TACOMA HARBOR, WA
FEASIBILITY STUDY
PIERCE COUNTY, WASHINGTON

APPENDIX C – SUPPLEMENTAL INFORMATION ON THE AFFECTED ENVIRONMENT

April 2022

US Army Corps
of Engineers®
Seattle District

Port of Tacoma

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Supplemental Information on the Affected Environment

This appendix provides supplemental and background information that was used during the analysis of potential environmental effects.

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1. Water Quality

The Washington Department of Ecology tests water quality to comply with the Clean Water Act and to place waters of concern on the Section 303(d) list. The study area contains water bodies that are listed as Category 5 on the Washington State 2012 303(d) list (Figure 1) that was approved by the Environmental Protection Agency in 2016. Inner Commencement Bay is listed for Bis(2-Ethylhexyl)phthalate, polychlorinated biphenyls (PCBs); within the inner bay, Thea Foss Waterway is listed for PCBs, and Hylebos Waterway is listed for dieldrin, PCBs, chlorinated pesticides, dichlorodiphenyltrichloroethane (DDT), and high molecular weight polycyclic aromatic hydrocarbons (HPAH). The Blair Waterway is not on the 303(d) list, but it is listed under "waters of concern" for benzene, tetrachloroethylene, and trichloroethylene. Outer Commencement Bay is listed for bacteria, DO, PCBs, and Bis(2-Ethylhexyl)phthalate.

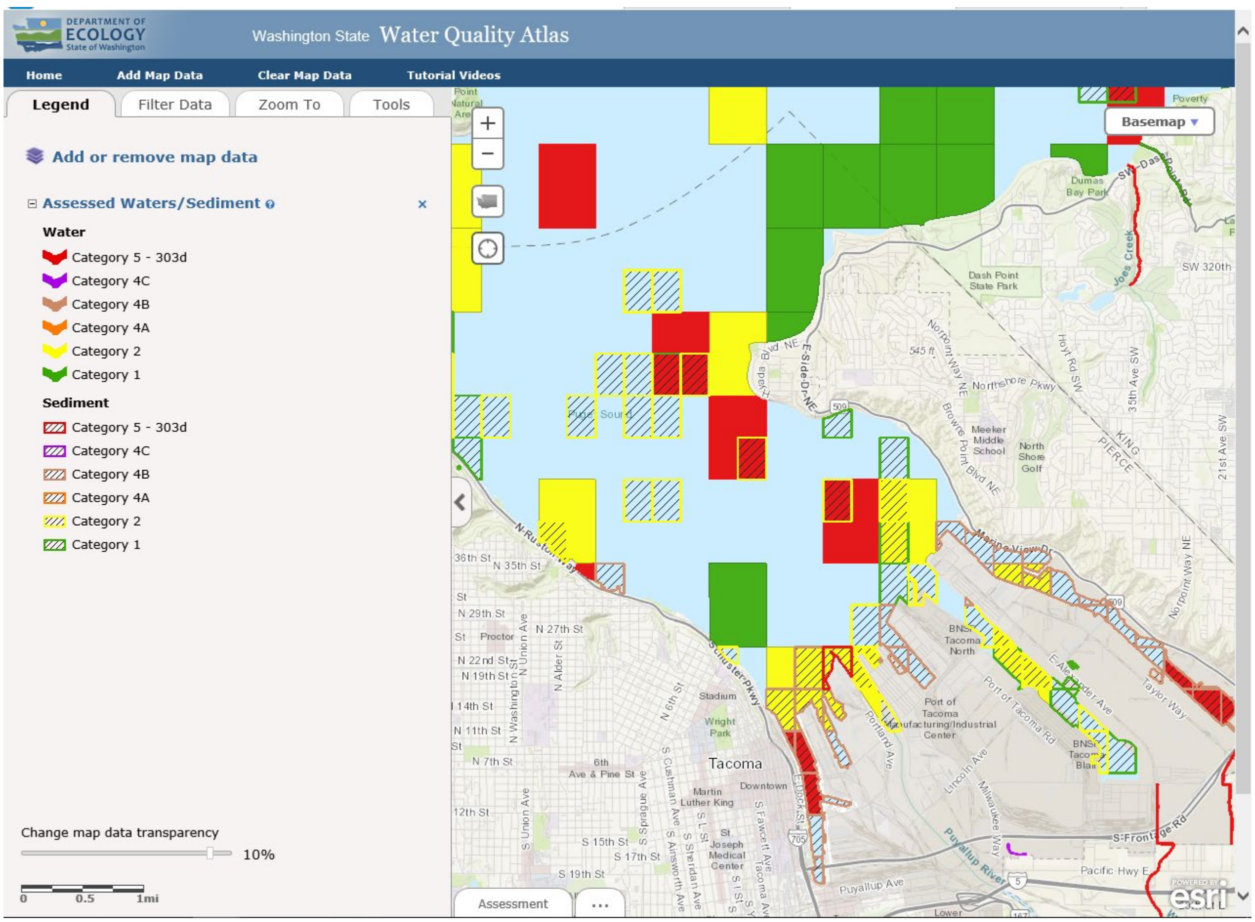


Figure 1. Map of assessed waters and 303(d) listing status (Ecology 2012).

Stormwater outfalls are managed under the Port of Tacoma Stormwater Management Program as a condition of the Western Washington Phase I Municipal Stormwater Permit (Figure 2).

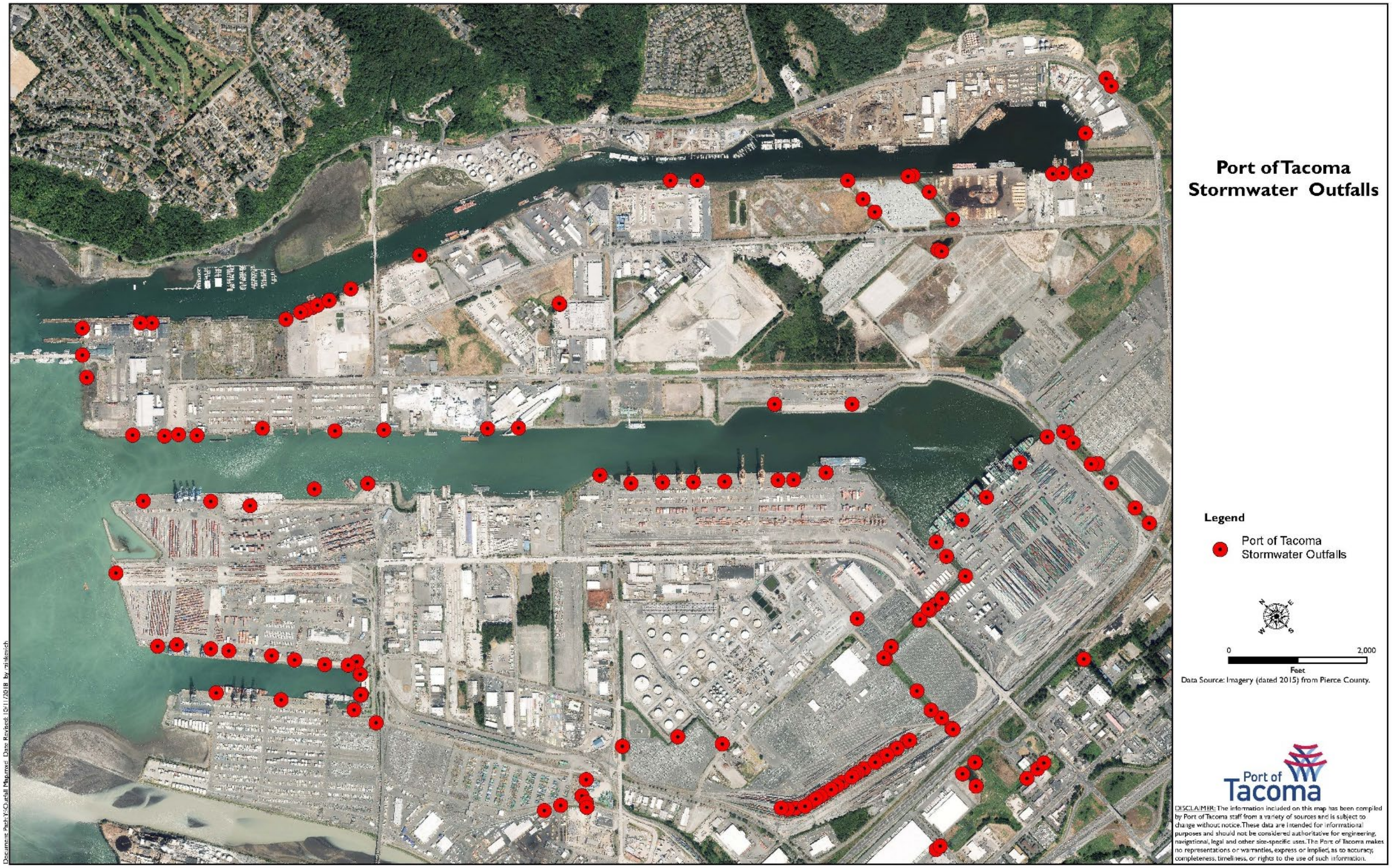


Figure 2. Map of stormwater outfalls around the Blair Waterway.

2. Vegetation

Commencement Bay has limited eelgrass and kelp beds. There is a small patch of eelgrass to the east of Saltchuk, the proposed site for beneficial use of dredged material (see section 3.6.2.1 of the IFR/EA for more information). There is little information on eelgrass beds prior to 1941, but historically eelgrass grew in several locations along the western shores of Commencement Bay.

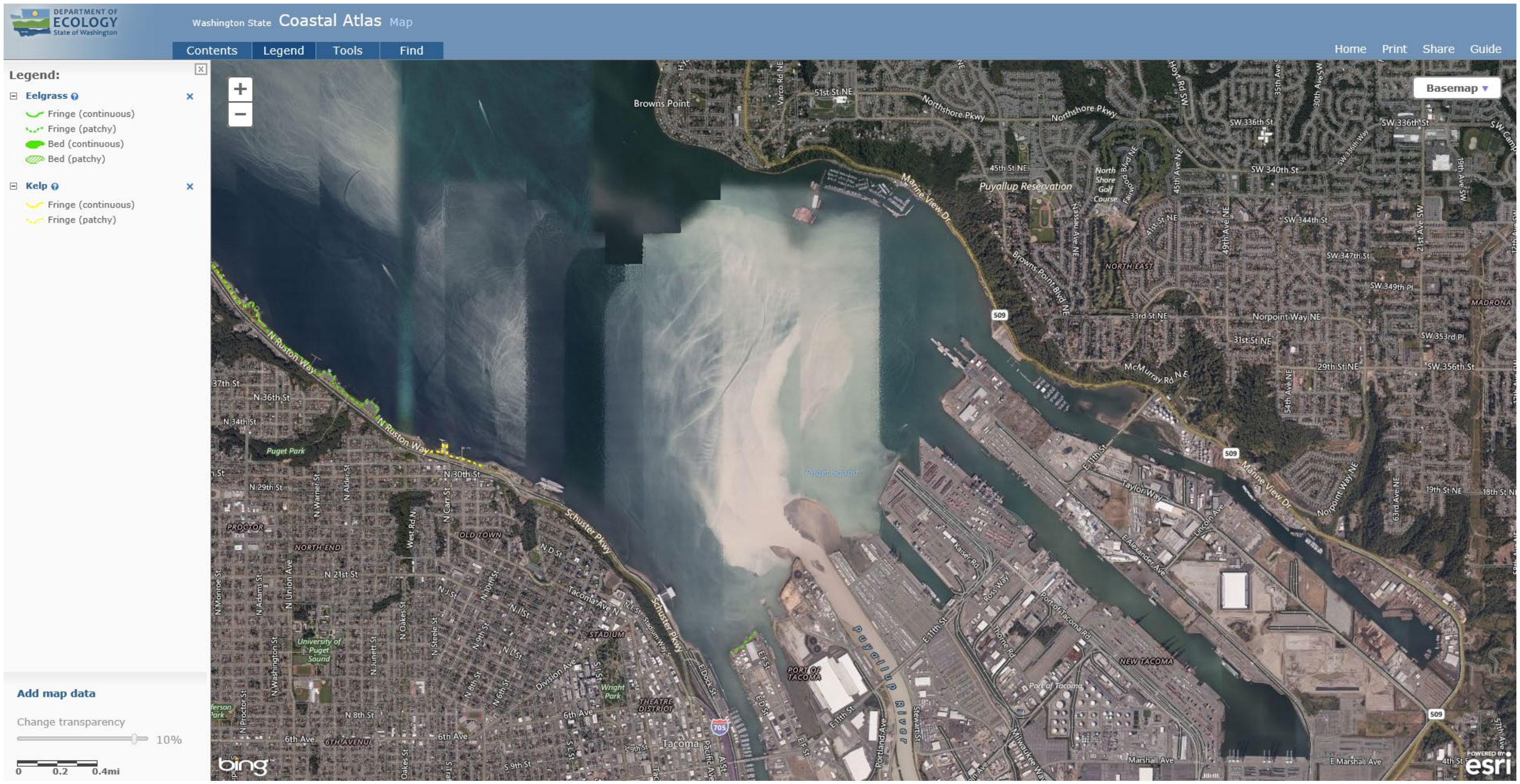


Figure 3. Washington Coastal Atlas Map of eelgrass and kelp in Commencement Bay (Ecology 2020).

3. Restoration and Mitigation Sites in Commencement Bay

There are numerous restoration and mitigation sites in and near Commencement Bay (Figure 4). Saltchuk is identified as a restoration site.

Figure 4. Restoration and Mitigation sites around and near Commencement Bay (adapted from EPA 2014). Saltchuk is identified as a restoration site, not a mitigation site.

4. Beneficial Use of Dredged Material

Estuaries and Chinook salmon, the target species for the habitat model, are institutionally recognized across Puget Sound. One of the most comprehensive is the Puget Sound Partnership (PSP), which was established by the Washington State Legislature in the Revised Code of Washington (RCW; 90.71) as the State agency leading the region's collective effort to restore and protect Puget Sound. The PSP facilitates collaboration among restoration projects and has several indicators to track progress, of which estuaries and Chinook salmon are indicators. The PSP Action Agenda guides restoration efforts. Most PSP funding comes from the federal Puget Sound National Estuary Program, but also from the State of Washington and National Oceanic and Atmospheric Administration. The greater Puget Sound ecosystem recovery effort is funded in a number of ways, including local, state, tribal, and federal government funding. Nonprofits, businesses, and foundations also make significant investments. In addition to the PSP, the Salmon Recovery Funding Board was established in 1998 (RCW 77.85) and coordinates lead entities and funding for salmon recovery projects. The Puyallup Tribe of Indians Fisheries Department's mission statement recognizes salmon and habitat by stating they shall "preserve, protect and enhance salmon in usual and accustomed areas, and the water resources that determine their viability." Finally, Chinook salmon are listed as threatened under the Endangered Species Act (ESA).

The general public considers estuaries and salmon an important part of Puget Sound and Commencement Bay. There are several volunteer and education opportunities for local residents to participate in managing and restoring Commencement Bay. According to their mission statement, Citizens for a Healthy Bay (CHB), which operates in Commencement Bay, "engages people to clean up, restore and protect Commencement Bay, its surrounding waters and natural habitat" and has volunteer opportunities related to habitat restoration. The City of Tacoma used the EnviroChallenger program to teach elementary students about salmon, and EarthCorps, a nonprofit organization, provides public volunteer opportunities at Natural Resource Damage Assessment (NRDA) restoration sites. WDFW's School Cooperative Program provides salmonid eggs to schools to be reared in a classroom aquarium, while the University of Washington-Tacoma has partnerships with local schools to collaborate on salmon projects.

Restoration around Puget Sound is needed because widespread modifications to beaches and bluffs, primarily as a result of shoreline armoring, have resulted in the reduction or loss of sediment supply and the interruption of sediment transport processes. About 27% of the shoreline of Puget Sound is armored; 59% of divergent zones (a major source of sediment to Puget Sound beaches) have some armoring associated with them. One third of divergent zones have more than 50% of their length armored (Fresh et al. 2011). A total of 33% of bluff-backed beaches, 27% of barrier beaches, and 8% of pocket beaches have been armored. One third of all bluff-backed beaches have been armored along half of their length.

The shorelines of Commencement Bay have been highly altered using riprap and other materials to provide bank protection. Blair Waterway comprises seven percent of the total of armored shoreline that covers 71 percent of the length of the Commencement Bay shoreline. Based on shoreline surveys and aerial photo interpretation of the area, approximately five miles, or 20 percent of the Commencement

Bay shoreline, is covered by wide, over-water structures (Kerwin 1999). The existing project area is presently altered using riprap that provides low to medium quality feeding and refuge habitat for juvenile salmon (Spence et al. 1996).

