Agreed Order Task 4e Deliverable
Interim Action Report Volume III: Alternatives Evaluation

Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

Prepared for
Rayonier A.M. Properties LLC

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FINAL

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REVISION RECORD

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Acronyms and Abbreviations

Acronym	Definition
°C	degree Celsius
ARAR	applicable or relevant and appropriate requirement
AST	aboveground storage tank
ATSDR	Agency for Toxic Substances and Disease Registry
BAZ	biologically active zone
bgs	below ground surface
BMP	best management practice
CAP	cleanup action plan
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm	centimeter
CPC	contaminants of concern
COPC	constituent of potential concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CSL	cleanup screening level
CSM	conceptual site model
CSO	combined sewer overflow
cy	cubic yard
DCA	disproportionate cost analysis
DMMP	Dredged Material Management Program
DNR	Washington State Department of Natural Resources
Ecology	Washington State Department of Ecology
ENR	enhanced natural recovery
EPA	United States Environmental Protection Agency
ERA	ecological risk assessment
ERH	electrical resistivity heating
ESI	Expanded Site Inspection
FS	feasibility study
FUA	functional use area
GRA	general response action
HEAST	Health Effects Assessment Summary Tables
HHRA	human health risk assessment
HI	hazard index
HPAH	high-molecular-weight PAH

Acronym	Definition
HQ	hazard quotient
IAO	interim action objective
IC	institutional control
IDW	inverse distance weighted
IHS	indicator hazardous substance
IRIS	Integrated Risk Information System
ISCF	in-situ chemical fixation
ISCO	in-situ chemical oxidation
kg	kilogram
LDW	Lower Duwamish Waterway
LOAEL	lowest-observed-adverse-effect level
LPAH	low-molecular-weight PAH
m	meter
µg	microgram
Marine Order	Agreed Order No. DE 02SWFAPSR-4570
mm	millimeter
MNA	monitored natural attenuation
MNR	monitored natural recovery
MTCA	Model Toxics Control Act
NCP	National Contingency Plan
NOAEL	no-observed-adverse-effect level
NRD	natural resource damage
Order	Agreed Order DE 6815
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCUL	preliminary cleanup level
PLP	potentially liable party
POC	point of compliance
POTW	publicly-owned treatment works
PPRTV	Provisional Peer Reviewed Toxicity Value
PQL	practical quantitation limit
PRB	permeable reactive barrier
RBC	risk-based concentration
RCW	Revised Code of Washington
RCRA	Resource Conservation and Recovery Act

Acronym	Definition
REL	remediation level
RfD	reference dose
RFH	radio frequency heating
RI	remedial investigation
RL	reporting limit
RME	reasonable maximum exposure
S/S	solidification/stabilization
SAP	sampling and analysis plan
SCO	sediment cleanup objective
SCU	sediment cleanup unit
SF	slope factor
Site	Rayonier mill site
SMA	sediment management area
SMP	Shoreline Master Program
SMS	Washington State Sediment Management Standards
SQS	sediment quality standard
SRS	sediment remediation subarea
SRZ	sediment recovery zone
SSL	spent sulfite liquor
SVE	soil vapor extraction
SVOC	semivolatile organic compound
SWAC	spatially weighted average concentration
SWAN	Simulating Waves Nearshore
TEF	toxic equivalency factor
TEQ	toxic equivalent
TPH	total petroleum hydrocarbons
Trustees	Natural Resource Trustees
TRV	toxicity reference value
Uplands Order	Agreed Order No. DE 04SWFAPSR-6025
UTL	upper tolerance limit
VOC	volatile organic compound
WAC	Washington Administrative Code

1 INTRODUCTION

The former Rayonier mill site (Site) is located on the eastern side of Port Angeles Harbor in Clallam County, Washington. The Site is largely within the limits of the city of Port Angeles on the north side of the Olympic Peninsula on the shoreline of the Strait of Juan de Fuca (Figure 1-1).

Corporate predecessors of Rayonier A.M. Properties LLC (the company[1]), owned and operated a dissolving sulfite pulp mill on a portion of the Site from 1930 until early 1997, when the company closed the mill and dismantled the mill buildings. During its operation, the mill stacks, machinery used at the mill Site, the mill wastewater outfalls, and the log storage pond released hazardous substances.

In 1997 and 1998, the U.S. Environmental Protection Agency (EPA) conducted an Expanded Site Inspection (ESI) at the Site. EPA's ESI report identified areas of marine sediment, soil, and groundwater contamination that exceed applicable state criteria for the protection of human health and the environment on the Site. Hazardous substances identified during the ESI at levels above applicable State of Washington criteria include dioxins/furans, carcinogenic polycyclic aromatic hydrocarbons (cPAHs), polychlorinated biphenyls (PCBs), and metals.

In 2002, the company and the Washington State Department of Ecology (Ecology) entered into Agreed Order No. DE 02SWFAPSR-4570 (Marine Order) under which the company agreed to conduct remedial investigation (RI) activities. In 2004, the company and Ecology entered into Agreed Order No. DE 04SWFAPSR-6025 (Uplands Order) under which the company agreed to conduct additional RI and feasibility study (FS) activities. In addition to the 2002 Marine Order and 2004 Uplands Order, there have been other enforcement and agreed orders for interim actions on the Site. In 2010, Rayonier and Ecology entered into Agreed Order No. DE 6815 (Order) to complete the first four volumes of an Interim Action Report, which will assist Ecology in developing an Interim Action Plan to address groundwater, freshwater and marine sediments, and upland soils at a Study Area within the Site (Ecology 2010). The Order supersedes all previous orders.

The purpose of this document is to present the evaluation of a range of alternatives for remediation of contaminated sediment, soil, and groundwater for both the upland and marine environment in the Study Area of the former Rayonier mill in Port Angeles, Washington, as required by the Order. This Interim Action Alternatives Evaluation Report Volume III has been prepared in accordance with the requirements of the Washington State Model Toxics Control Act (MTCA) cleanup regulations (Washington Administrative Code [WAC] 173-340, Ecology 2013a) and the Sediment Management Standards (SMS) (WAC 173-240, Ecology 2013b) administered by Ecology for the former Rayonier mill Site. The Site Study Area includes an Upland Study Area and a Marine Study Area (Figure 1-1).

This document was prepared by Tetra Tech with assistance from Windward Environmental and Integral Consulting. Also, please note that this document makes use of evaluations and documentation prepared by GeoEngineers for the Agency Review Draft of this Volume III report.

[1] Rayonier A.M. Properties LLC (formerly known as Rayonier Properties LLC) is the current owner of the property and is responsible for the project. In this document, "company" refers to Rayonier A.M. Properties LLC and its corporate predecessors.

1.1. PURPOSE AND SCOPE

The purpose of this Interim Action Report Volume III is to develop and evaluate remedial alternatives for the Study Area, including both the upland and marine environments, which will enable interim actions to be selected for the upland and marine portions of the Study Area. To meet the requirements of WAC 173-340-350 through 370 for the Study Area, Volume III accomplishes the following:

(1) Identification of applicable local, state, and federal requirements (i.e. applicable or relevant and appropriate requirements: ARARs);

(2) Definition of the preliminary cleanup standards for the Study Area;

(3) Development of interim action alternatives; and

(4) Detailed evaluation of the interim action alternatives for the Study Area in accordance with the requirements of WAC 173-340-360.

1.2. PRINCIPAL OBJECTIVES

An important factor in the selection and evaluation of remediation alternatives is the planned use of the upland property post-remediation because land use plans can affect exposure pathways, appropriate remediation levels, final site configuration, and potential institutional controls. There may also be opportunities to coordinate future construction with remediation and restoration in ways that allow for a more cost-effective and efficient project.

Residential use is not a foreseeable future use of this property. Most of the property is zoned "Industrial-Heavy" (Figure 1-2) in the City of Port Angeles zoning ordinance (Ordinance #2801) and has been used for industrial activities for many decades. The company is the primary property owner and is willing to place appropriate institutional controls on the property to ensure future land uses are compatible with the implemented remediation and restoration activities. A portion of the upland property (the City Purchase Area) has been sold to the City of Port Angeles and is being used for a wastewater treatment facility. The northernmost portion of the property is being leased from the State of Washington.

Portions of the upland property (e.g., along Ennis Creek) will be restored to provide substantial ecological benefits. Realistic and conservative human-exposure scenarios for the entire property will be used to establish appropriate cleanup levels and remediation levels. Unrestricted-use exposure assumptions (e.g., residential habitation for 365 days per year for all of adolescence) are inappropriate for use throughout the Upland Study Area. Nevertheless, as a starting point, unrestricted-use assumptions are used to derive conservative preliminary cleanup levels (PCULs). Then remediation levels appropriate for more reasonable exposure scenarios – such as occasional trespassing or visitation of open areas – are derived for use in defining some upland soil remedial alternatives. Industrial use is assumed when setting PCULs for human exposures in areas zoned "Industrial-Heavy" that continue to be used as industrial areas (i.e. the City Purchase Area).

The company is engaged in discussions with the Natural Resource Trustees (Trustees) to resolve any potential natural resource damage (NRD) claims. Settlement of the NRD claims could involve undertaking restoration activities within the Study Area that are independent of MTCA cleanup. However, Ecology, the company, and the Trustees recognize that there are often benefits to conducting restoration and remediation activities simultaneously. Therefore, the alternatives presented in this document provide for MTCA-compliant cleanup actions that assume future restoration actions. The Ennis Creek restoration project is premised upon reaching an NRD settlement with the Trustees under the Comprehensive Environmental

Response, Compensation, and Liability Act (CERCLA). The Ennis Creek estuary restoration project is shown conceptually in Figure 1-3.

The company recognizes that the Port Angeles Shoreline Master Plan includes a 200-foot-wide “open-space” future land use buffer area along the shoreline. In this context, human exposures in the open-space areas will include occasional visitors but not full-time residents. Note that the company reserves the right to place institutional controls on property it owns in order to achieve limited human access, regardless of designated future land uses in master planning documents.

The company also has certain obligations under DNR Aquatic Lands Lease No. 22-002356 for the dock, jetty, and other fill that is located on the Washington State Department of Natural Resources (DNR) leasehold and has initiated discussions with DNR about the removal of the dock and jetty and restoration of the shoreline. As shown in Figure 1-3, the company anticipates that marine structures (i.e., the dock and jetty) would be removed and the shoreline east of Ennis Creek would be stabilized based on results of the final shoreline engineering design.

The depiction of the future use in Figure 1-3 is conceptual and intended to facilitate the MTCA alternatives evaluation. It is not based on any specific agreement between the company and the DNR or Trustees.

1.3. REPORT ORGANIZATION

Following this introductory section, the remainder of this document is organized into the following sections:

- Section 2 – Site Background and Environmental Setting
- Section 3 – Interim Action Objectives
- Section 4 – Identification and Screening of Remedial Technologies
- Section 5 – Development of Alternatives
- Section 6 – Detailed Evaluation of Alternatives
- Section 7 – Recommended Interim Action
- Section 8 – References

2 SITE BACKGROUND AND ENVIRONMENTAL SETTING

The Site is located on the eastern side of Port Angeles Harbor in Clallam County, Washington (Figure 1-1). The only highway to Port Angeles is Highway 101; there is no active rail service. Resources such as landfills that can accept contaminated soil are located at some distance from the site (e.g., in Arlington, Oregon, approximately 350 miles away).

Most of the Site is located within the Port Angeles city limits, in an area of mixed industrial, commercial, recreational, and residential land uses. Most of the site is zoned heavy industrial (Figure 1-2). The area associated with the steep bluffs and ravine along the southern margin of the site is zoned for public buildings and parks.

The Study Area (approximately 1,405 acres) consists of an Upland Study Area and a Marine Study Area (Figure 1-1). The Upland Study Area comprises approximately 93 ac of terrestrial land, some of which is owned by the company, some by the City of Port Angeles, and some by the State of Washington. The State-owned land is managed by the Department of Natural Resources (DNR). The Marine Study Area is in the southeastern part of Port Angeles Harbor and includes a portion of the Strait of Juan de Fuca immediately east of Port Angeles Harbor. The Marine Study Area was defined in the Order (Ecology 2010). It comprises approximately 1,312 acres of aquatic land and is owned by the State of Washington. In-water structures within the Study Area include a jetty (enclosing a portion of the former log pond) and the former mill dock, which extends into the harbor.

2.1. SITE HISTORY

Prior to the arrival of Europeans in the late 1850s, the Port Angeles area was home to the Lower Elwha Klallam Tribe (Wegmann et al. 2010). The arrival of the Puget Sound Co-Operative Colony in 1887 initiated one of the earliest periods of population growth in Port Angeles. The colony was established on the western bank of Ennis Creek, next to the I'e'nis village, and was home to nearly 400 people at its peak.

In 1917, the United States Government Spruce Production Corporation constructed a spruce saw mill to support aircraft construction during World War I. A large portion of the saw mill was constructed on pilings. The saw mill was never operated and sat idle until Olympic Forest Products purchased it in 1929. From 1929 to 1930, the spruce mill was renovated, and a pulp mill was constructed. The pulp mill was operated by Olympic Forest Products from 1930 to 1937. In 1937, Olympic Forest Products merged with two other independent Olympic Peninsula companies to form Rayonier Inc. Mill ownership shifted to ITT Rayonier Inc. between 1968 and 1994, after which it returned to Rayonier Inc. Rayonier Inc. permanently ceased pulp production at the mill in 1997 and dismantled the mill facilities between 1997 and 1999. The mill decommissioning was completed by October 1999.

2.2. CULTURAL FEATURES

There are known historic and prehistoric cultural archaeological resources located on and near the Rayonier property (Figure 2-1). The I'e'nis village was located on the eastern bank of the Ennis Creek. These areas will receive additional attention – including the presence of a monitor – during any excavation or disturbance. This represents a special site condition that may limit some remediation alternatives.

2.3. SITE PHYSICAL FEATURES

The present-day conditions within the Study Area are shown in Figure 2-2. The upland area contains remnant building foundations and support pilings. Soil from the excavation of a trench to accommodate City of Port Angeles sewer pipes is stockpiled in the West Mill Area (west of Ennis Creek) and in the East Mill Area (east of Ennis Creek). Much of the West Mill Area is covered with several feet of crushed concrete that was left onsite after demolition of the above-ground mill structures. The mill property is bounded on the south by high, tree-covered bluffs that rise to a plateau above the property. The mill property is mostly flat between the bluffs and Port Angeles Harbor to the north (Figure 2-3). Residential and commercial properties, including Olympic Memorial Hospital, are located on the plateau to the south of the mill property. Ennis Creek flows from the Olympic Mountains through the Upland Study Area, and discharges into Port Angeles Harbor.

The majority of the Upland Study Area is vacant. The Olympic Discovery Trail, a pedestrian pathway constructed along the former Seattle and North Coast Railroad right-of-way, is located at the foot of the bluff in the southern portion of the Upland Study Area (Figure 2-3). The trail is located on an access easement granted to the City of Port Angeles by the company. The pedestrian pathway is separated from the majority of the Upland Study Area by a fence; it includes a bridge that crosses Ennis Creek near the northeastern corner of the former mill parking lot. A municipal wastewater treatment plant owned by the City of Port Angeles is located east of, and adjacent to, the southern portion of the Upland Study Area. In 2011, the City purchased a portion of the Upland Study Area immediately northwest of the wastewater treatment plant. The parcels comprising the purchased property are referred to as the City Purchase Area. An easement for a new city sewer pipeline that connects to the City's wastewater treatment system was granted to the City by the company.

The Marine Study Area includes a dock and a jetty. The dock extends north into Port Angeles Harbor. The jetty is constructed of rock, pilings, and timbers and extends to the northwest into the harbor from the northwestern corner of the property. The peninsula extending northwest from the Upland Study Area to the jetty is considered to be part of the jetty in this report.

2.3.1. Upland Study Area

The Upland Study Area was divided into eleven functional use areas (FUAs) in the Volume I Report (GeoEngineers 2012a). For the purpose of developing preliminary cleanup standards, these FUAs have been grouped into five larger areas based on past and anticipated future land use and current site conditions. These five areas are referred to in this document as "land use areas" to distinguish them from the FUAs defined in the Volume I Report (GeoEngineers 2012a). The five land use areas include the West Mill, East Mill, City Purchase, Ennis Creek, and Marine Bluffs Areas (Figure 2-4).

A zoning map for the Upland Study Area is shown on Figure 1-2. The majority of the Upland Study Area is currently zoned Heavy Industrial. Areas south of the footprint of historical industrial activities are zoned for non-industrial uses. The largest of these is zoned Public Buildings and Parks and encompasses portions of the Ennis Creek, Marine Bluffs, and City Purchase Areas. Smaller portions of the Upland Study Area are zoned Light Industrial, Commercial Arterial, and Residential Single Family.

A Shoreline Master Program (SMP) has been developed for the City of Port Angeles and surrounding areas. This SMP designates the Site area within 200 feet of the shoreline west of Ennis Creek as being within a segment of "high-intensity mixed-use environment." East of Ennis Creek, the shoreline area is designated as "urban conservancy – recreation environment." These designations complement, but do not supersede, zoning designations. Any future development in the shoreline segments must consider the restrictions and goals specified for the SMP segments.

The land use and current conditions of the West Mill, East Mill, City Purchase, Ennis Creek, and Marine Bluffs Areas are described in more detail in the following subsections.

2.3.1.1. West Mill Area

Most of the historical heavy manufacturing operations occurred in the West Mill Area. The digesters, acid plant, bleach plant, powerhouse, machine and maintenance shops, wood mill, auto and paint shops, sludge building, boilers, and two large fuel oil aboveground storage tanks (ASTs) were in this area. Since 1999, when the mill decommissioning was completed, the property has remained a vacant, former industrial site with restricted access. The West Mill Area is zoned Heavy Industrial (Figure 1-2).

The present-day character of the West Mill Area reflects its historical industrial use. Most of the former mill structures in this area have been demolished and either removed or used as a source of concrete rubble to stabilize shallow soil. Much of the ground surface consists of a mixture of pavement and concrete rubble and is generally barren to semi-vegetated and devoid of topsoil. There are many subsurface structures present, including concrete footers and wood pilings.

The West Mill Area currently has limited habitat value due to the relic structures and debris present on the ground surface and use of the property by wildlife is limited. Similarly, use of the property by humans is limited. Currently, access to the fenced mill property is restricted to temporary construction workers and visitors who are aware of the potential risks associated with the property and take appropriate precautions. Trespassers may occasionally gain unauthorized access to the property. Restoration activities in the West Mill Area may improve the habitat value of this property.

2.3.1.2. East Mill Area

Support operations for the main pulp manufacturing activities (in the West Mill Area) took place in the East Mill Area. Major facilities in the East Mill Area included the primary wastewater clarifier, the spent sulfite liquor (SSL) lagoon, the chlorine dioxide generator, and the PreFab area. The portion of the East Mill Area within the City of Port Angeles is zoned Heavy Industrial (Figure 1-2). The easternmost part of the East Mill Area is outside the City limits and is in the Open Space zone, which is an overlay of the Urban Very Low Density zone in Clallam County (Clallam County Code, Title 33).

Most of the former mill structures in the East Mill Area have been demolished and removed. The ground surface in the western portion of this area consists of a combination of gravel, pavement, foundations, and grass. In addition to the remnant surface structures, there are subsurface structure remnants, including concrete footers and wood pilings.

The majority of the East Mill Area currently has limited habitat value. However, native grasses and dunes support ecological functions in the eastern and shoreline portions of this area. These grasses and dunes constitute high-quality habitat. Like the West Mill Area, access to the East Mill Area by humans is currently limited to temporary construction workers and visitors, as well as occasional/infrequent trespassers. Restoration activities in the East Mill Area may improve the habitat value of this property.

2.3.1.3. City Purchase Area

The City Purchase Area refers to the 12.6-acre property purchased by the City from the company in November 2010. The area is mostly flat and includes a 5-million-gallon AST, small buildings, and areas covered by gravel, foundations, and pavement. The City is using this area and the AST to improve and expand the City's publicly owned treatment works (POTW). The northern portion of the City Purchase Area is zoned Heavy Industrial; the southern portion is zoned Public Buildings and Parks (Figure 1-2).

The City Purchase Area currently has little habitat value due to its industrial character and use of the property by wildlife is limited. Access to the property by humans is controlled due to the City's efforts to expand and operate the POTW.

2.3.1.4. Ennis Creek Area

The Ennis Creek Area extends from the southernmost tip of the Upland Study Area northward, passing between the West and East Mill Areas, to the shore of Port Angeles Harbor (Figure 2-4). It consists of Ennis Creek, adjacent riparian and forested areas, and the estuary area near the mouth of the creek. Ennis Creek and White Creek converge in the southern portion of the Upland Study Area, and Ennis Creek flows northward from this convergence along its original (natural) alignment until it reaches the southern edges of the West and East Mill Areas. The segment of Ennis Creek that flows between these two areas was straightened during the early filling and development of the mill property. The former Finishing Room and former East Roll Storage Building, respectively, existed in the western and eastern portions of the Ennis Creek area. A portion of the bank along this stretch of Ennis Creek was later modified to improve habitat following a 2002 interim action (GeoEngineers 2012a).

The northern portion of the Ennis Creek Area is zoned Heavy Industrial, and the southern portion is primarily zoned Public Buildings and Parks. The southernmost portion of the Ennis Creek Area, near the boundary of the Upland Study Area, is zoned Commercial Arterial.

The riparian and forested areas adjacent to Ennis Creek constitute moderate-quality secondary growth habitat. Like other areas of the mill property, access to the Ennis Creek Area by humans is currently limited to temporary construction workers, visitors, and trespassers. Although trespassers have been encountered in recent years in the Ennis Creek Area by the Site caretaker; these persons have been routinely made to leave the premises by the Site caretaker, as well as the City of Port Angeles Police Department.

2.3.1.5. Marine Bluffs Area

The Marine Bluffs Area is composed of steep, vegetated bluffs that rise from the low, flat topography of the West Mill, East Mill, and City Purchase Areas (Figure 2-4). The southern edge of the Marine Bluffs Area is bordered by commercial and residential areas that are outside of the Upland Study Area boundary. The steep slopes of the Marine Bluffs Area are not conducive to development and act as a natural vegetative buffer to the industrial-zoned properties of the West Mill, East Mill, and City Purchase Areas. The western portion of the Marine Bluffs Area is zoned Public Buildings and Parks, whereas the eastern portion is primarily zoned Residential Single Family (Figure 1-2). The forested slopes of the marine bluffs constitute moderate-quality habitat. The Marine Bluffs Area may occasionally be accessed by trespassers.

2.3.2. Marine Study Area

The Marine Study Area (Figure 1-1) includes the intertidal and shallow submerged lands offshore of the West Mill Area, the estuary and shallow water environment offshore of Ennis Creek, and an area offshore of the East Mill Area (Figure 2-4). The Marine Study Area also includes deeper water offshore habitat that includes the area around Rayonier's former deepwater outfall.

2.3.2.1. West Mill Area Shoreline

Intertidal habitat along the West Mill Area ranges from moderate-quality beach and dune habitat to riprapped shoreline. Nearshore aquatic structures along the West Mill Area shoreline include the former mill dock and the former log pond, which is formed by a rock and pile jetty. Dredging historically occurred in the log pond and along the former mill dock structure in order to maintain operational capability. Prior to the construction of the mill's wastewater treatment facility, mill outfalls were located along the shoreline and discharged to the log pond and along the West Mill Area shoreline. Subtidal habitat in this area currently consists of silty sand. During the time that outfalls discharged along the shoreline, portions of the subtidal habitat area were covered by a wood fiber mat that formed by the settling of wood fibers contained in the discharge.

2.3.2.2. East Mill Area Shoreline

Intertidal habitat along the shoreline of the East Mill Area consists of high-quality beach and dune habitat. Subtidal habitat ranges from cobbles to silty sands.

2.4. NATURE AND EXTENT OF CONTAMINATION

Multiple investigations of contamination in the Rayonier study area have been conducted since the late 1990s, including studies by Rayonier, EPA, and Ecology. The investigation of legacy contamination in Port Angeles Harbor began in the 1990s as part of EPA's site investigation program and has continued under MTCA. Both Ecology and EPA have historically conducted regulatory compliance inspections at the former Rayonier mill. A multimedia compliance investigation was conducted in in 1993 and an ESI was conducted in 1997 (Ecology and Environment 1998). Upon completion of the ESI, EPA opted to defer a CERCLA listing of the former Rayonier mill and allow investigation and cleanup to proceed under Ecology's direction.

2.4.1. Soil

The Volume I Report (GeoEngineers 2012a) provides a detailed description of the nature and extent of soil contamination. This section provides a summary of this information. Appendix A also provides maps of measured soil concentrations in various depth ranges.

Various reconnaissance surveys and site assessments conducted in the 1980s and 1990s identified several distinct areas of the mill property where contaminant concentrations in soil were elevated. In some of these areas, visible soil staining was observed. The elevated concentrations were detected primarily in the main process area of the West Mill Area and in the SSL lagoon area of the East Mill Area. Some of the elevated concentrations were addressed in prior interim actions; Section 3.2 describes the interim actions conducted to date.

The results of soil sampling conducted in previous interim action areas indicated that the actions were successful in removing a substantial volume of contaminated soil from the Upland Study Area. The sampling results also indicated that residual soil contamination is present outside of the limits of previous soil excavations. In general, the highest remaining contaminant concentrations were detected in shallow soil (0 to 2 feet below ground surface [bgs]) in the West Mill Area, where the main mill operations were located. Concentrations in deeper soil (> 2 feet bgs) were generally less than concentrations in shallow soil.

2.4.2. Groundwater

The Volume I Report (GeoEngineers 2012a) provided detailed descriptions of the nature and extent of groundwater contamination. This section presents a summary of this information. Appendix A also provides maps of groundwater concentrations.

Groundwater contamination in the Upland Study Area is spatially dispersed. Upland investigations have not identified any remaining significant contamination sources responsible for the groundwater conditions. Several upland contamination sources were removed during previous interim actions.

As discussed in Section 3 and the Volume I Report (GeoEngineers 2012a), reported exceedances of groundwater screening levels are often attributable to reducing conditions in the saturated zone below the groundwater table. The reducing conditions enhance the solubility and mobility of some contaminants, especially metals. Reduction-oxidation (redox) conditions are variable throughout the upland, resulting in spatially variable conditions.

The groundwater is not suitable for potable use due to the proximity and hydraulic connection to marine surface water; therefore, drinking-water exposures are not expected (further discussion provided in Section 2.5.4.3). Groundwater beneath the upland discharges to marine surface along the shoreline. As groundwater migrates toward the shoreline, tidal effects are conducive to both physical and chemical attenuation of groundwater contaminants, and this attenuation is expected to reduce contaminant concentrations.

2.4.3. Sediment

Volume II (Windward 2014) provides a detailed description of the nature and extent of sediment contamination. This section provides a summary of this information.

From 1997 to 2008, four major sediment investigations were conducted within the Marine Study Area; a total of 168 locations were sampled. Contaminants and the area of sediment impacts requiring remediation based on these data are summarized in this section.

The highest contaminant concentrations were generally detected in the eastern portion of the log pond area, with decreasing concentrations away from the shoreline and toward the west. In the mill dock area, concentrations in surface sediment were generally highest near the mill dock. Concentrations were generally low or not detected outside these areas. Subsurface sediment samples from the log pond area had higher contaminant concentrations than did the subsurface samples from other portions of the Study Area. In the log pond, the samples from the deeper intervals (i.e., 1 to 2 and 2 to 3 ft) generally had lower concentrations than those in the shallower intervals.

2.5. CONCEPTUAL SITE MODEL

A conceptual site model (CSM) for the former Rayonier mill Study Area has been developed based on the known history of the former Rayonier mill and the past and current uses of the former mill property, as well as the results of investigations completed to date (Figure 2-5). The CSM is a qualitative description of the contaminant sources, release and transport mechanisms, and exposure pathways of potential concern. The nature and extent of contamination and the components of the CSM specific to the Upland and Marine Study Areas, were described in detail in the Volume I and II Reports (GeoEngineers 2012a; Windward 2014).

2.5.1. Historical Contaminant Sources

The industrial processes associated with the historical pulp manufacturing operations used or produced petroleum and other chemical products and by-products that may have been sources of some of the constituents of potential concern (COPCs) identified in the Study Area. The three major categories of historical mill operations that may have served as sources of COPCs include:

- Power and steam generation
- Pulp production
- Support operations

These potential historical sources were discussed in detail in the Volume I Report (GeoEngineers 2012a). In addition, many of the mill structures such as buildings, piping, tanks, and utility raceways were constructed of various metals, including iron and steel. These metal structures were exposed to corrosive/reactive environments through the use of steam and caustic materials (e.g., acids, bases, oxidizers). Consequently, these metal structures may have been a historical source of diffuse metals contamination.

Another potential source of COPCs is the naturally occurring metals in soil/fill beneath the mill property. Under certain geochemical conditions (e.g., anoxic/reducing and/or acidic or alkaline pH), which may have been created as a result of the pulp manufacturing process, naturally occurring metals in the soil matrix may have leached to groundwater and may be continuing to leach to groundwater.

Pulp production ended in 1997 when the mill closed. The primary historical sources of contaminants associated with the active mill operations were removed when the mill was decommissioned. Discharge from outfalls along the shoreline ended in the early 1970s, and discharge from the deeper outfall ended in 1997. Some of the residual contamination present at the Site at the time of decommissioning was addressed in prior interim remedial actions.

2.5.2. Primary Release Mechanisms

During pulp mill operations, the following primary mechanisms may have released COPCs to the environment:

- Stack emissions from power and steam generation may have released COPCs to the atmosphere; downwind fallout of airborne particulates from the stack emissions may have resulted in deposition to soil, surface water, and/or sediment.
- Discharge of mill wastewater to Port Angeles Harbor may have released COPCs to surface water and/or sediment.
- Leaks, spills, and drips from process machinery, equipment, petroleum/chemical product tanks and pipelines, and marine vessels using the pier may have released COPCs to soil, surface water, and/or sediment.
- Direct deposition of process residues and by-products such as boiler ash and wood/pulp residue (e.g., used as fill) in the uplands may have released COPCs to soil.
- Corrosion and flaking of aboveground metal structures may have released metals to soil, surface water, and/or sediment.
- Direct deposition of wood waste in the former log pond and dock areas, followed by subsequent degradation, may have released COPCs to surface water and/or sediment.

These primary release mechanisms (excluding the degradation of wood waste) would have been active only during the time the mill was in operation and would have ceased once the mill had been decommissioned.

2.5.3. Transport Mechanisms

Under current conditions, the primary physical and chemical transport mechanisms that may contribute to the migration of COPCs in the environment include:

- Erosion of contaminated soil/fill
- Leaching of COPCs from soil to groundwater via stormwater infiltration, percolation, and diffusion
- Migration of COPCs in groundwater via advection and diffusion, including possible discharge of contaminated groundwater to marine surface water and sediment

- Erosion and transport of contaminated marine sediment via scouring/currents

These transport mechanisms are identified in Figure 2-5. The Volume I and II Reports (GeoEngineers 2012a; Windward 2014) included detailed discussions of contaminant transport mechanisms and the physical and chemical conditions in the Study Area that may affect the mobility of COPCs.

2.5.4. Exposure Pathways of Potential Concern

This section identifies the exposure pathways of potential concern for the COPCs identified in sediment, soil, groundwater, and surface water. The primary exposure pathways of potential concern are identified in Figure 2-5.

2.5.4.1. Sediment

COPC concentrations in marine sediment are generally higher adjacent to the former upland mill property and decrease with distance from the shoreline. The sediment exposure pathways associated with human health risks include both direct contact with COPCs in sediment (i.e., dermal contact or incidental ingestion) and indirect contact through the consumption of aquatic organisms (i.e., seafood) that contain COPCs as a result of bioaccumulation. Populations that may come into direct contact with sediment include fishers and recreational users. Seafood consumers include subsistence and recreational fishers. Exposure pathways to the benthic invertebrate community include direct contact with, or uptake of, COPCs in sediment. The primary exposure pathway for fish, birds, and mammals is the ingestion of aquatic organisms that contain COPCs as a result of bioaccumulation.

2.5.4.2. Soil

Six major interim cleanup actions were completed between 1993 and 2006. These interim actions removed a combined total of approximately 34,000 tons of contaminated soil and hog fuel from areas where high contaminant concentrations had been previously identified. The COPCs that remain in soil are generally present at lower concentrations and are more widely distributed across the former mill property.

The primary exposure pathways and receptors of potential concern for COPCs in soil include:

- Construction workers, visitors, occasional trespassers, recreational users, and/or future workers (depending on land use) who may be exposed to COPCs in soil through direct contact (i.e., dermal contact, incidental ingestion, or the inhalation of dust.
- Soil biota and/or plants that may be exposed to COPCs in soil via direct contact (e.g., root uptake), and terrestrial wildlife that may be exposed via direct contact with soil and/or indirect contact through the consumption of impacted biota or plants.

2.5.4.3. Groundwater

COPCs in groundwater have been detected at relatively low concentrations across much of the Upland Study Area. As discussed in the Volume I Report (GeoEngineers 2012a), redox conditions are variable throughout the Upland Study Area, resulting in variable COPC concentrations in groundwater. The dissolution of metals in fill and native soil has been caused to some degree by reducing conditions in the saturated zone below the groundwater table. These reducing conditions enhance the solubility and mobility of some COPCs, especially metals. The effect of reducing conditions on metals speciation and mobility is well documented (e.g., Krauskopf 1979) and has been noted at other tidally influenced sites (e.g., Environmental Partners et al. 2006).

Upland investigations have not identified any remaining significant contamination source(s) responsible for the sporadic groundwater conditions. Several upland contamination sources were removed during previous interim actions (GeoEngineers 2012b).

