLLW). The average depth-averaged flow velocity in the open tidal channels for Options 3 and 4 is very low (below 2 fps). For other concerns such as coastal flood elevations, wave propagation, high freshwater flow events, water quality, and SLR, both Options 3 and 4 essentially perform equally. The most significant difference between Options 3 and 4 is the velocity through the channel inlet being slightly higher for the narrower channel with bridge abutments (Option 3) compared to the wider channel without the bridge (Option 4).

Flooding potential was also assessed as part of this evaluation. While Options 2, 3, and 4 will result in increased water levels in the cove at higher tides, flooding of homes is not expected as a result of either option. There will be some flooding along the shorelines of properties, especially in the western end of the cove, and private docks structures will likely need to be modified to function over the range of water levels that would be present in the cove due to the proposed options. Option 1 could be used to limit the higher tidal levels from affecting the cove and surrounding shoreline properties during high tide and coastal flood events.

At low tides in Case Inlet, the water level in the cove would drop approximately 6 feet lower than the current water level based on proposed Options 3 and 4. This would result in most of the cove going dry at tides lower than 3 feet NAVD88 (7 feet MLLW). For Options 1 and 2, water levels in the cove would remain at their current levels near elevation 9 feet NAVD88 (13 feet MLLW).

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