The nearshore zone of the Puyallup River delta has been almost entirely filled and developed, creating a large gap in historical delta services in the Central Puget Sound Subbasin (Simenstad et al. 2011). Large deltas provide a unique habitat for a range of estuarine dependent fish and bird species (Fresh et al. 2011). One of the major nearshore characteristics of the large Puyallup River delta prior to industrialization was the estuarine transition zone. This provided ideal conditions for the proliferation of many different species, including juvenile salmonids (Simenstad 2000). The most significant species that was affected by changes to Commencement Bay was the Chinook salmon, particularly juveniles that rely on estuarine shallow marsh and mudflat habitat for rearing and abundant food resources after they migrate from the Puyallup River (Puyallup River Watershed Council 2014).

At present, the small amount of functional salmonid habitat within Commencement Bay shorelines is gradually increasing in acreage because of habitat restoration projects and natural processes. The importance of nearshore marine habitat as part of a restoration strategy for habitat function within the estuary has been emphasized by the Salmon Habitat Protection and Restoration Strategy for the Puyallup Watershed (Pierce County 2012) and is an important step toward improving the overall ecological functionality of the area.

Per ER 1105-2-100, the U.S. Army Corps of Engineers (USACE) encourages consideration of placement options that provide opportunities for aquatic ecosystem restoration. Where environmentally beneficial use of dredged material is the least cost, environmentally acceptable method of disposal, it is cost shared as a navigation cost. The Saltchuk site is approximately 64 acres of low quality or degraded habitat. Of the 64 acres, approximately 8 acres (13%) is covered in wood waste. The wood waste present at Saltchuk is the result of historic logging practices that utilized waterways for storage and transport timber products. The wood waste present at Saltchuk is not known to be chemically treated and thus not a suspected source of Hazardous, Toxic, and Radiological Waste (HTRW). See section 4.11 in the IFR/EA for discussion of Saltchuk in relation to HTRW. The feasibility study evaluated the potential for beneficial use of dredged material at Saltchuk with the objective to restore nearshore intertidal and subtidal habitat substrate conditions for several fish and wildlife species, including ESA-listed species. The target species to benefit from the proposed project include juvenile and adult Chinook salmon, steelhead, and bull trout. Restoration actions aim to improve habitat conditions for these species and their prey species, such as forage fish and epibenthic and benthic invertebrates. The Saltchuk site is mostly (60.7 acres) deep water habitat that does not benefit the target species as much as shallower habitat. This action would potentially improve the quality of feeding and refuge habitat in the Commencement Bay area (Pierce County 2012) by increasing the amount of shallower nearshore habitat through the placement of dredged material. See Section 4.3.2 in the Feasibility Report/Environmental Assessment (IFR/EA) for more detail on the Saltchuk site.

4.1 Cost Effectiveness and Incremental Cost Analysis

The Saltchuk site is not the least cost placement site and is not the Base Plan. However, USACE is evaluating the environmentally beneficial use of dredged material at the Saltchuk site for consideration of this as a multiple purpose project, including also ecosystem restoration. For environmentally beneficial disposal methods with incremental federal costs that exceed 25% of total base plan disposal costs or $300,000, USACE guidance requires the incremental costs be justified by demonstrating that the monetary and non-monetary benefits (outputs) of the ecosystem restoration project justify its incremental costs above the Base Plan. The analysis must demonstrate that the environmental resources restored by the placement method are valuable, describe and quantify the environmental outputs, and show federal and state resource agencies support for the environmentally beneficial disposal method.

This section describes the model inputs for performing the cost effectiveness and incremental cost analyses using the USACE Institute for Water Resources (IWR) Planning Suite, version 2.0.9.1 (USACE certified model). The USACE IWR developed this software to assist with the formulation and comparison of alternative plans. The software can assist with plan formulation by combining solutions to planning problems and calculating the additive effect of each combination, or "plan," by utilizing inputs on outputs (Average Annual Habitat Units, or AAHUs), costs, and rules (combinability and dependency relationships) for combining solutions into plans. Plans are then compared in IWR Planning Suite by conducting cost effectiveness and incremental cost analyses (CE/ICA), identifying the plans which are the best financial investments, and displaying the effects of each on a range of decision variables.

The Puget Sound Nearshore Habitat Valuation (NHV) Model was developed by the National Marine Fisheries Service (NMFS) in 2015 (Ehinger et al. 2015). Additional background on the NHV and why it was chosen appears in Section 3.6.2.1 of the IFR/EA.The NHV model uses a checklist scoring system to define habitat value, based primarily on elevation, vegetation, substrate conditions, anthropogenic impacts, and landscape context to provide a criteria-based and repeatable method for establishing habitat value (Table 1 and Table 2). The USACE used this model to establish base habitat values for the two elevation zones within the assessment area: Lower Shore Zone (LSZ; +5 to -10 MLLW) and Deeper Critical Habitat Zone (DZ; below -10 MLLW).

The evaluation of habitat units (HU) will take into consideration changes over the 50-year period of analysis for the Tacoma Harbor feasibility study with an analysis of years 0, 3, and 50. The LSZ indicators are about submerged aquatic vegetation (SAV; e.g., kelp and eelgrass) and shallow water habitat (which includes foraging habitat, i.e., benthic invertebrates). Depth, water quality, and sediment are all immediately functioning. The time for the establishment of benthic invertebrates is estimated to be 3 years in the LSZ and DZ. The DZ indicators are similar to LSZ, with 3 years for the establishment of benthic invertebrates. The NHV model will be expanded to include quality scores (i.e., normalized habitat quality scores between 0 and 1) for each year and scenario analyzed. The maximum quality score is 0.3 for DZ and 1.0 for LSZ. Results of scoring each zone appear in Table 3 and Table 4. The Riparian Zone (RZ) and Shallow Subtidal Zone (SSZ) portions of the model will not be used due to real estate limitations and the scope of this proposed beneficial use. The HUs are then used to calculate AAHUs, for use in the EC/ICA. This beneficial use analysis is very preliminary and will continue to be evaluated.

Scenario A (No-Action), Scenario B (Bench 1 placement to -20 MLLW), Scenario C (Bench 1 plus Bench 2 placement to -10 MLLW), Scenario D (Benches 1 and 2 plus placement to -5 MLLW), and Scenario E (Benches 1, 2, and 3 plus island creation to +5 MLLW). Scenarios are additive, building upon the material placed in preceding scenarios. These scenarios are described in the IFR/EA in Section 3.6.2.2.

Table 1. Deep Zone (DZ) Excel Worksheet.

				Scenario A (No Action)			Scenario B						Scenario C						Scenario D						Scenario E					
				Years 0, 3, and 50			Year 0			Years 3, 50			Year 0			Years 3, 50			Year 0			Years 3, 50			Year 0			Years 3, 50		
#	Indicator of Physical Habitat	Question	Maximum Possible Points	Site Condition	Project Points	Summary Project Points by Category	Site Condition	Project Points	Summary Project Points by Category	Site Condition	Project Points	Summary Project Points by Category	Site Condition	Project Points	Summary Project Points by Category	Site Condition	Project Points	Summary Project Points by Category	Site Condition	Project Points	Summary Project Points by Category	Site Condition	Project Points	Summary Project Points by Category	Site Condition	Project Points	Summary Project Points by Category	Site Condition	Project Points	Summary Project Points by Category
Shallow Water Habitat																														
1	Water Habitat, Accessibility and Presence	What water area [in sqft] is lost to Chinook use? This loss could be the result of the construction of three-dimensional structures that result in the loss of shallow water habitat during some tides. Such structures include piles, bulkheads, and fill.	3.00	0	3.00	3.00	0.00	3	3.00	0	3	3.00	0	3	3.00	0	3	3.00	0	3	3.00	0	3	3.00	0	3	3.00	0	3	3.00
Primary Production																														
	Primary Productio	Primary production from algae. Assumed always present.	1		1	1		1	1		1	1		1	1		1	1		1	1		1	1		1	1		1	1
Water Quality																														
6a	Water Quality, select one (y/n)	Is water quality in action area optimal? Use location as surrogate if no data. If action area is in undeveloped part of Puget Sound choose "yes".	2	n	0.00		n	0.00		n	0.00		n	0.00		n	0.00		n	0.00		n	0.00		n	0.00		n	0.00	
6b		Is water quality in action area free of major contaminants associated with industrial and urban development like harbors, water treatment plants, and untreated storwater inputs? Use location as surrogate if no data. If action area is in little to medium developed part of Puget Sound, like Wollochet Bay, Horshead Bay, Gig Harbor, choose "yes".	1	n	0.00		n	0.00		n	0.00		n	0.00		n	0.00		n	0.00		n	0.00		n	0.00		n	0.00	
6c		Is WQ impacted by major contaminants associated with industrial and urban development like harbors, water treatment plants, and untreated storwater inputs? Use location, as surrogate if no data. If action area is very developed and has WQ effects from industrial sources, like Commencement Bay, Duwamish, choose "yes".	0	y	0.00	0.00	y	0.00	0.00	y	0.00	0.00	y	0.00	0.00	y	0.00	0.00	y	0.00	0.00	y	0.00	0.00	y	0.00	0.00	y	0.00	0.00
Sum		Sum of maximum possible points	6.00		Total	4.00		Total	4.00		Total	4.00		Total	4.00		Total	4.00		Total	4.00		Total	4.00		Total	4.00		Total	4.00
NHV					NHV	0.20		NHV	0.20		NHV	0.20		NHV	0.20		NHV	0.20		NHV	0.20		NHV	0.20		NHV	0.20		NHV	0.20
						14	Number added to divisor to set maximum possible																							

Table 2. Lower Shore Zone (LSZ) Excel Worksheet.

				Scenario A (No Action)			Scenario B						Scenario C						Scenario D						Scenario E					
				Years 0, 3, and 50			Year 0			Years 3, 50			Year 0			Years 3, 50			Year 0			Years 3, 50			Year 0			Years 3, 50		
#	Indicator of Physical Habitat	Question	Maximum Possible Points	Site Condition	Project Points	Summary Project Points by	Site Condition	Project Points	Summary Project Points by	Site Condition	Project Points	Summary Project Points by	Site Condition	Project Points	Summary Project Points by	Site Condition	Project Points	Summary Project Points by	Site Condition	Project Points	Summary Project Points by	Site Condition	Project Points	Summary Project Points by	Site Condition	Project Points	Summary Project Points by	Site Condition	Project Points	Summary Project Points by
Submerged Aquatic Vegetation (SAV)																														
1a	**SAV condition, select one (y/n)**	Aquatic vegetation value high	4	n	0		n	0		n	0		n	0		n	0		n	0		n	0		n	0		n	0	
1b		Aquatic vegetation value medium, incl. native oyster beds	3	n	0		n	0		n	0		n	0		n	0		n	0		n	0		n	0		n	0	
1c		Aquatic vegetation value medium low	2	n	0		n	0		y	2		n	0		y	2		n	0		y	2		n	0		y	2	
1d		Aquatic vegetation value very low	1	y	1		y	1		n	0		y	1		n	0		y	1		n	0		y	1		n	0	
1e		Aquatic vegetation value none	0	n	0	1	n	0	1	n	0	2	n	0	1	n	0	2	n	0	1	n	0	2	n	0	1	n	0	2
Shallow Water Habitat																														
2a	**Shallow Water Habitat, Accessibility and Presence**	What shallow water area [in sqft] is lost to juvenile rearing? This loss could be the result of the construction of three-dimensional structures that result in the loss of shallow water habitat during some tides. Such structures include piles, bulkheads, and fill, or the conversion of shallow water habitat to deep water habitat via dredging. Not included as impacts to this habitat parameter are low profile structures like boat ramps, rails, and low concrete rubble. The effect of boat ramps and debris are considered with the	1.00	0	1.00		0	1.00		0	1.00		0	1.00		0	1.00		0	1.00		0	1.00		0	1.00		0	1.00	
2b	**Dredging**	Is habitat loss dredging related? Y or N. If so, NHV for LSZ gets multiplied with 0.3, because maximum habitat value for deeper habitat is 0.3.		n	1.00	1.00	n	1.00	1.00	n	1.00	1.00	n	1.00	1.00	n	1.00	1.00	n	1.00	1.00	n	1.00	1.00	n	1.00	1.00	n	1.00	1.00
Sediment																														
3a	**Substrate Size select one (y/n)**	Is the surface substrate in the littoral zone of the action area >25% mud or mixed fines?	0.5	y	0.50		y	0.50		y	0.50		y	0.50		y	0.50		n	0.00		n	0.00		n	0.00		n	0.00	
3b		Is the surface substrate in the littoral zone of the action area >25% sand or larger grained gravels?	1	n	0.00		n	0.00		n	0.00		n	0.00		n	0.00		y	1.00		y	1.00		y	1.00		y	1.00	
3c		Is the surface substrate in the littoral zone of the action area >25% rocky?	1	n	0.00	0.50	n	0.00	0.50	n	0.00	0.50	n	0.00	0.50	n	0.00	0.50	n	0.00	1.00	n	0.00	1.00	n	0.00	1.00	n	0.00	1.00
	Habitat Loss from Developme	**Sediment lost to low and high structures:** What area [in sqft] is lost to structures including boat ramps, riprap, concrete rubble, jetties, and bulkheads.		36,100	0.37		36,100	0.37		36,100	0.37		36,100	0.47		36,100	0.47		0	1.00		0	1.00		0	1.00		0	1.00	
3d	**Habitat Degradation Resulting from Development**	**Habitat Reduction:** % for entire affected area not covered up by low structures. Is the substrate in the affected area unnaturally compacted or coarsened as a result of a bulkhead or riprap; has the beach grade lowered? Consider effects within the affected area, only, like downdrift part of drift cell. This is the area calculated by dividing habitat loss from development (sq ft) by total area (sq ft).		0.25	0.37	0.37	0.25	0.37	0.37	0.25	0.37	0.37	0.06	0.47	0.47	0.06	0.47	0.47	-	1.00	1.00	-	1.00	1.00	-	1.00	1.00	-	1.00	1.00
Water Quality																														
4a	**Water Quality Condition, select one**	Is water quality in action area optimal? Use location as surrogate if no data. If action area is in undeveloped part of Puget Sound choose "yes".	1	n	0.00		n	0.00		n	0.00		n	0.00		n	0.00		n	0.00		n	0.00		n	0.00		n	0.00	
4b		Is water quality in action area free of major contaminants associated with industrial and urban development like harbors, water treatment plants, and untreated storwater inputs? Use location as surrogate if no data. If action area is in little to medium developed part of Puget Sound, like Wollochet Bay, Horshead Bay, Gig Harbor, choose "yes".	0.5	n	0.00		n	0.00		n	0.00		n	0.00		n	0.00		n	0.00		n	0.00		n	0.00		n	0.00	
4c		Is WQ impacted by major contaminants associated with industrial and urban development like harbors, water treatment plants, and untreated storwater inputs? Use location, as surrogate if no data. If action area is very developed and has WQ effects from industrial sources, like Commencement Bay, Duwamish, choose "yes".	0	y	0.00	**0.00**	y	0.00	**0.00**	y	0.00	**0.00**	y	0.00	**0.00**	y	0.00	**0.00**	y	0.00	**0.00**	y	0.00	**0.00**	y	0.00	**0.00**	y	0.00	**0.00**
		Sum of maximum possible points	**7.00**		**Total**	**2.37**		**Total**	**2.37**		**Total**	**3.37**		**Total**	**2.47**		**Total**	**3.47**		**Total**	**3.00**		**Total**	**4.00**		**Total**	**3.00**		**Total**	**4.00**
					NHV	**0.34**		NHV	**0.34**		NHV	**0.48**		NHV	**0.35**		NHV	**0.50**		NHV	**0.43**		NHV	**0.57**		NHV	**0.43**		NHV	**0.57**

Table 3. Deep Zone NHV Scores by Alternative and Year.

		Scenario A (No-Action)		Scenario B		Scenario C		Scenario D		Scenario E	
Indicator of Physical Health	**Max. Score**	**Years 0, 3**	**Year 50**	**Years 0, 3**	**Year 50**	**Years 0, 3**	**Year 50**	**Years 0, 3**	**Year 50**	**Years 0, 3**	**Year 50**
Shallow Water Habitat											
1: Shallow Water Habitat accessibility and presence - Shallow water area lost to Chinook use (sq. ft.)	**3**	0	0	0	0	0	0	0	0	0	0
Shallow Water Habitat Score		***3***	***3***	***3***	***3***	***3***	***3***	***3***	***3***	***3***	***3***
Primary Production											
Primary Production	**1**	***1***	***1***	***1***	***1***	***1***	***1***	***1***	***1***	***1***	***1***
Water Quality											
6a-6c: Water quality condition	***2***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***
Total Scores	**6**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**
NHV (Total Score divided by 20)		**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**

Table 4. Lower Shore Zone Scores by Alternative and Year.