The primary exposure pathway of potential concern for the COPCs in groundwater is discharge to marine surface water in Port Angeles Harbor. The potential for groundwater COPCs to absorb to marine sediments is also considered. Groundwater is not considered to be potable at this Site because these conditions, as specified in the rule (WAC 173-340-720), apply:

- Groundwater is not a current source of drinking water (720(2)(a))
- It is unlikely that contaminated groundwater will transport to groundwater that is a current or potential future source of drinking water (720(2)(c))
- There are known or projected points of entry into surface water (720(2)(d)(ii))
- Surface water is not a domestic water supply source (720(2)(d)(iii))
- Groundwater is sufficiently hydraulically connected to surface water that the groundwater is not practicable to use as a drinking water source (720(2)(d)(iv))

Therefore, groundwater associated with the Upland Study Area is not a current or reasonable future source of drinking water. Further details regarding groundwater flow and use are included in the Volume I report (GeoEngineers, 2012a). That report points out that:

- Drinking water wells in the area generally withdraw from water-bearing bedrock zones more than 60 feet deep.
- The City of Port Angeles withdraws water from a well 8 miles west of the Site.
- Based on potentiometric head maps, potentially impacted groundwater (less than 30 feet deep) flows northward to the Port Angeles Harbor.
- Water levels in monitoring wells in the upland study area near the shoreline are strongly influenced by tidal fluctuations.

The Volume I report also points out that groundwater migrates northward through a highly dynamic, freshwater-seawater transition zone beneath the shoreline before discharging to Port Angeles Harbor. COPCs in upland groundwater are expected to attenuate significantly through physical and chemical processes in the subsurface tidal transition zone prior to discharge to marine surface water. As shown in the CSM (Figure 2-5), groundwater is expected to discharge to marine surface water in a relatively narrow band along the shoreline. As groundwater migrates, it encounters oxygenated seawater in the tidal transition zone. The tidal transition zone is influenced by a saltwater wedge that consists of denser saline water that prevents downward migration of freshwater. The tide- and wave-influenced circulation within the saltwater wedge along with the seaward flow of overlying fresh groundwater causes the discharge of both fresh and saline groundwater in a narrow zone where there is a transition from freshwater to saltwater.

Despite the potential importance of tidal-transition-zone attenuation in reduction of groundwater contaminant concentrations (see, for example, Jamieson et al. 2003; Patoczka and Wilson 1984; Raveendran et al. 2001, Post 1999), these attenuation processes have not been studied in detail at the Site and are not factored into development of remediation strategies presented in this report. This adds some conservatism in the groundwater remediation alternatives presented in Section 5.

2.5.4.4. Surface Water

There have been only isolated detections of COPCs (i.e., metals and dioxins/furans) in surface water samples collected from Ennis Creek. None of the detected metals exceeded the conservative screening levels used in the Volume I Report (GeoEngineers 2012a). The dioxin/furan detections only slightly exceeded the low parts-per-quadrillion analytical reporting limits (RLs). Therefore, the risks associated with exposure to surface water in Ennis Creek are considered insignificant relative to other pathways of potential concern.

Protection of marine surface water is considered in evaluating remedial alternatives for Site groundwater. Attenuation of COPCs in marine surface water is likely to be significant due to mixing of marine waters along coastal shorelines. All Site outfalls associated with the former pulp mill have been decommissioned.

2.6. HUMAN HEALTH AND ENVIRONMENTAL RISK

For soil and groundwater, human-health and environmental risks are taken into account when setting PCULs and indicator hazardous substances (IHS). Appendix A provides the rationale for the PCULs that are discussed further in Sections 3.4.2 and 3.4.3. Upland environmental risk has been evaluated by Malcom Pirnie (2007b) and updated by GeoEngineers (Appendix B). These analyses are used in establishing PCULs protective of terrestrial ecological receptors at the site, as explained in Appendix A.

For sediment, a screening-level ecological risk assessment (ERA) and a screening-level human health risk assessment (HHRA) were conducted for Port Angeles Harbor by Ecology as part of the sediment characterization study (Ecology 2012a). This section summarizes the conclusions of these documents that were described in more detail in Appendix B of Volume II (Windward 2014). Sections 2.6.1 and 2.6.2 discuss the methods and results of the ERA and HHRA, respectively. These assessments are summarized only for reference; their inclusion in this manner does not imply concurrence with the methods or the results.

2.6.1. Screening-Level Ecological Risk Assessment (Sediment)

This section summarizes the results of the screening-level ERA conducted by Ecology (2012a) for Port Angeles Harbor. Included are summaries of the selection of IHS, the assessment endpoints and measures, the risk evaluations[2] for plants, benthic invertebrates, fish, and wildlife.

2.6.1.1. SELECTION OF IHS

A screening process was conducted to select the chemicals to be included in the ERA; these chemicals were identified as IHS. This screening process was conducted for both sediment and biota. Sediment was evaluated separately in two ways: as intertidal and subtidal sediment combined or as intertidal sediment alone. Nine different biological sample types were separately screened for IHS: bull kelp, eel grass, coonstripe shrimp, Dungeness crab hepatopancreas, Dungeness crab muscle, geoduck, horse clam, lingcod, and rock sole.

For sediment, the total number of IHS selected for inclusion in the ERA was 54 for intertidal sediment alone and 66 for intertidal and subtidal sediment combined (Table 2-1). For biota, the total number of IHS was 15 for eelgrass and bull kelp, 10 for fish, and 33 for shellfish.

2.6.1.2. RISK EVALUATION FOR MARINE PLANTS AND MACROALGAE

Risks to marine plants and macroalgae were evaluated based on one measure – sediment habitat quality – as determined by the presence of wood debris in Port Angeles Harbor as measured in several previous studies (Ecology 2012b; GeoSea 2009; SAIC 1999). These studies found that 20% to 25% of the sediment surface area in the harbor was affected by wood debris. The primary areas of accumulation are in the western

[2] The term "risk evaluation" was used in the ERA for individual risk characterizations for plants, benthic invertebrates, fish, and wildlife.

portion of the harbor along the base of Ediz Hook, in the lagoon area at the base of Ediz Hook, along the waterfront at the Port of Port Angeles Management Area, in the former Rayonier mill log pond, and in the area on the west side of the former Rayonier mill dock. Because a portion of the nearshore sediment in Port Angeles Harbor has wood waste, it was hypothesized (Ecology 2012a) that the ability of the harbor to support marine plants and macroalgae has been compromised in areas of the inner harbor that have wood waste accumulation.

2.6.1.3. BENTHIC COMMUNITY RISK EVALUATION

The benthic community evaluation was based on a comparison of sediment chemical concentrations with sediment benchmarks, sediment bioassay results, and sediment habitat quality. Sediment chemical concentrations in the Port Angeles Harbor sediment characterization study (Ecology 2012b) were compared with the sediment quality standards (SQS) and cleanup screening levels (CSLs) of the SMS. Four metals (arsenic, cadmium, mercury, and zinc) and four organic compounds (bis(2-ethylhexyl) phthalate, butyl benzyl phthalate, 4-methylphenol, and phenol) had sediment concentrations that exceeded criteria (Ecology 2012a).

Toxicity data evaluated in Ecology's ERA were collected from 59 surface sediment locations as part of the Port Angeles Harbor sediment characterization study (Ecology 2012b). Three sediment bioassay tests were conducted for each location: 1) a 10-day amphipod bioassay test using *Eohaustorius estuarius*, 2) an acute larval bioassay test using *Dendraster excentricus* (echinoderm), and 3) a chronic 20-day juvenile polychaete bioassay test using *Neanthes arenaceodentata*. Twenty-nine locations had an exceedance of either the SQS or CSL criteria for bioassays. Five locations were identified as having co-occurring chemical and bioassay test SMS exceedances. It should be noted that the study design for selecting bioassay locations was unusual because it involved the selection of bioassay locations prior to determining where exceedances of SMS occurred. As a result, toxicity data were obtained at some locations that did not have SMS exceedances, and some locations that had SMS exceedances were not evaluated for toxicity.

Sediment habitat quality was evaluated based on the presence of wood debris in Port Angeles Harbor, as determined from several previous studies (Ecology 2012b; GeoSea 2009; SAIC 1999). These previous studies reported that 20 to 25% of the sediment surface area of the harbor had wood debris. It was concluded in Ecology (2012a) that the ability of the harbor to support a healthy benthic community was compromised in the inner harbor in areas with wood waste accumulation.

2.6.1.4. FISH RISK EVALUATION

To evaluate risk to fish, chemical concentrations in whole-body fish were compared with critical tissue-residue risk-based concentrations (RBCs) obtained from the scientific literature for the 10 IHS for fish (arsenic, inorganic arsenic, chromium, copper, mercury, selenium, methylmercury, HPAHs, PCBs, and dioxins/furans). According to the ERA (Ecology 2012a), these results indicated that fish in Port Angeles Harbor are unlikely to be adversely affected by the concentrations of chemicals in their tissue, with the possible exception of arsenic. Arsenic is evaluated in this study as a groundwater IHS that may affect marine surface water.

2.6.1.5. WILDLIFE RISK EVALUATION

Six wildlife species representing different functional groups were evaluated for the wildlife risk evaluation: brant, double-crested cormorant, greater scaup, harbor seal, raccoon, and bald eagle. The chemicals evaluated for wildlife were metals and organic compounds. Chemical exposure for each of these species was calculated as the sum of exposures from diet and incidental sediment ingestion. According to the ERA (Ecology 2012a), risks to wildlife were low, as indicated by the following results:

- No unacceptable risks were calculated for brant, eagle, cormorant, and scaup (all hazard quotients [HQs] were less than 1.0)
- For the raccoon, HQs based on the no-observed-adverse-effect level (NOAEL) toxicity reference value (TRV) were greater than 1.0 for hexachlorobenzene and arsenic. The hexachlorobenzene HQ was based on an elevated detection limit for this chemical in horse clams. The arsenic HQ based on the lowest-observed-adverse-effect level (LOAEL) TRV was less than 1.0, so an adverse effect from arsenic exposure was not necessarily indicated for raccoon.
- For the harbor seal, the HQ based on the NOAEL TRV was greater than 1.0 for hexachlorobenzene. As noted in the previous bullet, the hexachlorobenzene result was an artifact of the elevated detection limit for this chemical.

Based on the above results, the ERA (Ecology 2012a) stated that risks to threatened and endangered bird and mammal species that use Port Angeles Harbor were expected to be negligible.

2.6.2. Screening-Level Human Health Risk Assessment (Sediment)

This section summarizes the methods and results of the screening-level HHRA conducted by Ecology for Port Angeles Harbor (Ecology 2012a). Included are summaries of the selection of IHS, the exposure assessment, the toxicity assessment, and the risk characterization.

2.6.2.1. Selection of IHS

The MTCA rule includes a provision for focusing risk assessments by eliminating from further consideration those chemicals that represent only a small contribution to the overall threat to human health and the environment. The remaining hazardous substances are referred to as IHS for the purpose of defining site cleanup requirements. The IHS selection process included consideration of the following four factors:

- Screening values based on toxicological and physical characteristics of each chemical
- Reference area concentrations
- Evaluation of essential nutrients
- Frequency of detection

For a chemical to be designated as an IHS, the maximum concentration had to be greater than the applicable screening value and reference area concentrations, not be an essential nutrient, and be frequently detected (e.g., in 5% or more) of the samples, unless it was identified as an IHS in other media. IHS were selected separately for intertidal and subtidal sediment (combined), beach/intertidal sediment, fish and shellfish, and bull kelp (Table 2-2). Carcinogenic PAHs, dioxins and furans, and PCBs were evaluated as groups of compounds. The total number of IHS ranged from 6 for bull kelp to 48 for other fish and shellfish tissue.

2.6.2.2. Exposure Assessment

The Port Angeles HHRA evaluated risks from site-related chemicals to four populations:

- Subsistence fisher
- Recreational fisher
- Residential user
- Recreational user

The manner in which the exposure of these groups to site-related chemicals was quantified is summarized in Appendix B of Volume II (Windward 2014).

2.6.2.3. Toxicity Assessment

Toxicity values used in the HHRA, including cancer slope factors (SFs) and reference doses (RfDs), were selected according to the following hierarchy:

1. Integrated Risk Information System (IRIS) (EPA 2010)
2. EPA's Provisional Peer Reviewed Toxicity Values (PPRTVs)
3. Other values
    a. Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels
    b. California EPA toxicity values
    c. EPA Superfund Program's Health Effects Assessment Summary Tables (HEAST)

EPA (2004) has not developed SFs or RfDs for all chemicals but has provided a method for extrapolating dermal toxicity values from oral toxicity values by applying a gastrointestinal absorbance factor to the oral toxicity values. cPAHs, dioxins and furans, and PCBs were evaluated as groups of compounds using the toxic equivalency factor (TEF) methodology. The TEFs used in the HHRA were all derived from MTCA.

2.6.2.4. Risk Characterization

Excess cancer risks and non-carcinogenic hazards were estimated by combining the exposure parameters discussed in Section 2.6.2.2 with the toxicity values discussed in Section 2.6.2.3. Excess cancer risks and hazards were summed for each target population across all pathways to obtain an estimate of total potential excess cancer risk and across all pathways with the same target organ to obtain an estimate of hazard.

Excess cancer risks for all scenarios are presented in Table 2-3 (Ecology 2012a). Excess cancer risk estimates were integrated over both child and adult exposures, so a single estimate was given for each pathway/scenario combination.

Excess cancer risks for tissue ingestion were approximately 100 to 1,000 times higher than those for direct sediment contact (Table 2-3). The highest excess cancer risk for all pathways combined was for the subsistence fisher reasonable maximum exposure (RME) scenario (1×10^{-2}). Excess cancer risks for the other scenarios that included tissue ingestion were lower than those for the subsistence fisher RME scenario, but still greater than MTCA's 1×10^{-5} acceptable target risk level for multiple pathways or multiple chemicals. Excess cancer risks for the residential and recreational users, which included only direct sediment contact, were 5×10^{-6} and 8×10^{-7}, respectively, well below the MTCA threshold for multiple pathways. The chemicals that contributed most significantly to the excess cancer risk estimates included arsenic (risks represented 62% of the total excess cancer risk across all pathways) followed by dioxins/furans (18%) and PCBs (12%).

HQs were also estimated for 14 different target organs for both adults and children. HQs were highest for the developmental pathway (54 and 110, for subsistence fisher RME for the adult and child, respectively), with the highest concentrations from PCBs, dioxins/furans, and mercury, in that order. The HQ for arsenic was the third highest of all IHS (behind PCBs and dioxins/furans), with a maximum of 29 for the subsistence fisher RME for the child. HQs were greater than 1 for up to 10 metals (depending on the scenario), PCBs, and 2,3,7,8-tetrachlorinated dibenzo-p-dioxin toxic equivalent (TEQ). The highest HQ was for PCB Aroclors for the subsistence fisher (child) RME scenario.

3 INTERIM ACTION OBJECTIVES

Interim action objectives have been developed for the Study Area. Under MTCA, interim action objectives are established to specify the results that a proposed remedy is expected to accomplish and to focus the development and evaluation of alternatives. The objectives are intended to be protective of human health and the environment by eliminating, reducing, or otherwise controlling risks posed through each exposure pathway and migration route of potential concern.

The interim action objectives are summarized in Table 3-1. The objectives for soil focus on the protection of humans and terrestrial wildlife that could potentially come into contact with contaminated soil in the upland. The objectives for groundwater focus on the protection of aquatic life and humans that could potentially be exposed to groundwater via the discharge of groundwater to marine surface water and sediment (aquatic life). The objectives for sediment focus on the protection of humans who could be exposed to contaminated sediment or indirectly through the consumption of seafood. Objectives were also established for the benthic invertebrate community and for higher-trophic-level organisms that could be exposed to contaminated sediment. The PCULs referred to in the objectives are developed in Section 3.4.

3.1. OVERALL APPROACH

The company's overall approach to site remediation is to develop a MTCA-compliant cleanup that can be integrated with site restoration activities. Future site construction activities could include one or more of the following:

- Removal of remnant subsurface mill structures
- Reuse of stockpiled soil as appropriate during construction
- Grading, as needed, for surface drainage
- Restoration of the Ennis Creek estuary, including removal of structures and contamination within this area
- Removal of dock and jetty

These activities will provide opportunities for additional contaminant removal, localized groundwater remediation, and the elimination of exposure pathways beyond those that may be needed to achieve a MTCA-compliant cleanup. The company's preference is to minimize the need for long-term, active treatment technologies and long-term maintenance and monitoring wherever possible.

In developing the alternatives, significant consideration was given to the remoteness of Port Angeles, limited site access, distance to disposal sites, and potential resource and community impacts from long-distance hauling of materials for disposal. The use of sustainable onsite management options also was considered. Specifically, future site construction plans will include a material management plan based on the Ecology-approved management plan for the City of Port Angeles combined sewer overflow (CSO) construction project (GeoEngineers 2012b) with the goal to reuse uncontaminated materials onsite.

3.2. PRIOR REMOVAL ACTIONS AND INTERIM REMEDIAL ACTIONS

In addition to integrating cleanup with future site construction as summarized in Section 3.1, the company's overall approach to site remediation builds upon prior interim cleanup and removal actions. These interim actions eliminated known contaminant sources and were successful in removing a significant mass of contaminants from the marine (sediments) and upland (soil and groundwater) environments.

Historical sources of contaminants to sediments included discharge from mill outfalls while the mill was operating. In the early 1970s, the mill's five outfalls were consolidated and re-configured to discharge as a single outfall into deeper waters in the harbor, and wastewater began undergoing primary and secondary treatment prior to discharge. None of the mill outfalls have discharged to the marine environment since the mill was decommissioned in 1997.

In addition, previous in-water actions have included removal of approximately 2,500 sunken logs from the log pond in late 2000 (Malcolm Pirnie 2007a) and annual maintenance dredging from 1977 to 1997 in portions of the log pond and berths adjacent to the mill dock where sediments and log debris accumulated.

The company has completed interim actions in seven areas of the uplands to clean up soil and groundwater contamination from past mill operations. The Volume I Report (GeoEngineers 2012a) provided detailed descriptions of these previous interim actions. Five of these locations were completed between 1993 and 2003 and are shown in Figure 3-1, which is from the 2007 remedial investigation report (Integral 2007). A sixth interim action removed contaminated wood residue and soil from an area where hog fuel was historically stockpiled. A total of approximately 29,300 tons of contaminated soil and 2,700 cubic yards (cy) of contaminated wood residue were removed for offsite disposal as part of these interim actions, as summarized below (Integral 2007):

- Finishing Room/Ennis Creek (1991 to 2002) – 10,150 tons of soil/sediment
- Former Fuel Oil Tank 2 (1993 and 2002) – 5,400 tons of soil
- Hog Fuel Pile Interim Action (2001) – 2,700 cy of wood residue
- Spent Sulfite Liquor Lagoon Interim Action (2001) – 4,800 tons of soil
- Former Machine Shop Interim Action (2002) – 970 tons of soil
- Former Fuel Oil Tank 1 and Wood Mill Interim Actions (2006) – 7,980 tons of soil

In addition, in 2012 and 2013 a total of approximately 28,200 cy of soil were excavated to facilitate the construction of the City's Combined Sewer Overflow Phase 1 Upgrade Project (CSO project). The excavated materials were managed in general accordance with the Ecology-approved materials management plan (GeoEngineers 2012b). A total of approximately 110 tons of soil contaminated by petroleum and other contaminants were disposed of offsite at a permitted facility and the remainder of material was placed in temporary stockpiles onsite for future characterization and potential reuse. These activities are documented in a 2013 materials management completion report (GeoEngineers 2013).

3.3. ARARs AND OTHER REQUIREMENTS TO BE CONSIDERED

In developing Volume III, the company has identified all ARARs for the project in accordance with Order Section VIII.P (Compliance with Applicable Laws). These laws are presented in Tables 3-2 through 3-4. Cleanup actions conducted under MTCA must comply with these applicable state and federal laws.

3.4. PRELIMINARY CLEANUP STANDARDS

Preliminary cleanup standards for the COPCs were identified in marine sediment, soil, and groundwater in the Study Area in accordance with the Order. The preliminary cleanup standards are used in Sections 5, 6 and 7 of this report to develop and evaluate remediation alternatives.

As defined in the MTCA (WAC 173-340-700(3)), cleanup standards consist of the following: a) cleanup levels for hazardous substances present at the site; b) the location where these cleanup levels must be met (point of compliance [POC]); and c) other regulatory requirements that apply to the site because of the type of action and/or location of the site ("applicable state and federal laws"; see Section 3.3). According to WAC 173-340-700(2), "A cleanup level is the concentration of a hazardous substance in soil, water, air or sediment that is determined to be protective of human health and the environment under specified exposure conditions. Cleanup levels, in combination with POCs, typically define the area or volume of soil, water, air or sediment at a site that must be addressed by the cleanup action."

According to MTCA (WAC 173-340-700(5)), the first step in setting cleanup levels is to identify the nature of the contamination, the potentially contaminated media, the current and potential pathways of exposure, the current and potential receptors, and the current and potential land and resource uses. The nature and extent of contamination have been investigated in the upland and marine portions of the Study Area. The results of the upland and marine investigations were presented in Volumes I and II of the Interim Action Report (GeoEngineers 2012a; Windward 2014), hereafter referred to as the Volume I and Volume II Reports, respectively. In those reports, potential contaminated media, exposure pathways, and receptors were summarized within the context of a CSM. Updates to portions of the CSM have been further evaluated since the Volume I Report (GeoEngineers 2012a). These updates are addressed in Section 2.5.

3.4.1. Sediment

In the revised Washington State SMS rule (WAC 173-204) that went into effect September 1, 2013, Ecology redefined how sediment cleanup standards are determined. The establishment of these standards requires specification of the following per WAC 173-204-505: a) the chemical concentration or level of biological effects for a contaminant in sediment that is determined by Ecology to be protective of human health and the environment (sediment cleanup level); b) the location at the site or sediment cleanup unit (SCU) where those sediment cleanup levels must be achieved (i.e., POC); and c) additional regulatory requirements that apply to a cleanup action because of the type of action and/or the location of the site (i.e., ARARs). These requirements are specified in applicable laws and are generally established in conjunction with the selection of a specific cleanup action.

In WAC 173-204-505, a sediment cleanup level is defined as the concentration or level of biological effects for a contaminant in sediment that must be achieved to be protective of human health and the environment. The sediment cleanup level can be established between the sediment cleanup objective (SCO) and the CSL in accordance with the requirements in WAC 173-204-560. Figure 3-2 presents Ecology's two-tiered paradigm that forms the basis for the new SMS rule. In this paradigm, a cleanup level for a contaminant is established as the highest of the following:

- Lowest of the three risk-based levels[3] and ARARs
- Natural or regional background (depending on tier)
- Practical quantitation limit (PQL)

Under the new rule, a sediment cleanup level is initially established at the SCO but may be adjusted upward from the SCO (only as high as the CSL) based on the following site-specific factors (WAC 173-204-560(2)(a)(ii)) (see Section 3.4.1.6).

- Whether it is technically possible to achieve the sediment cleanup level at the applicable POC within the site or SCU

[3] Risk-based levels are established for human health, higher-trophic-level ecological species, and the benthic community. It should be noted that these levels can be established and applied at different scales (e.g., station by station vs. larger areas).

- Whether meeting the sediment cleanup level will have a net adverse environmental impact on the aquatic environment, taking into account the short- and long-term positive effects on natural resources, habitat restoration, and habitat enhancement and the short- and long-term adverse impacts on natural resources and habitat caused by cleanup actions

In developing the preliminary sediment cleanup standards, the company has used the *Preliminary Sediment Cleanup Objectives for Port Angeles Harbor* report (NewFields 2013), an Agency Review Draft report of *Preliminary Cleanup Standards* for the Study Area (Agreed Order Task 4a deliverable, GeoEngineers and Windward 2013), Ecology's comments on the draft *Preliminary Cleanup Standards* for the Study Area (Ecology 2014d), and the *North Olympia Peninsula Regional Background Sediment Characterization* (Ecology 2016a).

3.4.1.1. Indicator Hazardous Substances

This section identifies IHSs in sediment and provides a brief overview of their distribution, derives PCULs for sediment, discusses POCs, and presents the basis for the delineation of an in-water remediation area. This section presents a brief summary of the IHSs identified by Ecology and their distribution in the Marine Study Area. A detailed description of IHSs identified by Ecology and their distribution in the Marine Study Area is provided in the Volume II Report (Windward 2014).

In NewFields (2013), Ecology identified the following IHSs for human health based on their human health risk assessment: arsenic, cadmium, copper, selenium, methylmercury, zinc, alpha-benzene hexachloride, cPAHs, PCBs, and dioxins/furans.[4]

For the benthic community, in total, surface sediment samples from 151 locations in the Study Area were analyzed for at least one SMS chemical (Figures 3-3A, 3-3B, and 3-3C). Of these 151 locations, samples from 26 locations had an exceedance of the SCO criteria for at least one chemical. The SCO or CSL was exceeded for the following chemicals: mercury, acenaphthene, benzo(g,h,i)perylene, chrysene, dibenzofuran, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, phenanthrene, pyrene, total high-molecular-weight PAHs (HPAHs), total low-molecular-weight PAHs (LPAHs), bis(2-ethylhexyl) phthalate, 2,4-dimethylphenol, 2-methylphenol, 4-methylphenol, phenol, and total PCBs.

For some SMS chemicals (primarily butyl benzyl phthalate, 1,2,4-trichlorobenzene, 2,4-dimethylphenol, hexachlorobenzene, and hexachlorobutadiene) analytical laboratory RLs were greater than the SCO or CSL. Only one sample had a detected concentration of one of these chemicals (2,4-dimethylphenol) that was greater than the SCO or CSL.

The highest IHS concentrations in surface and subsurface sediment were detected in the log pond area and in the vicinity of the mill dock, with decreasing concentrations away from the shoreline and the jetty and mill dock (Windward 2014). This concentration gradient was observed for all of the human health IHSs; a similar pattern was observed for SMS exceedances as well (Figures 3-3A, 3-3B, and 3-3C). IHS concentrations east of the deep-water outfall were low (Windward 2014).

Sediment habitat degradation by wood waste was also identified by Ecology (2012b) as a potential stressor to the benthic community. Wood debris, including logs and large bark or wood fragments, has been observed (Ecology 2012b; Appendix C of this report). Surface sediment samples collected from the log pond and jetty

[4] Two metals (cobalt and iron) were considered COPCs based on the HHRA (Ecology 2012a) but were not further evaluated in the NewFields (2013) final evaluation of preliminary cleanup goals because they were considered to be naturally occurring and not cause for concern. In addition, there were no sediment data for cobalt or iron in the dataset from NewFields (2012) that was used to calculate biota-sediment accumulation factors and to determine natural background concentrations for metals.

area as part of Ecology's sediment investigation and the sediment trends analysis contained wood, whereas samples from other areas in the Marine Study Area contained trace amounts or no wood (Ecology 2012b).

3.4.1.2. Risk-Based Levels

The risk-based level is based on the lowest of the following but applied at different spatial scales:

- The concentration of the contaminant based on the protection of human health
- The concentration or level of biological effects of the contaminant based on benthic toxicity
- The concentration or level of biological effects of the contaminant estimated to result in no adverse effects on higher-trophic-level species (i.e., fish, crabs, or wildlife)
- ARARs

The human health direct contact–based levels (i.e., sediment ingestion and dermal exposure) should be applied over relevant exposure areas. The benthic invertebrate risk-based levels are generally applied on a station-by-station basis, and the risk-based levels for protection human health via seafood ingestion, protection of fish, and protection of wildlife are generally applied to averaged concentrations. Each of these levels is discussed below.

3.4.1.2.1. Human Health

On behalf of Ecology, NewFields (2013) calculated risk-based levels for human health direct contact and seafood ingestion scenarios using the RME scenario in the screening-level HHRA (Ecology 2012a). These levels are presented in Table 3-5.

Risk-based levels were calculated for both excess cancer risk and non-cancer hazard thresholds. Per the rule, for individual known or suspected carcinogens, the SCO risk threshold is one in one million ($1x10^{-6}$), and the CSL risk threshold is one in one hundred thousand ($1x10^{-5}$). If there are multiple carcinogens and/or exposure pathways, such as in the Marine Study Area, then the total excess cancer risk threshold is one in one hundred thousand ($1x10^{-5}$) for both the SCO and the CSL.

There is no tiering of the non-cancer risk threshold, which is the same for both the SCO and the CSL. For individual non-carcinogens, the risk threshold is equal to an HQ of 1. If there are multiple non-carcinogens and/or exposure pathways at the site, then the threshold is equal to a hazard index (HI) of 1 (for a single mode of action).

NewFields (2013) identified the risk drivers for human health as those with estimated excess cancer risk estimates ≥ $1x10^{-6}$ or HQs ≥ 1 with a relative percent total risk ≥ 1%. Based on these criteria, a subset of contaminants was identified as risk drivers, and risk-based levels were derived for each of the exposure pathways (Table 3-5).

The risk-based levels for seafood ingestion represent areas throughout Port Angeles Harbor, whereas the levels for direct contact represent only beach and intertidal areas where human contact was assumed to occur in the HHRA (Ecology 2012a) (see NewFields (2013) for a discussion of uncertainties in their analysis).

3.4.1.2.2. Benthic Invertebrates

Risk-based levels for benthic invertebrates are defined in the SMS, which include both chemical and biological criteria. Under the SMS, contaminant concentrations at or below the SCOs correspond to a sediment quality that results in no adverse effects to the benthic community. Contaminant concentrations at or below the CSL, but greater than the SCO, correspond to a sediment quality that results in minor adverse effects to the benthic community.

The contaminant-specific level for the protection of benthic invertebrates is based on the SCO, although this level can be increased up to the CSL based on a determination whether the SCO is technically possible or would have a net adverse environmental impact (Figure 3-2). Table 3-6 presents both the SCOs and CSLs for contaminants with detected concentrations greater than the SCO within the Marine Study Area.

An analysis of the remediation area for the protection of benthic invertebrates would also include an evaluation of available sediment toxicity test data, consistent with the provision of WAC 173-204-530. According to WAC 173-204-530, sampling locations that meet the SMS biological standards based on confirmatory bioassay results are in compliance with the SMS rule (i.e., the sediment chemistry data are trumped by the toxicity test results).

3.4.1.2.3. Higher-Trophic-Level Species

As part of the new SMS rule, SCOs and CSLs must be considered for contaminants based on the protection of species at trophic levels not addressed in WAC 173-204-562 or WAC 173-204-563 (hereafter referred to as higher-trophic-level species). These levels, as described in WAC 173-204-564, are established at concentrations that have no adverse effects on higher-trophic-level species based on an ERA.

NewFields (2013) presented an analysis that evaluated whether risk-based levels for human health would be protective of the higher-trophic-level species assessed in the screening-level ERA conducted by Ecology (2012a). Because risks for fish and wildlife were low (Ecology 2012a), NewFields (2013) concluded that the risk-based levels derived for human seafood consumption are protective of fish and wildlife. Therefore, risk-based levels for higher-trophic-level species were not derived for Port Angeles Harbor.

3.4.1.3. Background Levels

3.4.1.3.1. Natural Background

Consistent with Ecology's SMS paradigm (Figure 3-2), SCOs can be set at natural background, which is defined as the concentration of a hazardous substance that is consistently present in the environment and has not been influenced by localized human activities. Natural background was statistically defined based on the upper 90th percent confidence limit on the 90th percentile (90/90 upper tolerance limit [UTL]). The natural background concentrations derived by Ecology for the human health risk drivers are summarized in Table 3-7. These concentrations were derived using a "proximal" dataset, defined by Ecology (NewFields 2013) as "samples collected near the Strait of Juan de Fuca and around the San Juan Islands as part of the 2008 Bold Survey as well as the locations sampled in Freshwater Bay and Dungeness Bay."

The natural background concentrations derived by Ecology for the human health risk drivers are summarized in Table 3-7. Note that natural background was determined by Ecology for PCBs and dioxins/furans separately (Ecology 2016a). However, in 2016, Ecology issued a site-specific rationale memorandum (Ecology 2016b) for Port Angeles Harbor, requiring that sediment cleanup levels protective of human health be based on a total TEQ approach. The separate levels for PCBs and dioxins/furans are no longer applicable.

3.4.1.3.2. Regional Background

In the 2013 SMS rule, regional background is defined as "the concentration of a contaminant within the department-defined geographic area that is primarily attributable to diffuse sources, such as atmospheric deposition or storm water, not attributable to a specific source or release" (WAC 173-204-505(16)). Regional background levels are compared against the risk-based levels and PQLs to establish preliminary CSLs.

One of the key components in defining regional background is to determine the most representative geographic area in which to sample. Originally, Ecology proposed collecting regional background data from various locations along the North Olympic Peninsula to establish regional background for Port Angeles (Ecology 2013c). Since that time, the regional background concept has evolved, and samples used to derive concentrations of contaminants associated with diffuse urban sources have been selected from locations closer to the urban environment in question. The sampling and analysis plan (SAP) for Bellingham Bay (Ecology 2014b) provides a good example. In addition, greater care has been taken to exclude samples that would be more representative of natural background or river deltas.

To this end, Ecology has re-assessed the approach used in Port Angeles for cPAH regional background (Ecology 2016a). Ecology has decided that some of the locations sampled as part of the North Olympic Peninsula regional background effort are less urbanized than Port Angeles, and thus should be excluded from the regional background dataset, and some locations within Port Angeles Harbor should be included. A Port Angeles Harbor-specific regional background value for cPAH was calculated by Ecology by pooling the cPAH data from Discovery Bay, Sequim Bay, and Port Townsend Bay with 13 samples from central Port Angeles Harbor. The total sample size for the combined data set was 40 samples. According to Ecology, such an approach effectively maintains stratified populations for Discovery Bay, Port Townsend Bay, and Sequim Bay, as the sample counts in these bays were based on their area. This approach also, per Ecology, gives more weight to the Port Angeles Harbor samples than would be warranted based on area alone, which is suitable for a Port Angeles Harbor-specific value. Using this pooled 90/90 UTL statistical metric, the cPAH regional background value for Port Angeles Harbor was established by Ecology as 64 micrograms (µg) TEQ/kilogram (kg) (Ecology 2016a). In addition, a regional background level for total TEQ specific to Port Angeles Harbor was determined by summing the regional background concentrations for PCBs and dioxins/furans (Ecology 2016b). The regional background concentrations derived by Ecology for human health risk drivers are summarized in Table 3-8.