		Scenario A (No-Action)		Scenario B		Scenario C		Scenario D		Scenario E	
Indicator of Physical Health	**Max. Score**	**Years 0, 3**	**Year 50**	**Years 0, 3**	**Year 50**	**Years 0, 3**	**Year 50**	**Years 0, 3**	**Year 50**	**Years 0, 3**	**Year 50**
Submerged Aquatic Vegetation											
1a-1e: SAV Condition	**4**	***1***	***1***	***1***	***2***	***1***	***2***	***1***	***2***	***1***	***2***
Shallow Water Habitat											
2a: Shallow Water Habitat accessibility and presence - Shallow water area lost to juvenile rearing (sq. ft.)	**1**	0	0	0	0	0	0	0	0	0	0
2b: Dredging (y/n)		n	n	n	n	n	n	n	n	n	n
Shallow Water Habitat Score		***1***	***1***	***1***	***1***	***1***	***1***	***1***	***1***	***1***	***1***
Sediment											
3a-3c: Substrate Size	**1**	0.5	0.5	0.5	0.5	0.5	0.5	1	1	1	1
Habitat Loss from development (sq. ft.)		36,100	36,100	36,100	36,100	36,100	36,100	0	0	0	0
3d: Habitat degradation resulting from development		25%	25%	25%	25%	6%	6%	0%	0%	0%	0%
Sediment Score		***0.37***	***0.37***	***0.37***	***0.37***	***0.47***	***0.47***	***1***	***1***	***1***	***1***
Water Quality											
4a-4c: Water quality condition	**1**	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***
Total Scores	**7**	**2.37**	**2.37**	**2.37**	**3.37**	**2.47**	**3.47**	**3**	**4**	**3**	**4**
NHV		**0.34**	**0.34**	**0.34**	**0.48**	**0.35**	**0.50**	**0.43**	**0.57**	**0.43**	**0.57**

HUs are quantity multiplied by quality of habitat, where quantity is the acres for a given zone and quality is the NHV quality score. HUs were computed for each scenario, year, and habitat zone (Table 5). The NHV quality scores reference the computations in their respective sheets in the Excel file on the'D Z' and 'LSZ' tabs (Adapted from Ehinger et al. 2015; Table 1 and Table 2).

Table 5. Average Annual Habitat Unit (AAHU) Inputs: Saltchuk NHV Quantity and Quality Scores.

Metric	**Scenario A (No-Action)**		**Scenario B**		**Scenario C**		**Scenario D**		**Scenario E**	
	DZ	**LSZ**	**DZ**	**LSZ**	**DZ**	**LSZ**	**DZ**	**LSZ**	**DZ**	**LSZ**
Acreage	60.7	3.3	60.7	3.3	49.8	14.2	49.3	14.7	23.1	40.9
Year 0 NHV	0.20	0.34	0.20	0.34	0.20	0.35	0.20	0.43	0.20	0.43
Year 3 NHV	0.20	0.34	0.20	0.48	0.20	0.50	0.20	0.57	0.20	0.57
Year 50 NHV	0.20	0.34	0.20	0.48	0.20	0.50	0.20	0.57	0.20	0.57

The total HU for a scenario and year is the sum of HUs for DZ and LSZ, as shown in the following formula.

$$Total\ HUs_{year\ x} = (DZ\ acres_{year\ x} \times DZ\ NHV_{year\ x}) + (LSZ\ acres_{year\ x} \times LSZ\ NHV_{year\ x})$$

For example, the computation of Scenario D HUs for year 0 is as follows:

$$Scenario\ D\ HUs_{year\ 0} = (Scenario\ D\ DZ\ acres_{year\ 0} \times Scenario\ D\ DZ\ NHV_{year\ 0}) + (Scenario\ D\ LSZ\ acres_{year\ 0} \times Scenario\ LSZ\ NHV_{year\ 0})$$

$$= (49.3 \times 0.2) + (14.7 \times 0.57) = 16.2$$

Table 6 displays AAHUs that are calculated from NHV quality scores that are carried forward for the computation of HUs and AAHUs. Total HU values for each scenario and year are used for computing AAHU using the IWR Planning Suite Annualizer Tool. Years 0, 3, and 50 Total HU values shown in the green cells from Table 5 are input for a given scenario (or Annualization Set). Linear interpolation between years is assumed.

Table 6. Saltchuk Habitat Unit Inputs and Average Annual Habitat Units.

Year	Scenario A (No-Action)			Scenario B			Scenario C			Scenario D			Scenario E		
	DZ	LSZ	Total, by Year	DZ	LSZ	Total, by Year	DZ	LSZ	Total, by Year	DZ	LSZ	Total, by Year	DZ	LSZ	Total, by Year
0	12.1	1.1	**13.3**	12.1	1.1	**13.3**	10.0	5.0	**15.0**	9.9	6.3	**16.2**	4.6	17.5	**22.1**
3	12.1	1.1	**13.3**	12.1	1.6	**13.7**	10.0	7.0	**17.0**	9.9	8.4	**18.3**	4.6	23.4	**28.0**
50	12.1	1.1	**13.3**	12.1	1.6	**13.7**	10.0	7.0	**17.0**	9.9	8.4	**18.3**	4.6	23.4	**28.0**
AAHU	***13.3***			***13.7***			***16.9***			***18.2***			***27.8***		
Total Output	***0.0***			***0.4***			***3.6***			***4.9***			***14.5***		

4.2 Inputs

Traditional benefit-cost analysis is not possible for the beneficial use placement evaluation because costs and benefits are expressed in different units. Rather, cost effectiveness and incremental cost analysis (CE/ICA) is used to assist the process of determining what project features and design alternatives should be built based on a comparison of quantified habitat benefits (outputs) and estimated costs of alternative feature designs. Cost effectiveness analysis is conducted to ensure that the least cost plan is identified for each possible level of environmental output; and that for any level of investment, the maximum level of output is identified. Subsequent incremental cost analysis of the cost-effective plans is conducted to reveal changes in costs as output levels are increased. Output or net AAHU gain over the No-Action (Scenario A), and average annual cost in $1,000s are the two inputs to the cost effectiveness and incremental cost analysis. Five scenarios at Saltchuk were input for the cost effectiveness and incremental cost analysis, including Scenario A (No-Action), Scenario B (Bench 1 placement to -20 MLLW), Scenario C (Bench 1 plus Bench 2 placement to -10 MLLW), Scenario D (Benches 1 and 2 plus placement to -5 MLLW), and Scenario E (Benches 1, 2, and 3 plus island creation to +5 MLLW). Alternative scenarios are additive, building upon the material placed in preceding scenarios.

Costs of the beneficial use placement are the incremental costs above the base plan or disposal at Commencement Bay for the -57’ MLLW alternative for purposes of navigation improvements. Table 7 summarizes the base plan costs and the incremental costs of the five scenarios. The incremental average annual equivalent (AAEQ) costs are used for the CE/ICA.

Table 7. Beneficial Use Incremental Costs ($1000, October 2019 prices, 2.75% discount rate).

Plan	Project First Costs	IDC	LSF	Total Economic Cost	Total OMRR&R	AAEQ Cost
Base Plan						
Scenario A (No-Action)	$0	$0	$0	$0	$0	$0
Scenario B	$2,616	$110	$0	$2,726	$0	$101
Scenario C	$3,520	$147	$0	$3,667	$0	$136
Scenario D	$3,915	$164	$0	$4,079	$0	$151
Scenario E	$10,205	$427	$0	$10,632	$0	$394

4.3 Results

Section 3.6.2.2 provides a summary of incremental costs and benefits associated with each scenario.

There were two best buy plans identified from the incremental analysis: Scenario A (No-Action), and Scenario E (Saltchuk full build-out with benches and islands; Figure 2). Additional details of the model results are in Section 3.6.2.2 of the IFR/EA.

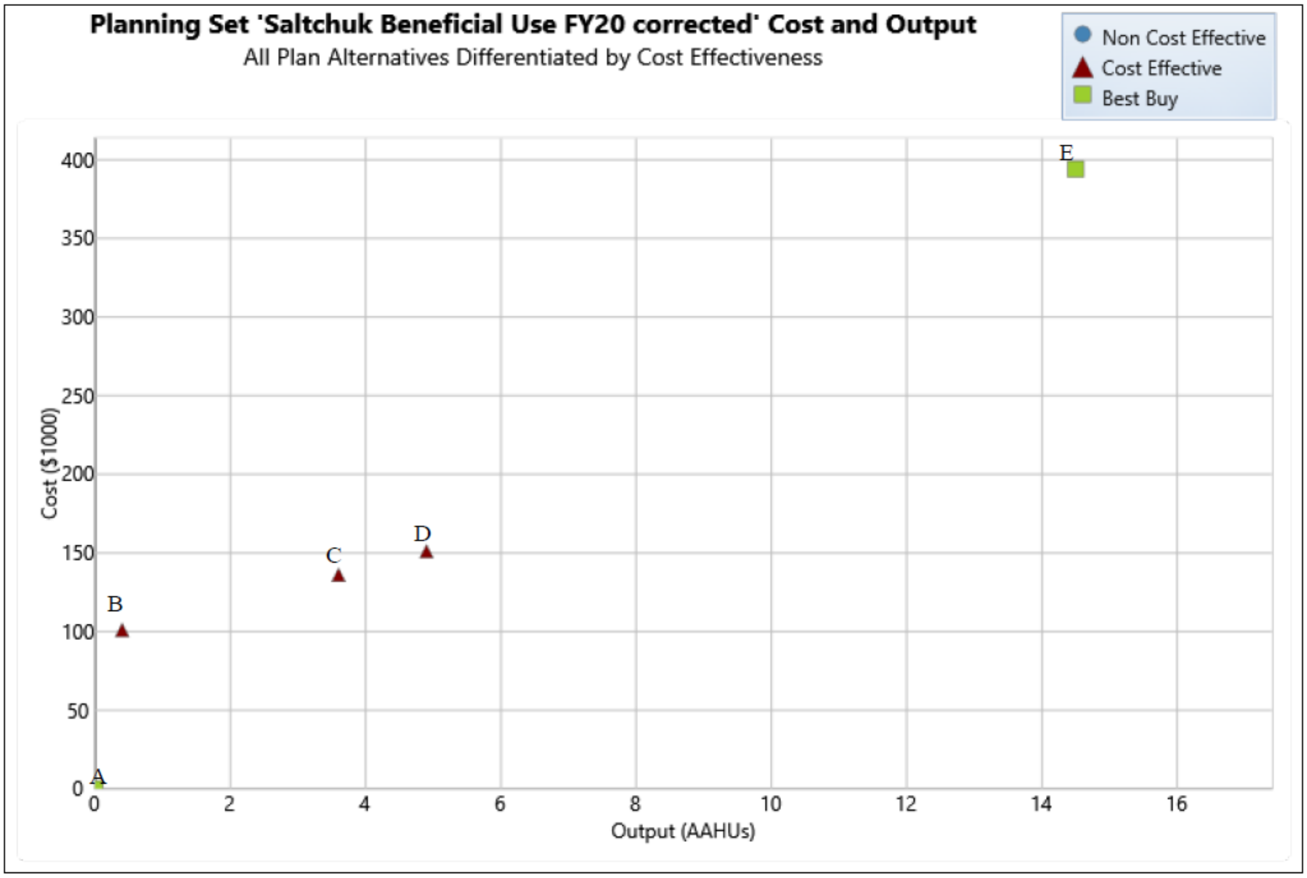


Figure 5. Saltchuk Alternative Cost and Output Plot

The objective of beneficial use of dredged material at Saltchuk is to restore nearshore intertidal and subtidal habitat substrate conditions for several fish and wildlife species, including ESA-listed species. The target species to benefit from the proposed project include juvenile and adult Chinook salmon, steelhead, and bull trout. Restoration actions aim to improve habitat conditions for these species and their prey species, such as forage fish and epibenthic and benthic invertebrates.

The incremental cost of the beneficial use disposal alternative to create nearshore habitat at Saltchuk site is reasonable in relation to the environmental benefits it achieves. Natural shorelines provide many important functions for PS Chinook salmon. In addition to the strictly vegetation related functions, addressed in the riparian assessment, the shallow water along natural shorelines in the upper shore zone provides refuge from predators and a migratory corridor. Stabilized shorelines, to varying degrees, cut off the shallow water regions of the beach. Further, hard bank stabilization has been shown to frequently result in modified wave regime, beach degradation, including lowering of beach profile, and coarsening of substrate (Sobocinski 2003; Dugan et al. 2008; Shipman 2010; Dugan et al. 2011). All three effects from shoreline stabilization, harsher wave regime, lowered beach profile, and coarser substrate reduces the suitability for forage fish spawning and their reproductive success. Fewer forage fish means a reduced food base for salmon in Puget Sound.

Natural shorelines include bluffs, woody vegetation, and wetlands/saltmarshes. Regardless of which geology/vegetation combination is present, literature shows that highly stabilized shorelines provide significantly lower habitat values (Tonnes 2008; Holsman and Willing 2007; Sobocinsk 2003; Brennan 2007; MacDonald 1994).

5. Air Quality

Ambient air quality standards, as adopted by the State of Washington (WAC 173-476), are in Table 8.

Table 8. NAAQS as adopted by the State of Washington**.

Pollutant		Averaging Time	Level	Remarks	Measurement Method	Interpretation Method
Particle Pollution	PM-10	24-hour	150 $\mu g/m^3$	Not to be exceeded more than once per year averaged over 3 years	40 C.F.R. Part 50, Appendix J	40 C.F.R. Part 50, Appendix K
	PM-2.5	Annual	12.0 $\mu g/m^3$	Annual mean, averaged over 3 years	40 C.F.R. Part 50, Appendix L	40 C.F.R. Part 50, Appendix N
		24-hour	35 $\mu g/m^3$	98th percentile, averaged over 3 years		
Lead		Rolling 3-month average	0.15 $\mu g/m^3$	Not to be exceeded	40 C.F.R. Part 50, Appendix G	40 C.F.R. Part 50, Appendix R
Sulfur Dioxide		Annual*	0.02 ppmv	Not to be exceeded in a calendar year	40 C.F.R. Part 50, Appendix A-1 or A-2	WAC 173-476-130(3)
		24-hour*	0.14 ppmv	Not to be exceeded more than once per year		
		3-hour	0.5 ppmv	Not to be exceeded more than once per year		
		1-hour	75 ppbv	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years		
Nitrogen Dioxide		Annual	53 ppbv	Annual Mean	40 C.F.R. Part 50, Appendix F	40 C.F.R. Part 50, Appendix S
		1-hour	100 ppbv	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years		
Ozone		8-hour	0.070 ppmv	Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years	40 C.F.R. Part 50, Appendix D	40 C.F.R. Part 50, Appendix P
Carbon Monoxide		8-hour	9 ppmv	Not to be exceeded more than once per year	40 C.F.R. Part 50, Appendix C	WAC 173-476-160(3)
		1-hour	35 ppmv			

*Annual and 24-hour SO_2 standards have a "sunset provision". They will no longer apply to those areas that have been in attainment status (designated by EPA) for the one-hour SO_2 standard for one year. (See WAC 173-476-130 and 40 C.F.R. 50.17 for additional details.)

**Table taken from http://apps.leg.wa.gov/WAC/default.aspx?cite=173-476-900 ppmv – parts per million (ppm) by volume, ppbv – parts per billion (ppb) by volume, µg/m^3 – micrograms per cubic meter of air

Emissions of air pollutants were estimated by the following methodology:

engine power rating * hours of engine operation * emissions factor = emissions

Engine power ratings are typically expressed in terms of kilowatts (kW). Emission factors are specific to the pollutant and type of engine for which the emission estimate is being made and are typically expressed in terms of metric tons of pollutant emitted per kilowatt hour. Emissions are typically express in terms of metric tons of pollutant.

Short-term, direct impacts to air quality from construction activities air emissions were estimated for each project alternative. Air emissions estimates for construction activities considered the emissions for off-road diesel equipment and harborcraft, such as tug boats and the clamshell dredge. Emissions factors for off-road diesel equipment were obtained from the website of the South Coast Air Quality Management District (SCAQMD 2016). Emissions factors for harborcraft operations were derived from the Harborcraft, Dredge, and Barge Emission Factor Calculator from the Sacramento Metropolitan Air Quality Management District (SMAQMD). Equipment and harborcraft types, engine power ratings, and hours of operation were provided by the cost engineering analysis for the project. Trucks would be used under all alternatives to transport dredged material not suitable for open water disposal to an upland disposal site. The analysis assumes that the upland disposal site would be the LRI Landfill in Graham, Washington, which is approximately 30 miles from the project location.

Long-term, indirect impacts to air quality consisting of air emissions due to port activities (local transit, maneuvering, and hoteling of ocean going vessels (OGVs)) were qualitatively estimated for each project alternative. The number of vessel calls used for the estimate of long-term, indirect air quality effects was based on the vessel traffic information presented in Appendix A – Economics, and Section 4.4 of the document.

6. Greenhouse Gas Emissions

GHGs have differing abilities to reflect infrared radiation and therefore have differing potentials to alter Earth's greenhouse effect. GHG emissions are typically standardized to metric tons of carbon dioxide (CO_2) equivalent by multiplying the tons of GHG by its 100-year global warming potential (IPCC 2013). For standardizing the estimate of methane (CH_4) emissions, the 100-year global warming potential incorporating climate carbon feedbacks was selected (IPCC 2013).

Greenhouse gas (GHG) emissions were estimated by the following methodology:

engine power rating * hours of engine operation * emissions factor = emissions

Engine power ratings are typically expressed in terms of kilowatts (kW). Emission factors are specific to the GHG and type of engine for which the emission estimate is being made and are typically expressed in terms of metric tons of GHG emitted per kilowatt hour. Emissions are typically express in terms of metric tons of GHG.

Greenhouse gas emissions were modeled for short-term sources during construction and considering the following three components: off-road diesel equipment emissions, harborcraft emissions, and locomotive emissions. Results appear in Section 4.9 of the IFR/EA.

An estimate of CO_2 and CH_4 (methane) emissions under the various proposed alternatives was performed. These are the two primary GHGs produced by diesel engines in construction equipment, marine vessels, and locomotives. Nitrous oxide (N_2O) is a greenhouse gas that is produced by the combustion of fossil fuels in internal combustion engines. However, N_2O emissions from diesel powered engines are much lower than those from gasoline engines. The equipment and marine vessels used to construct the maximum extent proposal is assumed to be all diesel powered. The associated N_2O emissions are assumed to be negligible and therefore were not calculated.

Emissions factors for off-road diesel equipment used during construction were obtained from the website of the South Coast Air Quality Management District (SCAQMD 2015). Number of vessels and types of equipment, along with estimated operating hours were used from the cost estimate to provide the most conservative estimate of emissions. Emissions factors for clamshell dredge and tugboat operations (i.e., harborcraft) were derived using the Harborcraft, Dredge, and Barge Emission Factor Calculator from the Sacramento Metropolitan Air Quality Management District (SMAQMD 2017). It is assumed that dredged material not suitable for open water disposal would be transported via truck to the LRI Landfill in Graham, Washington.

7. Underwater Noise

To analyze the proposed action's potential effects of underwater noise on aquatic resources, some fundamental characteristics of sound and the existing conditions (i.e., the status of underwater noise in Puget Sound) are laid out here for a basic understanding for the analysis.

Sources of Sound

Ambient noise is the combination of all sound sources, which creates a steady background noise. Underwater sound source categories are biological (caused by marine life), hydrodynamic (caused by wind, waves, and rain), marine vessel traffic, and seismically produced such as during earthquakes or seismic surveys for oil exploration. Ambient noise conditions underwater in Puget Sound have many contributors including shipping traffic to the Ports of Everett, Seattle, and Tacoma, U.S. Navy activities, the Washington State ferry routes across Puget Sound with up to 23 vessels operating at a time, cruise ships, commercial fishing vessels, and recreational boats. As one example location, permanent ambient underwater noise in Admiralty Inlet, a major route for shipping traffic near Port Townsend, is around 98 dB (1 µPa @ 1 m; Bassett 2010). Mean ambient level in most marine waters is 80 to 100 dB (Richardson et al. 1995).

Sources of sound are intermittent as well as ambient. Some temporarily occurring noises include dredging, ships passing nearby, naval sonar testing, and pile driving, or other construction-related activities. For example, in addition to the ambient noise in Admiralty Inlet, the Washington state ferry vessel in the Port Townsend-Coupeville route emits roughly 179 dB (1 µPa @ 1 m; Bassett 2010). Small ships around 100 to 150 feet long are common in Puget Sound, and their engines emit broadband sound (20 Hz to 1 kHz) at

150 to 170 dB (1 µPa @ 1 m; Richardson et al. 1995). Larger commercial vessels emit lower frequency noise as loud as 170 to nearly 200 dB (1 µPa @ 1 m). Naval active sonar testing is likely the loudest sound produced, emitting 230 dB (1 µPa @ 1 m) in the range of 2 to 5 kHz.

Animals in Puget Sound Potentially Affected by Underwater Noise

The major groups of animals in Puget Sound that can be affected by underwater noise are fish, diving birds, pinnipeds (seals, sea lions, and sea otters), and the two types of whales, mysticetes (baleen whales) and odontocetes (toothed whales). The species of focus for this analysis are identified as significant biological resources or are otherwise protected by the Marine Mammal Protection Act.

Fish can be harmed in different ways, particularly through their swim bladder because of the large difference in impedance between the gas-filled bladder and the surrounding water-filled body tissues (Nedwell et al. 2004). Intense sound pressure waves can cause physical harm and mortality. Fishes' sensitivity to hearing varies, but most exhibit a response to sounds in the range of 50 Hz to 2 kHz, with a minimum threshold around 70 dB (Hastings 1995). Herring, a forage fish with declining populations, have high sensitivity to sound due to their specialization of pressure-sensing mechanisms (Blaxter and Hoss 1981); this is in contrast to Cottids (sculpins), which have no swim bladder and are therefore not sensitive to sound waves (Nedwell et al. 2004).

Diving birds, such as marbled murrelets, are vulnerable to excessive underwater noise because it affects their ability to catch prey while diving and can cause disorientation and injury. Excessive noise can cause a range of problems, including aborted feeding attempts, disorientation, and even injury if the sound pressure wave is strong enough.

Marine mammals use vocalizations to identify themselves, their location, territory, or reproductive status and communicate with each other about the presence of prey, another animal, or danger. Loudness, frequency, duration, and types of sounds vary widely among the species and can be compared to the audiogram for the species if one has been developed. Audiograms are the graphic display of hearing sensitivity, which plot frequency against the hearing threshold. Available data show that whales' auditory thresholds can extend as low as 10Hz for the mysticetes and as high as 500kHz for some odontocetes (Gordon and Moscrop 1996). California sea lions are most sensitive to sounds between 1 kHz and 28 kHz, with peak sensitivity around 16 kHz (Schusterman et al. 1972). Harbor seals have a slightly broader range with the ability to hear up to about 50 kHz for sounds over 60 dB (1 µPa @ 1 m; Richardson et al. 1995). The Steller sea lion hearing range is 500 Hz to 32 kHz with less sensitivity at the low and high frequencies.

Killer whales rely on their highly developed acoustic sensory system for navigating, locating prey and communicating with other individuals (Ford 1989). Noise pollution from marine vessel traffic is one of the main concerns with the decline in the endangered Southern Resident killer whale population because of how it may affect their vocalizations and hearing. Excessive noise levels may mask echolocation and other signals the species use, as well as temporarily or permanently damage hearing sensitivity (NMFS 2005). Vessel traffic negatively affects the foraging behavior of the Southern Resident killer whales, which can have biologically significant consequences and is likely a factor in their low population level (Lusseau et al. 2009).

For a determination on whether construction related noise would affect marine mammals, fish, and birds, one must consider the frequency, location, intensity, and duration of the sound source as well as the audiogram of the recipient species. If an audiogram is available for a species, then using that audiogram helps to analyze the effects of noise on important biological resources; otherwise, the hearing frequency range may be the best available information. Effects analysis requires calculating the sound exposure level (SEL) that the animal receives. Table 9 displays data collected on the hearing capabilities of potentially affected species in the project area. The National Marine Fisheries Service (NMFS) has provided technical guidance on the effects of underwater noise on the hearing of marine mammal species. The hearing ranges and acoustic thresholds at which marine mammals are predicted to experience changes in hearing due to non-impulsive anthropogenic underwater noise, such as dredging, are summarized in Table 4. There are different thresholds for temporary (TTS) and permanent threshold shifts (PTS) of hearing sensitivity. For non-impulsive sounds, the thresholds are presented using the cumulative sound exposure level (SELcum) (NMFS 2016).

Table 9. Hearing capabilities of aquatic species and sound threshold for continuous and pulsed noise that can cause behavioral disruption and injury.

Species	**Audible Frequencies**	**Level B harassment (continuous)**	**Level B harassment (pulsed)**	**Level A injury**
Fish (general)[2]	50Hz – 2kHz	150 dB_{RMS}	187 dB_{RMS}	206 dB_{RMS}
Herring[2]	70Hz – 200Hz	150 dB_{RMS}	187 dB_{RMS}	206 dB_{RMS}
Salmonids[2,7]	10Hz – 600Hz	150 dB_{RMS}	187 dB_{RMS}	206 dB_{RMS}
Rockfish[8]	50Hz – 2kHz	150 dB_{RMS}	187 dB_{RMS}	206 dB_{RMS}
Pinnipeds[5]	500Hz – 50kHz	120 dB_{RMS}	160 dB_{RMS}	190 dB_{RMS}
California sea lions	1kHz – 28kHz	120 dB_{RMS}	160 dB_{RMS}	190 dB_{RMS}
Harbor seals	1kHz – 50kHz	120 dB_{RMS}	160 dB_{RMS}	190 dB_{RMS}
Steller sea lions	500Hz – 32kHz	120 dB_{RMS}	160 dB_{RMS}	190 dB_{RMS}
Mysticete whales[4]	10Hz – 8kHz	120 dB_{RMS}	160 dB_{RMS}	180 dB_{RMS}
Minke whale[4]	10Hz – 500Hz	120 dB_{RMS}	160 dB_{RMS}	180 dB_{RMS}
Odontocete whales[4]	100Hz – 500kHz	120 dB_{RMS}	160 dB_{RMS}	180 dB_{RMS}
Killer Whale (orca)[3]	500Hz – 105kHz	120 dB_{RMS}	160 dB_{RMS}	180 dB_{RMS}
Diving birds[9] (developed for marbled murrelet)	Not available, presumed at 1kHz – 5kHz	150 dB_{RMS} (guideline)	183 dB_{RMS} (onset of injury)	202 dB_{RMS}

[1] square root of the mean of the squares of the values recorded over a given time interval [2]Blaxter and Hoss 1981; [3] Hall and Johnson 1971, Bain et al. 1993, Szymanski et al. 1999; [4] Gordon and Moscrop 1996; [5] Schusterman et al. 1972; [6] Bailey et al. 2010; [7] Knudsen et al. 1992; [8] Skalski et al. 1992; [9] SAIC 2011

Table 10. Generalized Hearing Ranges, PTS, and TSS Thresholds for Non-impulsive Sounds.

Hearing Group	Generalized Hearing Range	PTS Onset Acoustic Thresholds (received level)	Weighted TTS onset acoustic threshold (SEL_{cum})
Low frequency (LF) cetaceans (baleen whales)	7 Hz to 35 kHz	L_E,LF,24h: 199 dB	179 dB

Mid-frequency (MF) cetaceans (dolphins, toothed whales, beaked whales, bottlenose whales)	105 Hz to 160 kHz	L_E,MF,24h: 198 dB	178 dB
High-frequency cetaceans (true porpoises, *Kogia*, river dolphins, cephalorhynchid, *Lagenorhynchus cruciger* & *L. australis*)	275 Hz to 160 kHz	L_E,HF,24h: 173 dB	153 dB
Phocid pinnipeds (PW) (underwater) (true seals)	50 Hz to 86 kHz	L_E,PW,24h: 201 dB	181 dB
Otariid pinnipeds (PW) (underwater) (sea lions and fur seals)	60 Hz to 39 kHz	L_E,OW,24h: 219 dB	199 dB

NMFS 2016. In the PTS column, L_E is the cumulative sound exposure level, other abbreviations, like LF, represent the auditory weighting function for that group of marine mammals, and the accumulation period is 24 hours.

A 2018 BiOP issued to USACE for eight maintenance dredging projects assumed dB_{RMS} and dB_{SEL} to be equal for continuous noise (NMFS 2018). Behavioral changes from noise avoidance are the most likely impacts to marine mammals. Few marine mammals, other than seals and sea lions, frequent inner Commencement Bay or waterways, so the impacts within the bay itself are predicted to be low. The sound exposure level (SEL), the threshold that causes a temporary shift in hearing ability, is 181 dB and 199 dB for seals and sea lions, respectively, which is above the level of noise generated by studies cited in NMFS 2016. Additionally, the sound would attenuate quickly with distance from the dredge and would not cause any greater harm than avoidance of the immediate dredging area.

Overall, the dredge is not expected to cause more than the usual amount of disturbance that occurs to birds or marine mammals in Commencement Bay; however, the constant noise from the dredge may cause wildlife to avoid the immediate project area during the approximately 6 months of dredging and disposal. They would return to normal habits once the dredging is complete. No long-term significant impacts to wildlife populations are anticipated.

Impacts related to noise are likely to occur but should be temporary, and behavioral changes related to avoiding the noise are the most likely response by fish. High intensity underwater noise can result in temporary threshold shifts (TTS), a non-injurious temporary reduction in hearing sensitivity. No permanent hearing loss has been documented in fish (NOAA 2016). Hearing varies depending upon the species of fish. However, most react to sounds in the range of 50 Hz to 2 kHz with a minimum threshold of around 70 dB (Hastings, 1995). Noise generated by hydraulic dredges are characterized as continuous (or non-pulsed) since the elevated sound pressure occurs over seconds (not milliseconds, as is the case with pulsed noise; Agness, NMFS, personal comm., July 23, 2013). The following are noise thresholds for various forms of effects on salmonids for both impact and vibratory pile driving (note that, like dredging, vibratory pile driving is considered continuous):

- 150 dB_{RMS}[1] for harassment for continuous noise for fish of all sizes (Hastings 2002)
- 187 dB cumulative SEL[2] for injury of fish ≥ 2 grams[3] (NMFS et al. 2008)

[1] Decibels root mean square over a period of time
[2] Decibels sound exposure level over a 24 hour period (cumulative)
[3] Injury thresholds are based on pile driving (pulsed noise)

- 183 dB cumulative SEL for injury of fish < 2 grams (NMFS et al. 2008)
- 206 dB_{peak}[4] for injury of fish of all sizes (NMFS et al. 2008)

A more recent study lists the following continuous noise[2] thresholds based on Popper et al. 2014:

- For fish with swim bladders that are involved in hearing (e.g., herring, sardines, and anchovies)
    - 170 dB_{RMS} for 48 hours for recoverable injury
    - 158 dB_{RMS} for 12 hours for TTS (Temporary Threshold Shift, or complete recovery of hearing loss)
- There is no direct evidence for mortality or potential mortal injury for continuous noise
- There are no continuous noise thresholds set for fish without swim bladders (sculpins) or those with bladders that are not involved in hearing (salmonids)

The operation of most large marine vessels, including tugs that would have the barges for open-water sediment disposal, produce up to 180 dB. While the operation of the tug and barge would increase ambient noise levels along the immediate travel route, impacts of any sound disturbance would likely result in a temporary, short-range displacement of animals rather than injury. A 2010 study recorded a tugboat with peak sound pressure levels in the range of 148-168 dB with the hydrophone placed 350 m away from the tugboat. This study also reported measurements of noise levels from clamshell dredging in the Snohomish River as high as 164 dB re µP (dB_{peak}) and 164 dB_{RMS} for a clamshell dredge when the bucket hits the bottom (Pentec Environmental 2010). Another study in Cook Inlet recorded a peak sound level of 124 dB re µP (dB_{peak}) when the clamshell hit a coarse substrate bottom (Dickerson et al. 2001). It is likely that the dB_{RMS} noise levels for this study were lower than the peak noise levels, although they were not reported. This Cook Inlet study also found that softer substrates are more effective at absorbing sound from the impact of the dredge bucket, and the peak sound measurements in these softer substrates did not exceed thresholds for continuous sound. The sound levels generated in the Snohomish River study exceeded the NMFS harassment (all fish) and Popper TTS (fish with swim bladders used for hearing) thresholds, but no injury thresholds for fish. The substrate in Commencement Bay is similar to that of the Snohomish River (mostly sand). Therefore, sound levels (both in dB_{peak} and $_{RMS}$) are likely to be lower than the Snohomish study, and thresholds are not expected to be exceeded.