3.4.1.4. Practical Quantitation Limits

In the new SMS rule, PQLs are defined as the lowest concentrations that can be reliably measured within specified limits of precision, accuracy, representativeness, completeness, and comparability during routine laboratory operating conditions using Ecology-approved methods.

The PQLs defined in NewFields (2013) are presented in Table 3-9 without modification; a critical analysis of the identification of PQLs has not been conducted for this report.

3.4.1.5. Preliminary Point of Compliance

In the new SMS rule, the POC is defined as the location within a site or SCU where sediment cleanup levels must be met. The POC is established in accordance with the requirements in WAC 173-204-560(6).

Cleanup levels should be applied in a manner consistent with the resource being protected. Therefore, for benthic invertebrates, which are evaluated on a station-by-station basis, the POC depth is the biologically active zone (BAZ). In marine environments, the BAZ is generally set at 10 centimeters (cm). This depth is supported by sediment profile images in Port Angeles Harbor that show apparent redox potential discontinuities ranging from 0 to 5.59 cm (SAIC 1999). The apparent redox potential discontinuity provides an estimate of the degree of oxygenation in the sediment column as well as the degree of biogenic sediment mixing.

For human health, protection from exposure to bioaccumulative chemicals (via seafood consumption) is evaluated on a spatially weighted average concentration (SWAC) basis. Therefore, depths to which seafood (fish and shellfish) may be exposed are relevant. Fish and crabs are exposed through direct or indirect (diet) exposure pathways, which are applicable to the top 10 cm of sediment. Smaller bivalves (e.g., little neck clams) are also exposed to the upper 10-15 cm of sediment. Larger bivalves, such as geoducks and horse clams, which can be harvested by hand from the lower edge of the intertidal, exist deeper in the sediment up to 3 feet. Bivalves are filter or deposit feeders, and thus their primary exposure is through their siphons in the upper sediment horizon.[5] Exposure studies have established that the most important clam exposure pathway is through their inhalant siphons at the sediment/water interface (Kamermans 1994; Lin and Hines 1994). Based on this information, the company supports a 10-cm POC for protection of human health seafood consumption of bivalves. Ecology is requiring a POC of 0-45 cm for seafood consumption of clams in the intertidal in order to have a consistent POC across the entire Port Angeles Harbor, including the Western Harbor. Ecology notes that larger bivalves can live at depths greater than 10 cm and can have siphons that do not extend to the sediment/surface-water interface.

With respect to potential exposure to deeper sediments through physical disturbance (e.g., scour, prop wash), case studies conducted for similar sites have indicated that physical mixing is generally limited to a depth much shallower than 10 cm (Blake et al. 2007).

Deeper exposure scenarios (up to 45 cm) are applicable for direct human contact, such as during clamming, when sediment comes into direct contact with skin. Thus, this deeper POC depth is only relevant in the intertidal sediment area if clamming may occur in this area in the future. Ecology has designated sediment management areas (SMAs) within Port Angeles Harbor and near the former Mill (Ecology 2017b). Near the former mill, the SMA is limited to intertidal areas within the SCU where there is, or may be in the future, reasonable access to the shoreline for shellfish harvest by the public. The POCs are summarized in Table 3-10.

3.4.1.6. Preliminary Cleanup Standards

The sediment risk-based levels, background levels, and PQLs were compared to determine the SCO for the Marine Study Area in accordance with the requirements of WAC 173-204-560. These values are summarized in Table 3-11.

Sediment cleanup levels can be adjusted upward (up to the CSL) if it is not technically possible to achieve the SCO or if cleanup to the SCO would result in a net adverse environmental impact (WAC 173-204-560).

As discussed in the SMS regulation and the Sediment Cleanup Users' Manual (Ecology 2017c), an upward adjustment from the SCO is based upon the following considerations:

Technical possibility. Whether it is technically possible to achieve and maintain the cleanup level at the applicable point of compliance (WAC 173-204-560(2)(a)(ii)(A)d)

Net adverse environmental impacts. Whether achieving and maintaining the cleanup level will have a net adverse environmental impact on the aquatic environment, WAC 173-204-560(2)(a)(ii)(B)

In WAC 173-204-505(23), technically possible is defined as "capable of being designed, constructed and implemented in a reliable and effective manner, regardless of cost." Determining technical possibility is dependent on a variety of site-specific factors that include the ability to achieve the cleanup level using available cleanup technologies and the ability to maintain the cleanup level after construction (Ecology

[5] The geoduck orients itself with the posterior siphon towards the surface, where seawater that contains dissolved oxygen and suspended microalgae is circulated via ciliated ctenidia down through the inhalant siphon. The ctenidia perform both gas exchange and feeding functions. The ctenidia trap, sort, and transport food particles to the stomach (Straus et al. 2009). This position is supported by Newfields (2013): "Clams are generally filter feeders, consuming floating algae or detritus at the sediment-water interface or sediment surface."

2013b). As stated in Ecology (2013b), if the potentially liable party (PLP) has addressed potential sources of contamination under its authority and there are still ubiquitous diffuse sources causing the site to exceed the SCO, then the SCO cannot be maintained in the Harbor, and the sediment cleanup level may be adjusted upwards, but no higher than the CSL (Ecology 2013b).

Concentrations of cPAHs and total PCBs near natural background concentrations are not maintainable in the urban area of Port Angeles, particularly with six major urban creeks carrying sediment loads into the harbor and a CSO outfall located just to the west of the log pond projected to continue discharging to the harbor (with a goal of no more than one CSO discharge event per year) despite considerable source control efforts by the City (City of Port Angeles 2014).

In addition to technical possibility, other factors need to be considered and balanced to determine the appropriate SCL, including net adverse environmental impacts. Determining net adverse environmental impacts is based on the short- and long-term positive and negative impacts of the cleanup actions on natural resources, including shellfish, forage fish, and eelgrass beds; aquatic habitat; habitat restoration opportunities; and habitat enhancement opportunities (WAC 173-204-560(2)(a)(ii)(B)).

As demonstrated in NewFields (2013), SCO achievement in the Harbor would require large-scale remediation, resulting in extensive adverse environmental impacts due to widespread remedial activities. For this reason, targeting the CSL rather than the SCO would reduce the extent of habitat impacts associated with remedial construction. Thus, based on considerations of the technical possibility and net adverse environmental impacts, the sediment cleanup level in the Marine Study Area should be based on the CSL for the human health risk drivers, which is the highest of their risk-based levels, regional background values, and PQLs (Table 3-12).

For contaminants other than the human health risk drivers listed in Tables 3-9 and 3-10, the cleanup levels would be based on the benthic criteria presented in the rule (WAC 173-204-562) and in the Sediment Cleanup Users' Manual, Volume II (Ecology 2017c) (Table 3-6). These contaminants were identified because they had at least one SCO exceedance for benthic invertebrates within the Study Area.[6]

3.4.2. Groundwater

Appendix A discusses IHSs in groundwater, groundwater PCULs, and the POC for groundwater. As discussed in the Volume I Report (GeoEngineers 2012a), groundwater associated with the Upland Study Area is not a current or reasonable future source of drinking water due to the availability of municipal water and the proximity of the Study Area to marine surface water. Accordingly, preliminary cleanup standards for groundwater are based on the protection of marine surface water and sediment.

Eight groundwater IHSs are identified in Appendix A: acenaphthene, ammonia, arsenic, copper, cPAHs, manganese, nickel, and pH. These IHSs, their associated PCULs, and the basis for the PCULs are listed in Table 3-13. Appendix A provides the logic used to set the PCULs in accordance with MTCA requirements and the rationale for selecting these eight constituents as the IHSs for Site groundwater.

Appendix A also provides groundwater plume maps for the IHSs and for other constituents that were considered in developing IHSs. Finally, Appendix A shows the upland area where PCULs are exceeded for one or more IHSs.

[6] These contaminants include eight individual PAHs, total LPAHs, total HPAHs, dibenzofuran, total PCBs, mercury, bis(2-ethylhexyl) phthalate, 2,4-dimethylphenol, 2-methylphenol, 4-methylphenol, and phenol.

Under MTCA, the standard POC is all groundwater at all depths throughout the site (WAC 173-340-720(8)(b)). For the most aggressive groundwater remediation alternatives considered in this report, the preliminary POC will use this standard POC definition. That is, for certain groundwater remedial alternatives, the goal will be to meet the PCULs at all monitoring wells.

At sites where the groundwater cleanup levels are based on the protection of surface water beneficial uses and the site directly abuts surface water, MTCA allows a conditional POC to be established that is located either within the surface water as close as technically possible to the point or points where groundwater flows into the surface water or in the groundwater near the surface-water discharge location. A conditional POC is appropriate when it is not practicable to meet groundwater cleanup levels throughout the groundwater at the Site (i.e., at the standard POC) within a reasonable restoration time frame and all practicable methods of treatment are to be used in the cleanup (WAC 173-340-720(8)(c)). Other conditions are also applicable depending on whether the conditional POC is within the surface water or groundwater (Ecology 2017a). Ecology has noted that there is an opportunity to utilize this approach at portions of the Upland Study Area through the installation and collection of data from wells located close to the shoreline (Ecology 2014a). The disproportionate cost analysis (DCA) for groundwater remediation alternatives (Section 6.5.2) evaluates the use of a conditional POC for groundwater. For these alternatives, PCULs would need to be met at existing shoreline wells and/or new shoreline wells that monitor groundwater prior to surface-water discharge. The location of future compliance-related monitoring would be determined following final design of site improvements.

Though not proposed for any groundwater alternatives considered in this report, it is noted that MTCA also allows for the establishment of conditional POCs in surface water near groundwater discharge locations subject to certain conditions (WAC 173-340-720(8)(d)(i)). By establishing conditional POCs in groundwater upgradient of discharge locations, the approach to groundwater remediation for the Upland Study Area is more conservative.

3.4.3. Soil

Appendix A also discusses how soil IHSs were selected for human health and terrestrial ecological receptors. IHSs in soil are presented in Table 3-14 along with associated PCULs. Direct-contact (human health) PCULs are developed for both unrestricted-use and industrial-use scenarios/areas. Ecological PCULs are based on the Terrestrial Ecological Evaluations previously done for the Site, along with Ecology's comments on those evaluations (Appendix B).

As explained in Appendix A, leaching to groundwater may be a concern for a few IHSs, but existing Site data do not identify a particular source area where leaching to groundwater should be addressed in the interim action. PCULs are therefore not established for leaching to groundwater.

Appendix A also provides maps of where measured soil concentrations exceed PCULs. A final map in Appendix A shows where one or more PCUL is exceeded.

For protection of human health and ecological receptors, the standard POC is throughout soil from 0 to 15 feet bgs. For soil PCULs based on the protection of terrestrial ecological receptors, a conditional POC from 0 to 6 feet bgs may be applied (WAC 173-340-7490(4)(a)), which is based on the MTCA-defined biologically active zone for soil. MTCA rules stipulate that soil cleanup actions using this conditional POC for the protection of terrestrial ecological receptors must include institutional controls (ICs) to ensure that the cleanup action remains protective. All of the soil remediation alternatives developed in Section 5 include ICs.

Risk-based concentrations protective of occasional Site visitors/trespassers are also derived in Appendix A. These concentrations may be used to define remediation levels (RELs) for certain soil alternatives that are protective of visitors/trespassers and ecological receptors (Table 3-14). The RELs use an exposure scenario proposed by WDOE that assumes an occasional Site visitor (trespasser) visits the site 104 days per year (approximately twice per week) during adolescence. The exposure frequency suggested by WDOE likely overestimates actual reasonable maximum exposures from occasional trespassers/visitors. Lower exposure frequencies (and therefore increased RELs) could also be supported with appropriate property use controls but are not used in this document.

3.5. REMEDIATION AREAS

3.5.1. Upland Soil

Soil remedial alternatives are based on the soil PCULs summarized in Table 3-15. These levels were derived for the protection of human health and terrestrial ecological receptors. Maps showing the approximate extents where IHS concentrations in upland soil exceed PCULs are provided in Appendix A. Further refinement of these areas will be completed during design.

Appendix A also contains maps showing approximately where risk-based concentrations protective of occasional visitors/trespassers and terrestrial ecological receptors are exceeded in upland soil. RELs for these areas (Table 3-14) may be used in the development of soil remedial alternatives. Refinement of these areas may also be completed during design.

3.5.2. Groundwater

Groundwater wells throughout much of the site had exceedances of PCULs during the most recent sampling events in 2010-2011. However, the exceedances were often slight or not likely due to Site sources, as explained in Appendix A. The groundwater remediation area is initially defined to be much of the Upland Study area (Appendix A). However, this area may be refined during design following additional sampling and data analysis if concentrations of IHSs have declined below PCULs at certain wells or if metals concentrations at certain wells are shown to be indicative of background concentrations in the area.

The groundwater cleanup action will be selected and designed to achieve PCULs (Table 3-13) at the standard POC (i.e., all points in groundwater) unless this proves to be impracticable, in which case a conditional POC (shoreline groundwater) will be proposed.

3.5.3. Sediment

To develop the sediment remediation area (Figure 3-4), a layering approach was employed. First, the locations of SMS exceedances (based on both chemistry and toxicity testing information) were assessed (Figures 3-3A, 3-3B, and 3-3C). The remediation footprint shown on Figure 3-4 encompasses all of the detected SMS exceedances with one exception (i.e., a 4-methylphenol SCO/CSL exceedance in a sample collected near the historical deep-water outfall). This isolated 1997 exceedance is surrounded by clean locations from more recent datasets and is thus not included in the active remediation area. As shown on Figure 3-3A, some contaminants had RLs greater than SMS outside of the active area. However, with the exception of 2,4-dimethylphenol,[7] none of these contaminants were detected within the Marine Study Area. Therefore, these contaminants are unlikely to be present at harmful concentrations.[8]

[7] 2,4-dimethylphenol was detected in 1 of 83 samples in which it was analyzed within the Study Area.
[8] Non-detect exceedance factors (RL/SMS) ranged from 1 to 5.8. Most were between 1.1 and 2.8.

Next, potential impacts from historical wood waste were considered. No SMS criteria exist for wood waste. Instead, wood waste is managed only if it poses a risk to benthic invertebrates as a result of toxicity generated through wood degradation or through significant physical impacts to habitat. Site-specific toxicity testing has been conducted using samples collected from locations where wood waste has been observed in the log pond and between the jetty and the mill dock. No toxicity was reported for samples collected between the jetty and the mill dock (except for one sample just west of the mill dock, which is included in the remediation area) (Figure 3-3A). In contrast, toxicity was reported for many of the samples collected from within the log pond, especially those along the west side of the jetty. The areas with toxicity are within the sediment remediation subareas (SRSs) identified based on SMS exceedances.

To address the protection of human health (direct contact), the lowest of the two risk-based levels for direct contact (Table 3-5) was compared with the PQLs and background concentrations. The highest of these concentrations was then compared with sediment data from the intertidal area along the former mill shoreline (the SMA, see Table 3-10). The initial comparison was made on a point-by-point basis to be conservative even though area-averaged concentrations would be more relevant to human exposures in the scenarios assessed. Based on this comparison, two intertidal areas were identified for active remediation (i.e., the log pond intertidal/nearshore SRS and the mill dock landing SRS).

To address the protection of human health (seafood ingestion) and higher-trophic-level species, compliance was assessed using an area-averaged approach because fishers, fish, and/or crabs integrate their exposure, and thus, point-by-point comparisons are not appropriate. Using existing data, SWACs based on an inverse distance weighted (IDW) interpolation were calculated for the human health risk drivers across the SCU. Per SMS, the SCU is defined as the area in which any contaminant has a concentration greater than the cleanup level (Table 3-12). By applying the SMS rule to the Ecology-approved dataset, the SCU would have been 403 acres. Based on comments and discussions with Ecology, the SCU was reduced to 205 acres (Figure 3-5). The smaller SCU resulted from exclusion of one data point (SD-67), where selenium was detected at 0.93 J mg/kg, which is above the cleanup level of 0.6 mg/kg set by the PQL. The data point was excluded because of the uncertainty associated with this selenium result in the context of the remainder of the selenium data for the Site. This data point had an estimated concentration that was within the range of detection limits. The original lab packages to check the validity of this result were not located.

For each human health risk driver, pre-remediation SWACs were calculated based on the 205-acre SCU and compared with the highest of the seafood ingestion RBC, the PQL, or the background concentration as an initial screen. If the SWAC was less than the highest of these three values, then the remediation area was determined to be adequate for the protection of human health for seafood ingestion and higher-trophic-level species. As shown in Table 3-15, this was the case for all of the metals and alpha- benzene hexachloride, indicating that the active remediation area shown on Figure 3-4 addresses human health risks for these risk drivers.

If the SWAC was greater than the highest of these three values for a risk driver, as was the case for cPAHs and total TEQ (Table 3-15), then the concentrations within the active remediation area shown on Figure 3-4 were replaced with natural background concentrations,[9] and a post-remediation SWAC was calculated. The post-remediation SWACs were less than or equal to the regional background concentrations for these two risk drivers (Table 3-15) indicating that the active remediation area is appropriate. Therefore, in summary, all of the interim action objectives for sediment will be met by remediation in the area shown on Figure 3-4.

For human health and ingestion of clams, a 0-45 cm POC was required by Ecology within the SMA. As discussed above for human health (direct contact), two intertidal areas were identified for active remediation

[9] The replacement values for cPAHs and total TEQ were 16 µg/kg and 1.3 ng/kg, respectively.

(i.e., the log pond intertidal/nearshore SRS and the mill dock landing SRS) to bring the intertidal concentrations of cPAHs below background in the 0-45 cm interval in the SMA. No additional remediation areas are needed to address the 45-cm POC for clam ingestion.

To identify individual SRSs within the overall 51.7-acre sediment remediation area, physical site characteristics (e.g., bathymetry, dredged areas, in-water structures/features, and grain size information) were also assessed. The application of remedial technologies and development of alternatives for these areas are discussed in Sections 4 and 5.

The jetty and mill dock are the two principal in-water structures that physically define the SRSs. Together with a portion of the West Mill Area shoreline, the jetty (including the jetty peninsula) define much of perimeter of the log pond. The log pond has unique sediment quality characteristics, operational history, and conditions that directly affect the analysis and selection of remediation technologies.

The mill dock structure also plays a key role in defining the SRSs. Over the years, the mill dock has likely influenced the quality and nature of sediment accumulated among the hundreds of piles supporting the structure, as well as the bathymetry in the dock vicinity (Figure 3-6). Shell hash that has sloughed off the piles has likely accumulated beneath the dock, and the stilling influence of the piles has likely increased sediment deposition. These factors have contributed to a shallow bottom area relative to the surrounding berths and approach.

In contrast to the under-dock area, the adjacent berths and approach SRSs are relatively accessible and because they have been historically dredged, are areas that tend to accumulate smaller grain-sized materials (Figure 3-6). These historically dredged SRSs need to be considered in terms of their unique remediation needs and applicable technologies. The SMS, for example, place a priority on permanent remedial actions that minimize the potential for recontamination. Technologies that would shallow-up these dredged areas, such as filling (see Section 5), would likely reduce the potential for the future accumulation of contaminated fines from offsite sources.

4 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

Identification and screening of sediment, soil, and groundwater remediation technologies were performed based on general response actions for each media for the former Rayonier Mill Study Area in Port Angeles, Washington. The primary objective of this evaluation is to identify a sufficient range of remediation technologies to be used for the development of the upland and in-water (sediment) remediation alternatives in Section 5. Under the MTCA (WAC 173-340) (Ecology 2013a), the development of remediation alternatives involves a screening evaluation of remediation technologies with the demonstrated ability to meet cleanup goals. The screening and evaluation of technologies are based on their applicability to the Study Area and ability to address the cleanup standards and the interim action objectives (IAOs) described in Section 3. Technologies identified in this section as applicable to and useful for the Study Area are retained and used in Sections 5 and 6 to develop and evaluate remediation alternatives.

The screening of technologies includes the following steps:

1. Identify general response actions (GRAs), which are general categories of actions for addressing one or more components of the IAOs.
2. Identify applicable technologies under each GRA.
3. Screen and select appropriate technologies for the Study Area that can be combined with other technologies to formulate the remediation alternatives.

Technology screening was based on a qualitative evaluation of effectiveness and implementability. The key criteria considered in evaluating these technologies included:

- Reliability and proven effectiveness with respect to the Study Area IHSs
- Applicability to site-specific conditions
- Anticipated effectiveness
- Technical implementability within a reasonable time frame
- Commercial availability

In addition, certain technologies were eliminated from further consideration if an equally effective, lower-cost technology was identified or if institutional barriers to their implementation were anticipated to render the technology unavailable for the upland and in-water sediment remediation areas.

4.1. GENERAL RESPONSE ACTIONS

This section identifies GRAs for the remediation of contaminated soil, groundwater, and sediment located within the remediation areas.

For all affected media, the GRAs broadly include:

- Removal
- In-situ treatment
- Containment
- Monitored natural attenuation (MNA) or monitored natural recovery (MNR)

- Enhanced attenuation or enhanced natural recovery (ENR)
- Engineering Controls
- ICs

The GRAs listed above are represented by a broad spectrum of technologies and process options that can be used to develop remediation alternatives.

4.1.1. Removal

Removal is a relatively aggressive GRA involving physical extraction of contaminated media via excavation, dredging, or groundwater withdrawal. Once extracted, the contaminated media may be treated ex situ by a variety of physical, thermal, chemical, and biological methods (see Section 4.1.8). The final disposition of the extracted media (whether treated or not) and any treatment residuals (such as sludge or used filter media) must also be determined (see Section 4.1.8). Removal is a permanent remedial approach for the contamination in the removed media; however, removal can be difficult to implement, costly, and – particularly in the case of groundwater withdrawal – relatively time consuming.

Removal technologies specific to soil, groundwater, and sediment are presented and screened in Sections 4.2.1, 4.3.1, and 4.4.1, respectively.

4.1.2. In-Situ Treatment

Treating contaminated media in place typically involves engineered modifications to the local environment to reduce the toxicity, mobility, or volume of contamination. The in-situ treatment may be physical, thermal, chemical, or biological and a variety of methods may be used to produce the specific local conditions required for the desired effects. Depending on the technology and the method of implementation, there can be challenges in achieving the desired treatment conditions where the contamination exists. One key advantage of in-situ treatment over removal for ex situ treatment is that there are no (or very limited) residuals to dispose of.

In-situ treatment technologies and process options specific to soil, groundwater, and sediment are presented and screened in Sections 4.2.2, 4.3.2, and 4.4.2, respectively.

4.1.3. Containment

Containment actions allow contamination to remain at the site but limit migration by creating a boundary beyond which contaminants do not traverse (at concentrations exceeding established criteria such as cleanup levels or remediation levels). For surface soil contamination, a cap serves as a containment measure because it prevents erosion and sedimentation of the contaminated soil. A cap may also prevent water infiltration that would lead to leaching of contaminants from unsaturated soil to groundwater. Groundwater containment may be achieved by a physical barrier such as a slurry wall, an in-situ treatment zone such as a permeable reactive barrier (PRB), establishment of a hydraulic capture zone using extraction wells, or some combination of approaches (e.g. a funnel-and-gate system). A sediment cap that prevents resuspension of contaminated sediment is also a containment technology.

Note that a containment approach may involve some removal (e.g., hydraulic containment with groundwater withdrawal), in-situ treatment (e.g., with a PRB), or engineering controls to prevent exposure (e.g., soil cap). Typically, an approach primarily designed to keep contamination in a particular place is considered a containment action rather than a removal or in-situ action. Similarly, if the primary function of an engineered system such as a soil cover is to block potential human or ecological contact with contaminated media, then the system is considered to be an engineering-control approach (see Section 4.1.6) rather than a containment approach.

Containment technologies and process options specific to soil, groundwater, and sediment are presented and screened in Sections 4.2.3, 4.3.3, and 4.4.3, respectively.

4.1.4. Natural Attenuation and Recovery

Natural environmental processes such as dispersion, sorption, geochemical speciation/precipitation, and chemical changes due to respiration of natural microbes often have the effect of reducing the toxicity, mobility, volume, or concentration of contamination in the environment. Reliance on these natural processes to address contamination can often be part of a successful remediation strategy for a site. In such cases, some type of monitoring is typically used to demonstrate that the natural processes are having the desired effects on contamination. For groundwater plumes (and sometimes for soil), this GRA is usually called “monitored natural attenuation” (MNA). For sediment, the term “monitored natural recovery” (MNR) is often used. MNA is discussed in Sections 4.2.4 and 4.3.4 and MNR is discussed in Section 4.4.4.

In some cases, natural processes are enhanced through modification of the local environment – e.g., by adding nutrients, carbon, microbes, or heat. These types of enhancements are typically considered to be in-situ treatment technologies (Section 4.1.2).

4.1.5. Enhanced Attenuation or Recovery

Another way to improve the effectiveness of natural processes for remediation is to add uncontaminated environmental media. For groundwater that discharges to a surface water, a sand filter may be installed at the discharge location to promote natural attenuation processes in near-surface groundwater (see Section 4.3.5). For sediment, a layer of sand or other suitable material may be placed over contaminated sediment in a manner that allows for resuspension and deposition but that results in average exposure concentrations meeting remediation objectives. This sediment approach is called ENR and is discussed in Section 4.4.5.

4.1.6. Engineering Controls

Exposure pathways may be blocked by a variety of engineered physical barriers such as soil covers and structures. Where the engineered barriers are primarily to block an exposure route (rather than to prevent environmental migration) the approach is considered to be an engineering control. Sometimes a containment approach such as a soil cap also serves as an engineering control to prevent direct contact with contaminated media.

Engineering-control technologies specific to soil, groundwater, and sediment are presented and screened in Sections 4.2.5, 4.3.6, and 4.4.6, respectively.

4.1.7. Institutional Controls

ICs also serve to limit exposure to contaminated media, but they use administrative rather than physical means. ICs can include land and water use restrictions documented in restrictive covenants or local regulations, warning signs, and other means of informing site occupants of contamination and the potential for exposure.

IC approaches for soil, groundwater, and sediment are presented and screened in Sections 4.2.6, 4.3.7, and 4.4.7, respectively.

4.1.8. Residuals Handling

Removal actions require further consideration of how the removed soil, groundwater, or sediment will be handled. Ex situ treatment may be appropriate and various treatment technologies may be effective depending on the contaminants and media. Some ex situ treatment technologies result in treatment residuals such as ash, sludge, or brine which require disposal. The final disposal or end use of the removed media, whether treated or not, must also be defined.

Some in-situ treatment actions may also periodically result in residuals that need to be considered. For instance, a PRB may become less reactive over time and thus need replacement. The removed PRB medium would be a residual requiring treatment and/or disposal.

Residuals handling options are presented and screened in Section 4.5.

4.2. UPLAND SOIL TECHNOLOGY SCREENING

The soil technology screening evaluation identified a broad spectrum of potentially applicable technologies that can be used to develop the soil remediation alternatives. The GRAs and technologies retained for the development of the soil remediation alternatives are identified below:

- Soil removal (excavation)
- Containment (capping)
- ICs

The technology screening results are summarized in Table 4-1 and discussed in the subsections that follow.

4.2.1. Excavation

The excavation and removal of contaminated soil from a site is an effective technology for permanently reducing the potential for direct contact with, or leaching from, contaminated soil, and excavation is a proven and well-established technology in the remediation construction industry. Soil removal is performed using various types of heavy equipment, such as excavators, front-end loaders, and backhoes. The type of equipment used depends on the type of material to be removed, the load-bearing capacity of the ground in the removal area, the depth and areal extent of removal, the required rate of removal, and the depth to the groundwater table. Large-scale construction dewatering would only be needed for large excavations below the groundwater table.

The implementation of this technology could require additional equipment if excavation was sufficiently deep to encounter relict subsurface structures (e.g., in the West Mill Area). Depending on the remedy selected, technologies for managing construction debris might be needed. For example, buried concrete structures (if encountered) could potentially be reused as aggregate in upland caps. Demolition equipment, including stingers attached to backhoes, specialized cranes and grappling/extraction systems, are readily available and can be used to remove concrete foundations, footings, and piles to facilitate access to adjacent or underlying soil.

4.2.2. In-Situ Treatment

As shown in Table 4-1, none of the in-situ treatment technologies were retained for inclusion in the remediation alternatives. The reasons for this include difficulties with applying treatment media effectively throughout the in-place soil mass, inability to treat a sufficiently broad range of soil COPCs, and the heterogeneous nature of subsurface materials and structures.

In particular, the presence of dioxin in soil above PCULs and RELs throughout the soil remediation areas (Appendix A) limits the effectiveness of the in-situ treatment GRA for addressing soil. No proven, practicable in-situ treatment option is available to treat dioxin. Therefore, in-situ treatment would not result in meeting RELs or PCULs for any sizeable area of the Site.

4.2.2.1. Thermal Treatment

Thermal treatment involves heating the contaminated soil to desorb constituents, volatilize constituents, or chemically alter constituents (to reduce toxicity or affect mobility).

Thermal desorption is the process by which heat is used to facilitate the mobilization and subsequent capture of contaminants in soil by, for example, groundwater extraction or soil vapor extraction (SVE). Heating the soil enhances mobility in four ways: (1) contaminant vapor pressure and diffusivity are increased by heating; (2) the soil permeability is increased by drying; (3) the volatility of the contaminant may increase from in-situ steam stripping by the water vapor; and (4) viscosity may decrease which improves mobility. Some of the soil contaminants at this site (e.g., metals, dioxin) are not significantly influenced by temperature.

In-situ thermal destruction (by chemical alteration or combustion) of contamination is typically only effective for organic contamination at very high concentrations. For non-organic and low-concentration organic soil contamination, thermal destruction is either ineffective or much less cost-effective than alternative treatment technologies such as bioremediation, soil flushing or solidification/stabilization.

Process options for thermal treatment include electrical resistivity heating, radio frequency heating, thermal conductive heating, and steam injection; these process options are discussed below. None of the process options would be effective on inorganic contaminants and in all cases more cost-effective technologies are available for this Site. Therefore, no thermal treatment technologies are retained for the development of alternatives.

4.2.2.1.1. Electrical Resistivity Heating

Electrical resistivity heating (ERH) uses an electrical current to heat low-permeability soils, causing water and entrapped contaminants to vaporize and facilitating their removal via vapor extraction. In ERH, electrodes are placed in the ground and resistance to the current as it moves between electrodes causes the soil to heat up. The heating of the soil also dries it out, resulting in fractures that enhance the permeability of the soil. The technique can heat soils to over 300 degrees Celsius (°C).

4.2.2.1.2. Radio Frequency Heating

Radio frequency heating (RFH) is an in-situ process that uses electromagnetic energy to heat soils.

4.2.2.1.3. Thermal Conductive Heating

In conductive heating, heat is applied to the subsurface via conductive heat transfer. The heat may be applied via thermal wells or a thermal blanket.

4.2.2.1.4. Steam Heating

In steam heating, volatile contaminants are stripped from soil through injection of steam into the subsurface. The steam is then removed via an SVE system.

4.2.2.2. Biological Treatment

Biological treatment of contaminants involves stimulating microbial activity in the subsurface that utilizes target contaminants as a source of food and energy, thus facilitating the destruction of the contaminants or degrading them into non-toxic or immobile compounds.

Several different process options for biological treatment are presented in the subsections below. However, none of the biological treatment process options would be effective on the variety of soil contaminants at the Site. In particular, dioxin, cPAHs, PCBs, and some inorganics would not likely be effectively treated by enhanced microbial activity in soil. Given the ubiquity of dioxin within the remediation zone, in-situ biological treatment is screened out as a potential remediation technology at the Site.

4.2.2.2.1. Enhanced Reductive Bioremediation

Enhanced bioremediation involves the introduction of nutrients and other materials into the subsurface to stimulate the growth of indigenous microorganisms (bacteria) that use the contaminants as a food and energy source. Reduction of contaminants by bacteria is facilitated by the introduction of nutrients, electron donors, electron acceptors, or some combination thereof. This can be effective on total petroleum hydrocarbons (TPH) and certain other organic compounds but is relatively ineffective or not feasible within reasonable treatment time frames for dioxin, PCBs, cPAHs, and most inorganics.

4.2.2.2.2. Enhanced Aerobic Bioremediation

Under aerobic conditions and in the presence of other nutrient elements, microorganisms (bacteria) can convert many organic compounds into carbon, water, and microbial cell mass. Enhanced aerobic bioremediation involves the introduction of nutrients and oxygen into the subsurface to stimulate the growth of indigenous microorganisms that use the contaminants as a food and energy source. Bioventing – injection of air into the subsurface – is one version of enhanced aerobic bioremediation. Again, this process option can be effective on certain Site constituents but is not broadly applicable for all Site soil contaminants, particularly dioxin.

4.2.2.2.3. Bioaugmentation

In some instances, microorganisms (bacteria) capable of degrading the target compounds are also introduced to the subsurface. Typically, microorganisms from the project site are collected, separately cultured, and returned to the subsurface to quickly increase the population of the microorganisms. The inability to effectively apply this technology in-situ and the likely need to continuously sustain a selected microbial population make this technology infeasible for the Site. This technology would also not likely be effective for dioxin. It is therefore not retained for alternative development.

4.2.2.2.4. Phytoremediation

Phytoremediation utilizes plants to remove contamination from the soil or shallow groundwater based on the plants' natural ability to take up and accumulate or degrade organic and inorganic constituents. Phytoremediation is generally applicable to treating relatively low levels of contamination in groundwater that is within a few feet of ground surface. Mechanisms for remediation are (1) uptake and phytodegradation, (2) uptake and phytoaccumulation, and (3) rapid rhizodegradation. This technology is not proven for dioxin and is not retained as a potential remediation technology.

4.2.2.3. Chemical Treatment

Chemical treatment involves altering the geochemistry within a contaminant plume in order to produce (or enhance) chemical reactions that either: (1) chemically convert a contaminant into a less toxic substance,

(2) chemically convert a contaminant into a less mobile substance (e.g., a solid precipitate), (3) cause the contaminant to adsorb to immobile solids (e.g., soil particles), or (4) chemically convert a contaminant into a more mobile substance that can then be more readily extracted. The primary process options for doing this are oxidation and reduction.