Data for how continuous sound affects fish is limited, and in the technical report of sound exposure guidelines prepared by Popper et al. (2014), they rank the level of risk of injury as high, moderate, or low for most categories of fish instead of presenting number thresholds for harm. According to Popper, the risk of mortality for continuous sound such as this is low for all categories of fish at all distances from the sources of sound; the risk of recoverable injury is the same except for fish with a swim bladder used for hearing. Their threshold for recoverable injury is 170 dB rms, and 158 dB_{RMS} for a temporary threshold shift. The peak sound level during the Snohomish River study falls between these thresholds. The risk of temporary threshold shift for the other groups of fish, those without swim bladders and those with swim

[4] Peak sounds in decibels

bladders that do not use them for hearing, is moderate near the source of the sound but low for intermediate or far distances (Popper 2014).

Seals and sea lions in the area are likely accustomed to a higher level of underwater noise due to the heavy vessel traffic around Commencement Bay. Large shipping vessels can generate noise levels well above harassment and injury thresholds depending on variables like vessel speed, oceanic conditions, water temperatures, and bathymetry (McKenna et al. 2013; Richardson et al. 1995). Many commercial and recreational vessels transit the area multiple times a day.

According to the Washington Department of Fish and Wildlife's Atlas of Seal and Sea Lion Haulout Sites in Washington (Jeffries et al. 2000), the nearest harbor seal and sea lion haulout sites are in northeast Commencement Bay on buoys, floats, and discontinued log booms. Commencement Bay is not considered a major pupping and nursing site, and although the number of haul outs and sightings of pups were increasing in 2009, the discontinuation of log booms removed a major haul out location in Commencement Bay.

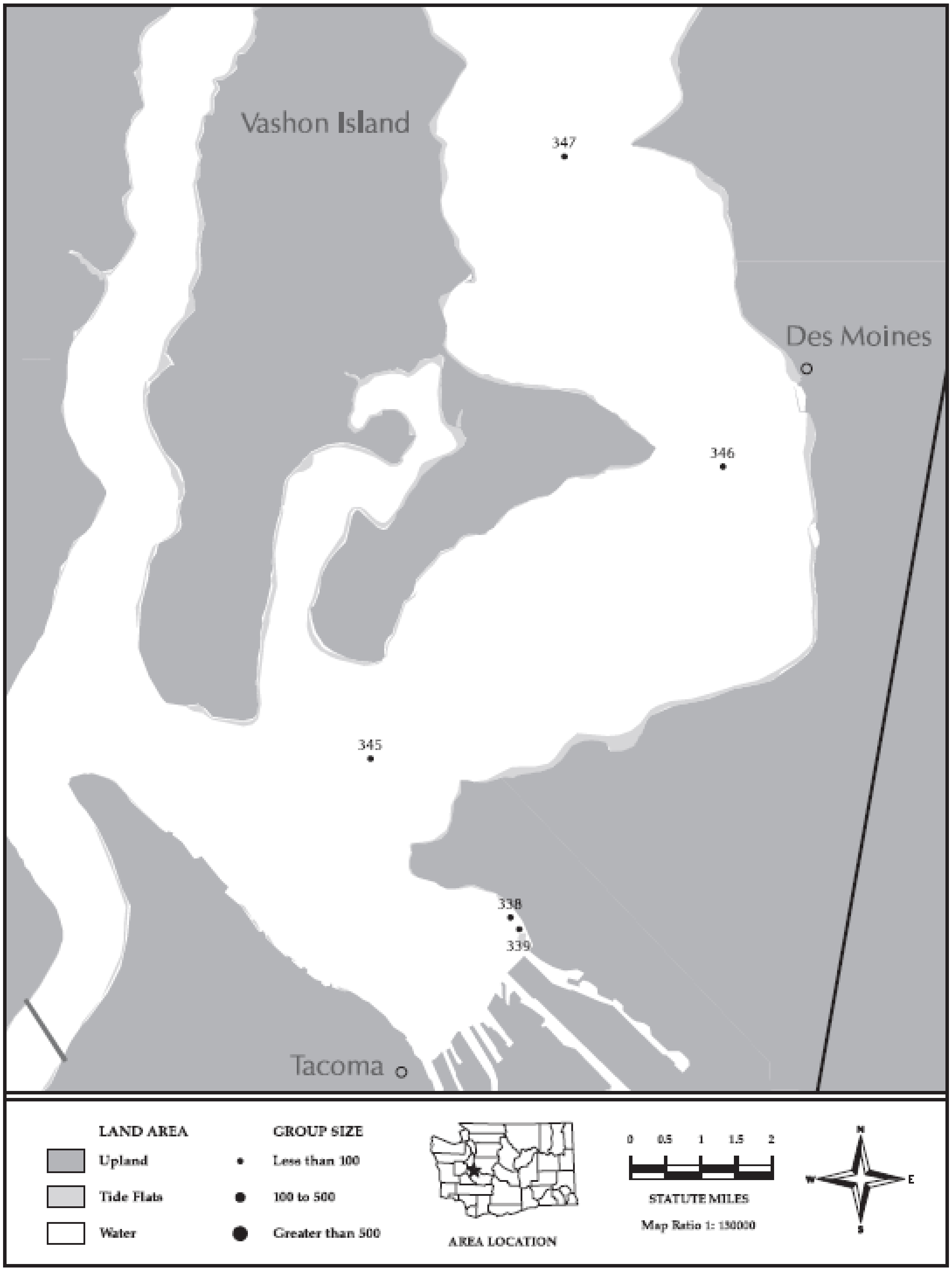


Figure 6. Seal and sea lion haulout sites in central Puget Sound from WDFW (Jeffries et al. 2000). Harbor seals and sea lions have historically hauled out onto buoys, floats, and the discontinued log booms in northeast Commencement Bay.

8. Invasive Species

The relevant vectors for invasive species are transport in shipping containers, ship fouling, and exchange of ballast water. It is assumed trade routes, container ship sizes, and the number of containers will not change, so the risk of introducing species that may be transported via hull or ballast water biofouling or in containers such as Asian gypsy moth would not change. A check was performed to determine whether the New Zealand mudsnail (NZMS) has been documented within the project area. The site and surrounding areas are not listed in the most recent NZMS action summary (WDFW 2015, as cited in Anchor QEA 2019).

9. Recreation Resources

The Port of Tacoma provides public access to Commencement Bay as required by the City of Tacoma Shoreline Master Program. Public access to launch boats, sit along the water, or access the shoreline are available at the Dick Gilmur Shoreline Restoration and Kayak Launch along Marine View Drive north of the Hylebos Waterway, Balfour Dock and Youth Marine Foundation on the Foss Waterway, and Observation Tower at the head of Sitcum Waterway. Some access sites around Commencement Bay have been combined with habitat restoration, such as at Gog-Le-Hi-Te 1 &2 on the Puyallup River, and along the Hylebos Waterway with Julia's Gulch to the north and Place of Circling Waters at the mouth of Hylebos Creek. On the Blair Waterway, there is a public overlook with views of the Rhone-Poulenc saltmarsh and mudflat habitat site without direct shoreline access.

10. Socioeconomics and Environmental Justice

An Environmental Justice (EJ) analysis was conducted and described below to describe the population currently residing in the vicinity of the proposed project with emphasis on quantifying the minority and low-income populations.

The proposed project is in Pierce County, Washington. Pierce County's 2019 population totaled 860,000. Minority residents comprise approximately 27 percent of the population. The Port of Tacoma facilities are mostly in industrial areas at the mouth of the Puyallup River and east of downtown Tacoma. Port facilities are fully surrounded by Interstate 705 to the West, Highway 509 to the South and East, and Commencement Bay to the North. While there are limited properties directly adjacent to the Port, most of the population of the city of Tacoma is within a 5-mile radius. The Port of Tacoma is almost fully located within Census Tract 602, which includes large, waterfront condominiums and apartment buildings East of Interstate 705 as well as homes along Marine View Drive to the North. The estimated population of Census Tract 602 as of 2019 was 2,522. Per the 2019 American Communities Survey 5-Year Estimates, Census Tract 602 consists of 23 percent minority residents.

Any individual with total income less than an amount deemed sufficient to purchase basic needs of food and shelter, clothing, and other essential goods and services is considered below the poverty line. The 2019 poverty level according to the US Census Bureau for an individual under 65 years of age is any individual with total income below $13,300. For the population surrounding the Port of Tacoma residing within Census Tract 602, a total of 1,054 residents, or 42 percent of the population, live below the poverty line (2019 American Communities Survey). This is significantly higher than the 2019 Pierce County average of 10 percent.

Executive Order 12898, Federal Actions to Address EJ in Minority Populations and Low-Income Populations, states "*each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations*." Executive Order 14008, "Tackling the Climate Crisis at Home and Abroad", amends Executive Order 12898 and has updated Federal agencies' responsibilities for assessing environmental justice consequences of their actions. Environmental Justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. The USACE evaluated the nature and location of the proposed action and used the EPA Environmental Justice Viewer to determine whether minority populations, low-income populations, or Indian tribes are present and may be affected in a 5-mile radius around the center of the Blair Waterway. The Puyallup Tribe of Indians is included in this analysis so effects to members and associated resources must be evaluated for disproportionately high effects. Analysis is present here, Sections 6.7 (Federal Trust Responsibility), 6.14 (Executive Order 12898 Environmental Justice and Executive Order 14008 Climate Crisis) and for applicable resources in Chapter 4. The area of analysis was chosen to encompass potential impacts from construction and operation at the Blair Waterway and Saltchuk and is large enough to include locations of surrounding local communities who are adjacent to the Port of Tacoma and ones that submitted comments during scoping. The proposed project is within a highly industrialized environment that has been substantially modified and impacted over the last 100 years. Analysis for environmental justice evaluates potential project effects within the context of this previously altered setting.

Under Alternative 1 (No-Action Alternative/Future Without-Project Conditions), the amount of cargo moving through the Port is predicted to increase the same amount as under all action alternatives. Under Alternative 1, more vessels would likely be required to transport the same forecasted increase in cargo volumes. This would result in greater rates of air pollutants and GHG emissions over time. With the implementation of any deepening alternative, the total number of vessels would likely decrease, leading to lower transportation costs compared to Alternative 1. Channel improvements are not likely to induce additional growth or lead to additional traffic, noise, or lighting compared to the future without-project condition.

Since the total cargo throughput is not predicted to increase because of deepening, minimal landside changes in air pollutant emissions would result from channel improvements. Sections 4.7 (Air Quality) and 4.8 (Greenhouse Gas Emissions) in the IFR/EA evaluated effects to these resources, which are not substantial. While the action alternatives would lead to temporarily increased truck traffic during construction to remove unsuitable material (approximately 16% of dredged material over four years), channel deepening would likely reduce the number of vessel calls used to transport cargo in the long-term. As a result, total air emissions at the harbor could decrease because of the project. Additionally, increased depths could reduce congestion and allow vessels more flexibility of movement than in the future without-project conditions. Decreased congestion could allow traffic to be spread over wider time ranges rather than concentrating all the largest vessel traffic during high tides.

No significant construction or operational impacts on the human environment are expected. Implementation of commitments listed in Sections 5.9.3 (PED Activities) and 5.9.5 (Environmental Commitments and BMPs) will avoid and minimize effects to environmental justice communities and actions by specific groups such as fishing by the Puyallup Tribe of Indians. While some degree of sediment resuspension is inevitable for navigation dredging, increased risk associated with contaminant body burden in fish is not anticipated. For this project, USACE will follow all necessary steps to ensure environmental impacts are minimized, including water quality monitoring requirements under Clean Water Act Section 401, dredging during designated in-water work windows, and thorough characterization of dredge material through the Dredged Material Management Program (DMMP). During the Preconstruction Engineering and Design phase of the project, USACE will engage the Puyallup Tribe and offer the opportunity to review and comment on the sampling design for the DMMP suitability characterization. USACE will also engage the Tribe regarding criteria for placement of sediments at the Saltchuk beneficial reuse site. Outside of the USACE proposed project and Blair Waterway, the US EPA continues to monitor contaminant levels in fish tissue and the potential changes resulting from previously completed remedial actions as part of the Commencement Bay Nearshore Tideflats Superfund project.

Populations of minority, juvenile, elderly, and low-income families would not experience disproportionately high and adverse effects from any of the proposed alternatives. Schools/childcare facilities and hospitals are dispersed throughout the area and are not disproportionately located near the industrial project area. Thus, no disproportionately high and adverse impacts on children are expected. Overall, based on the absence of adverse impacts to human health and safety risk noted above, this project would not have disproportionately high and adverse impacts on any communities, including environmental justice communities or children.

The dredging project would maintain the important socioeconomic benefits for the local area and continue supporting the indirect jobs associated with direct employment and local business expenditures. There would be cumulative benefits to the economy from maintenance dredging in combination with other dredging in the area that supports the industry by improving conditions for vessel access in the Blair Waterway. See Section 4.4 of the Main Report (Navigation and Economic Conditions) for more details on the economic impacts of the project.

EJSCREEN Report (Version 2019)

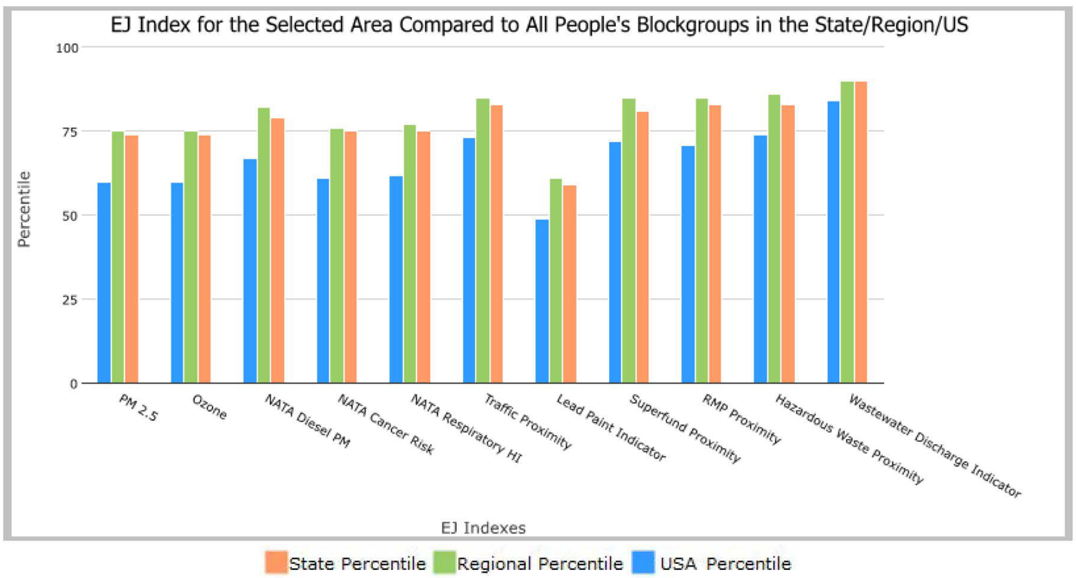
5 miles Ring Centered at 47.266161,-122.393575, WASHINGTON, EPA Region 10

Approximate Population: 217,778

Input Area (sq. miles): 78.53

Harbor Navigation Improvement Project (The study area contains 1 blockgroup(s) with zero popu

Selected Variables	State Percentile	EPA Region Percentile	USA Percentile
EJ Indexes			
EJ Index for PM2.5	74	75	60
EJ Index for Ozone	74	75	60
EJ Index for NATA* Diesel PM	79	82	67
EJ Index for NATA* Air Toxics Cancer Risk	75	76	61
EJ Index for NATA* Respiratory Hazard Index	75	77	62
EJ Index for Traffic Proximity and Volume	83	85	73
EJ Index for Lead Paint Indicator	59	61	49
EJ Index for Superfund Proximity	81	85	72
EJ Index for RMP Proximity	83	85	71
EJ Index for Hazardous Waste Proximity	83	86	74
EJ Index for Wastewater Discharge Indicator	90	90	84



This report shows the values for environmental and demographic indicators and EJSCREEN indexes. It shows environmental and demographic raw data (e.g., the estimated concentration of ozone in the air), and also shows what percentile each raw data value represents. These percentiles provide perspective on how the selected block group or buffer area compares to the entire state, EPA region, or nation. For example, if a given location is at the 95th percentile nationwide, this means that only 5 percent of the US population has a higher block group value than the average person in the location being analyzed. The years for which the data are available, and the methods used, vary across these indicators. Important caveats and uncertainties apply to this screening-level information, so it is essential to understand the limitations on appropriate interpretations and applications of these indicators. Please see EJSCREEN documentation for discussion of these issues before using reports.