Due to the variety of contaminants in soil, and in particular the resistance of dioxin and PCBs to chemical reactions, no chemical treatment technologies are retained for development of alternatives.

4.2.2.3.1. Oxidation

Chemical oxidation is a process by which contaminants are oxidized to compounds that are less toxic, more stable, less mobile, and/or inert. The oxidizing agents most commonly used are ozone, hydrogen peroxide, persulfate, permanganate, hypochlorites, chlorine, and chlorine dioxide. Oxidizing agents may be added to soil via soil mixing or injection (liquid, gas, or suspension of nano-particulates).

4.2.2.3.2. Reduction

Similarly, chemical reduction is a process wherein reducing agents (e.g., zero-valent iron, ferrous sulfate, ferrous sulfide, calcium polysulfide, or sodium metabisulfite) are added to the soil to produce chemical reactions that result in decreased toxicity or altered mobility of contaminants. Chemical reduction requires an anoxic environment and is often not applicable to surface soil.

4.2.2.4. Solidification/Stabilization

In solidification/stabilization (S/S), treatment agents are mixed or injected into the contaminated material to form a crystalline, glassy, or polymeric framework surrounding the contaminated soil particles. This process reduces the contaminant solubility, decreases the exposed surface area across which mass transfer loss of contaminants may occur, and/or limits the contact between the contaminants and the transport fluid by reducing the material’s permeability. Treatment agents are typically either inorganic binders (e.g., cement, fly ash) or organic binders such as bitumen. The greatest challenge to successful in-situ S/S is achieving a complete and uniform mixing of the binder with the contaminated material. In-situ S/S has been demonstrated to depths of 30 feet and more.

In-situ S/S treatment is not effective at eliminating direct contact risks which are a key consideration at this Site. This technology also creates excess material to manage and is complicated by heterogeneous subsurface conditions that include relic structures. Therefore, this technology is not retained for alternative development.

4.2.2.5. Soil Vapor Extraction

SVE is an in-situ unsaturated zone soil remediation technology in which a vacuum is applied to the soil to induce the controlled flow of air and remove volatile and some semi-volatile contaminants from the soil. Most Site contaminants would not be substantially affected; therefore, this technology is not retained for alternative development.

4.2.2.6. Soil Flushing

Soil flushing typically involves the injection or infiltration of water or some other aqueous solution (e.g., water with a solvent or a surfactant to enhance effectiveness) into the unsaturated zone and subsequent extraction of the contaminated solution for ex situ treatment and disposal. Soil flushing can also be accomplished using steam or gas. The primary target contaminants for soil flushing are often inorganics. Process options are discussed below. Due to ineffectiveness on certain Site contaminants (e.g., dioxin) and complications from the presence of subsurface discontinuities and structures, soil flushing is not retained as a technology for use in remedial alternatives

4.2.2.6.1. Water

The use of water as the only flushing liquid may be appropriate when treating soil contaminated with relatively soluble contaminants. However, at this Site many of the site contaminants are relatively insoluble.

4.2.2.6.2. Solvent

Water enhanced with a solvent can be used as a flushing liquid for soils contaminated with compounds that have relatively low solubility. However, no solvent has been identified that would be effective for the variety of contaminants found at the Site, and solvents can lead to additional environmental concerns.

4.2.2.6.3. Surfactant

Water enhanced with a surfactant can be used as a flushing agent for soils contaminated with contaminants that are sorptive not highly soluble. However, no environmentally safe and effective surfactant has been identified for the contaminant mix at the Site.

4.2.2.6.4. Steam

Steam may be injected below the contaminated zone to heat up contaminated soil. The heating enhances the release of contaminants form soil matrix. Some volatile organic compounds (VOC) and semivolatile organic compounds (SVOC) are stripped from the contaminated zone and extracted from the subsurface through soil vapor extraction or groundwater extraction. This technology option is discussed with other thermal treatment options in Section 4.2.2.1.

4.2.2.6.5. Air/Gas

Air or another gas may also be used to flush volatile (or gas soluble) contaminants from soil, with subsequent extraction via SVE. The carrier may be heated or amended to promote gas solubility or contaminant destruction. Again, no particular gas has been identified for use on the mix of soil contaminants at the Site.

4.2.3. Containment: Capping

Soil capping is implemented at sites that contain large volumes of environmental media with relatively low levels of hazardous substances and the treatment of the hazardous substances is impracticable (WAC 173-340-370). This technology has been retained as a soil remediation technology for the Study Area because of the low-level concentrations and disperse nature of COPCs, which would not be cost-effective to treat. Capping is both a containment and engineering-control response.

Capping is a well-established and proven containment technology for preventing direct contact with contaminated soil through the establishment and maintenance of a physical barrier between contaminated soil and potential human and ecological receptors. For example, capping has been selected by the Ecology as one of the remedies used to address contaminated soil within the 1,000-square-mile fallout area of the former Tacoma Asarco smelter (Ecology 2012c). Contaminated soil is contained using caps constructed of soil, geotextiles and/or geomembranes, aggregate, or pavement or covered by structures such as buildings. The location and design of caps should be compatible with land use and are often integrated with redevelopment plans. Examples include:

A paved parking lot for cars and boat trailers was constructed on top of an upland contaminated sediment containment cell at the Cascade Pole Company site in Olympia, Washington.

A landscaped berm was constructed on top of contaminated soil at the former J.H. Baxter wood treatment plant site to provide spectator viewing at the Seattle Seahawks football team training facility in Renton, Washington.

4.2.3.1. Soil Cover (Aggregate Cap)

Construction of a soil cover such as an aggregate cap would consist of placing clean aggregate and soil (likely a gravel or crushed-rock base layer and a finer-grain soil cover layer) over contaminated soil. A woven geotextile fabric would be used to separate the clean cap materials from the underlying contaminated soil. The type of geotextile selected for use would permit the infiltration of stormwater.

4.2.3.2. Low Permeability Soil Cap (Geomembrane)

A cap that incorporates a flexible geomembrane (e.g., high-density polyethylene) liner in place of a woven geotextile was identified and retained as a candidate remediation technology. The cap's aggregate layer would keep the liner anchored in place and protect it from photodegradation. The geomembrane liner used in this application would be impermeable; as a result, this type of cap would be designed to provide for the drainage of stormwater that would infiltrate the top of the cap.

4.2.4. Natural Attenuation

MNA involves monitoring over time of the reduction of contaminant concentrations resulting from intrinsic natural processes such as volatilization, biodegradation, adsorption, and chemical reactions. While this can be effective for TPH, it not expected to be effective for most Site IHSs, including metals, cPAHs, dioxin, or PCBs. Therefore, this technology is not retained for development of soil alternatives.

4.2.5. Engineering Controls

Engineering controls for soil are designed Site components that eliminate the potential for direct contact with soil by humans or biota. Engineering controls may also limit vapor migration of contaminants into human-occupied structures.

4.2.5.1. Soil Cap

As discussed in Section 4.2.3, soil capping is both a containment and engineering control technology in that the cap can mitigate migration of contamination (by limiting erosion and potentially limiting infiltration) and the cap provides a barrier to direct contact with the underlying soil. Capping is retained as a viable technology for use in alternatives development.

4.2.5.2. Fence

Fences can be used to control Site access, thereby reducing potential human exposure and risk. Though ineffective for ecological receptors and not 100% effective in preventing trespassing, fences are retained as a viable technology to reduce the potential human health risks associated with direct contact of Site soils.

4.2.6. Institutional Controls

ICs are measures undertaken to limit or prohibit activities that interfere with the integrity of a remedial action or that may result in exposure to hazardous substances in the Study Area. Examples of ICs include environmental covenants limiting site uses, warning signs, and Site management plans. These IC options are retained for use in alternatives development.

4.3. GROUNDWATER TECHNOLOGY SCREENING

Groundwater technologies were screened in this section to develop groundwater alternatives in Section 5 that meet PCULs at standard POCs or at conditional POCs, if approved.

A broad spectrum of potentially applicable technologies is available for the development of groundwater remediation alternatives. Groundwater technologies were retained if they could potentially be applied to address specific COPCs (or groups of COPCs) in select portions of the Upland Study Area. The GRAs and technologies retained for consideration in the development of groundwater remediation alternatives include:

- Containment (physical flow barriers)
- In-situ treatment (permeable reactive barrier, air sparging, in-situ chemical oxidation, in-situ chemical fixation, nearshore sand filtration)
- ICs
- MNA

Table 4-2 presents these technologies and describes the screening results.

4.3.1. Groundwater Extraction

Groundwater extraction and ex situ treatment was not retained as a GRA or technology for addressing potential COPCs in groundwater and meeting PCULs. If groundwater treatment is determined to be needed, there are retained in-situ treatment methods that could be applied on a localized basis and at lower cost. This technology, also referred to as “pump and treat,” typically requires significant treatment system equipment/infrastructure and very long time frames to meet PCULs.

However, groundwater extraction may be used on a limited basis as part of a soil excavation remedy to achieve beneficial contaminant mass reductions in a cost-effective manner using temporary piping and treatment facilities.

4.3.2. In-Situ Treatment

In-situ treatment technologies provide for the treatment of groundwater without extraction. In-situ treatment technologies retained for consideration if groundwater treatment were to be necessary include a PRB, air sparging, in-situ chemical oxidation (ISCO), and in-situ chemical fixation (ISCF).

4.3.2.1. Permeable Reactive Barrier

PRBs, which were retained as a potential technology, are permeable treatment walls constructed perpendicular to the flow path of contaminated groundwater in the subsurface at the downgradient perimeter of the area to be treated (DOD et al. 2002). A PRB represents both a containment and an in-situ treatment response. A PRB provides passive treatment of groundwater as it flows through the wall. Reactive media in PRBs can treat contaminants in-situ through physical or chemical processes or stimulate secondary processes (e.g., biological activity) that reduce contaminant concentrations in groundwater. PRBs have been used to treat both organic and inorganic compounds (including metals); multiple contaminants can sometimes be treated by a single PRB. PRBs are often used to contain groundwater contamination and can enhance attenuation that is already occurring at a site by reducing contaminant mass.

The effectiveness of PRBs relies on the selection of effective treatment media. Reactive media potentially useful in the treatment of metals and organic constituents include phosphate additives, zero valent iron, bauxite derivatives, iron and steel furnace slag, activated carbon, and organo-clay (DOD et al. 2002). These materials sequester contaminants through different processes, including ion exchange, precipitation, and adsorption. PRBs have been used at other sites to address some of the same COPCs found in groundwater in the upland area (e.g., manganese, copper, arsenic, mercury, and nickel). Examples include the Bodo Canyon disposal site in Colorado, the Monticello Mill tailings site in Utah, the Cyprus AMAX Minerals/AMAX Realty development site in New Jersey, the Tonolli Superfund site in Pennsylvania, the Nickel Rim Mine site in Ontario, the Zeneca/Campus Bay site in California, and the Columbia Nitrogen site in South Carolina (Bronstein 2005). Reactive media used at these sites included zero-valent iron, copper and steel wool, limestone, sodium carbonate, and compost materials. The selection of the proper treatment medium, or combination of media, for groundwater would require additional evaluation, likely including bench-scale testing. Performance monitoring and maintenance, including replacement of the treatment media as needed to ensure the continued effectiveness of a PRB, would be required.

4.3.2.2. In-Situ Chemical Oxidation

ISCO was retained as a potential technology. It involves the injection of a solution of water and a chemical oxidant into the subsurface to oxidize metallic ions and chemically convert organic compounds to less-toxic compounds. The specific oxidant used is selected based on contaminant oxidation/reduction chemistry. This technology has proven effective in treating some metals and PAHs. There is currently no known commercially available oxidant capable of treating all groundwater contaminants. Effectiveness could be inhibited by subsurface heterogeneity and relict structures or the presence of high organics (e.g., wood debris).

ISCO results in the destruction of both adsorbed and dissolved-phase organic compounds through chemical reactions with the oxidant injected into the subsurface. For organic compounds such as PAHs, the ultimate result of chemical oxidation is total mineralization; ISCO end products include water and other inorganic compounds and carbon dioxide. The changing prevailing redox conditions also result in precipitation of manganese oxides and can generally reduce the dissolved-phase concentrations of other metals.

A modified Fenton's reagent may be the best choice of oxidant for the organic groundwater COPCs (e.g., PAHs) based on its general effectiveness relative to other reagents and lack of detrimental/deleterious chemical byproducts (Haskins 2014). Reagent selection would be finalized during design based on bench tests using site groundwater. ISCO can be a cost-effective treatment option. Vertical or horizontal wells or direct-push technology can be used to inject the ISCO solution. A series of oxidant applications is often used to reduce chemical mass in the groundwater plume. Chemical oxidation has a relatively rapid treatment time and can be implemented with readily available equipment.

4.3.2.3. In-Situ Chemical Fixation

ISCF involves the placement of a reductant or reductant-generating material into the subsurface to chemically degrade organic compounds to potentially non-toxic or less toxic compounds, immobilize metals by adsorption or precipitation, or degrade non-metallic oxyanions, such as nitrate. ISCF has proven to be effective for the immobilization of arsenic and may also be a viable technology for other metals (e.g., copper, mercury, nickel) and possibly ammonia. There is currently no known commercially available reductant capable of treating all identified groundwater contaminants. Effectiveness could be inhibited by subsurface heterogeneity and relict structures.

The most commonly used reductant is zero-valent iron, which is used to treat some organic compounds and metals/metalloids including arsenic (EPA 2014a). Other reductants that are used to treat metals include ferrous iron, sodium dithionite, sulfide salts (calcium polysulfide), and hydrogen sulfide. Like ISCO, vertical or horizontal wells or direct-push technology can be used to inject the ISCF solution. A series of reductant applications is often used to immobilize metals in groundwater.

4.3.2.4. Sparging

Air sparging was also retained as a potential technology. Air sparging involves the injection of compressed air through remediation wells screened at depths below the seasonal low groundwater table elevation. The injected air increases dissolved oxygen concentrations in groundwater, which can increase the rate of aerobic biodegradation of organic contaminants (e.g., PAHs). The increased dissolved oxygen concentrations may also attenuate dissolved manganese and un-ionized ammonia through oxidation. The attenuation of dissolved manganese via precipitation of manganese oxides may lead to the attenuation of other dissolved metals due to the adsorption capacities and scavenging capabilities of the manganese oxides (Post 1999). Air sparging is typically applied using vertical remediation wells connected to above-ground blowers and control equipment. Air sparging has been proven effective for contaminants that biodegrade slowly and is most effective in less heterogeneous subsurface conditions.

Where pH is high, sparging of carbon dioxide may accelerate a return to circumneutral conditions.

4.3.2.5. Thermal Treatment

In-situ thermal treatment technologies for groundwater – such as electrical resistance heating and steam injection – were also considered but were screened out because they are generally ineffective for Site IHSs. These technologies are generally best suited for VOC contamination and VOCs are not IHSs for groundwater.

4.3.3. Containment

Hydraulic containment technologies were retained. These actions could reduce or cut off groundwater migration from the upland to marine environment during construction activities.

4.3.3.1. Hydraulic Containment

Hydraulic containment would only be implemented to support potential construction activities such as soil excavation that might require groundwater controls. Containment would be accomplished through the extraction of groundwater (via pumping from extraction wells or trenches) to establish a hydraulic capture zone and restrict groundwater flow and contaminant migration. This technology has been retained for potential use in localized areas for short time periods should extraction for hydraulic containment or excavation dewatering become necessary.

4.3.3.2. Cutoff Walls

Another commonly applied containment technology includes cutoff walls (e.g. sheet pile walls or slurry walls). Similar to hydraulic containment, this technology can be used on a localized basis to facilitate soil excavation. Cutoff walls may also be used in design of a PRB in development of a funnel-and-gate flow system: the cutoff walls essentially direct groundwater flow toward PRB treatment zones.

4.3.4. Monitored Natural Attenuation

MNA is a potentially viable approach to addressing relatively low-level groundwater contamination remaining at the Site and can be employed with other active remedial technologies. As such, this technology is retained for use in alternatives development.

MNA refers to a variety of physical, geochemical, and biological processes that occur in the subsurface and result in decreasing concentrations of constituents. Such processes include hydrodynamic dispersion (natural mixing), adsorption, chemical precipitation caused by redox changes, and natural biodegradation (aerobic and anaerobic). At this site, an important aspect of MNA is likely to be oxygenation of groundwater in the tidal transition zone which results in oxidizing conditions, thereby reducing ammonia concentrations, causing dissolved manganese to form precipitates (with scavenging of other metals), and promoting aerobic degradation of organic constituents.

MNA would require further site-specific field studies to quantify concentration reductions, particularly within the tidal transition zone.

4.3.5. Nearshore Sand Filter

Nearshore sand filtration reduces COPC concentrations by enhancing tidal physical and chemical attenuation processes in the intertidal zone. Nearshore sand filtration was retained as technology for use in alternatives development. It consists of the construction of a sand horizon at the shoreline (generally the intertidal zone) to enhance hydrodynamic dispersion and physical and chemical attenuation of COPCs. The enhanced attenuation of COPCs occurs in the sand filtration horizon, before groundwater discharges to marine surface water. Nearshore sand filtration has been used or selected for use at other cleanup sites to provide additional attenuation when existing attenuation processes do not fully address discharge of dissolved contaminants to surface water. One site in Washington where nearshore sand filter horizons (also known as attenuation layers or isolation caps) has been selected for use is the Cornwall Landfill site in Bellingham (Ecology 2014c).

The design of a sand filter would require consideration of groundwater and sediment quality in the nearshore area, as well as methods for protecting the sand filtration horizon from erosive forces. Future site use (e.g., potential navigation and anchoring activities) and constraints on bathymetry also would need to be considered. The construction of a nearshore sand filtration horizon in the intertidal zone could be accomplished using standard construction methods and readily available materials.

4.3.6. Institutional Controls

An environmental covenant may be required to prevent human exposures to contaminated groundwater. For example, deed restrictions would be appropriate to restrict potable uses of groundwater. Environmental covenants also can be used to restrict actions that could reduce remedy effectiveness (e.g., intrusive construction activity in areas of installed PRBs or nearshore sand filter horizons). ICs are retained as a potential component of remedial alternatives.

4.4. SEDIMENT TECHNOLOGY SCREENING

This section identifies GRAs and technologies potentially applicable to the remediation of contaminated sediment located within the sediment remediation area. Supplemental technologies for dredged material management and disposal are also identified and evaluated.

GRAs for sediment include those potentially applicable actions ("cleanup action components") set forth in the SMS WAC 173-204-570(4)(b) (Ecology 2013a), as identified below:

- Removal
- In-situ treatment
- Containment

- MNR
- ENR
- ICs

Recent sediment remediation projects in the Puget Sound region have included evaluations of a comprehensive range of potential sediment remediation technologies, including those that are emerging or have not yet been proven for full-scale implementation. These projects, such as an investigation undertaken for the Lower Duwamish Waterway (LDW) (RETEC 2005), have screened out unproven technologies in sediment remediation, specifically, in-situ treatment technologies (e.g., biodegradation, vitrification, ground freezing) and provided a basis for focusing on those that are potentially effective and ready to be implemented. This and similar work serve as a useful point of departure for narrowing the list of candidate technologies to those that are proven and commonly applied to regional nearshore marine sediment sites.

The GRAs listed above are represented by a broad spectrum of technologies that can be used to develop sediment remediation alternatives. The technology screening results are summarized in Table 4-3 and discussed in the subsections that follow.

4.4.1. Dredging

Dredging is retained as a technology and can be performed using various methods. Mechanical dredging of contaminated sediment is a well-known and established technology (EPA 2005) that has been successfully implemented in the Puget Sound region. For example, dredging using barge-mounted equipment was recently conducted at Slip 4 on the LDW (Integral 2012). Mechanical dredging is typically used in subtidal areas but can also be used to remove intertidal sediment during high tides. Sediment closer to shore can be removed from the upland using excavation equipment.

Hydraulic dredging is an appropriate technology for areas where mechanical dredging or excavation cannot be used. Hydraulic dredging is generally less desirable because it can generate a dredged material slurry that must typically undergo a significant degree of dewatering before the residual solids are suitable for transport or disposal. Hydraulic dredging rates can also be low relative to the rates for other sediment removal methods, particularly if a diver must be used to direct the suction hose inlet. For this reason, hydraulic dredging is only considered for use in areas where access would be limited.

The excavation of intertidal sediment from the upland/beach areas can be done using backhoes, excavators, front end loaders, drag lines, and dump trucks. Contaminated sediment can be excavated, and if necessary, placed in lined trucks, and transported to an appropriate staging area or disposal location. Shore-based sediment excavation has been successfully implemented elsewhere in the region (e.g., Port Gamble Bay cleanup, Port of Seattle Terminal 117 cleanup, Boeing Plant 2 cleanup) and can use conventional heavy equipment similar to that used for previous excavation work at the former Rayonier Mill.

4.4.2. In-Situ Treatment

In-situ treatment technologies were evaluated for the Marine Study Area, including the addition of sequestering or treatment agents, such as activated carbon, to thin-layer material placed on the sediment surface (i.e., as an amendment for ENR), reactive mats, direct biological/chemical treatment, and solidification. The addition of activated carbon to an applied ENR layer is considered to be a form of in-situ treatment.

Carbon amendment application was not retained because it is not anticipated to be necessary as an adjunct to ENR to achieve the PCULs. This assumption will be confirmed during the remedial design of those alternatives that include ENR as a technology.

Reactive mats were not retained because they typically consist of localized structural components more appropriately applied to relatively small areas of highly contaminated sediment (e.g., product seeps in shoreline areas) and only as short-term treatment measures. Biological/chemical treatment and solidification were also not retained because they require the direct application of treatment agents onto the sediment profile through intrusive mechanical mixing (with the potential for extensive sediment resuspension).

4.4.3. Containment

Containment was retained as an engineered control for sediment. It can be accomplished through the placement of fill or using sediment caps (Figure 4-1).

4.4.3.1. Fill

As a containment technology, clean fill can be placed in dredged depressions (i.e., near the mill dock in berth areas) and covered with an ENR layer (Figure 4-1, top cross-section). The purpose of the fill would be to shallow up the formerly dredged areas so that they would no longer be areas of deposition and potential recontamination. The final fill bathymetry would reduce the likelihood that potentially contaminated fines imported from offsite would settle in these areas.

One measure of the performance of a fill system is its ability to meet PCULs within a specified depth of compliance, which is dependent on several factors, including the placement method, fill stability, fill thickness, and fill material characteristics. Sediment COPC concentrations in the Study Area are sufficiently low such that the potential for long-term diffusion of contaminants through the fill layer is likely to be low as well. Fill areas will contain subtidal sediment, but ICs are not needed for permanence. An analysis of potential mobilization associated with various current and storm conditions (Appendix C) shows that typical fill material will remain in place. Final fill thickness would depend on bathymetry, and a top gravel layer could be used, if needed, to assure long-term stability. Specific fill thicknesses and materials (e.g., clean sand, silt, gravel) would be determined during design.

4.4.3.2. Sediment Cap

Caps can include layers of sand, gravel, or other materials designed to have characteristics similar to those of the surrounding sediment to encourage the re-establishment of habitat. As noted in Table 4-3, sediment cap is retained as a containment technology for the Study Area (Figure 4-1, bottom cross section). The purpose of a cap would be to keep underlying fill in place and further control diffusion of underlying contaminants by acting as an isolation layer. A long-term monitoring program and ICs are required to verify and maintain the integrity and performance of the cap. ICs will include sufficient constraints on future activities, such as dredging or anchoring, that could potentially disturb capped areas.

4.4.4. Monitored Natural Recovery

MNR is typically applied where sediment contaminant concentrations are only slightly above cleanup goals and are expected to decrease due solely to indigenous biodegradation, volatilization, or dilution/burial through natural sediment deposition processes. Although some portions of the SRSs have concentrations at these levels, MNR is not anticipated to have the same level of reliability and permanence throughout an SRS as ENR and is less likely to achieve cleanup throughout an SRS within a 10-year time frame. This technology is therefore not retained.

4.4.5. Enhanced Natural Recovery

ENR generally consists of the placement of a thin layer (e.g., 6 inches) of sand in areas where COPC concentrations are sufficiently low that the addition and mixing of clean substrate with the existing shallow sediment is adequate to meet the PCULs within the post-remediation depth of compliance. Baseline sampling of the treated areas followed by periodic follow-up monitoring is used to monitor the long-term effectiveness and evaluate the degree of recovery within the ENR areas. Should monitoring results indicate an issue with the ENR effectiveness (e.g., erosion of the placed ENR layer), a contingency plan developed during design that includes adaptive management to address the long-term effectiveness of the remedy would be implemented. The contingency plan will include performance criteria and milestones, monitoring methods and schedule, and a decision-chart specifying actions to be taken for locations where ENR is not performing as expected (e.g., supplementing ENR and armoring with coarser sand or gravel). Periodic maintenance of ENR-treated areas is included in the life-cycle costs presented in Section 6.

The effectiveness and applicability of ENR as a sediment remediation technology has been evaluated at various sediment sites (Merritt et al. 2009), including a former pulp mill site in Ward Cove, Alaska (Becker et al. 2009), and results have indicated that ENR is an effective method to speed up, or enhance, the natural recovery processes likely to be occurring at a site (e.g., burial and mixing). Natural recovery processes are accelerated through the addition of a thin layer of clean sediment (EPA 2005). ENR is commonly implemented at locations where contaminants are less than approximately three times the target cleanup levels and natural recovery processes are accelerated through the addition of a thin layer of clean sediment (EPA 2014b). The three times guideline applies only to benthic contaminants of concern (COCs), which have cleanup levels applicable on a station-by-station basis. The guideline does not apply to human health COCs (such as total TEQ and cPAHs), which have cleanup levels that are applied to a spatially averaged exposure area (e.g., as a SWAC over the SCU). For human health COCs, single locations or even interpolated subareas can have concentrations greater than three times the cleanup level without the SWAC for the whole exposure area having a value greater than the cleanup level.

ENR is a significant component of the selected remedy for the LDW Superfund site in Seattle, Washington. The implementation of the technology will take into account calculated “ENR upper limits,” which are three times the remedial action levels in identified areas of expected sediment recovery with low potential for scour or disturbance (EPA 2014b).

ENR is also often preferred for use in areas where there are established or unique benthic communities that might otherwise be destroyed by more intrusive actions, such as capping or dredging.

The ENR design must consider the physical and biological nature of the existing substrate, as well as the long-term stability of the treated benthic environment, which is dependent on whether the area is subject to deposition or erosion. Therefore, the long-term performance of ENR depends to large degree on the stability of the treated sediment and the ability of the added ENR material to become incorporated into the shallow benthic layer.

The hydrodynamics and potential for sediment transport in the Study Area were evaluated under various conditions to assess the stability of an ENR layer within the sediment remediation area (Appendix C). The evaluation found that the conditions are appropriate within the sediment remediation area for coarse sandy material to be used for physical stabilization in an ENR remedy, and that an appropriately designed cap or ENR layer is at negligible risk of mobilization. A summary of the hydrodynamic modeling is presented in Section 5.3.1. Detailed discussion of hydrodynamics and sediment transport investigation, field work, and modeling results are presented in Appendix C.

4.4.6. Institutional Controls

ICs may be needed to ensure the long-term integrity of some containment technologies (e.g., sediment caps). ICs may include the institution of maintenance requirements, as well as measures to discourage activities that might disturb remediated areas and result in the exposure of underlying contamination. They could also include restrictions on navigational dredging, anchoring, or use by large vessels (to prevent prop wash). An IC plan would be developed during design if needed. ICs are retained for use in alternatives that have a containment component.

4.5. RESIDUALS HANDLING TECHNOLOGY SCREENING

Depending on the remedial methods chosen for soil, groundwater, and sediment, various materials may be generated that will potentially require handling, treatment, storage, recycling, or disposal. Some of the residual materials that may require ex situ handling are discussed below along with treatment technologies and disposal methods.

4.5.1. Building Materials

Site restoration and remediation activities will result in removal of building materials such as pilings, slabs, and foundations. All such materials will be handled in accordance with a materials management plan and in accordance with all applicable regulations. Some of the options for handling building materials are identified below.

4.5.1.1. Decontamination

Depending on presence of contamination, levels of contamination, and end use of the materials, building materials may require decontamination. This could involve a variety of different processes that would be specific to the materials and contaminants encountered. Physical or chemical decontamination processes may be considered. Specific decontamination methods for building materials would be determined after characterization of the materials.

4.5.1.2. On-Site Stockpile and Reuse

Building materials that do not pose exposure risks or that have been properly decontaminated may be stored at the Site and reused in Site landscaping or architectural elements. This approach minimizes the landfilling of debris and reduces the carbon footprint of the remedy by limiting material transportation.

Materials that are stored at the Site for future use will be stored in a secure and environmentally appropriate manner in accordance with a materials management plan.

4.5.1.3. Off-Site Reuse

Building materials may also be sold or donated for reuse at off-Site locations. For instance, pressure-treated pilings removed from the Site may be used for structural support at other locations provided that such reuse would not present a significant risk to human health or environment where the materials are reused. Criteria and methods for such reuse, if employed, would be specified in the materials management plan.

4.5.1.4. Off-Site Disposal

Off-site disposal would consist of transporting removed building debris to a permitted off-site disposal facility. Building materials that are not considered to be hazardous waste under Resource Conservation and Recovery Act (RCRA) or dangerous waste under Washington State Dangerous Waste Regulations could be disposed of in a RCRA Subtitle D solid waste landfill or, in certain circumstances, in a demolition debris landfill. Materials characterized as RCRA hazardous waste or dangerous waste would need to be disposed of in a RCRA Subtitle C hazardous waste facility, although this is not anticipated for building materials removed from the Study Area. Permitted facilities and transport services are available in Washington and Oregon. However, the large-scale transport of materials from this remote Site presents logistical considerations that must be taken into account in the evaluation of alternatives.

4.5.2. Soil and Sediment

Ex situ treatment technologies for soil were identified and evaluated for potential application to excavated soil from the upland portion of the Study Area (Table 4-1). Physical soil separation and screening to remove debris and other material was retained as a means for preparing the soil for subsequent reuse or disposal. Other treatment technologies that make use of chemical, biological and thermal processes were not retained because they were either not applicable or not sufficiently effective to treat the range, types, and/or concentrations of soil COPCs. Soil washing was not retained because physical separation/screening is a superior alternative and does not require the management of aqueous or solvent-based waste streams.

Two technologies for the management of excavated soil were retained (Table 4-1) and are discussed in the subsections that follow. These technologies would be used to manage material onsite or dispose of excess material offsite following site-specific protocols similar to those previously approved by Ecology (GeoEngineers 2012b).

For sediment remediation alternatives that have a dredging or excavation component, supplemental technologies necessary to manage removed materials are identified and screened in Table 4-4.

In general, upland disposal and consolidation options are determined based on the physical and chemical characteristics of the dredged material. Sediment that meets contaminant concentration limits and is approved for either confined or unconfined open-water disposal could be managed in accordance with the DNR Dredged Material Management Program (DMMP). Some or all of the sediment removed could potentially be used onsite (e.g., placed under an upland soil cap) or transported to a remote upland disposal site or Subtitle D landfill. The disposal options for dredged sediment (including management at an in-water DMMP site) will be re-examined during remedial design.

As summarized in Table 4-4, dewatering, water treatment technologies, disposal at an upland solid waste landfill, and use as fill or consolidation in the Upland Study Area were retained as supporting technologies for managing dredged or excavated sediment. Hazardous waste disposal sites should not be needed unless unexpected hazardous waste is encountered during dredging (which is unlikely).

4.5.2.1. Treatment

Ex situ soil or sediment treatment may be employed to reduce the mobility, toxicity, or mass of contaminants present. Depending on the type of contamination present and levels of contamination relative to treatment goals, a variety of physical, chemical, and biological treatment technologies may be considered.

4.5.2.2. On-Site Stockpile and Use

This technology consists of consolidating excavated soil from two or more areas of a site in a designated onsite location for containment, typically under a cap. On-site consolidation and containment of excavated soil can be an effective alternative to offsite disposal when appropriate engineering controls and ICs (e.g., capping, environmental covenant, fencing/signage) are implemented. This technology can also be applied to dredged or excavated sediment generated as part of the in-water sediment remediation.

4.5.2.3. Off-Site Use

Soil (including drained sediment) may also be used as fill for off-Site projects where such uses are practical and provided that the soil meets applicable contamination criterion applicable for the use.

4.5.2.4. Off-Site Disposal

Off-site disposal consists of transporting excavated soil that potentially includes debris to a permitted offsite disposal facility. Excavated soil that is not considered to be hazardous waste under RCRA or dangerous waste under Washington State Dangerous Waste Regulations could be disposed of in a RCRA Subtitle D solid waste landfill. Soil characterized as RCRA hazardous waste or dangerous waste would need to be disposed of in a RCRA Subtitle C hazardous waste landfill, although this is not anticipated for soil excavated from the Study Area. Permitted facilities and transport services are available in Washington and Oregon. However, the large-scale transport of materials from this remote site presents logistical considerations that must be taken into account in the evaluation of alternatives.

4.5.3. Water

For alternatives that require groundwater extraction, the extracted groundwater would need to be disposed of or otherwise managed. The disposal options retained for this purpose are the discharge of extracted groundwater to the sanitary sewer for conveyance to the local POTW, discharge of treated groundwater to marine surface water at the shoreline, or discharge of treated groundwater to an upgradient re-injection well or infiltration gallery (Table 4-5).

The discharge of groundwater to the city's POTW would require authorization from the City of Port Angeles and possibly from the POTW's permitting authority (Ecology). The pre-treatment of extracted groundwater may be necessary prior to discharge to meet POTW pretreatment limits. In addition, a POTW may place limits on the volume of treated groundwater that can be discharged daily. If pre-treatment prior to discharge is necessary, periodic sampling of treated groundwater would be required to ensure compliance with discharge limits.

The discharge of treated groundwater to marine surface water would require the issuance of a National Pollutant Discharge Elimination System permit by Ecology and monitoring of the discharge would be required to ensure compliance with stipulated contaminant concentration limits and discharge volumes. The discharge of extracted groundwater to an upgradient re-injection well or infiltration gallery would be technically possible if the treated discharge were to meet groundwater PCULs.

4.5.3.1. Treatment

A number of ex situ treatment technologies identified in Table 4-5 were retained for the treatment of extracted groundwater in the event that excavation dewatering or hydraulic containment of groundwater becomes necessary. For example, physical filtration could be used in combination with ion exchange and/or chemical oxidation. Ex situ treatment would only be required if: 1) groundwater extraction were implemented to support potential construction activities, such as excavation of soil or shoreline modifications, that may require groundwater controls, and 2) the extracted groundwater exceeded applicable discharge limits. Bench-scale testing would likely be required to determine the appropriate treatment media for addressing targeted groundwater COPCs.

4.5.3.2. Water Discharge

Various options are available for the discharge of water, including land application (for infiltration), underground injection, discharge to the harbor (via an outfall pipe) or discharge to the local City sewer system.

4.6. SUMMARY OF RETAINED TECHNOLOGIES

A summary of the retained technologies for sediment, soil, and groundwater remediation is presented in Table 4-6. The remediation technologies retained as a result of the screening presented here are used in Section 5 to assemble remediation alternatives for each medium.

5 DEVELOPMENT OF ALTERNATIVES

This section describes the development of remediation alternatives for soil, groundwater, and sediment. These alternatives represent a range of remedial actions that meet MTCA threshold criteria and have been developed using the technologies identified and retained in Section 4. These technologies were retained because they have proven to be effective at other sites and are compatible with site-specific conditions in the Study Area.

Separate sets of remediation alternatives were defined for soil, groundwater, and sediment. The alternatives were developed using representative technologies retained in the technology screening process (Section 4) in in ways that are expected to meet PCULs in each medium. The individual alternatives defined for each medium cover a range of approaches and expected costs, allowing for a robust evaluation of benefits and costs of differing response levels. The design of remediation alternatives is conceptual at this stage. Further work will be needed after remedy selection to prepare detailed designs and conduct design optimization; this work will likely include pre-design investigation (e.g., sampling) and treatability testing.

5.1. UPLAND SOIL REMEDIATION ALTERNATIVES

This section presents the soil remediation alternatives for the Upland Study Area. In addition to the No-Action alternative (Alternative SL-0), five alternatives (Alternatives SL-1 through SL-5) were developed. The alternatives use unrestricted land use PCULs and ecological PCULs. For some alternatives, RELs reflective of reasonable exposure scenarios (Table 3-15; Appendix A) are used along with ecological PCULs to define areas where physical remediation technologies (e.g., excavation and covers) are applied.

The various soil alternatives presented in this section involve differing degrees of excavation and covers. The presentation order is generally from least complex to most complex. One alternative (SL-5) involves excavation and off-site disposal of all soil that exceeds PCULs. The other alternatives involve less extensive excavation and include containment and institutional controls to ensure that exposure to soils with concentrations exceeding PCULs is limited. Two of the alternatives (SL-2 and SL-4) use RELs to limit the areas where excavation and covers are required.

Except for the obligatory No-Action alternative, all soil remediation alternatives involve excavation of soil exceeding unrestricted-use PCULs in the Ennis Creek restoration area. This will facilitate clean closure of the restored Ennis Creek corridor. Depending on the alternative, excavated soil is either placed in an on-site consolidation area where it is covered with soil meeting PCULs or is disposed of at an off-Site landfill.

5.1.1. SL-0 – No Action

The No-Action alternative would involve no future remediation or monitoring activities. It is included in accordance with the National Contingency Plan (NCP) for comparison purposes only.

5.1.2. SL-1 – Cover

In Alternative SL-1, a permeable soil cover would be constructed over areas where soil PCULs are exceeded in the shallow subsurface (Figure 5-1).

First, soils exceeding direct-contact or ecological PCULs in the Ennis Creek restoration area (at any depth) would be removed and placed on-Site adjacent to (immediately west of) the existing materials management area (soil stockpiles) in the West Mill Area. Any removed subsurface pilings and similar construction materials would be recycled, reused, or disposed of off-Site in accordance with a materials management plan that would be developed during design. The Ennis Creek restoration plan will define the amount of clean backfill required for final grading.

Next, all areas of the Site that meet either of the following conditions would receive a cover: (a) soil concentrations in the upper 15 feet exceed unrestricted-use PCULs for direct human contact, or (b) soil concentrations in the upper 6 feet exceed ecological PCULs. The approximate cover area for Alternative SL-1 is shown in Figure 5-1; the final cover area would be defined during design.

The cover would consist of woven geotextile overlain by clean, compacted aggregate material (e.g., crushed rock, crushed concrete, or sand and gravel) and a surface layer of clean soil (Figure 5-2). The cover would be monitored and maintained to include elimination of deep-rooting plants and removal of burrowing animals.

Final grading of the remediated Ennis Creek restoration area would be defined by a separate restoration plan. If backfill is needed for such restoration, clean soil would be used.

Note that this alternative makes use of a conditional POC for ecological receptors defined as the upper 6 feet of soil for terrestrial ecological receptors. ICs would prevent disturbance of soil with PCUL exceedances deeper than this conditional POC. In the covered containment area, the soil below the cover would be allowed to exceed PCULs and the cover design (along with maintenance and ICs) would prevent human or ecological contact with the soil beneath. ICs may include fences, periodic inspections, woody vegetation control, and burrowing pest control.

Based on the analysis presented in Appendix A, no major secondary sources of groundwater contamination by leaching from soil are apparent from site soil and groundwater data. Thus, there is no known location where use of a low-permeability cap would be needed to curtail leaching from contaminated soil. Furthermore, such a cap would serve to reduce the amount of oxygen delivered to groundwater through infiltration which could be counterproductive for contaminants that are elevated due to prevalent reducing conditions in groundwater. Nonetheless, if design-phase sampling indicates areas of elevated unsaturated-zone soil concentrations that are likely acting as an ongoing source of groundwater contamination, then this soil would be addressed either through: (a) excavation with off-site disposal, or (b) installation of an impermeable cap (Figure 5-2) in selected areas with additional measures employed as needed to avoid exacerbation of reducing conditions that cause exceedances of PCULs in groundwater.

Note that this alternative assumes that shoreline-area restoration on the upland in areas of PCUL exceedances will involve a clean cover that can be maintained to avoid direct contact of underlying soil by humans or terrestrial organisms.

Alternative SL-1, and other soil-cover alternatives as applicable, could make use of the following materials in the West Mill Area, either as fill beneath the cover or as cover material, depending on the physical and chemical characteristics of the materials:

- Soil currently stockpiled onsite from the City or Port Angeles’s 2012-2013 CSO upgrade project
- Soil that exceeds CULs at identified isolated locations outside of the proposed remediation areas
- Portions of marine sediment excavated or dredged as part of sediment remediation.

5.1.3. SL-2 – Consolidate and Cover with Remediation Levels

In Alternative SL-2, all soils that exceed direct-contact RELs protective of occasional Site visitors/trespassers (Table 3-15; Appendix A) in the upper 15 feet would be addressed through excavation or cover. Also, exceedances of ecological PCULs in the upper 6 feet would be addressed by excavation or cover. As shown in Figure 5-3, excavation would be employed in the Ennis Creek restoration area, areas east of Ennis Creek, and near the shoreline west of Ennis Creek. In most of this area, shallow excavation (1-foot deep or less) will be sufficient. Deeper excavation (typically less than 10 feet) will be required in some areas, as shown in Figure 5-3. Where conducted, excavation will be to the depth needed to meet PCULs. Subsurface structures such as foundation pilings may be left in place, removed, or partially removed.

Removed soil would be consolidated to an inner area of the Site west of Ennis Creek and the consolidated soil would be covered as described for Alternative SL-1. Institutional controls and cover maintenance would be included to preserve the integrity of the cover and to prevent uses of the Site inconsistent with assumptions used to derive the RELs. The final excavation and capping areas would be defined during design.

Any removed subsurface pilings and similar construction materials would be recycled, reused, or disposed of off-Site in accordance with a materials management plan that would be developed during design. Restoration plans will be defined for excavation areas and these plans will define the amount of clean backfill required.

Containment, a conditional POC for terrestrial receptors (as defined for Alternative SL-1) and RELs are used in this alternative. This requires monitoring and maintenance to ensure that erosion or other land disturbance does not result in exceeding ecological PCULs in the upper 6 feet outside of the covered containment area.

5.1.4. SL-3 – Consolidate and Cover

Alternative SL-3 is the same as Alternative SL-2, except that the extents of remediation areas are defined by unrestricted-use PCULs rather than RELs in the West Mill Area and East Mill Area (Figure 5-4). The larger excavation footprint avoids use of RELs.

5.1.5. SL-4 –Excavation with Remediation Levels

Alternative SL-4 involves excavation of all areas where either: (a) direct-contact RELs are exceeded in the upper 15 feet or (b) ecological RELs are exceeded in the upper 6 feet. All of this soil would be disposed of off-Site. Where conducted, excavation will be to the depth needed to meet PCULs. Preliminary estimated areas of shallow (less than 1 foot) and deeper excavation are shown in Figure 5-5; excavation extents and depths would be updated during design.

Restoration plans and a materials management plan would define the amount of clean backfill needed in the excavation areas and the proper handling of any subsurface structures removed with the excavation.

The existing soil stockpiles at the Site would be removed from the Site unless design-phase soil testing shows that certain stockpiles have concentrations that meet RELs and ecological PCULs. Soils meeting RELs and ecological PCULs may be temporarily set aside and potentially used as on-Site backfill outside the Ennis Creek restoration area.

ICs would be required to avoid land disturbance and incompatible land uses.

5.1.6. SL-5 – Excavation

Alternative SL-5 involves excavation and off-Site disposal of all soil exceeding unrestricted-use direct-contact PCULs or ecological PCULs. Figure 5-6 shows an initial estimate of the areas where shallow and deep excavation would be needed. Existing soil stockpiles would also be removed unless design-phase sampling indicates that certain stockpiles meet all PCULs; in this case, the stockpiled soil may be used as on-Site backfill. Backfill quantities and handling of subsurface materials would be defined by plans developed during design.

This Alternative would result in meeting PCULs at standard POCs, would not require ICs, and would not use RELs.

5.2. GROUNDWATER REMEDIATION ALTERNATIVES

This section presents preliminary groundwater remediation alternatives. These alternatives were evaluated to assess the practicability of groundwater remediation throughout the upland and to determine whether a conditional POC is appropriate for groundwater. If appropriate, the conditional POC would be in groundwater near discharge locations immediately upgradient of the adjacent surface water.

Note that, in addition to the No-Action alternative, there are three groundwater alternatives presented in the subsections below and the order is generally from least complex to most complex. The most complex alternative (G-3) includes treatment throughout the upland to ensure that PCULs are met at the standard POC (throughout groundwater) within a reasonable time frame. For the remaining two alternatives, a conditional POC is proposed in groundwater along the shoreline. These alternatives acknowledge that it may not be practicable to meet PCULs throughout groundwater in a reasonable time frame.

ICs would be utilized in each alternative (except for the requisite No-Action alterative) and would consist of an environmental covenant to prevent potable uses of groundwater and a restriction on future actions that could reduce the effectiveness of a remedy, such as the future use of the upland for stormwater infiltration or construction activities that could compromise the effectiveness of installed remediation systems.

5.2.1. G-0 – No Action

The No-Action alternative would involve no future remediation or monitoring activities. It is included in accordance with the NCP for comparison purposes only.

5.2.2. G-1 – Sparging

Alternative G-1 would include air sparging for in-situ treatment of portions of the contaminant plume with the goal of preventing discharge to surface water at concentrations above PCULs (Figure 5-7). A conditional POC would be proposed in groundwater prior to surface-water discharge. Air sparging would affect the redox conditions of the subsurface, resulting in oxidation of ammonia to nitrite/nitrate, and oxidation of metals to form precipitates (e.g., manganese oxides and other oxides) that would permanently immobilize certain IHSs. Air sparging would also promote the aerobic biodegradation of dissolved organic constituents such as cPAHs to nontoxic substances.

Air sparging would be applied in a phased manner beginning near shoreline well MW-56 (Figure 5-7). The phased approach allows for evaluation of sparging effectiveness and need during the remedy implementation phase, leading to a more optimized approach. It is envisioned that additional study of the groundwater plume and its discharge to surface water would be conducted, which could lead to a modified extent of the full-scale sparging system.

Application of sparging near MW-56 would lead to oxidizing conditions, lowering unionized ammonia concentrations and neutralizing pH. Carbon-dioxide sparging may be used in the MW-56 area to accelerate pH reduction if design testing indicates that this would result in meeting PCULs much faster or at lower cost.

Additional sparging would be applied at other locations along the shoreline where the additional study determines sparging is needed to meet PCULs at the conditional POC. If feasible, air sparging would be designed to be applied for a limited time period to achieve oxidizing conditions and permanent reduction in concentrations where applied. Rebound monitoring would be used to confirm that concentrations remain low and meet PCULs at the conditional POC. The required time frame for operation of air sparging would need to be assessed during design testing.

Specifications of the air-sparging, including final sparging locations, well spacing, and optimal flow rate would be determined during design and startup. Assumptions needed for initial cost estimates are included in Figure 5-7 (number and placement of wells) and in the cost estimates presented in Appendix D. Note that the full sparging system extent depicted in Figure-7 is used when comparing costs to benefits in the alternatives analysis presented in Section 6.

5.2.3. G-2 – Funnel and Gate with Permeable Reactive Barrier

Alternative G-2 would involve in-situ groundwater treatment using a funnel-and-gate system that incorporates a PRB. One or more PRBs would be installed in the upland near the shoreline to reduce dissolved IHS concentrations via passive groundwater flow through reactive media. A conditional POC would be proposed on the downgradient side of the PRBs at existing or new shoreline monitoring wells. The reactive media would be selected based on their ability to treat the groundwater IHSs present at specific locations (see Section 3). Bench-scale testing would be necessary prior to implementation.

The selected PRB material would likely immobilize IHSs by one or more processes including: chemical reduction to form precipitates; adsorption; chemical oxidation of ammonia, manganese, and other IHSs; and enhanced biodegradation. The specific biochemical processes and specifications for the PRB media would be determined in the bench-scale testing during the design phase.

For cost effectiveness and to facilitate future media change-outs, it is expected that the barrier system will consist of sections of impermeable groundwater diversion barriers (cutoff walls) and one or more permeable sections containing porous reactive media (PRBs). For cost-estimating purposes, sheet pile walls were assumed to be used as the diversion barrier. Hypothetical locations for the construction of the cutoff/PRB walls are shown on Figure 5-8. The actual locations, dimensions, and configuration of the PRBs would be determined during remedial design. Assumptions used for initial cost estimates are presented in Appendix D.

5.2.4. G-3 – In-Situ Chemical Treatment

Alternative G-3 would be a full-Site implementation of in-situ groundwater treatment without use of air sparging in select locations. The standard POC would apply. ISCO and/or ISCF would be implemented throughout the Upland Study Area along several transects roughly perpendicular to groundwater flow such that PCULs are achieved in groundwater throughout the Site within a reasonable time frame. ISCO/ISCF reagents would be delivered to groundwater via subsurface injection at multiple, closely spaced injection points. ISCO/ISCF reagents would be evaluated for potential use based on their ability to treat groundwater IHSs (see Sections 3 and 4). Bench- or pilot-scale testing would likely be necessary prior to the implementation of Alternative G-3.

For cost-estimating purposes, it was assumed that vertical injection wells would be installed at 30-foot spacing along transects that would promote concentration reductions as groundwater moved downgradient from treatment lines. Hypothetical ISCO/ISCF treatment transects are shown on Figure 5-9. Three treatment rounds are also assumed. The actual treatment configuration of the injection network, the injectate specifications, and the number of treatment rounds expected to achieve PCULs would be determined during remedial design. Assumptions used for initial cost estimates are presented in Appendix D.

5.3. SEDIMENT REMEDIATION ALTERNATIVES

Remedial alternatives were developed by combining representative technologies and associated process options into assemblages applicable to site-specific features. These assemblages focus on removal (dredging), containment (fill or cap), and ENR and as the primary active response actions. The assemblages of remedial alternatives were developed based on the analyses and findings summarized in previous sections of this document, including:

- Remediation subareas identified by the nature and extent of contamination and other considerations (Section 2)
- ARARs and preliminary cleanup standards (Section 3)
- Representative remedial technologies that were screened (Section 4)

All of the sediment remediation alternatives developed for the Marine Study Area are designed to meet the PCULs, and all apply to the same 51.7-acre sediment remediation area defined in Section 3.5.3. The locations where the PCULs must be met (i.e., POCs) are discussed in Section 3.4.1.5 and summarized in Table 3.10. Differences among the alternatives include the types of technologies used and associated costs, relative degree of permanence, long- and short-term effectiveness, time needed to meet PCULs, and other criteria discussed herein.

As discussed in Section 3.5.3 and shown in Figure 3-4, the sediment remediation area was divided into SRSs: log pond intertidal and nearshore (3.5 acres), long pond subtidal (5.7 acres), mill dock landing (0.3 acres), mill dock (3.9 acres), berth areas (6.1 acres), and mill dock subtidal (32.1 acres). Sediment remediation alternatives for each SRSs are summarized in Table 5-1.

There are two common remedy elements applicable to all the alternatives. These include:

- Site restoration includes removal of dock and jetty (i.e., subaqueous portion and the peninsula) followed by shoreline stabilization and restoration as discussed in Section 1.
- Removal of contaminated sediment in the intertidal/nearshore portion of the log pond (3.5 acres) and the mill dock landing (0.3 acre).

The remedial alternatives are as follows:

- **Combined Action.** Alternatives S-1 through S-4 combine active remedial technologies (removal, containment and ENR) to meet PCULs. The assignment of each remedial technology to SRSs differs between the alternatives.

- **Complete Removal.** Alternative S-5 would dredge all sediments within the SRSs where the COPCs are greater than the PCULs.

A summary of these remediation alternatives is presented in Table 5-1.

Note: A No-Action alternative (S-0) was also considered (in accordance with the NCP), but rejected in alternative screening because it would not meet MTCA threshold requirements.

Removal of contaminated sediment from the intertidal/nearshore portion of the log pond (3.5 acres) and the mill dock landing (0.3 acre) would be accomplished by excavation from the shoreline using upland-based excavation equipment in all alternatives. If sediment from the subtidal portions of the Site is removed (Alternatives S-3 through S-5), a conventional barge-mounted mechanical dredge would be used. For costing purposes, an average 3-foot excavation/dredging depth was assumed for the log pond, although some areas may require different removal depths to be determined by pre-design sampling.

Following sediment excavation in the nearshore areas, these areas will be backfilled to restore the elevations in these areas and to control dredge residuals (i.e., the deposition of suspended sediment that could be deposited in the vicinity of excavation operations). During sediment removal, any residuals would be addressed through adaptive management, including the proper sequencing of actions in adjacent SRSs, and confirmation sampling to ensure that the IAOs would be met upon the completion of construction. A similar approach would be used following any dredging event in the sediment remediation area.

It is assumed that sediment excavated using upland-based equipment from the nearshore areas would be placed in the upland, either beneath a cap or used as fill, depending on the characteristics and residual contaminant levels in the excavated/dredged material. For the purpose of this evaluation, it is assumed that sediment removed from offshore areas using in-water equipment would be transferred by barge to an off-site transload facility for transfer to an upland disposal site. Final disposition of dredged sediment may change during design depending on dredged material characteristics, disposal site availability, acceptance criteria, and costs.

ENR is a component of all of the sediment remediation alternatives except complete removal, Alternative S-5. The inclusion of ENR as a remediation technology reflects its high degree of compatibility with the oceanographic and benthic conditions of the subtidal areas. ENR sand material would be imported from an upland natural source and would meet physical and analytical requirements determined during the design. An assessment of the ENR technology and discussion of conditions under which ENR can be effectively applied to achieve sediment cleanup standards is included in Section 5.3.1. A detailed study report including hydrographic survey, hydrodynamic field work, and wave modeling results is presented in Appendix C. A brief overview of each sediment remediation alternative is presented in Sections 5.3.2 through 5.3.6.

5.3.1. Long-Term Stability of ENR

ENR involves the application of a 6-inch-thick clean sand layer. ENR provides a surface layer of clean sediment, which results in an immediate reduction in surface chemical concentrations that facilitates the re-establishment of benthic organisms, minimizes short-term disruption of the benthic community, and accelerates the process of physical isolation continued over time by natural sediment deposition (USEPA, 2005a). Through ENR placement, PCULs will be met throughout the depth of compliance. This layer can also be readily re-colonized.

Sediment transport field investigations and site-specific hydrodynamic modeling have been conducted to predict the long-term stability of ENR following the removal of the dock and jetty. An extreme value probability distribution function analysis was performed for a near continuous 13-year record of local metocean measurements to determine 100-year storm conditions. These conditions were applied to the wave and hydrodynamic and sediment transport models to evaluate the long-term stability of ENR. The sediment transport study based on the combined results of a site-specific field investigation and hydrodynamic modeling is discussed in detail in Appendix C.

Field investigation data were used to validate the propagation of waves offshore of the former Rayonier mill, as well as to provide model initial parameters that are representative of 100-year storm conditions from westerly and northeasterly directions. An open-source program, SWAN (Simulating WAves Nearshore; Booij et al. 1996) model was developed for bathymetric cases representative of: (1) current conditions and (2) the proposed removal of the dock and jetty. Two model conditions were employed with storm wave and wind conditions, characterized as: (1) 100-year storm conditions in a western direction (wind direction from 292.5° and wind speed equal to 18 m/s) and (2) 100-year storm conditions in a northeastern direction (wind direction from 67.5° and wind speed equal to 17 m/s) that would result in a northeasterly swell. The field observations, together with National Oceanic and Atmospheric Administration wind data, provided information necessary for initializing the SWAN wave propagation model as well as to validate the propagation of waves and movement of sediment offshore of the former Rayonier mill (Figure 5-10).

Using SWAN model results, a grain size mobility analysis was conducted to assess the potential for sediment mobilization in the vicinity of the former Rayonier mill for conditions predicted following the removal of the dock and jetty (Figures 5-11 and 5-12). The modeled northeasterly storm case (17 meter/second winds from 67.5°) show the highest potential for sediment mobilization in the vicinity of the former Rayonier mill for conditions following the removal of the dock and jetty (Figure 5-12). During the extreme conditions and resultant maximum bed shear stresses generated by a 100-year northeasterly storm, fine to medium gravel (up to a maximum Phi (Φ) size of -2.5) may be mobilized. The term mobility does not imply suspension or erosion, but simply the ability to move. The results from a more detailed sediment transport model (summarized below) show that the proposed placement of 1 millimeter (mm) coarse sand (0 Φ) sediment would be effective in resisting 100-year storm forces.

A sediment bed consisting of a 15 cm (approximately 6 inches) layer of 1 mm sediment (0 Φ) was assumed in the ENR areas to assess the response to hydrodynamic and wave forces. The removal of shoreline structures allows for unobstructed flow and waves to propagate through the area. Northeasterly 100-year storm, which is more critical than the western 100-year storm, produced minimal erosion, no greater than 1 cm throughout the ENR areas (Figure 5-13). In the active remediation area, sediment with very coarse sand and larger grain sizes (greater than 1 mm; see Appendix C, Table 5) would remain stable under both the western and the northeast storm conditions (Figure 5-13).

The threat of sea level rise due to climate change was also assessed to ensure the success of the remedy over its design life. Two estimates of sea level rise for the years 2050 and 2100 were included to address potential changes in circulation patterns, wave heights, and stability of the ENR remedy. Sea level rise in the state of Washington is predicted to result in net water level increases of 0.121 meters (m) by 2050 and 0.369 m by 2100 (Miller 2018). These sea level increases were added to the overall water levels and tidal boundaries used for the storm scenarios. Results show that sediment in the ENR areas is predicted to be stable with an average erosion of less than 1 cm in the most extreme storm conditions presented by a 100-year storm after dock and jetty removal (Figure 5-14).

The hydrodynamic and sediment stability modeling results demonstrate that the use of very coarse sand (greater than 1 mm) as ENR material would be expected to largely resist mobilization and remain physically stable during hydrodynamic conditions caused by extreme storm events. The model results suggest that fine-grained material (less than 1 mm) is expected to mobilize where coarser grained sediment mobilizes but fines in the interstitial regions of coarser non-mobile sediment are likely to remain in place. Refer to Appendix C for details for the study.

5.3.2. S-1 – Excavate/Dredge Intertidal Log Pond, ENR in Remainder

Under Alternative S-1, contaminated sediment from the intertidal/nearshore portion of the log pond and dock landing would be excavated from the shoreline using upland-based excavation equipment. The excavated area would be backfilled to stabilize the area and control any residuals, followed by gravel beach placement to restore the shorelines. ENR would be used in the remainder (i.e., subtidal portion) of the log pond and in other SRSs. Following the removal of the dock, additional sampling will be conducted to confirm the suitability of ENR under the mill dock. Confirmation samples will also be taken over the excavated/dredged areas to verify that the PCULs are met. Construction sequence and standard operating procedures will be detailed during the remedial design. Figure 5-15 shows the locations where the technologies included in Alternative S-1 would be applied.

5.3.3. S-2 – Excavate/Dredge Intertidal Log Pond, Fill and ENR Berth Areas, ENR in Remainder

Alternative S-2 is the same as Alternative S-1, with the following differences.

The berth and approach areas would be addressed by filling with clean material to restore these historically dredged areas to an elevation similar to the surrounding area. The fill material would consist of a mix of clean sand, silt, and gravel. Filling the berth and approach areas would be sufficient to contain underlying sediment contamination and would achieve a bathymetry less prone to the accumulation of fine particulates and potential contaminants from offsite. The appropriate placement methods for fill material would be determined during remedial design. A clean ENR sand layer in the berth and approach areas and in the remainder of the sediment remediation area would be placed to address sediment contamination and to provide suitable habitat. Construction sequence and standard operating procedures will be detailed during the remedial design. Figure 5-16 shows the locations where the technologies included in Alternative S-2 would be applied.

5.3.4. S-3 – Dredge Intertidal and Cap Subtidal Log Pond, Dredge under Dock, Fill and ENR Berth Areas, ENR in Remainder

This alternative consists of the same actions and technologies as those described for Alternative S-2, except that the subtidal portion of the log pond would be capped, and dredging would be conducted under the mill dock (assumed 2-foot cut). The berth areas would be filled to match the post-dredge elevations under the mill dock area and would achieve a bathymetry less prone to the accumulation of fine particulates and potential contaminants from offsite. ICs would be established to protect capped areas. Figure 5-17 shows the locations where the technologies included in Alternative S-3 would be applied.

5.3.5. S-4 – Full Log Pond Dredge, Fill and ENR around Dock, ENR in Remainder

This alternative consists of the same actions and technologies as those described for Alternative S-2, except that the subtidal portion of the log pond would be dredged (assumed 3-foot cut). Construction sequence and standard operating procedures will be detailed during the remedial design. Figure 5-18 shows the locations where the technologies included in Alternative S-4 would be applied.

5.3.6. S-5 – Dredge all Subareas

Under Alternative S-5, all of the SRSs would be excavated/dredged (assumed 3-foot cut in all dredge areas), including the entire log pond, the berth, approach, under the mill dock and the mill dock subtidal area. Figure 5-19 shows the locations where the technologies included in Alternative S-5 would be applied.

6 DETAILED EVALUATION OF ALTERNATIVES

This section provides a detailed analysis of the alternatives developed in Section 5 for remediation of contaminated soil, groundwater, and sediment in the Study Area.

6.1. PROCESS FOR EVALUATING ALTERNATIVES

Cleanup actions performed under MTCA must meet certain minimum requirements per MTCA (WAC 173-340-360(2)(a)(b); Ecology 2013a) and SMS (WAC 173-204-570(3); Ecology 2013b). The minimum requirements consist of “threshold” requirements and “other” requirements.

The MTCA threshold requirements for cleanup actions include:

- Protect human health and the environment
- Comply with cleanup standards
- Comply with applicable state and federal laws
- Provide for compliance monitoring
- The other MTCA requirements include:
- Use permanent solutions to the maximum extent practicable
- Provide for a reasonable restoration time frame
- Consider public concerns

MTCA also provides a mechanism to consider costs and rank alternatives to determine whether some remedial options have a disproportionate cost in relation to the remediation benefit as part of a DCA. This analysis considers protectiveness, permanence, cost, long-term effectiveness, management of short-term risks, technical and administrative implementability, and consideration of public concerns.

The identification and screening of remedial technologies is described in Section 4, and the detailed evaluations of remedial alternatives against MTCA criteria and the DCA are presented in this section.

The conclusions of the evaluation are presented below and organized by media: soil, groundwater, and sediment. The alternatives presented in this section involve technologies that have been proven to be effective when applied under conditions similar to those in the Study Area. They can also achieve the preliminary cleanup or remediation levels as required by MTCA. Consideration was given to the unique site conditions described in Section 2.0 and integration of remediation and restoration elements. The results of the DCA presented below are used to select preferred alternatives from the multiple alternatives evaluated for each media. The alternatives presented do not represent a project plan or remedy design, which will be performed in the future.

6.2. EVALUATION CRITERIA

This section describes the MTCA and SMS criteria used to evaluate the remediation alternatives developed in Section 5.0.

6.2.1. Threshold Requirements

Cleanup actions performed under MTCA (WAC 173-340-360(2)(a)) must meet certain minimum requirements defined as "threshold" requirements and "other" requirements. Alternatives that do not meet the minimum requirements are not considered to be suitable cleanup actions under MTCA. Similar minimum requirements for evaluating sediment remedial alternatives are set forth under the SMS (WAC 173-204-570).

The threshold requirements for MTCA cleanup actions (WAC 173-340-360(2)(a)) are discussed in the subsections that follow.

6.2.1.1. Protection of Human Health and Environment

Cleanup actions performed under MTCA must ensure that human health and the environment are protected. This is accomplished by using remedial alternatives that eliminate, reduce, or otherwise control risks posed through each exposure pathway and migration route.

6.2.1.2. Compliance with Cleanup Standards

Preliminary cleanup standards for sediment, groundwater, and soil are presented and discussed in Section 3.4.

For sediment, cleanup standards are developed in compliance with SMS (WAC 173 204-560 through 173-204-564) and MTCA (WAC 173-340-760), which describe the general requirements for sediment cleanup standards for the protection of human health, benthic communities, and higher-tropic-level species. For soil and groundwater, cleanup standards are based on the requirements set forth under MTCA (WAC 173-340-700). If a remedial action does not comply with cleanup standards, the remedial action is an interim action, not a cleanup action.

6.2.1.3. Compliance with Applicable State and Federal Laws

Cleanup actions conducted under MTCA must comply with applicable state and federal laws presented in Section 3.3. The term "applicable state and federal laws" includes legally applicable requirements and those requirements that Ecology determines to be relevant and appropriate as described in WAC 173 340-710.

Two principal applicable regulations are the MTCA cleanup regulations (WAC 173-340) and the SMS (WAC 173-204). The cleanup regulations were adopted under MTCA (Revised Code of Washington [RCW] 70.105D), and the SMS was adopted under different authorities for different parts of the rule; Part V was adopted under MTCA, and Parts I – IV and Part VI were adopted under MTCA and the Water Pollution Control Act (RCW 90.48), as well as other authorities. Additional regulations, codes, or ordinances, such as those governing construction, waste disposal, and other aspects of remedy implementation, were also identified and considered. A listing and description of these requirements and guidance, including MTCA, SMS, and other ARARs, are provided in Section 3.3.

6.2.1.4. Provision for Compliance Monitoring

A cleanup action must provide for compliance monitoring in accordance with WAC 173-340-410. Compliance monitoring consists of protection, performance, and confirmation monitoring. Protection monitoring is conducted to confirm that human health and the environment are adequately protected during construction, as well as during the operation and maintenance period of a cleanup action. Performance monitoring is conducted to confirm that the cleanup action has attained cleanup standards and, if appropriate, RELs or other performance standards, such as effective contaminant containment or reduction.

Confirmation monitoring is conducted to confirm the long-term effectiveness of the cleanup action once cleanup standards and, if appropriate, RELs or other performance standards have been attained.

6.2.2. Other Minimum Requirements

Remediation alternatives that fulfill the threshold requirements described in Section 3.1 must also meet the requirements listed below, which are specified under MTCA (WAC 173-340-360(2)(b)).

- Use of permanent solutions to the maximum extent practicable – MTCA specifies that the permanence of alternatives must be evaluated by balancing the costs and benefits of each of the alternatives using a DCA performed in accordance with WAC 173-340-360(3)(e). The DCA for soil, groundwater, and sediment is described further in Section 6.5.
- Reasonable restoration time frame – MTCA expresses a preference for those alternatives that, although equivalent in other respects, can be implemented in a shorter period of time. MTCA includes a summary of factors to be considered in evaluating whether a cleanup action provides for a reasonable restoration time frame (WAC 173-340-360(4)(b)).
- Consideration of public concerns – Ecology considers public comments submitted during the remedial investigation/feasibility study process in making its selection of a preferred alternative. This preliminary selection is subject to further public review and comment when the proposed remedy is published in the draft cleanup action plan (CAP). The selection of an alternative needs to consider concerns and comments expressed by the general public and affected landowners.

Additional requirements set forth in the SMS (Ecology 2013b) specific to sediment remediation alternatives are described below:

- Preference for most effective source control measures – Where source control measures are necessary as part of a cleanup action, preference is given to alternatives that include source control measures that are more effective in minimizing the accumulation of contaminants in sediment caused by discharges.
- Issuance of a sediment recovery zone (SRZ) – If a cleanup action cannot meet the cleanup objectives within a reasonable restoration time frame, Ecology may issue an SRZ with its corresponding requirements.
- Compliance with ICs – Alternatives must include, where needed, measures to limit or prohibit activities that may interfere with the integrity of a cleanup action or result in exposure to hazardous substances at a site.
- Provisions for periodic review – Periodic review is required to determine the effectiveness and protectiveness of sediment cleanup actions that use containment, ENR, MNR, ICs, or cleanup levels based on practical quantitation limits, or an SRZ.