January 24, 2020 1/3

EJSCREEN Report (Version 2019)

5 miles Ring Centered at 47.266161,-122.393575, WASHINGTON, EPA Region 10

Approximate Population: 217,778

Input Area (sq. miles): 78.53

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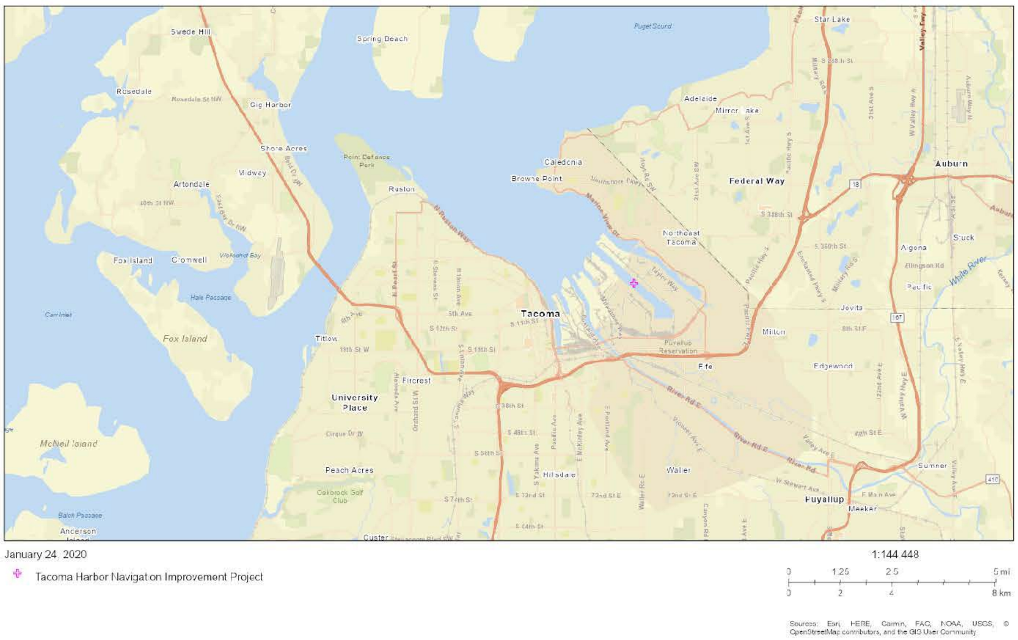

Sites reporting to EPA	
Superfund NPL	2
Hazardous Waste Treatment, Storage, and Disposal Facilities (TSDF)	23

EJSCREEN Report (Version 2019)

5 miles Ring Centered at 47.266161,-122.393575, WASHINGTON, EPA Region 10

Approximate Population: 217,778

Input Area (sq. miles): 78.53

Harbor Navigation Improvement Project (The study area contains 1 blockgroup(s) with zero popı

Selected Variables	Value	State Avg.	%ile in State	EPA Region Avg.	%ile in EPA Region	USA Avg.	%ile in USA
Environmental Indicators							
Particulate Matter (PM 2.5 in µg/m^3)	6.77	6.4	78	6.6	63	8.3	16
Ozone (ppb)	32.7	33.7	51	35.1	39	43	6
NATA* Diesel PM (µg/m^3)	1.12	0.583	91	0.479	90-95th	0.479	95-100th
NATA* Cancer Risk (lifetime risk per million)	40	34	84	31	90-95th	32	80-90th
NATA* Respiratory Hazard Index	0.64	0.5	90	0.46	90-95th	0.44	90-95th
Traffic Proximity and Volume (daily traffic count/distance to road)	650	600	75	500	79	750	73
Lead Paint Indicator (% Pre-1960 Housing)	0.35	0.23	75	0.23	76	0.28	66
Superfund Proximity (site count/km distance)	0.31	0.19	85	0.13	91	0.13	91
RMP Proximity (facility count/km distance)	1.3	0.63	86	0.65	85	0.74	83
Hazardous Waste Proximity (facility count/km distance)	2.9	1.9	80	1.5	85	4	83
Wastewater Discharge Indicator (toxicity-weighted concentration/m distance)	0.00094	50	78	31	74	14	66
Demographic Indicators							
Demographic Index	36%	29%	72	29%	73	36%	59
Minority Population	41%	30%	74	27%	78	39%	60
Low Income Population	31%	28%	62	31%	56	33%	53
Linguistically Isolated Population	4%	4%	70	3%	74	4%	69
Population With Less Than High School Education	10%	9%	68	9%	66	13%	54
Population Under 5 years of age	6%	6%	55	6%	55	6%	56
Population over 64 years of age	12%	14%	44	15%	42	15%	41

* The National-Scale Air Toxics Assessment (NATA) is EPA's ongoing, comprehensive evaluation of air toxics in the United States. EPA developed the NATA to prioritize air toxics, emission sources, and locations of interest for further study. It is important to remember that NATA provides broad estimates of health risks over geographic areas of the country, not definitive risks to specific individuals or locations. More information on the NATA analysis can be found at: https://www.epa.gov/national-air-toxics-assessment.

For additional information, see: www.epa.gov/environmentaljustice

EJSCREEN is a screening tool for pre-decisional use only. It can help identify areas that may warrant additional consideration, analysis, or outreach. It does not provide a basis for decision-making, but it may help identify potential areas of EJ concern. Users should keep in mind that screening tools are subject to substantial uncertainty in their demographic and environmental data, particularly when looking at small geographic areas. Important caveats and uncertainties apply to this screening-level information, so it is essential to understand the limitations on appropriate interpretations and applications of these indicators. Please see EJSCREEN documentation for discussion of these issues before using reports. This screening tool does not provide data on every environmental impact and demographic factor that may be relevant to a particular location. EJSCREEN outputs should be supplemented with additional information and local knowledge before taking any action to address potential EJ concerns.

January 24, 2020 3/3

11. References

Anchor QEA. 2019. Sampling and Analysis Plan. Dredged Material Characterization – Tacoma Harbor Deepening Study. Prepared for Port of Tacoma. February 2019.

Bain, D.E., B. Kriete and M. Dalheim. 1993. Hearing abilities of Killer whales (Orcinus orca). The Journal of the Acoustical Society of America 94(3):1829.

Bassett, C. 2010. Underwater Ambient Noise at a Proposed Tidal Energy Site in Puget Sound. Master's Thesis. University of Washington, Seattle.

Blaxter, J.H.S. and D.E. Hoss. 1981. Startle response in herring Clupea harengus: The effect of sound stimulus. Journal of the Marine Biological Association of the United Kingdom. 61:871-880.

Cohen, A.N., H.D. Berry, C.E. Mills, D. Milne, K. Britton-Simmons, M.J. Wonham, D.L. Secord, J.A. Barkas, B. Bingham, B.E. Bookheim, J.E. Byers, J.W. Chapman, J.R. Cordell, B. Dumbauld, A. Fukuyama, L.H. Harris, A.J. Kohn, K. Li, T.F. Mumford Jr., V. Radashevsky, A.T. Sewell, and K. Welch. 2001. Washington State Exotics Expedition 2000: A Rapid Survey of Exotic Species in the Shallow Waters of Elliott Bay, Totten and Eld Inlets, and Willapa Bay. Prepared for the Washington Department of Natural Resources Neashore Habitat Program. Olympia, WA.

Cordell, J., O. Kalata, A. Pleus, A. Newsom, K. Strieck, and G. Gertsen. 2015. Effectiveness of Ballast Water Exchange in Protecting Puget Sound from Invasive Species: Results from WDFW/US Ballast Water Sampling, 2001-2014. Funded by the Environmental Protection Agency.

Ecology (Washington Department of Ecology). 2012. Water Quality Assessment for Washington. Available online: https://fortress.wa.gov/ecy/wqamapviewer/default.aspx?res=1920x1080 (Accessed December 10, 2018).

Ecology. 2020. Coastal Atlas Map. Available online: https://fortress.wa.gov/ecy/coastalatlas/tools/Map.aspx (Accessed September 2020).

EPA. 2009. Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories. April 2009.

EPA. 2013. Record of Decision: Lockheed West Seattle Superfund Site. EPA. 2014. East Waterway Operable Unit Supplemental Remedial Investigation/Feasibility Study: Draft Feasibility Study.

Ford, J.K.B. 1989. Acoustic behaviour of resident killer whales (Orcinus orca) off Vancouver Island, British Columbia. Canadian Journal of Zoology 67(3): 727-745.

Fresh, K., M. Dethier, C. Simenstad, M. Logsdon, H. Shipman, C. Tanner, T. Leschine, T. Mumford, G. Gelfenbaum, R. Shuman, and J. Newton. 2011. Implications of Observed Anthropogenic Changes to the Nearshore Ecosystems in Puget Sound. Prepared for the Puget Sound Nearshore Ecosystem Restoration Project. Technical Report 2011-03.

Gordon, J. and A. Moscrop. 1996. Underwater Noise Pollution and its Significance for Whales and Dolphins, pp. 282-319 in: The Conservation of Whales and Dolphins, M.P. Simmonds and J.D. Hutchinson, eds. John Wiley & Sons Ltd.

Hall, J.D. and C.S. Johnson. 1971. Auditory thresholds of a killer whale Orcinus orca (Linnaeus). The Journal of the Acoustical Society of America 51:515-517.

Hastings, M.C. 1995. Physical effects of noise on fishes. Inter-noise 95, the 1995 International congress on noise control Engineering Vol 2: 979-984.

IPCC (Intergovernmental Panel on Climate Change). 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp, doi:10.1017/CBO9781107415324.

Jeffries, S.J., P.J. Gearin, H.R. Huber, D.L. Saul, and D.A. Pruett. 2000. Atlas of Seal and Sea Lion Haulout Sites in Washington. Washington Department of Fish and Wildlife, Wildlife Science Division, 600 Capitol Way North, Olympia WA. pp. 150.

Lusseau, D., D.E. Bain, R. Williams, and J.C. Smith. 2009. Vessel traffic disrupts foraging behaviour of southern resident killer whales Orcinus orca. Endangered Species Research 6:211-221.

Nedwell, J.R., B. Edwards, A.W.H. Turnpenny, and J. Gordon. 2004. Fish and Marine Mammal Audiograms: A Summary of Available Information. Subacoustech Report #534R0214. Available: www.subacoustech.com/information/downloads/reports/534R0214.pdf (Accessed 18 April 2012).

NMFS. 2005. Endangered and Threatened Wildlife and Plants: Endangered Status for Southern Resident Killer Whales. Final rule. Federal Register 70(222):69903-69912.Available: ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=A0IL.

NMFS. 2018. Endangered Species Act Section 7 Formal Consultation and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for U.S Army Corps of Engineers' (COE) Proposed 25-year Maintenance Dredging Program for Eight Federally-Authorized Navigation Channels in Western Washington State. Consultation Number: WCR-2016-6057. January 26, 2018.Richardson, W.J., C.R. Greene, Jr., C.I. Malme, and D.H. Thomson. 1995. Marine Mammals and Noise. Academic Press, Inc. San Diego, CA.

Puyallup River Watershed Council. 2014. Puyallup River watershed assessment (draft). Watershed Assessment Committee. February 2014.

SCAQMD (South Coast Air Quality Management District). Off-road mobile source emission factors (scenario years 2007-2025). Available from: http://www.aqmd.gov/home/rules-compliance/ceqa/air-quality-analysis-handbook/off-road-mobile-source-emission-factors.

Schusterman, R.J., R.F. Balliet, and J. Nixon. 1972. Underwater audiogram of the California sea lion by the conditioned vocalization technique. Journal of the Experimental Analysis of Behavior 17(3):339-350.

Simenstad, C.A., M. Ramirez, J. Burke, M. Logsdon, H. Shipman, C. Tanner, J. Toft, B. Craig, C. Davis, J. Fung, P. Bloch, K. Fresh, S. Campbell, D. Myers, E. Iverson, A. Bailey, P. Schlenger, C. Kiblinger, P. Myre, W. Gerstel, and A. MacLennan. 2011. Historical Change of Puget Sound Shorelines: Puget Sound Nearshore Ecosystem Project Change Analysis. Puget Sound Nearshore Report No. 2011-01. Published by Washington Department of Fish and Wildlife, Olympia, Washington, and U.S. Army Corps of Engineers, Seattle, Washington.

SMAQMD (Sacramento Metropolitan Air Quality Management District). 2017. Harborcraft, dredge and barge emission factor calculator. Available from: http://www.airquality.org/businesses/ceqa-land-use-planning/ceqa-guidance-tools.

Szymanski, M.D., D.E. Bain, K. Kiehl, S. Pennington, and K R. Henry. 1999. Killer whale (Orcinus orca) hearing: auditory brainstem response and behavioral audiograms. Journal of the Acoustical Society of America. 106(2):1134-1141.

USACE. 2016. Maintenance Dredging Combined Projects Biological Assessment: Fiscal Year 2017 through 2042 Maintenance Dredging of Selected Federal authorized Navigation Channels, with Disposal of Dredged material at Designated Disposal Sites. Seattle District. December 2016.

12. Monitoring and Adaptive Management Plan

This monitoring and adaptive management plan is intended to serve as a stand-alone document from Appendix C, so a separate table of contents and reference list is included below. The section and page numbers also restart at 1 to denote this difference.

The Tacoma Harbor, WA Deep Draft Navigation General Investigation Study (Tacoma Harbor GI) evaluated the feasibility of navigation improvements to the Port of Tacoma, Washington, including deepening Blair Waterway. The Base Plan is to dispose of material at the Commencement Bay open-water site, but there is an opportunity for beneficial use of dredged material at the Saltchuk site located along the northeastern shoreline of Commencement Bay (Figure 1).

Monitoring and Adaptive Management Plan

Monitoring and Adaptive Management Plan Contents

1. Introduction to the Project

The U.S. Army Corps of Engineers (USACE) is required to predict and quantify environmental benefits using models to justify federal investment in restoration projects.[1,2] For environmentally beneficial disposal methods with incremental federal costs that exceed the lesser of 25% of total Base Plan disposal costs or $300,000, the incremental costs must be justified by demonstrating that the monetary and non-monetary benefits (outputs) of the ecosystem restoration project justify its incremental costs above the Base Plan. It must be demonstrated that the environmental resources to be restored are valuable, the environmental outputs can be quantified and described, and federal, and state resource agencies support the environmentally beneficial disposal method.

As justification, USACE calculated preliminary Nearshore Habitat Values (NHV) of the deep zone (DZ; below -10 MLLW) and lower shore zone (LSZ; (from +5 to -10 MLLW) nearshore habitats in Puget Sound for ESA-listed juvenile and adult Puget Sound Chinook salmon using the NHV model. Section 3.6.2.2 of the IFR/EA contains additional information on this modeling. The NHV model scores habitat related to physical and biological features of Chinook salmon critical habitat. The DZ provides migratory and rearing habitat, but the depth and lack of submerged aquatic vegetation (SAV) means the DZ does not provide as much cover or food as the LSZ. The LSZ ends at the lower limit of forage fish spawning and encompasses the approximate upper and lower extents of eelgrass growth (+5 to -10 MLLW; Ehinger et al. 2015). The LSZ is within prime critical habitat for juvenile Chinook because it can contain SAV for food production and cover, and shallow water refuge for smaller juveniles from predators (Ehinger et al. 2015).

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[1] Planning Guidance Notebook, ER 1105-2-100, Appendix E. April 22, 2000.

[2] Implementation Guidance for Section 204 of the Water Resources Development Act of 1992, as amended by Section 1038(2) of the Water Resources Reform and Development Act of 2014 and Section 1122(i)(2) of Water Resources Development Act 2016 - Regional Sediment Management. February 16, 2018.