As noted above, preference is given to alternatives that feature shorter restoration time frames. Specific factors considered when evaluating the restoration time frame for sediment alternatives are set forth under WAC 173-204-570(5)(c). As described in SMS, and unless otherwise determined by Ecology, cleanup actions that achieve compliance with the sediment cleanup standards within 10 years of completion are presumed to have a reasonable restoration time frame. If the restoration time frame for a cleanup action is longer than 10 years, then an SRZ must be established. This is not expected to be necessary for the Marine Study Area.

6.2.3. Disproportionate Cost Analysis Criteria

A DCA involves an evaluation of the proportionality of remediation costs to the relative benefits expected from each alternative. Alternatives with costs that are disproportionate to benefits are excluded if retained alternatives with comparative benefits are permanent to the maximum extent practicable. MTCA specifies that the comparison of benefits and costs may be quantitative but will often be qualitative, requiring the use of best professional judgment. MTCA further specifies that when two or more alternatives are equal in benefits, Ecology will select the less costly alternative provided the minimum requirements for cleanup actions are met (WAC 173-340-360(3)(e)(ii)(c)).

The evaluation criteria for DCA are specified in WAC 173-340-360(3)(f). Each of these criteria is described in the subsections that follow. The comparative benefits analysis and DCA are presented in Sections 6.4 and 6.5, respectively.

6.2.3.1. Protectiveness

This criterion is used to evaluate the overall protectiveness of human health and the environment, including the degree to which existing risks are reduced, the time required to reduce risk and attain cleanup standards, the onsite and offsite risks resulting from the implementation of the alternative, and the improvement of the overall environmental quality.

6.2.3.2. Permanence

This criterion is used to evaluate the degree to which the alternative permanently reduces the toxicity, mobility, or volume of hazardous substances, including the adequacy of the alternative in destroying the hazardous substances, the reduction or elimination of hazardous substance releases and sources of releases, the degree of irreversibility of waste treatment process, and the characteristics and quantity of the treatment residuals generated.

6.2.3.3. Cost

This criterion consists of the estimated cost to implement the alternative, including the cost of construction, the net present value of any long-term costs, and agency oversight costs that are cost recoverable. Long-term costs include operation and maintenance costs, monitoring costs, equipment replacement costs, and the cost of maintaining ICs. Per WAC 173-340-360(3)(f)(iii), cost estimates for treatment technologies must include pretreatment, analytical, labor, and waste management costs. In addition, the design life of the cleanup action must be estimated, and the cost of replacement or repair of major elements must be included in the cost estimate. Estimated costs are compared directly with benefits to assess the cost-effectiveness and practicability of the remediation alternatives as part of the DCA.

6.2.3.4. Long-Term Effectiveness

Long-term effectiveness includes the degree of certainty that the alternative will be successful, the reliability of the alternative during the period of time that hazardous substances are expected to remain onsite at concentrations that exceed cleanup levels, the magnitude of residual post-remediation risk, and the effectiveness of controls required to manage treatment residues or remaining wastes. MTCA identifies several types of cleanup action components that may be used as a guide when assessing the relative degree of long-term effectiveness (WAC 173-340-360(3)(f)(iv)). Listed in descending order of long-term effectiveness, these components include: reuse or recycling; destruction or detoxification; immobilization or solidification; onsite or offsite disposal in an engineered, lined, and monitored facility; onsite isolation or containment with attendant engineering controls; and ICs and monitoring. MTCA recognizes that in most cases, alternatives will combine several of these components to accomplish cleanup objectives.

6.2.3.5. Management of Short-Term Risks

This criterion is used to evaluate the risk to human health and the environment associated with the alternative during construction and implementation and the availability and effectiveness of measures that will be taken to manage such risks. Cleanup actions can have short-term risks, such as the potential mobilization of contaminants during construction or safety risks associated with construction projects. Some short-term risks can be managed through the use of engineered controls during project design and construction; other short-term risks may be inherent to an alternative.

6.2.3.6. Technical and Administrative Implementability

This criterion is used to evaluate an alternative's ability to be implemented, including consideration of whether the alternative is technically possible; availability of necessary offsite facilities, services, and materials; administrative and regulatory requirements; scheduling challenges, project size and complexity; monitoring requirements; access for construction operations and monitoring; and integration with existing facility operations and/or other current or potential remedial actions. Technical factors for consideration include the availability of mature technologies and experienced contractors to accomplish the cleanup work. Administrative considerations include any permitting requirements.

6.2.3.7. Consideration of Public Concerns

This criterion is used to evaluate whether the community, including individuals, community groups, local governments, tribes, federal and state agencies, or other organizations may have concerns regarding the alternative and, if so, the extent to which the alternative addresses those concerns.

6.3. INITIAL EVALUATION

6.3.1. Upland Soil Remediation Alternatives

This section presents the evaluation of the soil alternatives (SL-0 through SL-5) described in Section 5.12 based on the criteria and methodology described in Section 6.2. Table 6-1 provides a summary of the soil remediation alternatives evaluation; specific requirements are discussed in subsections that follow.

6.3.1.1. MTCA Threshold Requirements

The No-Action alternative (SL-0) for soil does not meet MTCA threshold requirements and is dropped from further consideration.

All of the other soil remediation alternatives (SL-1 through SL-5) meet the threshold requirements. Alternatives SL-1, SL-2 and SL-3 will protect human health and the environment through a combination of soil removal for onsite consolidation, capping, cap monitoring and maintenance, and ICs. Alternatives SL-4 and SL-5 will protect human health and the environment by removing soil and disposing of it offsite. Alternatives SL-2 and SL-4 use RELs protective of occasional visitors/trespassers (Section 3.4.3 and Appendix A) rather than the default unrestricted-use PCULs protective of onsite residents, resulting in a reduced remediation area.

All of the soil alternatives comply with applicable state and federal laws (Section 3.3). Compliance with applicable laws is partially accomplished through compliance with cleanup standards. In addition, each of the alternatives would be implemented in accordance with applicable permitting or substantive requirements, workplace safety requirements, and best management practices (BMPs).

Protection monitoring will be performed during construction to ensure that worker and public health are protected, and confirmational CAP monitoring will be performed following construction to ensure that the caps remain protective. In addition, each alternative will include performance monitoring during soil excavation to verify that soil with IHS concentrations greater than PCULs or RELs (depending on the alternative) is removed. A compliance monitoring plan for the selected alternative will be presented in the CAP.

6.3.1.2. Other MTCA Requirements

As discussed in Section 6.2, cleanup actions selected from alternatives that fulfill the MTCA threshold requirements must use permanent solutions to the maximum extent practicable, provide for a reasonable remediation time frame, and consider public concerns.

The soil alternatives developed in Section 5.1 were evaluated through the MTCA DCA process according to the criteria described in Section 6.2.3. The DCA for the soil alternatives is presented in Section 6.5.1.

The restoration time frame for all soil remediation alternatives is expected to be immediate upon completion of the construction. Design and implementation of the alternatives should be accomplished in less than 7 years which is a reasonable time frame. Cap monitoring and maintenance (Alternatives SL-1, SL-2, and SL-3) would extend beyond this time frame to ensure long-term effectiveness of the soil remedy.

Public concerns are considered by Ecology in the selection of cleanup actions and are formally solicited during required public notice and participation periods per WAC 173-340-600. Ecology considered public concerns expressed during the public notice period for the Public Review Draft of Volume III and Ecology's scoring of public concerns is reflected in the evaluation of alternatives.

Table 6-1 includes a comparative evaluation of other MTCA criteria that are considered as part of the DCA.

6.3.2. Groundwater Remediation Alternatives

This section presents the evaluation of the groundwater remediation alternatives (G-0 through G-3) described in Section 5.2 based on the criteria described in Section 6.2. Table 6-2 provides a summary of the groundwater remediation alternatives evaluation; specific requirements are discussed in subsections that follow. Note that the standard POC (all points in groundwater) is used for Alternative G-3. For Alternatives G-1 and G-2, a conditional POC is proposed in groundwater along the shoreline.

6.3.2.1. MTCA Threshold Requirements

The No-Action alternative (G-0) for groundwater does not meet MTCA threshold requirements and is dropped from further consideration.

Groundwater remediation alternatives G-1 through G-3 meet the threshold requirements (Table 6-2). These alternatives will protect human health and the environment through active in-situ treatment by air sparging (Alternative G-1), passive in-situ treatment by permeable treatment vaults (G-2), or active in-situ chemical treatment (G-3); they also include ICs to ensure the effectiveness of the remedies and are expected to comply with applicable state and federal laws. Each alternative will be implemented in accordance with applicable permitting or substantive requirements, workplace safety requirements, and BMPs.

All of the groundwater remediation alternatives include provisions for compliance monitoring to ensure short-term and long-term effectiveness of the remedies. In addition, each alternative includes protection monitoring during construction to ensure that worker and public health are protected and performance monitoring during or immediately following construction to verify that cleanup standards are achieved. A compliance monitoring plan for the selected alternative will be presented in the CAP.

6.3.2.2. Other MTCA Requirements

The groundwater alternatives developed in Section 5.2 were evaluated through the MTCA DCA process according to the criteria described in Section 6.2.3. The DCA for the groundwater alternatives is presented in Section 6.5.2.

The restoration times frame for Alternatives G-1, G-2, and G-3 are expected to be no more than 10 years. This time frame is considered reasonable. Confirmational groundwater monitoring may extend beyond this time frame to ensure effectiveness of the groundwater remedy after construction is completed.

Public concerns are considered by Ecology in the selection of cleanup actions and are formally solicited during required public notice and participation periods per WAC 173-340-600. Ecology considered public concerns expressed during the public notice period for the Public Review Draft of Volume III and Ecology's scoring of public concerns is reflected in the evaluation of alternatives.

6.3.3. Sediment Remediation Alternatives

This section presents the evaluation of the sediment remediation alternatives (S-1 through S-5) described in Section 5.3 based on the criteria and methodology described in Section 3.0. Table 6-3 provides a summary of the sediment remediation alternatives evaluation; specific requirements are discussed in the subsections that follow.

6.3.3.1. MTCA Threshold Requirements

As presented in Table 6-3, all of the sediment remediation alternatives meet the following threshold requirements under MTCA:

- Are protective of human health and the environment
- Comply with cleanup standards and applicable state and federal laws within a reasonable time frame
- Meet the PCULs at the specified POC
- Include provisions for compliance monitoring commensurate with the expected effectiveness and permanence of the applied technologies

All of the sediment remediation alternatives were reviewed and found to comply with cleanup standards and ARARs.

Performance monitoring for alternatives that would include ENR would consist of observation and/or periodic sampling of ENR-treated areas to ensure that recovery is progressing as expected. Observations of filled areas (Alternatives S-2 through S-4) and monitoring of cap area (Alternative S-3) would also be made periodically. The nature and concentrations of COPCs in areas considered for filling/ENR are such that physical confinement of sediment, rather than control of chemical diffusion, will likely be the more relevant design and performance criterion. Sampling to evaluate chemical diffusion into the overlying fill is not expected to be necessary.

6.3.3.2. Other MTCA and SMS Requirements

MTCA and SMS both set forth additional criteria for evaluating and comparing alternatives that meet the threshold criteria discussed above. Each of these is discussed in the subsections that follow.

As presented in Table 6-4, all of the sediment remediation alternatives are expected to achieve cleanup within a 10-year period. PCULs are expected to be achieved upon completion of the construction phase and any necessary adaptive management actions (e.g., to address dredging residuals). Dredging, cap, ENR, and filling are expected to achieve PCULs upon placement soon after completion of construction. Alternatives that emphasize dredging would require more time to complete due to seasonal constraints for the protection of migratory fish species, the need for dredge prism verification, throughput limitations associated with dredged material transloading and processing, and follow-up dredging that might be required to address residuals. The fish window for in-water work is assumed to be from July 15 to February 15.

Public concerns are considered by Ecology in the selection of cleanup actions and are formally solicited during required public notice and participation periods per WAC 173-340-600. Ecology considered public concerns expressed during the public notice period for the Public Review Draft of Volume III and Ecology's scoring of public concerns is reflected in the evaluation of alternatives.

No primary upland sources remain in the upland Study Area because the mill ceased operations and has been demolished. Ongoing contaminant sources (e.g., CSOs) that might still be present or occur outside of the Study Area following remediation will not be directly addressed by any of the remediation alternatives. Control measures for these potential sources are therefore not part of the remediation alternatives.

Possible Site-related continuing secondary sources to sediment contamination include: (1) contaminated groundwater, (2) chemically treated products such as wood pilings in in-water structures, and (3) erosion of contaminated soil (or fill) from the upland. Each of these sources will be addressed as part of the overall remedial approach. Groundwater PCULs explicitly include evaluation of possible sediment impacts. In-water structures will be removed. And erosion of contaminated soil will be controlled as part of the upland soil remediation and the planned shoreline restoration project.

Among the sediment remediation alternatives, Alternatives S-2, S-3 and S-4 will have the greatest likelihood of resulting in a final offshore bathymetry that minimizes the potential for the accumulation of any offsite contaminants potentially transported into the Study Area (Figures 5-16 to 5-18).

ICs will be required for the cap area in Alternative S-3. None of the alternatives will result in conditions or structures that would interfere with IC implementation or compliance.

6.4. COMPARATIVE BENEFITS AND COSTS OF ALTERNATIVES

This section presents a comparative analysis of the alternatives for sediment, soil, and groundwater based on the evaluation criteria described in Section 6.2.3. The analysis describes how each alternative addresses each criterion. Scores were developed for each alternative in each criterion (on a 1 to 10 scale) and, together with weightings for each criterion, are used to calculate the overall benefits score used in the DCA (Section 6.5). Costs are also summarized based on the detailed cost estimates for each alternative included in Appendix D.

6.4.1. Upland Soil Remediation Alternatives

Following with the process and criteria described in WAC 173-340-360(3)(f), the soil remediation alternatives were ranked and scored based on their relative ability to achieve the specified criteria. Table 6-1 provides a summary of how well each alternative addresses each criterion, as well as the numeric (1 through 10) score.

6.4.1.1. Protectiveness

For all soil remediation alternatives considered (i.e., all but the no-action alternative), sampling data will be used to demonstrate the protectiveness of the remedy. Time frames to meet the preliminary cleanup standards will be similar. While protective for reasonable exposure scenarios, the two scenarios that use RELs (Alternative SL-2 and Alternative SL-4) score lower than the other three which allow for unrestricted use of the property. The protectiveness score also increases for soil alternatives that rely more on excavation as opposed to covers.

6.4.1.2. Permanence

Alternative SL-5 is most permanent because it removes all contaminated soil from the site; the only potential risk is a change in regulation or risk assumption that results in more strict cleanup standards in the future. More reliance on covers (containment) as opposed to excavation reduces the permanence score. Alternatives SL-4 and SL-2 also have slightly reduced permanence scores because they assume non-residential land use which could theoretically change (and notably could be addressed at the time of the land-use change).

6.4.1.3. Long-Term Effectiveness

All of the soil remediation alternatives will be effective long term provided covers and ICs are maintained. Alternative SL-2 scores higher than Alternative SL-1 on long-term effectiveness because the cover is smaller. Relative to Alternative SL-2, Alternative SL-3 scores higher because additional excavation is performed and Alternative SL-4 scores higher because excavation is used instead of a cover. Alternative SL-5 scores highest for this criterion because the largest amount of contamination is removed from the site.

6.4.1.4. Management of Short-term Risks

The principal short-term risks to human health are anticipated to be the physical hazards associated with earthwork and heavy equipment operations. The construction methods and safety protocols for soil covers and excavation are well established, and associated short-term risks are expected to be low for all of the soil alternatives. Chemical hazards associated with potential exposure to contaminants during construction also are expected to be low for all soil remediation alternatives because proper health and safety procedures and BMPs will be used.

Simpler soil alternatives scored higher in this category because they involve less handling of material (particularly contaminated material) and because they do not move contaminated soil offsite.

6.4.1.5. Technical and Administrative Implementability

Construction methods for soil covers and excavation are well established in the construction industry. Consequently, significant technical obstacles to implementation are not anticipated for any of the soil remediation alternatives. Alternatives SL-1, SL-2, and SL-3 are considered to be nearly equally implementable and thus are scored equally. Alternatives SL-4 and SL-5 are ranked lower for implementability because in addition to soil covers and excavation, they involve offsite transport and disposal of contaminated soil. Accordingly, Alternatives SL-4 and SL-5 will require more extensive site controls/BMPs and waste acceptance by a third-party permitted disposal facility.

The primary administrative component of soil remediation alternatives is the use of ICs to ensure that the remedy will remain protective over the long term. The use of ICs is common and should not affect implementability.

6.4.1.6. Consideration of Public Concerns

Ecology considered public concerns expressed during the public notice period for the Public Review Draft of Volume III. Ecology's scoring of public concerns ranked Alternative SL-5 highest, followed by Alternatives SL-3, SL-1, SL-2 and SL-4.

6.4.1.7. Comparison of Overall Benefits

To assess overall benefits for each alternative, the numeric scores for each of the above criteria (Table 6-1) were combined with a percentage-based weighting factor representing the criterion's relative importance. The weighted scores for all criteria for each alternative were summed, and the results were used to calculate the overall "benefits score" in the DCA (Section 6.5).

6.4.1.8. Estimated Costs

Detailed cost estimates for the soil remediation alternatives are presented in Appendix B. The estimated present-worth costs of the alternatives are:

- Alternative SL-1 – $10,723,000
- Alternative SL-2 – $7,463,000
- Alternative SL-3 – $10,142,000
- Alternative SL-4 – $28,209,000
- Alternative SL-5 – $37,170,000

In accordance with EPA FS cost estimating guidance (EPA 2000), these estimates have uncertainties of -30 to +50%.

6.4.2. Groundwater Remediation Alternatives

Following the process and criteria described in WAC 173-340-360(3)(f), the groundwater remediation alternatives were ranked and scored based on their relative ability to achieve the specified criteria. Table 6-2 provides a summary of how each alternative addresses each criterion, together with the numeric (1 through 10) score.

6.4.2.1. Protectiveness

For all groundwater alternatives, compliance monitoring will be conducted to ensure protectiveness of the remedy. Time frames to meet the PCULs at the POC identified for each alternative are similar for all alternatives. Since alternatives G-1 and G-2 require approval of a conditional POC in groundwater immediately upgradient of the groundwater discharge zone, these alternatives rank lower than Alternative G-3 which uses the standard POC. Alternative G-2 is scored as more protective than Alternative G-1 because all of Alternative G-2 would be installed at once rather than in a phased approach.

6.4.2.2. Permanence

Alternative G-3 scores highest for permanence because it will use irreversible treatment to permanently reduce the mass or mobility of dissolved groundwater contaminants throughout the upland portion of the Study Area. Alternative G-1 relies on air sparging which is slightly less reliably permanent than the other alternatives in that reducing conditions would be more likely to return to the groundwater environment with this technology.

6.4.2.3. Long-Term Effectiveness

Alternatives G-1 through G-3 are expected to be effective in the long term. However, Alternative G-1 scores lower than Alternatives G-2 and G-3 because Alternative G-1 relies on air sparging treatment rather than biochemically tailored in-situ treatment. Alternative G-3 scores slightly higher than G-2 because it uses active (ISCO/ISCF) rather than passive (permeable media) treatment technologies to permanently reduce contaminant concentrations in the upland.

6.4.2.4. Management of Short-term Risks

Alternative G-1 is scored the highest because the associated construction methods are less complicated than those required for Alternatives G-2 and G-3, and Alternative G-1 will not involve the use of reactive media or industrial chemicals. Alternative G-2 scores slightly lower than Alternative G-1 because the construction methods required to install a funnel and gate system in an upland setting with significant relic subsurface structures (e.g., pilings, building foundations/footings) will be more complicated than those required to construct air sparging systems. Alternative G-3 scores relatively low due to its use of large quantities of oxidants and/or other industrial chemicals for in-situ groundwater treatment.

6.4.2.5. Technical and Administrative Implementability

Construction methods for installing air sparging systems (wells and blowers) and funnel-and-gate systems (e.g., trenching, sheet pile installation) are well established in the construction industry. Consequently, significant technical challenges to implementation are not anticipated for Alternatives G-1 or G-2. Alternative G-1 scores slightly higher than Alternative G-2 because the associated construction methods for Alternative G-1 will be less complicated than those required for Alternative G-2. Alternative G-3 is scored lower for implementability due to the technical and permitting challenges of working with large quantities of oxidants and/or other industrial chemicals.

6.4.2.6. Consideration of Public Concerns

Ecology considered public concerns expressed during the public notice period for the Public Review Draft of Volume III. Ecology's scoring of public concerns ranked Alternative G-5 highest, followed by Alternatives G-1 and G-2.

6.4.2.7. Comparison of Overall Benefits

The overall benefits scores used in the DCA for the groundwater alternatives (Section 6.5) were calculated by summing the weighted scores for each of the above criteria.

6.4.2.8. Estimated Costs

Detailed cost estimates for the groundwater remediation alternatives are presented in Appendix D. The estimated present-worth costs of the alternatives are:

- Alternative G-1 – $2,138,000 to $5,714,000 depending on whether the full system is needed to meet PCULs at the POC.
- Alternative G-2 – $24,997,000
- Alternative G-3 – $34,926,000

In accordance with EPA FS cost estimating guidance (EPA 2000), these estimates have uncertainties of -30% to +50%.

6.4.3. Sediment Remediation Alternatives

In accordance with the process and criteria described in WAC 173-340-360(3)(f), the sediment remediation alternatives were ranked and scored based on their relative ability to achieve the specified criteria. Table 6-3 provides a summary of how well each alternative addresses each criterion, as well as a numeric ranking (1 through 10).

6.4.3.1. Protectiveness

Residual risks for all sediment remediation alternatives will be in compliance with SMS. For those alternatives that will include dredging or excavation, post-dredge monitoring will be conducted to ensure compliance with PCULs at the POC. Following ENR or fill/ENR, post-remediation monitoring will also be conducted to ensure compliance. Cap areas will require long-term monitoring to ensure permanence. Time frames to meet the standards will be similar. All alternatives will achieve the sediment cleanup standards once remedial construction is complete. The protectiveness of the remedy typically increases as more cap, fill and dredging are included. The protectiveness criterion of the alternatives was ranked accordingly.

6.4.3.2. Permanence

All alternatives include removal of contaminated sediment in the intertidal/nearshore portion of the log pond and the mill dock landing. Other than the removal component, Alternatives S-1 through S-4 rely primarily on attenuation. Alternative S-2 includes additional permanence associated with fill/ENR in the berths. Alternatives S-3 and S-4 ranked similar due to capping and removal actions. Alternative S-5 ranks the highest due to result of area-wide dredging.

6.4.3.3. Long-Term Effectiveness

Alternative S-1depends on the long-term performance of ENR, which may depend to some degree on long-term maintenance. Long-term effectiveness of Alternatives S-2, S-3, and S-4 are similar but ranked in increasing order as more intrusive remedial actions (fill/ENR, capping and dredging) are included. Alternative S-5 includes the most dredging and has less dependence on long-term monitoring and potential maintenance activities.

6.4.3.4. Management of Short-Term Risks

Dredging is the most intrusive of the remedial technologies and can generate dredging residuals that may have short-term impacts. The lower risks associated with the less intrusive technologies included in Alternatives S-1 and S-2 with less dredge residuals relative to those generated by increased dredging (Alternatives S-3, S-4 and S-5) result in a higher ranking. Transfer, processing, staging and transport of dredged materials also represents a possible risk to workers and the public.

6.4.3.5. Technical and Administrative Implementability

Alternatives S-1 and S-2 were ranked higher than the other sediment remediation alternatives due to the anticipated ease of implementation. These two alternatives (and Alternative S-3) are also less dependent on coordination with upland actions. Alternatives S-3 and S-4 are ranked lower than Alternative S-1 and Alternative S-2 due to the increased dependency on the procurement of suitable fill material and the administrative aspects associated with placing fill in DNR tidelands.[10] Capping requires additional administrative concurrence with the landowner but technically, can be readily implemented. Dredging is more intrusive and requires management of dredged materials that will require successful sediment dewatering, processing and final disposition. Alternatives with increased dredging component (Alternatives S-3 through S-5) may need coordination with upland actions regarding dredged materials that might be processed or placed in the upland. Alternative S-5 is ranked the lowest due to the complexity and potential schedule constraints associated with dredging and residuals management.

6.4.3.6. Consideration of Public Concerns

Ecology considered public concerns expressed during the public notice period for the Public Review Draft of Volume III. Ecology's scoring of public concerns ranked Alternative S-5 highest, followed by Alternatives S-4, S-3, S-2 and S-1.

6.4.3.7. Comparison of Overall Benefits

As discussed for soil in Section 6.4.1, the overall benefits scores used in the DCA for the sediment remediation alternatives (Section 6.5) were calculated by summing the weighted scores for each of the above criteria.

6.4.3.8. Estimated Costs

Detailed cost estimates for the sediment remediation alternatives are presented in Appendix D. The estimated present-worth costs of the alternatives are:

- Alternative S-1 – $9,953,000
- Alternative S-2 – $10,872,000
- Alternative S-3 – $15,213,000
- Alternative S-4 – $18,023,000
- Alternative S-5 – $55,343,000

In accordance with EPA feasibility study cost estimating guidance (EPA 2000), these estimates have uncertainties of -30 to +50%.

6.5. DISPROPORTIONATE COST ANALYSIS

This section presents the DCAs for the soil, groundwater, and sediment remediation alternatives. MTCA requires that the DCA specified in WAC 173-340-360(3)(e) be used to ensure that permanent solutions are used to the maximum extent practicable (WAC 173-340-360(3)(b)). In the DCA, costs are considered to be disproportionate to benefits "if the incremental costs of the alternative over that of a lower cost alternative

[10] The need for mitigation, if any, will be determined once the final remedy is determined. It is not expected to be a significant factor in the DCA.

exceed the incremental degree of benefits achieved by the alternative over that of the other lower cost alternative" (WAC 173-340-360(3)(e)(i)).

To perform the DCA, the overall benefits score for a particular alternative is combined with the alternative's estimated present-value cost to calculate a benefit-to-cost ratio. The benefit-to-cost ratios for all of the alternatives are then compared to determine whether any alternatives have costs that are disproportionate to benefits.

6.5.1. Upland Soil Remediation Alternatives

The results of the DCA for the soil remediation alternatives are summarized in Table 6-5 and shown in Figure 6-1. Figure 6-1 includes the estimated cost, the total (weighted) overall benefits score, and the benefits-to-cost ratio for each alternative.

The soil remediation alternatives involving excavation and onsite covers (SL-1, SL-2, and SL-3) have much higher benefit to-cost ratios than do the alternatives that involve offsite disposal without covers. Among the consolidate-and-cover alternatives, Alternative SL-2 has the highest benefit-to-cost ratio.

Based on the results of the DCA, the preferred soil remediation alternative is Alternative SL-2. Alternative SL-2 uses excavation, an aggregate soil cover, and ICs to prevent exposures that exceed MTCA risk criteria for reasonable exposure scenarios.

6.5.2. Groundwater Remediation Alternatives

The results of the DCA for the groundwater remediation alternatives are summarized in Table 6-6 and shown in Figure 6-2. Figure 6-2 includes the estimated cost, the total (weighted) overall benefits score, and the benefits-to-cost ratio for each alternative.

The analysis indicates that, relative to Alternative G-1, Alternatives G-2 and G-3 have estimated costs that are disproportionate to their incremental benefits and are therefore not practicable. Note that the full sparging (highest cost) scenario is assumed in the DCA for Alternative G-1; using the low-end of the cost range would make the benefit-to-cost ratio of Alternative G-1 even greater.

Based on the results of the DCA, the preferred groundwater remediation alternative is Alternative G-1.

Alternative G-3 with the standard POC is found to be impracticable based on this DCA, and no other remedial strategy appears to be likely to achieve PCULs throughout groundwater in the Upland Study Area within a reasonable time frame. Therefore, a conditional POC is proposed. The proposed conditional POC is in groundwater near where groundwater discharges to surface water; compliance would be measured at existing or new shoreline groundwater monitoring wells.

6.5.3. Sediment Remediation Alternatives

The results of the DCA for the sediment remediation alternatives are summarized in Table 6-7 and shown on Figure 6-3. All sediment remediation alternatives comply with MTCA threshold criteria. Per MTCA, alternatives that achieve cleanup standards within 10 years of completion of construction of the active components of the cleanup are presumed to have a reasonable restoration time frame. All sediment remediation alternatives have a reasonable restoration time frame per this criterion.

Costs are evaluated against remedy benefits in order to assess cost-effectiveness and remedy practicability. Based on this assessment, all alternatives are considered practicable except Alternative S-5. Figure 6-3 includes the estimated cost, the total (weighted) overall benefits score, and the benefits-to-cost ratio for each alternative. Alternatives S-1 and S-2 exhibit the maximum return on expenditures relative to realized benefits. The other alternatives (S-3 through S-5) represent substantial incremental increases in cost with correspondingly minor increases in benefits. This is particularly true for Alternative S-5, which emphasizes dredging and has significantly higher costs per realized benefits than those for other alternatives (Figure 6-3).

Alternative S-1 and S-2 have higher benefit-to-cost ratios than the rest of the alternatives. Alternative S-1 relies extensively on the use of ENR and will meet preliminary cleanup standards and comply with threshold requirements within all the SRSs. However, under Alternative S-1, the berth would consist of dredged depressions in the sediment bathymetry and could accumulate potentially contaminated fines from offsite sources. Alternative S-2 provides more benefits by filling of the berth, which provides important source control-related benefits. Based on the DCA evaluation, Alternative S-2 is identified as the preferred remedy. Alternative S-2 uses protective and effective performance technologies and achieves the best environmental benefits that are proportionate to the unit incremental costs while remaining practical. It should be noted that the selected alternative will be refined during design based on additional pre-design sampling. Refer to Section 7.3 for further description of the recommended sediment remediation action.

7 RECOMMENDED INTERIM ACTION

7.1. UPLAND SOIL REMEDIATION

All of the soil alternatives (except no-action) meet the MTCA threshold requirements. The DCA results indicate that the two consolidate-and cover alternatives (SL-2 and SL-3) have the highest benefit-to-cost ratios. The practicable alternative with the highest benefit-to-cost ratio is Alternative SL-2 – Consolidate and Cover with RELs. This alternative is the preferred alternative for soil remediation.

7.2. GROUNDWATER REMEDIATION

As summarized in Section 6, all of the groundwater alternatives (except no-action) meet the MTCA threshold requirements. The DCA results indicate that the alternative with the highest benefit-to-cost ratio is Alternative G-1 – Sparging. Evaluation of Alternative G-3 showed that meeting PCULs at the standard POC (all locations in groundwater) would be impractical at this Site. Alternative G-1 is the preferred alternative for groundwater remediation. As explained in Section 5.2.2, air sparging would be applied in a phased manner, allowing for evaluation of sparging effectiveness during the remedy implementation phase, leading to a more optimized approach. It is envisioned that additional study of the groundwater plume and its discharge to surface water would be conducted, which could lead to a modified extent of the full-scale sparging system.

7.3. SEDIMENT REMEDIATION

As summarized in Section 6, all five of the sediment alternatives (S-1 through S-5) meet the MTCA threshold requirements. The DCA results indicate that the alternatives with the highest benefit-to-cost ratios are Alternatives S-1 and S-2. Both alternatives include sediment removal from the intertidal portion of the long pond, and Alternative S-2 includes filling and ENR in the berth area around the dock. Based on the DCA evaluation, Alternative S-2 was selected as the recommended preferred alternative because it provides protective, effective and long-term reliability by including the filling of the area around the dock and achieves the best environmental benefits. Alternative S-2 includes the following elements: excavate/dredge and backfill the intertidal portion of the log pond and dock landing, fill and apply ENR in the berth area around the dock, and apply ENR through the remainder of the sediment remediation area. The total sediment remediation area is approximately 51.6 acre.

7.4. INTEGRATED INTERIM ACTION PLAN

Assuming integrated remediation and restoration plan (Redevelopment for Open Space in Coordination with MTCA Cleanup) were to be implemented, the combined cost for MTCA and SMS-related cleanup in the upland (Alternatives SL-2 and G-1) and in-water area (Alternative S-2) is estimated to be $24,049,000 assuming the full sparging system of Alternative G-1 is employed. These costs reflect only MTCA remediation components. Additional costs would be incurred for other components, including removal of the mill dock and jetty and restoration of the Ennis Creek Estuary (pending NRD-related agreement). The selection of integrated remediation and restoration plan is contingent upon reaching a settlement agreement with the Trustees.

Restoration work may afford opportunities for additional source removal, groundwater remediation, and the elimination of exposure pathways beyond those that may be needed to achieve a MTCA-compliant cleanup. Consequently, the MTCA remedial alternatives presented do not represent a project plan or remedy design, which will come in future documents.

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TABLES

TABLE 2-1. SUMMARY OF IHS FOR THE ERA

Chemical Group	Number of IHS				
	Intertidal and Subtidal Sediment[a]	Intertidal Sediment Only[a]	Eelgrass and Bull Kelp	Fish	Shellfish
PCBs[b]	2	1	2	1	2
PAHs[c]	2	2	2	1	2
Pesticides	19	16	0	0	8
SVOCs	8	4	0	0	2
Dioxins and furans	1	1	1	1	1
Organometals	2	0	0	1	2
Metals	15	4	10	6	17
Inorganics	3	1	0	0	0
Wood waste	1	0	0	0	0
Organic acids	11	17	0	0	1
Guaiacols	0	6	0	0	0
Petroleum	2	2	0	0	0
Total	**66**	**54**	**15**	**10**	**33**

[a] In addition, ammonia, sulfide, wood waste, diesel fuel, and motor oil were identified as IHS in sediment; these IHS do not have benthic cleanup criteria.

[b] IHS in the PCB chemical group included PCB Aroclors and dioxin-like PCBs.