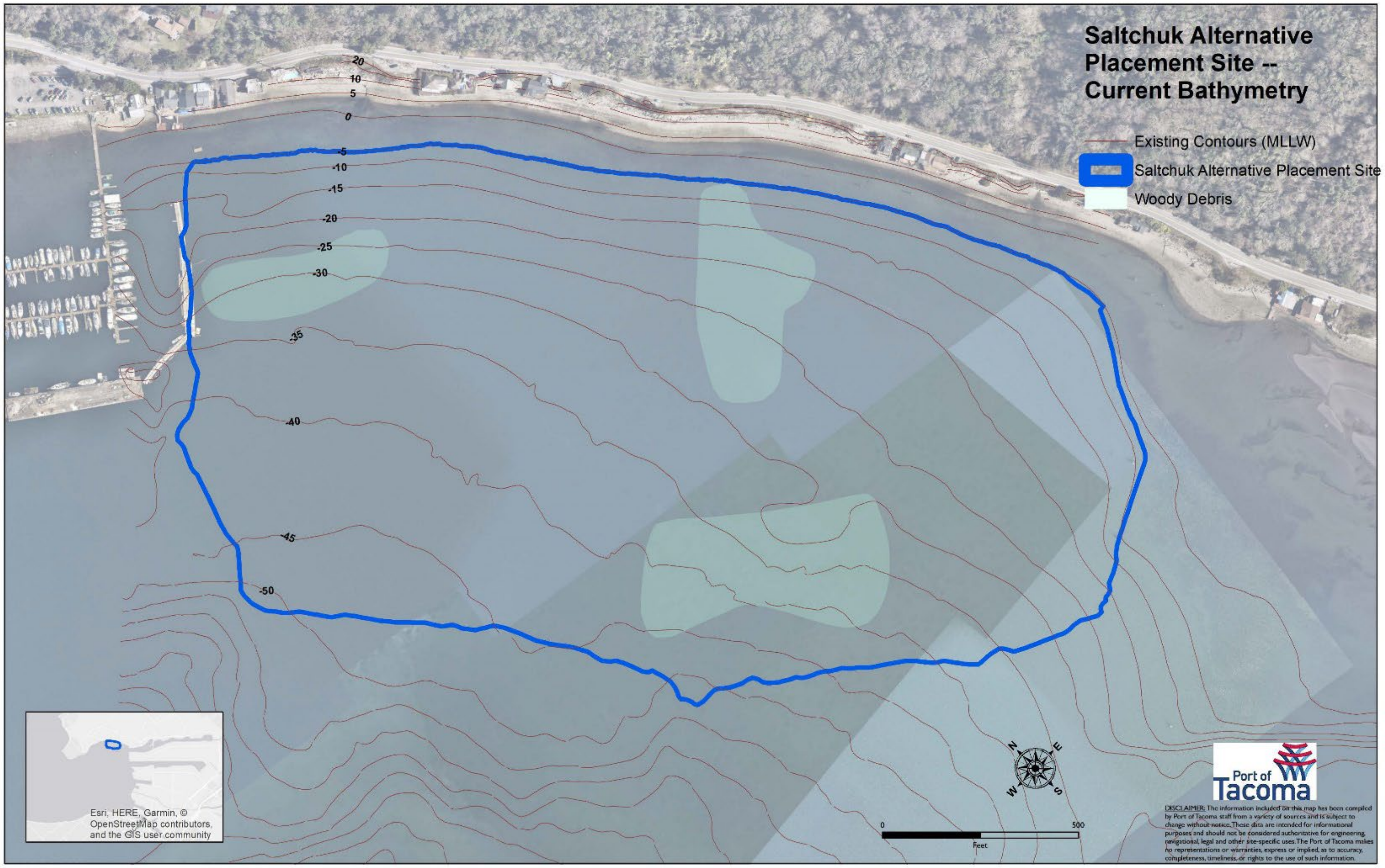

Figure 1. Saltchuk footprint within Commencement Bay with existing bathymetry and wood waste areas (Scenario A).

1.1 Existing Conditions

The proposed beneficial use site is referred to as Saltchuk and is located along the northeastern shoreline of Commencement Bay. Over approximately 120 years, almost all the natural habitat in Commencement Bay was lost to human development; prior to 1877, the main habitat types of Commencement Bay were 2,085 acres of intertidal mudflats and about 3,894 acres of salt/brackish marsh (USACE 1993). By 2015 there were 106 acres of mudflat habitat and 72 acres of saltwater marsh (Kerwin 1999; EarthCorps 2015). Existing conditions at Saltchuk were documented prior to 2015 by Leon 2014 and GeoEngineers 2014b, as cited in GeoEngineers 2015. No restoration projects have been implemented at Saltchuk, and it is assumed conditions have not changed significantly from the following description.

Lower Shore Zone (LSZ) habitat is composed of a substrate that transitions to sand and silt substrate near mean lower low water (MLLW). LSZ habitat includes significant amounts of wood waste, and one large area of wood waste starts at approximately MLLW. Based on previous wood waste studies, this wood waste concentration extends to a depth of approximately -30 MLLW. Macroalgae in the LSZ is largely composed of sea lettuce (*Ulva* spp.) at approximately the MLLW line. No eelgrass was observed within the project area; however, one patch of eelgrass was identified southeast of the project area at depths of approximately –6 feet to –10 MLLW during an underwater video survey conducted in August 2014.

The site contains approximately 60.7 acres of deeper critical habitat zone (DZ) habitat (below -10 MLLW). The majority of the DZ habitat at the site consists of brown and black silt with wood waste over gray clay. Wood waste has accumulated over approximately 100 years due to log storage at the Saltchuk site. Log storage is visible on a 1931 aerial photograph as well as all subsequent aerial photographs. Three primary locations within the log storage area were observed to contain large quantities of wood waste during a 1999 dive survey.

Macroalgae is present in areas of the DZ and generally consists of brown or red algae. Invertebrates were observed during the dive survey, including; polychaetes (unidentified species; only burrows observed), anemone (*Metridium senile*), sea stars (*Evasterias trochelii* and *Pisaster ochraceus*), red rock crab (*Cancer productus*), ghost shrimp (*Neotrypaea californiensis*), nudibranch (*Dirona albolineata*) and egg masses, and rosy octopus (*Octopus rubescens*; Leon 2014, as cited in GeoEngineers 2015). Ecology's Urban Bays monitoring program sampled the benthic community near Saltchuk at about -23 MLLW in 2014 and found 53% of the community was mollusks, and 45% was annelids; only 0.59% was arthropoda and 0.82% was Echinodermata (Weakland et al. 2016). At least 63 creosote-treated timber piles approximately 12 inches in diameter are present from -5 MLLW to -15 MLLW. These piles are no longer associated with structures and would be removed by the Port of Tacoma.

1.2 Proposed Action

Based on the project objectives listed above, the USACE worked with the Port of Tacoma to find a beneficial use site and an array of scenarios for beneficial use of dredged material in Commencement Bay. Through this process, USACE selected a recommended plan that includes the following measures:

Dredged material would be placed by bottom dump barge or via excavator to enhance deep subtidal habitat and create and enhance shallow subtidal habitat. A range of scenarios appear in Figure 2, including a minimum disposal scenario to build a bench to -20 ft MLLW (Scenario B), add benches to -10 ft MLLW (Scenario C) and -5 ft MLLW (Scenario D), and a full build-out (maximum disposal) to include island creation built on top of the benches (Scenario E; Figure 3). The full build-out, Scenario E, was chosen for implementation based on available material, habitat gain, and cost.

These proposed measures are the basis for this monitoring and adaptive management plan.

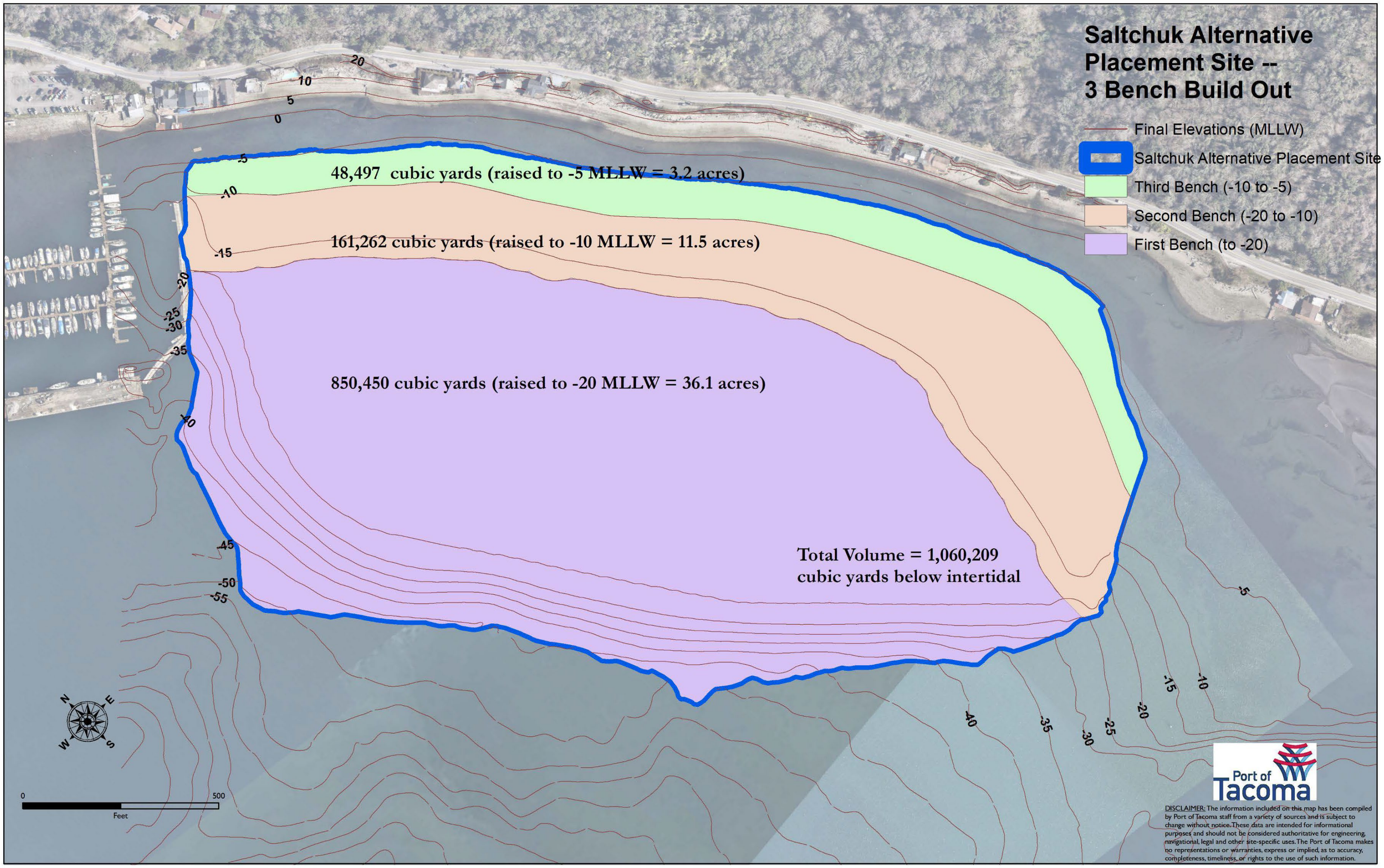

Figure 2. Proposed beneficial use of dredged material at Saltchuk. The first bench (to -20 MLLW) is Scenario B, the second bench (to -10 MLLW) is Scenario C, and the third bench (to -5 MLLW) is Scenario D.

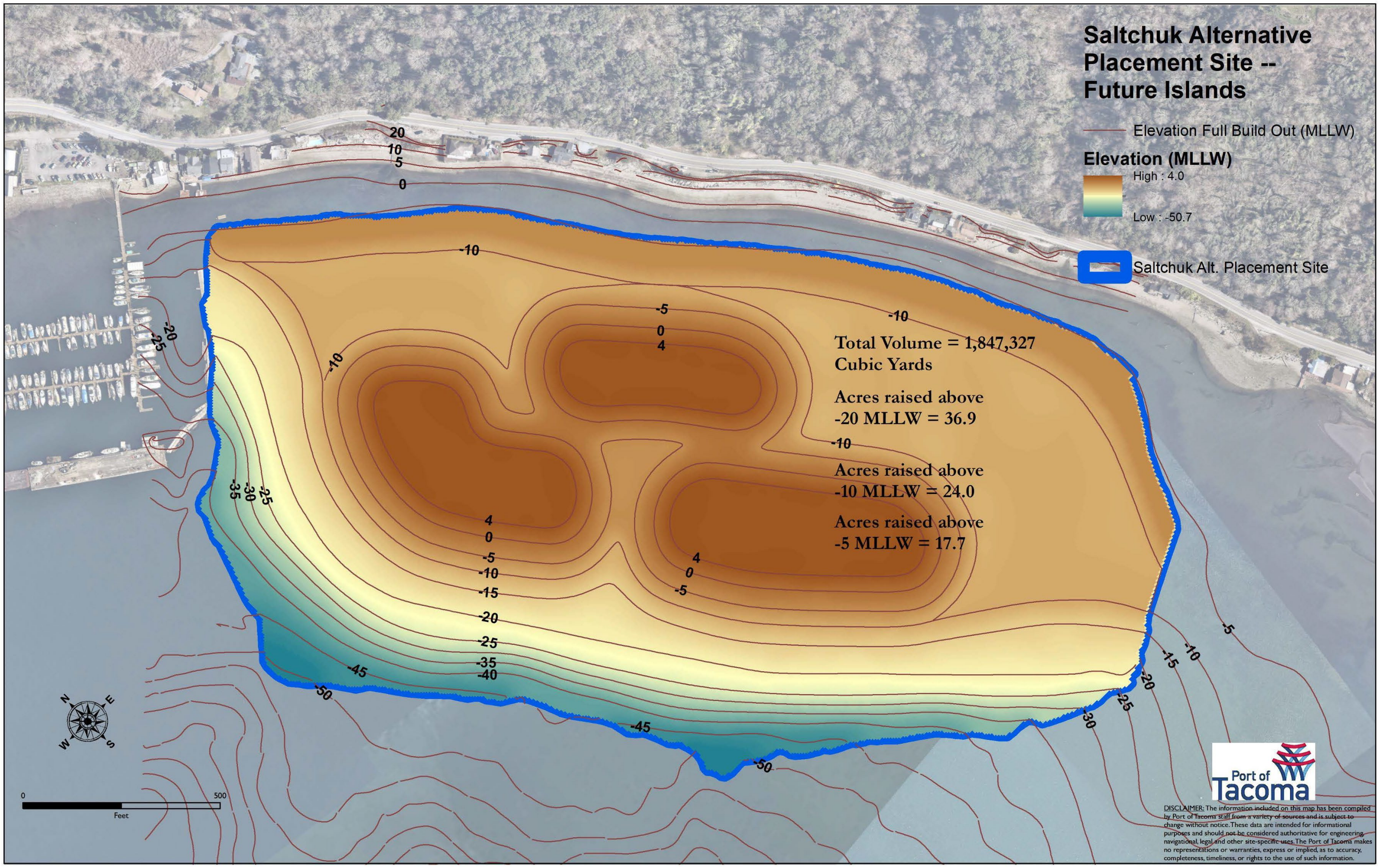

Figure 3. Full build-out of Saltchuk (Scenario E) has islands placed after the three benches (Scenarios B, C, and D) are constructed

1.3 Anticipated Benefits

The majority of the DZ habitat within the project area will be converted to LSZ. LSZ habitat will be extended waterward to replace up to approximately 40.9 acres of DZ habitat under the full build-out Scenario E (Figure 3). This habitat type provides the highest functional values in the NHV model.

Beneficial use of dredged material at Saltchuk will accomplish two goals: 1) the additional intertidal and shallow subtidal habitat will be created. Areas that remain as DZ habitat will be configured as a slope ranging from approximately -15 MLLW to -40 MLLW, and 2) wood waste will be capped with sediment. Proposed benefits within the DZ include decreasing bottom depth and capping existing wood waste, both of which may increase benthic production within this zone.

At full build-out, the shallow subtidal bench will start at approximately -10 MLLW and slope gradually up to approximately -6 MLLW across the bench. This is the observed elevation range of the eelgrass bed adjacent to the site to the east. Eelgrass may establish in this area naturally from the nearby eelgrass patch, or eelgrass could be artificially propagated through several methods, including transplanting and seeding. Increasing potential eelgrass habitat will increase potential spawning habitat for Pacific herring and create important nursery habitat for other marine species.

The target species of the proposed Saltchuk are Chinook salmon, steelhead (*O. mykiss*), and bull trout (*Salvelinus confluentus*), including their prey species such as forage fish and terrestrial and benthic invertebrates. In addition to improving habitat conditions for listed salmonids and their prey, the project will indirectly benefit additional listed species. Chinook salmon is the primary prey of ESA-listed Southern Resident Killer Whales (SRKW; *Orcinus orca*), while Pacific sand lance (*Ammodytes hexapterus*) and Pacific herring (*Clupea pallasii*) are the primary prey for ESA-listed marbled murrelets (*Brachyramphus marmoratus*). Although SRKW and marbled murrelets are not expected to occur within the project area, habitat enhancement for their prey species could increase prey populations and, in turn, increase dispersal and migration of these prey species into a suitable habitat for SRKW and murrelets. The benefits of the action would accrue to the ecosystem well beyond the project site.