[c] IHS in the PAH chemical group included HPAHs and LPAHs.

ERA – ecological risk assessment
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
IHS – indicator hazardous substances
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound

TABLE 2-2. SUMMARY OF IHS

Chemical Group	Number of IHS			
	Intertidal and Subtidal Sediment	Intertidal Sediment Alone	Fish and Shellfish Tissue	Bull Kelp
Inorganics	8	2	16	2
Organometals	2	0	2	0
Organic acids	0	23[a]	0	0
PAHs	10	4	14	3
PCBs	1	1	1	0
Dioxins/furans	1	1	1	1
Pesticides	15	6	11	0
SVOCs	2	1	2	0
VOCs	0	0	1	0
Total	**39**	**38**	**48**	**6**

[a] Not quantitatively evaluated because of the lack of relevant toxicity benchmarks.
IHS – indicator hazardous substances
PAH – polycyclic aromatic hydrocarbon
SVOC – semivolatile organic compound

TABLE 2-3. SUMMARY OF EXCESS CANCER RISK ESTIMATES

Pathway	Risk Estimate					
	Subsistence Fisher		Recreational Fisher		Residential User	Recreational User
	RME	CT	RME	CT		
Sediment – ingestion	5×10^{-6}	5×10^{-6}	2×10^{-6}	6×10^{-7}	2×10^{-6}	3×10^{-7}
Sediment – dermal	8×10^{-6}	9×10^{-7}	3×10^{-6}	1×10^{-7}	3×10^{-6}	5×10^{-7}
Tissue – ingestion	1×10^{-2}	6×10^{-3}	3×10^{-4}	2×10^{-4}	na	na
Total	**1×10^{-2}**	**6×10^{-3}**	**3×10^{-4}**	**2×10^{-4}**	**5×10^{-6}**	**8×10^{-7}**

Note: Excess cancer risk estimates based on PCBs (as Aroclors), cPAHs, and dioxins/furans were calculated using one-half the RLs for non-detect values. Risk estimates were also calculated assuming zero for non-detect values, but total risk estimates were very similar to those presented in this table.

cPAH – carcinogenic polycyclic aromatic hydrocarbon
CT – central tendency
PCB – polychlorinated biphenyl
RL – reporting limit
RME – reasonable maximum exposure

TABLE 3-1. INTERIM ACTION OBJECTIVES

Medium	Objectives
Sediment	Eliminate, reduce, or otherwise control to the extent practicable risks to benthic organisms through exposure to sediments that exceed benthic organism-based sediment quality standards or result in benthic toxicity. Eliminate, reduce, or otherwise control to the extent practicable risks to humans from dermal contact or incidental ingestion of intertidal sediments containing contaminants that exceed human health-based PCULs. Eliminate, reduce, or otherwise control to the extent practicable risks to humans from exposure through seafood ingestion to sediment-derived contaminants that exceed human health-based PCULs on an area-averaged basis. Eliminate, reduce, or otherwise control to the extent practicable risks to higher-trophic-level organisms from exposure through direct contact or seafood ingestion to sediment-derived contaminants on an area-averaged basis.[a]
Soil	Eliminate, reduce, or otherwise control to the extent practicable risks to humans from direct contact with soil containing contaminants exceeding human health-based PCULs for: • Unrestricted land use[b] in the West Mill, East Mill, and Ennis Creek Areas and within the 200-ft shoreline setback in all areas • Industrial land use in the City Purchase Area. Eliminate, reduce, or otherwise control to the extent practicable risks to terrestrial ecological receptors from direct contact with soil containing contaminants exceeding ecological-based PCULs in all areas (West Mill, East Mill, Ennis Creek, and City Purchase Areas). Eliminate, reduce, or otherwise control to the extent practicable leaching of constituents to groundwater that would lead to an exceedance of groundwater PCULs.
Groundwater	Eliminate, reduce, or otherwise control to the extent practicable risks to aquatic life and humans from the migration of upland groundwater to marine surface water and sediment. Prevent potable uses of groundwater. Upland groundwater is considered non-potable due to the proximity and hydraulic connection to marine surface water.

[a] Because risks for fish and wildlife were low (Ecology 2012a), NewFields (2013) concluded that the risk-based levels derived for human seafood consumption are protective of fish and wildlife. Therefore, PCULs were not derived for higher-trophic-level species.

[b] Unrestricted land use provides a basis for soil PCULs. This is not a commitment to establish unrestricted land use as part of a final site development. An alternate RME for open space is considered in the development of remediation levels.

PCUL – preliminary cleanup level

TABLE 3-2. APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS)

Medium	Standard/Criterion	Citation	Comments and Substantive Requirements
ARARs			
Sediment	Criteria used to identify sediments that have no adverse effects on biological resources and correspond to no significant health risk to humans	Sediment Management Standards (SMS; WAC 173-204)	SMS cleanup levels serve as ARARs for the development of PCULs.
Soil and groundwater	State cleanup levels for soils	Model Toxics Control Act (MTCA; WAC 173-340- 740 and -745)	Applicable for soil within the Upland Study Area.
	State cleanup levels for groundwater	Model Toxics Control Act (WAC 173-340-720)	Potentially applicable to groundwater as necessary to protect adjacent surface water.
Other Requirements to be Considered			
Surface water	Ambient water quality criteria for the protection of aquatic organisms and human health	Federal Water Pollution Control Act/Clean Water Act (33 USC 1251–1376; 40 CFR 100–149); Water Quality Standards (40 CFR 131)	MTCA requires the attainment of water quality criteria where relevant to the circumstances of the release. Remediation plans will include measures to comply with surface water standards during implementation.
	State water quality standards; conventional water quality parameters and toxic criteria	Washington Water Pollution Control Act (RCW 90.48); State Water Quality Standards for Surface Water (WAC 173-201A-130)	Narrative and quantitative limitations for surface water protection. Remediation plans will include measures to be taken to comply with surface water standards during implementation. Parts I – IV and Part VI of the SMS (WAC 173-204) were adopted, in part, under RCW 90.48.

CFR – Code of Federal Regulations
PCUL – preliminary cleanup level
RCW – Revised Code of Washington
USC – United States Code
WAC – Washington Administrative Code

TABLE 3-3. OTHER REQUIREMENTS TO BE CONSIDERED—CONSTRUCTION, TREATMENT, AND DISPOSAL

Activity	Requirement	Citation	Comments and Substantive Requirements
In-water sediment disposal or capping	USACE permitting requirements	Sections 401 and 404 of the Clean Water Act (40 CFR 230; 33 CFR 320, 323, 325, and 328)	Permitting requirements for discharges into waters of the United States.
		Section 10 of the Rivers and Harbors Act (33 CFR 320 and 322)	Permitting requirements for dredging or disposal in navigable waters of the United States. Project implementation will include USACE permitting.
	State HPA permitting	Washington Hydraulic Code Rules (WAC 220-110)	Permitting for work that would use, divert, obstruct or change the natural flow or bed of any salt or fresh waters. Project implementation and permitting will include coordination with Washington State Department of Fish and Wildlife staff. This coordination will address all substantive requirements of the HPA permitting process, including evaluation of potential mitigation requirements and definition of work procedures and timing. Dredging, capping, and other in-water work activities will be performed at appropriate times of the year to comply with fisheries protection requirements.
	PSDDA characterization and permitting procedures	Dredged Material Management Program guidelines (RCW 79.90; WAC 332-30)	Characterization and permitting process for sediments destined for unconfined open-water disposal (not anticipated under the remediation alternatives). Selected sediments from the site may be characterized and authorized for PSDDA disposal and/or beneficial reuse. Project implementation will follow PSDDA procedures, including obtaining DNR use authorization for sediment disposal at the PSDDA site. Additional sediment re-characterization may be required to comply with PSDDA standards depending on dates of sediment dredging and disposal.
	Multi-user disposal site operating agreements	Typically the use of multi-user disposal sites is governed by site-specific permits and/or agreements.	Use of a multi-user disposal site for sediment disposal is not anticipated as part of a remedial alternative.

Activity	Requirement	Citation	Comments and Substantive Requirements
In-water sediment disposal or capping	Rules for management of state-owned aquatic lands	State aquatic land management laws (RCW 79.90 through 79.96; WAC 332-30) State constitution (Articles XV, XVII, XXVII) Public trust doctrine	Sediment disposal, if performed on state-owned aquatic lands, must not be in conflict with state regulations. Project implementation for PSDDA sediment disposal will follow PSDDA procedures, including procurement of DNR use authorization for sediment disposal at the PSDDA site. If beneficial reuse of sediment is performed on state-owned lands, a sediment use authorization must be obtained. Sediment capping on state-owned lands, if performed as part of the remedy, must consider rules for management of state-owned aquatic lands.
Upland disposal of excavated soil and dredged sediment	State criteria for dangerous waste (which are broader than federal hazardous waste criteria)	Washington Dangerous Waste Regulations (WAC 173-303) Designation procedures (WAC 173-303-070)	State and federal laws prohibit land disposal of certain hazardous or dangerous wastes. Soil and sediment managed by upland disposal will comply with disposal site criteria. The need for additional waste profiling will be addressed as part of the engineering design for the project.
	Requirements for solid waste management	Solid Waste Disposal Act (42 USC Sec. 325103259, 6901-6991), as administered under 40 CFR 257 and 258; WAC 173-304, Minimum Functional Standards for Solid Waste Handling; WAC 173-350, Solid Waste Handling Standards.	Applicable to non-hazardous waste generated during remedial activities and disposed offsite unless wastes meet recycling exemptions. Soil and sediment managed by upland disposal will comply with disposal site criteria. Remediation alternatives are based on existing permitted facilities that are compliant with these regulations and are permitted to accept impacted materials. Upland beneficial reuse of sediments would be regulated under WAC 173-350.
Air emissions	State implementation of ambient air quality standards. Northwest Clean Air Agency ambient and emission standards. Regional emission standards for toxic air pollutants (Source of toxic air contaminant requires a notice of construction.)	Washington State Clean Air Act (70.94 RCW) General Requirements for Air Pollution Sources (WAC 173-400)	Potentially applicable to alternatives involving sediment treatment or upland handling. Onsite treatment of dredged materials using methods that may require an air pollution control permit is not contemplated in the removal action alternatives. Offsite sediment handling and/or treatment/disposal facilities that would be contemplated for use under the removal action alternatives would need to comply with applicable air regulations and maintain appropriate permits.
	Olympic Region Clean Air Agency regulations controlling dust emissions	Olympic Region Clean Air Agency regulations adopted by the Board of Directors December 3, 1969	To be considered – requirements would be addressed.

Activity	Requirement	Citation	Comments and Substantive Requirements
Wastewater	Permitting and treatment requirements for direct discharges into surface water.	NPDES (40 CFR 122, 125) State Discharge Permit Program; NPDES Program (WAC 173-216 and -220)	Anticipated to be relevant only if collected waters are discharged to surface water. Discharges must comply with requirements of the NPDES permit. Applicable for offsite discharges. Construction stormwater requirements will be satisfied for upland handling of soil and sediment, including development of a storm water pollution prevention plan and implementation of best management practices. NPDES program requirements will be reviewed as part of project final design.
	Permitting and pre-treatment requirements for discharges to a POTW	National Pretreatment Standards (40 CFR 403)	Discharges to POTWs may require pre-treatment, and permitting requirements would be applicable. If alternatives include water pretreatment and POTW discharge, such work would be subject to POTW permitting and pre-treatment standards. Project design and implementation must incorporate waste characterization, pretreatment and permitting. Permitting requirements will be reviewed as part of project final design.

DNR – Department of Natural Resources
HPA – hydraulic project approval
NPDES – National Pollutant Discharge Elimination System
POTW – publicly owned treatment works
PSDDA – Puget Sound Dredged Disposal Analysis
RCW – Revised Code of Washington
USACE – US Army Corps of Engineers
WAC – Washington Administrative Code

TABLE 3-4. OTHER REQUIREMENTS TO BE CONSIDERED—PROJECT PERMITTING AND IMPLEMENTATION

Activity	Requirement/Prerequisite	Citation	Comments and Substantive Requirements
Evaluation of environmental impacts	Evaluation of project environmental impacts and definition of appropriate measures for impact mitigation	State Environmental Policy Act (WAC 197-11) National Environmental Policy Act (42 USC 4321 et seq.)	SEPA/NEPA checklist will be prepared in conjunction with design and permitting to evaluate SEPA/NEPA requirements.
Construction activities within 200 ft of shoreline	Construction near shorelines of statewide significance, including marine waters and wetlands	Shoreline Management Act (WAC 173-14) Coastal Zone Management Act (16 USC 1451 et seq.)	Applicable for construction; is performed in upland areas adjacent to shorelines.
Construction in state waters	Requirements for construction and development projects for the protection of fish and shellfish in state waters.	Construction Projects in State Waters, Hydraulic Code Rules (RCW 75.20; WAC 220-1101)	Requirements will be considered and addressed as appropriate. Project implementation and permitting will include coordination with Washington State Department of Fish and Wildlife staff. Coordination will address requirements of the HPA permitting process, including information submittals, evaluation of potential mitigation requirements, and definition of work procedures and timing. Dredging, capping, and other in-water work activities will be performed at appropriate times of the year to comply with fisheries protection requirements.
Construction activities within waterways and wetlands	Regulates discharge of dredged or fill material into navigable waters, as well as incidental deposition resulting from shoreline construction/excavation	Rivers and Harbors Appropriation Act (33 USC 401; 40 CFR 230; 33 CFR 320, 322, 323, and 325)	USACE Section 404 Permit or Nationwide Permit requirements will be evaluated.
Activities within/adjacent to wetlands	Actions must be performed so as to minimize the destruction, loss, or degradation of wetlands as defined by Executive Order 11990, Section 7, requirement for no net loss of remaining wetlands.	Executive Order 11990, Protection of Wetlands (40 CFR 6, Appendix A) EPA wetland actions plan (EPA 1989)	Removal action alternatives will not result in net loss of any wetland areas.
Endangered and threatened species	Actions must be performed so as to conserve endangered or threatened species, including consultation with the US Department of the Interior.	Endangered Species Act of 1973 (16 USC 1531 et seq.; 50 CFR Parts 200 and 402	Chinook salmon listed as threatened species. Implementing entity must confer with National Oceanic and Atmospheric Administration Fisheries on any action that may impact listed species. Project permitting will include compliance with Endangered Species Act requirements, as necessary, including consultation with state and federal permitting agencies and incorporation of appropriate measures to avoid adverse impacts to endangered or threatened species.

Activity	Requirement/Prerequisite	Citation	Comments and Substantive Requirements
Habitat impacts and mitigation	Policies and procedures have been established by state and federal agencies to evaluate and mitigate habitat impacts.	Memorandum of Agreement between EPA and USACE (Mitigation under Clean Water Act Section 404(b)(1); US Fish and Wildlife Mitigation Policy (46 FR 7644) US Fish and Wildlife Coordination Act (16 USC 661 et seq.) Washington State Department of Fisheries Habitat Management Policy (Washington Department of Fisheries Policy 410) Compensatory Mitigation Policy for Aquatic Resources (RCW 75.20 and 90.48)	Mitigation requirements for projects are defined in project permitting and vary with the type of work conducted. Project final design will include evaluation of project impacts and definition of any mitigation required or appropriate to the work being performed.
Health and safety	Development of a health and safety plan with appropriate controls, worker certifications, and monitoring	WISHA (WAC 296-62) OSHA (29 CFR 1910.120)	Relevant requirement for environmental remediation operations. All work activities performed at the site will comply with OSHA/WISHA requirements. Project final design will include definition of contractor safety requirements, including preparation and compliance with a project health and safety plan, worker training and record-keeping requirements, and other applicable measures.
Noise control	Maximum noise levels	Noise Control Act of 1974 (RCW 70.107;WAC 173-60) Port Angeles Municipal Code	Potentially relevant depending on removal activities and equipment selected Construction activities will be limited to normal working hours, to the extent possible, to minimize noise impacts.
Within 100-year flood plain	RCRA hazardous waste facility designed, operated, maintained to avoid washout	40 CFR 257 40 CFR 264.18(b) 40 CFR 761.75	Onsite RCRA hazardous waste facility is not considered under any remediation alternative.
Grading activities	Any upland grading activity that may need to be performed.	Port Angeles Municipal Code	To be considered where grading activities are anticipated.
Stormwater	Ensure that permanent stormwater system meets current city codes	Port Angeles Municipal Code	Applicable stormwater control regulations relating to stormwater, grading, and drainage control

CFR – Code of Federal Regulations
EPA – US Environmental Protection Agency
FR – Federal Register
NEPA – National Environmental Policy Act
OSHA – Occupational Safety and Health Administration

RCRA – Resource Conservation and Recovery Act
RCW – Revised Code of Washington
SEPA – State Environmental Policy Act
WISHA – Washington Industrial Safety and Health Act

TABLE 3-5. SEDIMENT RISK-BASED LEVELS BASED ON RISK THRESHOLDS OF 1X10^{-6} EXCESS CANCER RISK AND HAZARD QUOTIENT OF 1

Risk Driver	Unit (dw)	Concentration					
		Seafood Ingestion (tissue-derived)			Direct Contact		Selected Risk-Based Level
		Tissue Type[a]	Excess Cancer Risk	Non-Cancer Hazard	Sediment Ingestion	Dermal Exposure	
Arsenic	mg/kg	Dungeness crab	0.0000707	0.0174	1.05	0.847	0.0000707
Cadmium	mg/kg	Dungeness crab	NC	0.0982	NC	NC	0.0982
Copper	mg/kg	Dungeness crab	NC	5.6	NC	NC	5.6
Selenium	mg/kg	Dungeness crab	NC	0.226	NC	NC	0.226
Zinc	mg/kg	Dungeness crab	NC	55	NC	NC	55
Mercury	mg/kg	Dungeness crab	NC	0.0552	NC	NC	0.0552
alpha-BHC	μg/kg	geoduck	0.00679	187	250	60.5	0.00679
cPAH	μg/kg	geoduck	0.748	NA	216	40.2	0.748
PCB Aroclors	μg/kg	Dungeness crab	0.164	3.57	790	140	0.164
PCB congener TEQ	ng/kg	Dungeness crab	0.000762	0.0626	10.5	8.47	0.000762
Dioxin/furan TEQ	ng/kg	Dungeness crab	0.00585	0.481	10.5	8.47	0.00585

Source: NewFields (2013).

Note: The equations and input parameters used to calculate risk-based levels are from the human health risk assessment by Ecology (2012a). Tissue-derived sediment risk-based levels were calculated in NewFields (2013) using the tissue risk-based levels and BSAF values.

[a] Seafood ingestion risk-based levels were calculated separately for each tissue type, and the tissue type that resulted in the lowest cleanup level was selected.

BHC – benzene hexachloride
cPAH – carcinogenic polycyclic aromatic hydrocarbons
dw – dry weight
μg/kg – microgram per kilogram
mg/kg – milligram per kilogram
NC – not calculated
ng/kg – nanogram per kilogram
PCB – polychlorinated biphenyl
RBC – risk-based concentration
TEQ – toxic equivalent

TABLE 3-6. SMS CRITERIA FOR THE PROTECTION OF THE BENTHIC COMMUNITY FOR CONTAMINANTS WITH CONCENTRATIONS GREATER THAN SCOs IN SURFACE SEDIMENT WITHIN THE MARINE STUDY AREA

Contaminant	SCO/CSL			Marine Sediment AETs[c]		
	Unit	SCO	CSL	Unit	SCO	CSL
Metals						
Mercury	mg/kg dw	0.41	0.59	mg/kg dw	0.41	0.59
PAHs						
Acenaphthene	mg/kg OC	16	57	µg/kg dw	500	500
Benzo(g,h,i)perylene	mg/kg OC	31	78	µg/kg dw	670	720
Chrysene	mg/kg OC	110	460	µg/kg dw	1,400	2,800
Dibenzofuran	mg/kg OC	15	58	µg/kg dw	540	540
Fluoranthene	mg/kg OC	160	1,200	µg/kg dw	1,700	2,500
Fluorene	mg/kg OC	23	79	µg/kg dw	540	540
Indeno(1,2,3-cd)pyrene	mg/kg OC	34	88	µg/kg dw	600	690
Phenanthrene	mg/kg OC	100	480	µg/kg dw	1,500	1,500
Pyrene	mg/kg OC	1,000	1,400	µg/kg dw	2,600	3,300
Total HPAH[a]	mg/kg OC	960	5,300	µg/kg dw	12,000	17,000
Total LPAH[b]	mg/kg OC	370	780	µg/kg dw	5,200	5,200
Phthalates						
bis(2-ethylhexyl) phthalate	mg/kg OC	47	78	µg/kg dw	1,300	1,900
Other SVOCs						
2,4-Dimethylphenol	µg/kg dw	29	29	µg/kg dw	29	29
2-Methylphenol	µg/kg dw	63	63	µg/kg dw	63	63
4-Methylphenol	µg/kg dw	670	670	µg/kg dw	670	670
Phenol	µg/kg dw	420	1,200	µg/kg dw	420	1,200
PCBs						
Total PCBs	mg/kg OC	12	65	µg/kg dw	130	1,000

[a] Total HPAHs were calculated as the sum of benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, total benzofluoranthenes, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, and pyrene.
[b] Total LPAHs were calculated as the sum of acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, and phenanthrene.
[c] Dry weight AETs should be considered when total organic carbon is outside the recommended range of 0.5 to 3.5% (Ecology 2017c).

AET – apparent effects threshold
CSL – cleanup screening level
dw – dry weight
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
µg/kg – microgram per kilogram
mg/kg – milligram per kilogram
OC – organic carbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SCO – sediment cleanup objective
SVOC – semivolatile organic compound

TABLE 3-7. NATURAL BACKGROUND CONCENTRATIONS BASED ON THE PROXIMAL DATASET AND 90/90 UTL

Risk Driver	Unit	Natural Background Concentration
Metals		
Arsenic	mg/kg dw	12
Cadmium	mg/kg dw	0.82
Copper	mg/kg dw	35[a]
Mercury	mg/kg dw	0.11
Selenium	mg/kg dw	NA
Zinc	mg/kg dw	77 [a]
Organic Compounds		
Alpha-BHC	µg/kg dw	NA[b]
cPAH TEQ	µg/kg dw	16
PCB congener TEQ	ng/kg dw	0.1[c]
Total PCBs (congener sum)	µg/kg dw	0.96[c]
Dioxin/furan TEQ	ng/kg dw	1.2[c]

Source: Ecology (2014a)

[a] Ecology (2014b), which presented 90/90 UTLs calculated by Ecology using the proximal dataset.

[b] Newfields (2013) notes that alpha-BHC not detected in 12 of 13 samples.

[c] Ecology (2016a) presented natural background concentrations for PCB congener TEQ, total PCBs (congener sum), and dioxin/furan TEQ. Ecology (2016b) directed a combined natural background concentration for PCBs and dioxins/furans (total TEQ)); the individual values are no longer relevant.

BHC – benzene hexachloride
cPAH – carcinogenic polycyclic aromatic hydrocarbon
dw – dry weight
µg/kg – microgram per kilogram
mg/kg – milligram per kilogram
NA - not available
PCB – polychlorinated biphenyl
UTL – upper tolerance limit
TEQ – toxic equivalent

TABLE 3-8. REGIONAL BACKGROUND CONCENTRATIONS

Risk Driver	Unit	Regional Background Concentration
Metals		
Arsenic	mg/kg dw	14
Cadmium	mg/kg dw	2.4
Copper	mg/kg dw	NA
Mercury	mg/kg dw	0.13
Selenium	mg/kg dw	NA
Zinc	mg/kg dw	NA
Organic Compounds		
Alpha-BHC	µg/kg dw	NA
cPAH TEQ	µg/kg dw	64[a]
PCB congener TEQ	ng/kg dw	0.21[b]
Total PCBs (congener sum)	µg/kg dw	5.3 [b]
Dioxin/furan TEQ	ng/kg dw	5.0 [b]

[a] Port Angeles-specific regional background, 90/90 UTL (Ecology 2016a).

[b] Ecology (2016a) presented regional background concentrations for PCB congener TEQ, total PCBs (congener sum), and dioxin/furan TEQ. Ecology (2016b) directed a combined regional background concentration for PCBs and dioxins/furans (total TEQ); the individual values are no longer relevant.

BHC – benzene hexachloride
cPAH – carcinogenic polycyclic aromatic hydrocarbon
dw – dry weight
µg/kg – microgram per kilogram
mg/kg – milligram per kilogram
NA - not available
PCB – polychlorinated biphenyl
UTL – upper tolerance limit
TEQ – toxic equivalent

TABLE 3-9. PRELIMINARY PQLS FOR THE HUMAN HEALTH RISK DRIVERS

Risk Driver	Unit	PQL
Arsenic	mg/kg	0.50
Cadmium	mg/kg	0.10
Copper	mg/kg	0.35
Selenium	mg/kg	0.60
Zinc	mg/kg	1.6
Total mercury	mg/kg	0.025
alpha-BHC	μg/kg	1.3
cPAH TEQ	μg/kg	0.76
PCB Aroclors	μg/kg	5.5
PCB congeners	ng/kg	0.4
PCB congener TEQ	ng/kg	0.052
Dioxin/furan TEQ	ng/kg	2.3

Sources: NewFields (2013) and Ecology (2014e)

BHC – benzene hexachloride
cPAH – carcinogenic polycyclic aromatic hydrocarbon
μg/kg – microgram per kilogram
mg/kg – milligram per kilogram
ng/kg – nanogram per kilogram
PCB – polychlorinated biphenyl
PQL – practical quantitation limit
TEQ – toxic equivalent

TABLE 3-10. POINTS OF COMPLIANCE

Area	Area Definition	Exposure Route	Point of Compliance	Applicable IHS	Comparison to Standards
Entire SCU	MHHW to boundary defined by COCs > SCL	Protection of human health - ingestion of fish and mobile shellfish (crab, shrimp)	10 cm	All	SWAC
Entire SCU	MHHW to boundary defined by COCs > SCL	Protection of aquatic life (benthic organisms)	10 cm	All	Station by station
SMA	MHHW to MLLW	Protection of human health - Ingestion of sessile shellfish (bivalves)	45 cm	Includes All (cPAHs, metals, etc.) except Total TEQ[a]	SWAC (SWAC beach segments separately if applicable)
Intertidal Area	MHHW to MLLW	Protection of human health - direct contact (contact with and ingestion of sediment)	45 cm	All	SWAC

[a] Total TEQ combines dioxin/furan and PCB TEQs.

cm - centimeter
COC – constituent of concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
IHS – indicator hazardous substance
MHHW – mean higher high water
MLLW – mean lower low water
PCB – polychlorinated biphenyl
SCL – sediment cleanup level
SCU – sediment cleanup unit
SMA – sediment management area
SWAC - spatially weighted average concentration
TEQ – toxic equivalent

TABLE 3-11. SEDIMENT CLEANUP OBJECTIVES FOR THE HUMAN HEALTH RISK DRIVERS FOR THE MARINE STUDY AREA

Risk Driver	Unit	Concentration			
		Sediment Risk-Based Level[a]	Natural Background Level[b]	PQL[c]	SCO[d]
Arsenic	mg/kg	0.0000707	12	0.50	12
Cadmium	mg/kg	0.0982	0.82	0.10	0.82
Copper	mg/kg	5.6	35	0.35	35
Selenium	mg/kg	0.226	NC	0.60	0.60
Zinc	mg/kg	55	77	1.6	77
Total mercury	mg/kg	0.0552	0.11	0.025	0.11
alpha-BHC	µg/kg	0.00679	NC	1.3	1.3
cPAH TEQ	µg/kg	0.748	16	0.76[e]	16
PCB congener TEQ	ng/kg	0.000762	0.1	0.052[e]	0.1
Dioxin/furan TEQ	ng/kg	0.00585	1.2	2.3[e]	2.3

[a] Sediment risk-based levels are the lowest of the risk-based levels for human health, higher-trophic-level species, and benthic invertebrates.

[b] Background concentrations are the 90/90 UTLs calculated by Ecology using the proximal dataset defined in NewFields (2013).

[c] PQLs are from NewFields (2013) and Ecology (2014e).

[d] The SCO is the highest of the sediment risk-based level, natural background, and PQL (Figure 3-2).

[e] The cPAH TEQ, PCB congener TEQ, and dioxin/furan TEQ values are not true PQLs but are instead PQL-based. A TEQ is calculated from the PQL using TEF values from MTCA rules.

BHC – benzene hexachloride
cPAH – carcinogenic polycyclic aromatic hydrocarbon
Ecology – Washington State Department of Ecology
µg/kg – microgram per kilogram
mg/kg – milligram per kilogram
NC – not calculated
ng/kg – nanogram per kilogram
PCB – polychlorinated biphenyl
PQL – practical quantitation limit
SCO – sediment cleanup objective
TEF – toxic equivalency factor
TEQ – toxic equivalent
UTL – upper tolerance limit

TABLE 3-12. CLEANUP SCREENING LEVELS FOR THE HUMAN HEALTH RISK DRIVERS

Risk Driver	Unit	Concentration			
		Sediment Risk-Based Level[a]	Regional Background Level	PQL[b]	CSL[c]
Arsenic	mg/kg	0.0000707	14	0.50	14
Cadmium	mg/kg	0.0982	2.4	0.10	2.4
Copper	mg/kg	5.6	NC	0.35	35[e]
Selenium	mg/kg	0.226	NC	0.60	0.6
Zinc	mg/kg	55	NC	1.6	77[e]
Total mercury	mg/kg	0.0552	0.13	0.025	0.13
alpha-BHC	µg/kg	0.00679	NC	1.3	1.3
cPAH TEQ	µg/kg	0.748	64	0.76[d]	64[h]
PCB congener TEQ	ng/kg	0.000762	0.21	0.052[d]	ND
Dioxin/furan TEQ	ng/kg	0.00585	5.0[f]	2.3[d]	ND
Total TEQ	ng/kg	NC	NC	NC	5.2[g]

[a] Sediment risk-based levels are the lowest of the risk-based levels for human health, higher-trophic-level species, and benthic invertebrates. Note that human health cleanup levels can be based on a 1×10^{-5} threshold for individual chemicals at the CSL level. However, the risk-based levels in this table are based on a 1×10^{-6} threshold because the cumulative risk (all carcinogens combined) must be $\leq 1 \times 10^{-5}$. Adjustments could be made if a risk-based level was sufficiently close to either regional background or the PQL to make this calculation warranted.

[b] PQLs are from NewFields (2013).

[c] The CSL is the highest of the sediment risk-based level, regional background value, or PQL (Figure 3-2).

[d] The cPAH, PCB, and dioxin/furan congener values are not true PQLs but are instead PQL-based. A TEQ is calculated from the PQL using TEF values from MTCA rules.

[e] Set equal to the SCO.

[f] Based on Ecology (2016a).

[g] Based on Ecology (2016b).

[h] Port Angeles-specific regional background, 90/90 UTL (Ecology 2016a).

BHC – benzene hexachloride
cPAH – carcinogenic polycyclic aromatic hydrocarbon
CSL – cleanup screening level
Ecology – Washington State Department of Ecology
µg/kg – microgram per kilogram
mg/kg – milligram per kilogram
NC – not calculated
ND – not determined
ng/kg – nanogram per kilogram
PCB – polychlorinated biphenyl
PQL – practical quantitation limit
TEF – toxic equivalency factor
TEQ – toxic equivalent

TABLE 3-13. GROUNDWATER INDICATOR HAZARDOUS SUBSTANCES AND PRELIMINARY CLEANUP LEVELS

IHS	PCUL	Basis
pH	7.0 – 8.5	Protection of marine surface water aquatic life
Ammonia (un-ionized) (µg/L)	35	Protection of marine surface water aquatic life
Arsenic (µg/L)	5	Natural background
Copper (µg/L)	3.1	Protection of marine surface water aquatic life
Manganese (µg/L)	910	Protection of marine surface water – human health
Nickel (µg/L)	8.2	Protection of marine surface water aquatic life
cPAHs (TEQ) (µg/L)	0.015	PQL
Acenaphthene (µg/L)	3.3	Protection of marine sediment

TABLE 3-14. SOIL INDICATOR HAZARDOUS SUBSTANCES, PRELIMINARY CLEANUP LEVELS, AND POTENTIAL REMEDIATION LEVELS

IHS	Unrestricted Use PCUL (mg/kg)	Industrial Use PCUL (mg/kg)	Ecological PCUL (mg/kg)	Potential REL * (mg/kg)
Arsenic	20	87.5		20
Iron	56,000			180,000
Lead	250	1,000		250
Zinc	24,000		302	302
Thallium	0.8	35		2.5
cPAHs TEQ	1.0	18		2.4
Pentachlorophenol	2.5	328		6.1
Dioxin TEQ	0.000013	0.0017	0.00022	0.000040
PCBs - Total	0.5	65.6		1.2
TPH-Diesel range	2,000	2,000	200	200
TPH-Heavy oil range	2,000	2,000		2,000

*The Potential RELs listed are protective of human health for occasional visitors/trespassers and are protective of terrestrial ecological receptors (Appendix A). These RELs may be used to define where certain remedial technologies are applied in remedial alternatives.