1.4 Project Planning Objectives

The goal of beneficial use of dredged material at Saltchuk is to restore nearshore intertidal and subtidal habitat substrate conditions for several fish and wildlife species, including ESA-listed species. The target species to benefit from the proposed project include juvenile and adult Chinook salmon, steelhead, and bull trout. Restoration actions are based on improving habitat conditions for these species and their prey species, such as forage fish and epibenthic and benthic invertebrates. USACE formulated the following objectives to achieve the anticipated benefits listed above:

1. Provide shallow nearshore habitat for target species for the 50-year period of analysis.
2. Cover existing Saltchuk wood waste for the 50-year period of analysis.

2. USACE Guidance on Monitoring

Monitoring guidance for USACE projects was detailed in ER 1105-2-100 in 2000 (USACE 2000). Since then, the USACE issued Implementation Guidance for Section 2039 of WRDA 2007- Monitoring of Ecosystem Restoration (USACE 2009) that supersedes the 2000 guidance. The 2007 guidance states that a plan for monitoring ecological success must be included in the decision document must include the rationale for monitoring and must identify key project-specific parameters and how they relate to achieving the desired outcomes for making a decision about the next phase of the project. The guidance also states that the monitoring and adaptive management costs will be included in the project cost estimate and cost-shared accordingly, allowing for a monitoring period of up to, but not exceeding, ten years. The monitoring plan should also identify the criteria for success and when adaptive management is needed. In addition, Implementation Guidance for Section 1161 of the WRDA 2016, which amends Section 2039 of WRDA 2007, directs the Secretary to ensure that, when conducting a feasibility study for a project (or component of a project) for ecosystem restoration, the recommended project includes a plan for monitoring the success of the ecosystem restoration. It also requires the development of an adaptive management plan.

The level of detail in this plan is based on currently available data and information developed during plan formulation as part of the feasibility study. Uncertainties remain concerning the exact project features, monitoring elements, and adaptive management opportunities. Components of the plan, including costs, were similarly estimated using available information. Uncertainties will be addressed in the preconstruction, engineering, and design (PED) phase; this plan will be revised to incorporate more detailed monitoring and adaptive management plans and cost breakdowns.

3. Purpose of the Plan

As described in the previous section on USACE guidance, the purpose of this plan is to demonstrate the ecological success of the project. This success is determined by monitoring metrics that are specifically tied to project objectives and setting performance targets. In addition, the plan identifies what adaptive management is proposed if the performance targets are not met.

This plan presents the framework for the above methodology and will be refined in collaboration with the non-Federal sponsor, as well as other stakeholders who may take responsibility for monitoring ecological variables in the watershed.

4. Project Monitoring

As a beneficial use of dredged material project, it is expected that this site will be fairly static. The monitoring and evaluation will focus on determining whether the overall project objectives of the habitat creation are being met. Monitoring efforts will be performed by using monitoring metrics listed in section 5 (Evaluation of Specific Objectives). All post-construction monitoring will be performed by qualified biologists and hydraulic engineers.

Evaluating the beneficial use site will be based on the establishment of the targeted habitat within the restoration site and on the ecological functioning of those habitats. All post-construction monitoring will be cost shared between the USACE and the non-Federal sponsor for the first 10 years of monitoring. The non-Federal sponsor may choose to monitor beyond this ten-year period, although the cost would be a 100% non-Federal sponsor’s responsibility. Data collection will be used to determine the success of the project with the focus on the presence of the target habitat. The USACE and the non-Federal sponsors will use the knowledge gained through this monitoring to adaptively manage the project site.

The following section lists monitoring metrics, performance targets, and potential adaptive management associated with the effectiveness monitoring, which aims to demonstrate how well the habitat is developing according to performance criteria.

5. Evaluation of Specific Objectives

The monitoring metrics listed below are grouped by the project objectives listed in section 1.4.

5.1 Evaluation of Objective 1

Provide LSZ and DZ nearshore habitat as designed in Scenario E for target species for the 50-year period of analysis.

Monitoring Metric 1: Nearshore depths

Methods and Timing: Conduct a bathymetric survey of Saltchuk annually. This parameter will be monitored in years 1, 5, and 10 after construction to verify project success and evaluate the movement of dredged material. Monitoring intervals were chosen based on preliminary sediment transport modelling, which suggested movement of dredged material would occur immediately (year 1) and incorporates mid-range and final verification of depths at years 5 and 10.

Performance Target: Depth, according to the habitat zones (LSZ and DZ) is the metric for this performance target. Shallow water along natural shorelines in the upper shore zone provides refuge from predators and a migratory corridor. Chinook salmon smolts use the shallow nearshore to avoid predation by piscivorous predators, such as staghorn sculpin and larger salmon. Willette (2001) found that juvenile pink salmon in Prince William Sound leave the shallow nearshore zone when the biomass of large copepods, their food, declined. With the juvenile pink salmon foraging in deeper water, the mean daily individual predator consumption of salmon increased by a factor of five.

Feeding habitats of juvenile salmon shift from the epibenthic zones to neritic (zooplankton) prey during downstream migration yet focus primarily on shallow-water habitats (Hiss and Boomer 1986). Juvenile Chinook, chum, and coho salmon in Commencement Bay feed primarily on epibenthic invertebrates such as copepods, amphipods, and aquatic insect larval and pupal stages (Meyer et al. 1981). Stomach contents of Chinook salmon less than 90 mm collected east of Saltchuk were primarily planktonic-neritic and marine benthic-epibenthic species, while fish greater than 90 mm fed mostly on marine planktonic-neritic prey species (Olson et al. 2008). The juvenile salmon transition from epibenthic prey to pelagic prey (such as aquatic insects, chironomids, and planktonic prey) with growth (Meyer et al. 1981; Simenstad 2000).

Adaptive Management: If target depths according to the Scenario E design for Saltchuk are not maintained, then additional sediment or a modified engineered design may need to be added to retain shallow depths. The metric will be met if depths are within the LSZ (+5 to -10 MLLW) and DZ (below -10 MLLW) boundaries of the Scenario E design for Saltchuk.

5.2 Evaluation of Objective 2

Cover existing Saltchuk wood waste for the 50-year period of analysis.

Monitoring Metric 2: Wood waste coverage

Methods and timing: Conduct a remotely operated vehicle (ROV) survey of Saltchuk annually. This parameter will be monitored in years 3, 5, and 10 after construction to verify project success and evaluate the movement of dredged material. Monitoring intervals were chosen based on expected time for the LSZ and DZ to be fully functioning and to align with depth monitoring.

Performance Target: The amount of wood waste that remains covered will be used for this metric because excess wood waste can be detrimental to the benthic environment. Ecology (2013) describes three main issues that excess wood waste can have on the benthic environment: 1) the physical presence of wood waste, which prevents biota from thriving and recruiting in and on the native, healthy substrate; 2) decreased dissolved oxygen due to microbial decomposition, which can create an unhealthy or toxic environment for biota, and; 3) decomposition by-products such as sulfides, ammonia, and phenols, which can cause or contribute to toxicity. Capping the wood waste with native material may initially harm habitat during early consolidation because any infauna and epifauna would be exposed to the pore water forced upwards from the wood waste below. Depending on the nature of the capping material and the wood waste being capped, this may be a transient, short-lived effect. Approximately eight acres (13%) of the 64-acre Saltchuk site are covered in wood waste.

Placement of clean sediment over the wood debris will improve habitat conditions for benthic invertebrates. The epibenthic invertebrate community at the surface of the substrate is mostly copepods and amphipods that feed on detritus and/or plants (Dames and Moore 1981). Juvenile Chinook, chum (Oncorhynchus keta), and coho salmon (O. kisutch) in the Commencement Bay estuary feed primarily on epibenthic invertebrates such as copepods, amphipods, and aquatic insect larval and pupal stages; they transition from epibenthic prey to pelagic prey (such as aquatic insects, chironomids, and planktonic prey) with growth (Meyer et al. 1981; Simenstad 2000). Log storage was discontinued to remove the input source for wood waste impacts to the benthic environment.

Several studies have demonstrated that benthic organisms rapidly recolonize habitats disturbed by dredging and dredged materials placement and return these habitats to reference conditions (Wilber and Clarke 2007; Ponti et al. 2009). Recovery begins with the early colonizers and takes less than a year for the short-lived organisms with rapid growth and re-population strategies; this is followed by the longer-lived species that grow larger but have a slower recovery time of two to three years (Newell et al. 1998; Desprez 2000).

Adaptive Management: If target depths according to the Scenario E design for Saltchuk are not maintained, the cause of sediment migration should be established. Potential solutions to retain shallow depths may be additional sediment or a modified engineered design. The metric will be met if depths are within the LSZ (+5 to -10 MLLW) and DZ (below -10 MLLW) boundaries of the Scenario E design for Saltchuk, without exposed wood waste.

5.3 Evaluation of Objective 3

Monitoring Metric 3: Submerged Aquatic Vegetation (SAV)

Methods and timing: Conduct ROV surveys of Saltchuk. This parameter will be monitored in years 3, 5, and 10 after construction to verify project success and evaluate the recruitment of SAV. The Corps chose monitoring intervals based on expected time for the LSZ and DZ to be fully functioning and to align with depth monitoring.

Performance Target: Juvenile salmon preferentially select eelgrass (Simenstad 2000; Johnson et al. 2010) and kelp (Johnson et al. 2010), and there is a correlation between salmon abundance and cover density. The preferentially selected eelgrass and kelp habitats provided more cover and vegetative biomass than the habitats (filamentous green algae, non-vegetated habitat) with less salmonid abundance. NMFS uses these studies that show a preference of juvenile salmon for some macroalgae that provide abundant structure to formulate a working hypothesis for the NHV model. The assumption underlying the quantification of SAV value in the NHV model is that the more structure native aquatic macrophytes provide, the higher is its value to juvenile Puget Sound Chinook salmon.

A project goal is to create habitat elevations that will support eelgrass and other macroalgae; however, eelgrass was not historically widespread in Commencement Bay, likely due to the high sediment loads from the Puyallup River (Kerwin 1999). SAV presence will depend on the recruitment of nearby eelgrass and macroalgae.

Adaptive Management: Monitoring results should be used to assess the underlying cause of inadequate cover, which may require that additional adaptive management actions be implemented to support successful vegetation recruitment. For example, scouring may prevent the successful establishment of vegetative communities.

Contingency measures (adaptive management) will be implemented if the monitoring program (or any other documented observations by qualified personnel) indicates performance targets are not being met and cannot be explained by extraneous variables. The USACE and the non-Federal sponsor would then assess monitoring metric parameters and initiate the implementation of corrective actions to address the identified issue. Monitoring and adaptive management activities in this plan will be refined in the preconstruction, engineering, and design phase. Additional metrics, methods, performance targets, and adaptive management measures may be added if needs are identified. The overall timeline for meeting performance targets is 10 years after construction. This is estimated to be ample time to determine ecological success through the measurement of the physical and biological parameters outlined in this monitoring and adaptive management plan.

6. Cost

The following table summarizes a total cost estimate for the monitoring efforts in this plan.

Table 1. Estimated cost of monitoring effort for the Tacoma Harbor GI

Type of Monitoring	Monitoring Metric	Time frame	Total Cost
Bathymetric Survey	MM1: Nearshore depths	Years 1, 5, 10.	$142,000
ROV	MM2: Wood waste coverage MM3: SAV coverage	Years 3, 5, 10. Years 3, 5, 10.	

7. Literature Cited

Dames and Moore. 1981. Baseline Studies and Evaluations for Commencement Bay Study/Environmental Impact Statement. Volume I Summary and Synthesis. Prepared for U.S. Army Corps of Engineers, Seattle District. Contract No. DACW67-80-C-0101. December 1981.

Desprez, M. 2000. Physical and Biological Impact of Marine Aggregate Extraction along the French Coast of the Eastern English Channel: Short and Long-term Post-dredging Restoration. ICES J. Mar. Sci., 57:1428-1438.

EarthCorps. 2015. Commencement Bay Stewardship Collaborative: Ecosystem Management Plan. NRDA Trust resources, Stewardship Framework and General Management Approach. May 12, 2015. Seattle, Washington.

Ecology (Washington State Department of Ecology). 2013. Wood Waste Cleanup: Identifying, Assessing, and Remediatinog Wood Waste in Marine and Freshwater Environments. Guidance for Implementing the Cleanup Provisions of the Sediment Management Standards, Chapter 173-204 WAC. Publication No. 09-09-044. September 2013.

Ehinger, S.I., J. P. Fisher, R. McIntosh, D. Molenaar and J. Walters. 2015. Working Draft, April 2015: Use of The Puget Sound Nearshore Habitat Values Model with Habitat Equivalency Analysis for Characterizing Impacts and Avoidance Measures for Projects that Adversely Affect Critical Habitat of ESA-Listed Chinook and Chum Salmon.

GeoEngineers. 2015. 30 Percent Basis of Design Report Saltchuk Aquatic Mitigation Site—Phase A. For Port of Tacoma. Tacoma, Washington. May 2015.

Hiss, J.M. and R.S. Boomer. 1989. Feeding Ecology of Juvenile Pacific Salmonids in Estuaries: a Review of the Recent Literature. Fisheries Assistance Office, U.S. Fish and wildlife Service. Olympia, Washington. October 1986.

Johnson, S.W., J.F. Thedinga, A. Neff, P.M. Harris, M.R. Lindeberg, J.M. Maselko, and S.D. Rice. 2010. Fish Assemblages in Nearshore Habitats of Prince William Sound, Alaska. Northwest Sci. 84:266-280.

Kerwin, J. 1999. Salmon Habitat Limiting Factors Report for the Puyallup River Basin (Water Resource Inventory Area 10). Washington Conservation Commission. July 1999. Olympia, Washington.

Meyer, J.H., T.A. Pearce, R.S. Boomer. 1981. An Examination of the Food Habits of Juvenile Chum and Chinook Salmon in Hylebos Waterway. U.S. Department of the Interior, Fisheries Assistance Office. U.S. Fish and Wildlife Service. Olympia, Washington. July, 1981.

NMFS (National Marine Fisheries Service). 2015. Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion, Section 7(a)(2) "Not Likely to Adversely Affect" Determination, Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Consultation, and Fish and

Wildlife Coordination Act Recommendations for Continued Use of Multi-User Dredged Material Disposal Sites in Puget Sound and Grays Harbor. WCR-2015-2975. December 2015.

Olson, O.P., L. Johnson, G. Ylitalo, C. Rice, J. Cordell, T.K. Collier, and J. Steger. 2008. Fish Habitat Use and Chemical Contaminant Exposure at Restoration Sites in Commencement Bay, Washington. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-88.

Ponti, M., A. Pasteris, R. Guerra, and M. Abbiati. 2009. Impacts of Maintenance Channel Dredging in a Northern Adriatic Coastal Lagoon II: Effects on Macrobenthic Assemblages in Channels and Ponds. Estuarine, Coastal and Shelf Science 85(2009): 143-150.

SAIC (Science Applications International Corporation). 2009. Reauthorization of Dredged Material Management Program Disposal Site Commencement Bay, Washington Supplemental Environmental Impact Statement. Prepared for the Dredged Material Management Program Agencies. Bothell, Washington. August 2009.

Simenstad, C.A. 2000. Commencement Bay aquatic Ecosystem Assessment: Ecosystem-Scale Restoration for Juvenile Salmon Recovery. University of Washington School of Fisheries. Seattle, Washington. May 2000.

USACE (U.S. Army Corps of Engineers). 1993. Commencement Bay Cumulative Impact Study. Vol. I Assessment of Impacts. May/June 1993.

USACE. 2009. Implementation Guidance for Section 2039 of WRDA 2007- Monitoring of Ecosystem Restoration (WRDA 2007)-Monitoring Ecosystem Restoration. August 2009. Available online: https://usace.contentdm.oclc.org/digital/collection/p16021coll11/id/2925/.

Weakland, S., V. Partridge, and M. Dutch. 2016. Urban Bays Monitoring 2014: Sediment Quality in Commencement Bay, Tacoma WA. Available online: https://fortress.wa.gov/ecy/publications/SummaryPages/1603011.html.

Wilber, D.H. and D.G. Clarke. 2007. Defining and Assessing Benthic Recovery Following Dredging and Dredged Material Disposal. Proceedings XXVII World Dredging Congress 2007:603-618.

Willette, T.M. 2001. Foraging behavior of juvenile pink salmon (*Oncorhynchus gorbuscha*) and size-dependent predation risk. Fisheries Oceanography 10 (Supplement 1):110-131.