TABLE 3-15. SCOS, CSLS, AND SWACS FOR HUMAN HEALTH RISK DRIVERS

Risk Driver	Unit	SCO (basis)	CSL (basis)	Pre-Remediation SWAC	Post-Remediation SWAC
Arsenic	mg/kg	12 (NB)	14 (RB)	4.8	6.2
Cadmium	mg/kg	0.82 (NB)	2.4 (RB)	0.69	0.71
Copper	mg/kg	35 (NB)	35 (NB)	18.7	21.2
Selenium	mg/kg	0.60 (PQL)	0.6 (PQL)	0.5	0.5
Zinc	mg/kg	77 (NB)	77 (NB)	41.7	48.7
Mercury	mg/kg	0.11 (NB)	0.13 (RB)	0.1	0.1
Alpha-BHC	µg/kg	1.3 (PQL)	1.3 (PQL)	0.7	0.9
cPAH TEQ	µg/kg	16 (NB)	64 (RB)	121.3	64
PCB TEQ	ng/kg	0.1 (NB)	0.21 (RB)	NC	NC
Dioxin/furan TEQ	ng/kg	2.3 (PQL)	5.0 (RB)	NC	NC
Total TEQ	ng/kg	NC	5.2	5.3	3.4

BHC – benzene hexachloride
cPAH – carcinogenic polycyclic aromatic hydrocarbon
CSL – cleanup screening level
µg/kg – microgram per kilogram
mg/kg – milligram per kilogram
NB – natural background
NC – not calculated
ND – not determined
ng/kg – nanogram per kilogram
PCB – polychlorinated biphenyl
PQL – practical quantitation limit
RB – regional background
RBL – risk-based level
SCO – sediment cleanup objective
SWAC – spatially weighted average concentration
TEQ – toxic equivalent

TABLE 4-1. SOIL REMEDIATION TECHNOLOGIES AND SCREENING RESULTS

Technology	Retained?	Screening Comments
Removal		
Excavation	Yes	Excavation of contaminated soil using common excavation methods. The type of equipment selected must take into consideration several factors, such as type of material to be excavated, horizontal and vertical extent of removal, load-bearing capacity of the ground surface around the excavation footprint, and depth of the groundwater table.
In Situ Treatment		
Thermal Treatment	No	Stripping of volatile contaminants from soil by increasing subsurface temperatures. Typically requires an SVE system to control buildup of volatilized contaminants, water vapor, and non-condensable gases. Generally not effective for dioxins/furans, PCBs, or metals. High organics in the subsurface, if present, could limit effectiveness.
Biological Treatment	No	Injection of amendments or air into contaminated soil to stimulate biodegradation. Can be effective for TPH; not expected to be effective for metals, most cPAHs, dioxins/furans, or PCBs.
Chemical treatment	No	Injection of a dilute solution of oxidant (e.g., hydrogen peroxide, ozone, potassium permanganate, sodium persulfate, ferric chloride) or reducing agent into contaminated soil to convert contaminants into non-hazardous or less-toxic substances by breaking chemical bonds. The specific chemical used is selected based on contaminant oxidation/reduction chemistry. Proven effective for treating metals; limited/no effectiveness for treating some cPAHs, dioxins/furans, and PCBs. In situ application could be inhibited by subsurface heterogeneity and relic structures or the presence of high organics (e.g., wood debris).
Solidification/Stabilization	No	Physical binding or encapsulating of contaminants in situ through the creation of a stabilized mass (solidification) or in situ chemical reactions between stabilizing agent and contaminants to reduce contaminant mobility (stabilization). Stabilization process can result in a significant increase in treated soil volume. Not effective for preventing direct contact exposures. Effectiveness limited by subsurface heterogeneity.
Soil Vapor Extraction (SVE)	No	Application of vacuum through extraction pipes screened in vadose zone to create a pressure/concentration gradient, which induces volatile contaminants to migrate through soil to the SVE wells. The process typically includes an off-gas treatment system. The induced air flow can also stimulate aerobic bioremediation of petroleum hydrocarbons. Not effective for the majority of contaminants (i.e., metals, dioxins/furans, cPAHs, and PCBs) due to their low volatilities and resistance to aerobic biodegradation.
Soil flushing	No	Removal of soil contaminants by flushing the soil with aqueous surfactants, detergents, acids, etc., introduced via injection or infiltration/percolation. After passing through contaminated soil, the injected liquids must be recovered and treated or disposed of to avoid contaminating groundwater. Effectiveness limited by the presence of fine-grained or low-permeability soil or subsurface structures/debris. Not effective for dioxin.
Containment		
Aggregate cap	Yes	Placement of an aggregate (e.g., gravel) layer over contaminated soil to isolate contaminants to prevent direct contact with underlying soil.
Geomembrane/aggregate cap	Yes	Placement of an HDPE geomembrane overlain by an aggregate (e.g., gravel) layer over contaminated soil to prevent infiltration and direct contact with underlying soil.

Technology	Retained?	Screening Comments
Natural Recovery		
MNA	No	Monitoring over time of the reduction of contaminant concentrations resulting from intrinsic natural biotransformation processes such as volatilization, biodegradation, adsorption, and chemical reactions. Can be effective for TPH; not expected to be effective for metals, cPAHs, dioxins/furans, or PCBs.
Institutional Controls		
Environmental covenant	Yes	Recording of a deed restriction to document the presence of potentially hazardous substances and restrict residential land use and actions that could reduce remedy effectiveness. Effective for the protection of human health provided that there is compliance with the conditions of the covenant.
Fencing and warning signs	Yes	Use of fencing and signs to control access by the general public. Effective for limiting human exposure.
Ex Situ Treatment (onsite)		
Ex situ stabilization/solidification	No	Physically binding or encapsulating contaminants ex situ in excavated soil by creating a stabilized mass (solidification), or inducing chemical reactions between stabilizing agent and contaminants to reduce contaminant mobility (stabilization). Stabilization process can result in a significant increase in treated soil volume. Generally not effective for preventing direct contact exposures
Soil washing	No	Treatment of contaminated soil with aqueous surfactants, detergents, etc., to separate fine-grained soil particles that contain adsorbed contaminants from larger soil particles. Fine-grained particles and residual liquids from the process are then further treated or disposed of. May be effective for some soil contaminants. However, the residuals management requirement makes this technology significantly less practicable than other retained technologies.
Soil separation/screening	Yes	Separation of large soil components (e.g., concrete, wood, rubble, and debris) from soil matrix by physical means such as screening. Process streams are treated or disposed of separately. Effective for segregating excavated soil into particle-size grades to meet requirements for other pre-treatment methods or offsite disposal.
Chemical oxidation	No	Treatment of contaminated soil with a dilute oxidant solution (e.g., hydrogen peroxide, ozone, potassium permanganate, sodium persulfate, ferric chloride) to convert contaminants to non-hazardous or less toxic substances by breaking chemical bonds. The specific oxidant used is selected based on contaminant oxidation/reduction chemistry. Chemical oxidation has been proven to be effective for treating metals but has shown limited effectiveness for treating cPAHs, dioxins/furans, PCBs, and TPH. Effectiveness is limited by subsurface heterogeneity.
Enhanced bioremediation	No	Treatment of contaminated soil by mixing with amendments to enhance biodegradation (microbial conversion of organic contaminants to innocuous, stable byproducts). Can be effective for TPH but not expected to be effective for the majority of contaminants (i.e., metals, cPAHs, dioxins/furans, and PCBs).
Thermal desorption	No	Consists of heating soil to 320 to 560 °C in a continuous-flow reactor to volatilize organic contaminants. A carrier gas or vacuum system transports volatilized organics to a gas treatment system. Can be effective for TPH but not expected to be effective for the majority of contaminants (i.e., metals, cPAHs, dioxins/furans, and PCBs).
Institutional Controls		
Environmental covenant	Yes	Recording of a deed restriction to document the presence of potentially hazardous substances and restrict residential land use and actions that could reduce remedy effectiveness. Effective for

Technology	Retained?	Screening Comments
		the protection of human health provided that there is compliance with the conditions of the covenant.
Fencing and warning signs	Yes	Use of fencing and signs to control access by the general public. Effective for limiting human exposure.
Excavated Soil Management/Disposal		
Landfill disposal	Yes	Disposal of contaminated soil at a permitted, offsite landfill. Common method of disposal for contaminated soil. Soil must meet land disposal requirements. Pretreatment may be required if material does not meet requirements.
Incineration	No	Use of high temperatures (1,600 to 2,200 °F) to combust organic contaminants present in excavated soil at a permitted offsite facility. Effective for the permanent destruction of organic contaminants; not effective for treating metals.
Consolidation for onsite containment	Yes	Consolidation of excavated soil from two or more areas in a designated onsite location for containment. Onsite consolidation and containment of excavated soil can be an effective alternative to offsite disposal when appropriate engineering controls or ICs (e.g., capping, environmental covenant, fencing/signage) are implemented. Dredged or excavated sediment, if generated as part of marine remedy, could be consolidated onsite as part of the upland containment remedy.

°C – degree Celsius
°F – degree Fahrenheit
cPAH – carcinogenic polycyclic aromatic hydrocarbon
HDPE – high-density polyethylene
IC – institutional control
PCB – polychlorinated biphenyl
TPH – total petroleum hydrocarbons
SVE – soil vapor extraction

TABLE 4-2. GROUNDWATER REMEDIATION TECHNOLOGIES AND SCREENING RESULTS

Technology	Retained?	Screening Comments
Extraction and Treatment		
Groundwater extraction and treatment (“pump and treat”)	No	Extraction of groundwater using extraction wells or interceptor trench and pumps. The primary objective of groundwater collection for ex situ treatment (as opposed to hydraulic containment [see below]) is to remove dissolved contaminant mass, thereby reducing contaminant concentrations over time. Requires significant treatment system equipment/infrastructure and may not achieve cleanup goals within a reasonable time frame.
Containment		
Groundwater extraction for hydraulic containment	Yes	Focused extraction of groundwater (via pumping from extraction wells) to establish a hydraulic capture zone and restrict groundwater flow and contaminant migration. Retained for potential use in localized areas should extraction for hydraulic containment or excavation dewatering become necessary.
Groundwater cutoff-wall (sheet pile or slurry wall)	Yes	Not estimated to be an effective stand-alone technology for this site. Similar to groundwater extraction this technology may be used at select locations to facilitate excavation. Barriers are considered in conjunction with some in situ treatment technologies(e.g., PRB [see below]).
In Situ Treatment		
PRB	Yes	Construction of a barrier (i.e., a trench or closely spaced boreholes backfilled with treatment media) along the upland margin to attenuate dissolved COPCs as groundwater migrates passively through the PRB. PRBs have been used at other sites to address a range of COPCs, including select organic compounds and metals.
ISCO	Yes	Injection of a dilute oxidant solution (e.g., hydrogen peroxide, ozone, potassium permanganate, sodium persulfate, ferric chloride) into contaminated groundwater to immobilize contaminants or convert them to non-hazardous or less toxic substances by breaking chemical bonds. Technology has been retained for potential application in select areas assuming that effective oxidant(s) could be identified through treatability testing for a sufficient range of groundwater contaminants.
ISCF	Yes	Placement of a reductant or reductant-generating material (e.g., zero-valent iron, ferrous iron, sodium dithionite, sulfide salts [calcium polysulfide], hydrogen sulfide) into the subsurface to chemically degrade organic compounds to potentially non-toxic or less-toxic compounds, immobilize metals by adsorption or precipitation, and degrade non-metallic oxyanions such as nitrate. Retained for potential application in select areas, assuming effective reductant(s) can be identified through treatability testing for a sufficient range of groundwater contaminants.
Air sparging	Yes	Injection of air into contaminated groundwater to increase dissolved oxygen content and change redox conditions to oxidizing environment. Increased oxygen content can enhance the biodegradation of organic contaminants (such as cPAHs) that biodegrade slowly under aerobic conditions. This can also enhance other attenuation processes (e.g., precipitation/oxidation).

Technology	Retained?	Screening Comments
Nearshore sand filtration	Yes	Placement of a layer of clean sand along the shoreline in the intertidal zone to promote enhanced tidal mixing and attenuation within the sand layer. Contaminant concentrations in groundwater would be reduced by adsorption, oxidation, and precipitation of dissolved-phase contaminants in the oxygenated filtration horizon. Nearshore sand filters have been used or selected for use at other cleanup sites in Washington to address a wide range of COPCs (e.g., metals, including manganese, copper, arsenic, and mercury, un-ionized ammonia, and cPAHs). The filtration layer may require armoring (e.g., with gravel and/or riprap) to protect against erosion.
MNA	Yes	Monitoring of groundwater for indicators of biodegradation, dispersion, volatilization, adsorption, and/or other intrinsic attenuation processes to document the intrinsic attenuation of contaminants over time. Groundwater monitoring will be a implemented as part of the long-term site remediation plan. MNA for groundwater is retained for use as part of a holistic remedial strategy.
Electrical resistance heating	No	Stripping of volatile contaminants from groundwater through generation of an electrical current between electrodes installed in the subsurface. The electrical resistance of the saturated soil causes subsurface temperatures to rise. Typically requires an SVE system to control the buildup of volatilized contaminants, water vapor, and non-condensable gases. Requires significant treatment system equipment/infrastructure. Expected to be predominately effective for volatile groundwater contaminants..
Steam heating	No	Stripping of volatile contaminants from groundwater through the injection of steam into the subsurface. The steam is generated by an onsite boiler and injected through wells; subsurface temperatures increase through thermal conduction, convection, and steam condensation. Typically requires an SVE system to control the buildup of volatilized contaminants, water vapor, and non-condensable gases. Requires significant treatment system equipment/infrastructure. Expected to be predominantly effective for -volatile groundwater contaminants.
Institutional Controls		
Environmental covenant	Yes	Recording a deed restriction to prohibit potable use of groundwater and actions that could reduce remedy effectiveness. Effective for protecting human health provided there is compliance with the conditions of the covenant.

COPC – contaminant of potential concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
ISCO – *in situ* chemical oxidation
ISCF – *in situ* chemical fixation
MNA – monitored natural attenuation
PRB – permeable reactive barrier
SVE – soil vapor extraction

TABLE 4-3. SEDIMENT REMEDIATION TECHNOLOGIES AND SCREENING RESULTS

Technology	Retained?	Screening Comments
Removal		
Excavation from upland using conventional construction equipment	Yes	Can be implemented and is useful as a means for sediment removal in nearshore/intertidal areas. Technology is proven and equipment is readily available. May not be allowed during certain times of year due to fish window limitations. Must be coordinated with tides.
Excavation from barge using long-arm backhoe	Yes	Can be implemented as a means for sediment removal in nearshore/intertidal areas that cannot be reached from the shoreline. May not be allowed during certain times of the year and can only be done during high tides.
Mechanical dredging (e.g., clamshell or environmental bucket)	Yes	Can be implemented with appropriate monitoring to ensure turbidity is controlled. May be available only seasonally, depending on other projects and fish windows.
Hydraulic dredging (diver assisted)	Yes	Available and applicable as a means of selectively removing sediment within small limited-access locations (none are expected). Not applicable over large areas where mechanical dredging is a better alternative.
Suction hopper dredging	No	Technology is not appropriate for the size of the areas that may be dredged. Mechanical dredging or smaller, diver-assisted hydraulic units are more appropriate.
In Situ Treatment		
Carbon amendment – adjunct to thin-layer material (e.g., ENR)	No	Technology is potentially applicable as an adjunct to ENR. Would require further evaluation to determine potential benefits.
Reactive mats	No	More appropriate for smaller areas or sites where active flux of separate-phase contaminants from sediment is a concern. Not practical to maintain and keep in place over large areas and for long periods of time.
Direct biological/chemical treatment	No	Difficult to ensure complete application and reliability. Biological treatment likely not effective for all contaminants within reasonable time frame.
In situ solidification	No	Difficult to ensure complete application/contact with affected media throughout the sediment column.
Containment		
Fill	Yes	Especially applicable to previously dredged areas having sufficient depth to accommodate clean fill formulated to be similar in composition to surrounding area.
Engineered cap composed of clean dredged material and/or sand (1 to 3 feet thick), with armoring as needed	Yes	The purpose of a cap would be to control diffusion of underlying contaminants by acting like an isolation layer.
Engineered multi-layer cap with clay layer	No	Not retained. Sediment contamination levels are sufficiently low such that diffusion through a fill layer or single-layer cap is not expected to be significant.
Engineered multi-layer cap with geomembrane barrier	No	Not appropriate for subtidal areas. Placement of geomembrane in marine environment is not practical.
Reactive cap/carbon-impregnated cap mats	No	Problematic to apply over large areas and maintain.
MNR		
Sediment deposition and quality monitoring	No	Appropriate in areas with concentrations just above cleanup levels and where natural sediment deposition is expected to meet cleanup goals within an acceptable time frame. MNR may be reconsidered once additional sediment characterization has been performed as part of remedial design.

Technology	Retained?	Screening Comments
ENR		
Application of thin-layer material (e.g., sand)	Yes	Enhanced recovery using application of thin sand layer. Material selection and placement method will be determined during remedial design.
Application of thin-layer material with amendment (e.g., activated carbon)	No	Carbon amendment not anticipated to be necessary. This assumption will be reviewed during final design.
Institutional Controls		
Prohibit future navigational dredging in sediment areas	Yes	Required to maintain long-term physical integrity of capped areas.
Prohibit anchoring	Yes	Retained, if needed, to ensure long-term physical integrity of capped areas.

ENR – enhanced natural recovery
MNR – monitored natural recovery

TABLE 4-4. SUPPLEMENTAL DREDGED MATERIALS MANAGEMENT TECHNOLOGIES AND SCREENING RESULTS

Technology	Retained?	Screening Comments
Dewatering/Water Treatment/Discharge		
Weir tanks, gravity solids separators	Yes	Used for dewatering of hydraulically dredged material.
Former clarifier structure	Yes	Potentially useful for dewatering dredged material.
Sand media filtration	Yes	Readily available as portable equipment. Can be used if needed to meet water discharge requirements.
Carbon absorption	Yes	Readily available as portable equipment. Can be used if needed to meet water discharge requirements.
Discharge of dewatering supernatant to POTW	No	Proximity of nearby sewage treatment facility makes transfer feasible; however, salinity of water would likely interfere with treatment facility processes (trickling filter).
Infiltration of dewatering supernatant in upland	Yes	Infiltration of sediment dewatering supernatant in the upland is feasible if the water is treated first to remove contaminants.
Discharge of dewatering supernatant to bay	Yes	Should be allowed if turbidity and contaminants are sufficiently removed from water prior to discharge. Treatment methods, monitoring, and discharge water quality limits would likely be stipulated in a discharge permit.
Staging/Transfer		
Upland confined stockpile	Yes	Necessary for managing sediment excavated from the upland.
Loaders, dump trucks, etc.	Yes	Necessary for upland stockpiling/loading.
Barge-to-shore remote transload facility (e.g., elsewhere in Puget Sound)	Yes	Necessary for sediment dredged offshore and transported for upland disposal.
Material transport barges	Yes	Necessary for receiving dredged material offshore and transferring to transload/disposal location.
Long-haul trucks (e.g., dump trucks/lowboys)	Yes	Used for over-road transport of dredged material. Free liquids must be limited and contained during transport.
Long-haul rail	Yes	Used for over-rail transport of dredged material. Free liquids must be limited and contained during transport. Applicable when a transload facility that transfers material to rail for upland disposal (e.g., the Lafarge facility in Seattle) is used.
Disposal		
Dispersive dredged material disposal site	Yes	This technology can only be applied to dredged sediment that meets DMMP limits for unconfined disposal and if capacity is available.
Non-dispersive dredged material disposal site	Yes	A feasible technology only if sediment meets DNR DMMP disposal limits and if capacity is available. Use of this technology may be reconsidered during remedial design.
Onsite CAD	No	Placement of contaminated dredged material in water would constitute a CAD and would require capping and long-term cap maintenance. Use of DNR subtidal areas for CAD would likely involve an extensive permitting/approval process.
Subtitle D upland landfill	Yes	Transloaded dredged sediment or sediment that is excavated and sufficiently dewatered can be transported to an upland landfill. It is unlikely that dredged material would contain contaminants at concentrations high enough to require management in a Subtitle C or TSCA -approved landfill.
Use or consolidation in Upland Study Area as fill and/or beneath an upland cap	Yes	Sediment excavated using upland-based equipment may have contaminant concentrations low enough to be used in the upland as fill or capping material. Sediment could require dewatering and/or amendments to achieve desirable in-place structural characteristics and stability. Sediment consolidation beneath an upland cap may also be feasible.

CAD – confined aquatic disposal
DNR – Department of Natural Resources
DMMP – Dredged Material Management Program

TABLE 4-5. EXTRACTED GROUNDWATER MANAGEMENT TECHNOLOGIES AND SCREENING RESULTS

Technology	Retained?	Screening Comments
Ex Situu Treatment of Extracted Groundwater		
Chemical oxidation	Yes	Treatment of extracted groundwater with a dilute oxidant solution (e.g., hydrogen peroxide, ozone, potassium permanganate, sodium persulfate, ferric chloride) to immobilize contaminants or convert them to non-hazardous or less-toxic substances by breaking chemical bonds. Proven effective for treating some metals and PAHs. Implementable assuming effective oxidant(s) can be identified through treatability testing for a sufficient range of groundwater contaminants.
GAC adsorption	Yes	Pumping of extracted groundwater through vessels containing GAC. Organic compounds with an affinity for carbon are transferred from the dissolved phase to the solid phase by sorption to the carbon. Effective for treating organic compounds and some metals. Could be combined with other treatment technologies as a polishing step after contaminants have first been removed from extracted groundwater using other treatment methods.
UV oxidation	Yes	Exposure of extracted groundwater to UV light, which is used in conjunction with an oxidant (e.g., ozone or hydrogen peroxide) to form highly reactive hydroxyl radicals. The hydroxyl radicals destroy dissolved organic contaminants by breaking chemical bonds. Effective in treating organic compounds. Could also be effective in treating some metals through precipitation reactions. Could be combined with other treatment technologies as a polishing step after contaminants have first been removed from extracted groundwater using other treatment methods.
Ion exchange	Yes	Pumping of extracted groundwater through columns containing ion exchange resin media for the removal of dissolved metals. Ion exchange removes metal ions by exchanging cations or anions between the groundwater and the exchange medium. Effective in treating metals. High suspended solids content may cause operational and maintenance problems with the ion exchange resin.. Wastewater generated during resin regeneration would require additional treatment and disposal.
Air stripping	No	Pumping of extracted groundwater through packed columns or stacked tray systems designed to deliver a steady stream of air that passes upward through the flowing water. The stream of air strips volatile contaminants from the water. The volatile-laden air is then treated, as necessary, prior to discharge to the atmosphere. Not expected to be effective for all identified groundwater contaminants.
Dissolved or cavitation air floatation/flocculation/ sedimentation	Yes	Pumping of extracted groundwater through dissolved or cavitation air floatation, flocculation, or sedimentation tanks to remove particulates. These processes can be used as a pre-treatment step to extend the lifespan of a primary treatment process/medium. Can be used to remove particulates and adsorbed contaminants. Typically combined with other treatment technologies as a pre-treatment step.
Physical filtration	Yes	Pumping of extracted groundwater through filters (e.g., bag filters, sand filters) to remove particulates. Filtration can be used as a pre-treatment step to extend the lifespan of a primary treatment process/medium. Can be used to remove particulates and absorbed contaminants. Typically combined with other treatment technologies as a pre-treatment step.
Bioreactor contact beds	No	Pumping of extracted groundwater through a reactor vessel that contains a fixed bacterial film. Contaminants are aerobically degraded by the bacteria as the water passes through the reactor vessel. Potentially effective for cPAHs; not effective for metals.
pH adjustment	Yes	Adjustment of pH as necessary to precipitate metal hydroxides. Effective for metals.

Technology	Retained?	Screening Comments
Extracted Groundwater Disposal		
Discharge to POTW	Yes	Discharge of extracted groundwater to the sanitary sewer for conveyance to local POTW. Requires authorization from POTW. Pre-treatment may be required to meet authorized discharge (concentration) limits. Discharge quantity limits may also apply. Effective disposal method for extracted groundwater.
Discharge to surface water	Yes	Discharge of extracted, treated groundwater to surface water under an NPDES permit. Can be an effective disposal method for extracted, treated groundwater, assuming NPDES discharge limits can be met.
Discharge to shallow aquifer using injection wells/infiltration trenches	Yes	Discharge of extracted, treated groundwater to onsite reinjection wells or infiltration trenches. Can be an effective disposal method for extracted, treated groundwater. Underground injection control registration may be required; anticipated hydraulic effects of reinjection must be accounted for during design.

cPAH – carcinogenic polycyclic aromatic hydrocarbon
GAC – granular activated carbon
NPDES – National Pollutant Discharge Elimination System
POTW – publicly owned treatment works
UV – ultraviolet

TABLE 4-6. SUMMARY OF RETAINED REMEDIATION TECHNOLOGIES

General Response Action	Sediment	Soil	Groundwater
Removal	• Excavation • Excavation from barge with backhoe • Mechanical dredging • Hydraulic dredging (diver assisted)	• Excavation	• None
Containment	• Filling of previously dredged areas to restore to surrounding bathymetry	• Aggregate cap • Geomembrane/ aggregate cap	• Groundwater extraction[a]
In situ treatment	• None	• None	• Nearshore sand filtration • PRB • ISCO/ISCF • Air sparging
Ex situ treatment	• Dewatering/screening only	• Soil separation/ screening	• Retained for treatment of water extracted for containment purposes • Chemical oxidation[b] • Granular activated carbon adsorption • UV oxidation • Ion exchange • Dissolved or cavitation air floatation/flocculation/ sedimentation • Physical filtration • pH adjustment
ENR	• ENR as a sand layer applied to surface sediment	• None[c]	• None[c]
Onsite residuals management	• Sediment consolidation in upland as fill or beneath upland cap • Water treatment for dewatering sediment (tanks, clarifiers, filters, carbon absorption) • Discharge to reinjection wells/infiltration trenches	• Pre-disposal stabilization/ solidification • Pre-disposal separation/ screening	• Discharge to surface water • Discharge to reinjection wells/ infiltration trenches
Offsite residuals management	• Landfill via truck or remote transload facility then truck/rail • Discharge of treated dewatering water to surface water • DMMP disposal sites (if available and able to accept material)	• Landfill disposal	• Discharge to POTW • Discharge to surface water • Discharge to shallow aquifer
ICs	• Dredging controls • Anchoring prohibition	• Environmental covenant • Fencing and warning signs	• Environmental covenant

[a] Retained for hydraulic containment or excavation dewatering, if needed, in conjunction with other technologies.
[b] The listed ex situ groundwater treatment technologies were retained for use in conjunction with groundwater extraction for hydraulic containment or excavation dewatering if needed.
[c] ENR is applicable only to sediment.

ENR – enhanced natural recovery
IC – institutional control
ISCF – in situ chemical fixation
ISCO – in situ chemical oxidation
POTW – publicly owned treatment works
PRB – permeable reactive barrier
UV – ultraviolet

Table 5-1. Sediment Remediation Alternatives Summary

<table>
<tr><th rowspan="2">Sediment Remediation Subareas</th><th colspan="5">Alternatives</th></tr>
<tr><th>S-1</th><th>S-2</th><th>S-3</th><th>S-4</th><th>S-5</th></tr>
<tr><td>Log Pond – Intertidal/Nearshore and Mill Dock Landing</td><td colspan="5">Excavate/Dredge</td></tr>
<tr><td>Log Pond - Subtidal</td><td colspan="2">ENR</td><td>Cap</td><td colspan="2">Dredge</td></tr>
<tr><td>Berth</td><td>ENR</td><td colspan="3">Fill and ENR</td><td>Dredge</td></tr>
<tr><td>Under Mill Dock</td><td colspan="2">ENR</td><td>Dredge</td><td>ENR</td><td>Dredge</td></tr>
<tr><td>Mill Dock (Subtidal)</td><td colspan="4">ENR</td><td>Dredge</td></tr>
</table>

TABLE 6-1. SUMMARY OF THE SOIL REMEDIATION ALTERNATIVES EVALUATION

Criteria	Alternative SL-1 Cover	Alternative SL-2 Consolidation with RELs	Alternative SL-3 Consolidation	Alternative SL-4 Excavation with RELs	Alternative SL-5 Excavation
Alternative components	• Clear and grub upland excavation and cover areas • Demolish concrete pads within the excavation area for repurposing onsite or for offsite disposal • Excavate Ennis Creek area to meet PCULs; place material in area to be covered • Backfill excavation to design grade • Install an aggregate cover (permeable geotextile covered by 1 ft of crushed rock) • Place and hydroseed topsoil (1-ft layer) in the capped areas • Install fence and/or signs as needed to protect cover • Conduct post-construction cover monitoring for 30 years • Record an environmental covenant for the property	• Clear and grub upland excavation and cover areas • Demolish concrete pads within the excavation area for repurposing onsite or for offsite disposal • Remove soil in excavation areas to meet RELs; place material in consolidation area to be covered • Backfill excavations to design grade • Install an aggregate cover (permeable geotextile covered by 1 ft of crushed rock) • Place and hydroseed topsoil (1-ft layer) in the capped areas • Install fence and/or signs as needed to protect cover and limit site trespassing • Conduct post-construction cover monitoring for 30 years • Record an environmental covenant for the property	• Clear and grub upland excavation and cover areas • Demolish concrete pads within the excavation area for repurposing onsite or for offsite disposal • Remove soil in excavation areas to meet PCULs; place material in consolidation area to be covered • Backfill excavations to design grade • Install an aggregate cover (permeable geotextile covered by 1 ft of crushed rock) • Place and hydroseed topsoil (1-ft layer) in the capped areas • Install fence and/or signs as needed to protect cover and limit site trespassing • Conduct post-construction cover monitoring for 30 years • Record an environmental covenant for the property	• Clear and grub excavation area • Demolish concrete pads within the excavation area for repurposing onsite or for offsite disposal • Remove soil in excavation areas to meet RELs; transport for disposal at Subtitle D landfill • Backfill to design grade • Install fence and/or signs as needed to limit site trespassing • Record an environmental covenant for the property	• Clear and grub excavation area • Demolish concrete pads within the excavation area for repurposing onsite or for offsite disposal • Remove soil in excavation areas to meet PCULs; transport for disposal at Subtitle D landfill • Backfill to design grade
Protection of human health and the environment	**Yes -** Alternative will protect human health and the environment through a combination of excavation, containment (aggregate cap), cap monitoring/maintenance, and ICs.	Same as Alternative SL-1.	Same as Alternative SL-1.	**Yes -** Alternative will protect human health and the environment through a combination of excavation with offsite disposal and ICs.	**Yes -** Alternative will protect human health and the environment through excavation with offsite disposal.
Compliance with cleanup standards	**Yes –** Alternative is expected to comply with cleanup standards.	Same as Alternative SL-1.	Same as Alternative SL-1.	Same as Alternative SL-1.	Same as Alternative SL-1.
Compliance with applicable state and federal regulations	**Yes -** Alternative will comply with applicable state and federal regulations.	Same as Alternative SL-1.	Same as Alternative SL-1.	Same as Alternative SL-1.	Same as Alternative SL-1.
Provision for compliance monitoring	**Yes -** Alternative will include provision for compliance monitoring.	Same as Alternative SL-1.	Same as Alternative SL-1.	Same as Alternative SL-1.	Same as Alternative SL-1.
Restoration time frame[a]	**No more than 7 years** Restoration time frame will include design, permitting, contracting and construction of the remedy, and implementation of ICs. Exposure pathways will be eliminated once construction has been completed and ICs have been implemented. The anticipated restoration time frame is considered to be reasonable.	Same as Alternative SL-1.	Same as Alternative SL-1.	Same as Alternative SL-1.	Same as Alternative SL-1.
Protectiveness	**Score = 8** Meets residential standards with reliance on containment (cover) and ICs (environmental covenant)	**Score = 6** Protective for any reasonable exposure scenario. Meets RELs with reliance on containment (cover) and ICs (environmental covenant)	**Score = 9** Meets residential standards with reliance on containment (cover) and ICs (environmental covenant). More excavation and smaller cover than SL-1.	**Score = 7** Protective for any reasonable exposure scenario; soil exceeding RELs removed from Site	**Score = 10** Most protective – meets residential standards throughout site
Permanence	**Score = 5** Requires maintenance of large covers and ICs for permanence.	**Score = 6** Requires maintenance of cover and ICs for permanence. Land use change could require additional action.	**Score = 7** Requires maintenance of cover and ICs for permanence. Most of site meets unrestricted criteria at standard POC.	**Score = 8** Permanent unless land use changed to require additional action.	**Score = 9** Most permanent. Returns site to uncontaminated condition (soil), provided regulatory limits do not become stricter.
Long-term effectiveness	**Score = 6** Alternative effectiveness depends on cover maintenance and maintenance of ICs.	**Score = 7** Smaller cover than SL-1 increases the expected long-term effectiveness.	**Score = 8** Larger excavation area than SL-2 increases the expected long-term effectiveness.	**Score = 8** More protective than SL-2 because uses excavation throughout area that exceeds RELs	**Score = 10** Most effective in long term because contamination removed from site.

Criteria	Alternative SL-1 Cover	Alternative SL-2 Consolidation with RELs	Alternative SL-3 Consolidation	Alternative SL-4 Excavation with RELs	Alternative SL-5 Excavation
Management of short-term risks	**Score = 9** Construction methods and safety protocols for excavation and cover are well established and associated short-term risks are expected to be low. Chemical hazards associated with potential exposure to contaminants during construction also are expected to be low because appropriate health and safety procedures and BMPs will be used.	**Score = 8** This alternative ranks between Alternatives SL-1 and SL-3 because it requires handling more contaminated soil than SL-1, but not as much as SL-3.	**Score = 7** This alternative ranks lower than Alternatives SL-1 and SL-2 because it requires handling more contaminated soil	**Score = 6** This alternative ranks lower than Alternatives SL-1, SL-2, and SL-3 because it will include the excavation, handling, and offsite transport of contaminated soil.	**Score = 5** This alternative ranks lower than Alternative SL-4 because it will include additional excavation and the handling and offsite transport of a larger volume of contaminated soil.
Technical and administrative implementability	**Score = 9** Construction methods for excavation and covers are well established; significant technical and administrative obstacles to implementation are not anticipated.	**Score = 9** Same as Alternative SL-1.	**Score = 9** Same as Alternative SL-1	**Score = 6** This alternative ranks lower than Alternatives SL-1, SL-2, and SL-3 because it will include the offsite transport and disposal	**Score = 6** Same as Alternative SL-4.
Consideration of public concerns	**Score = 4** As determined by Ecology following public comment on the Public Review Draft of Volume III.	**Score = 1** As determined by Ecology following public comment on the Public Review Draft of Volume III.	**Score = 5** As determined by Ecology following public comment on the Public Review Draft of Volume III.	**Score = 1** As determined by Ecology following public comment on the Public Review Draft of Volume III.	**Score = 10** As determined by Ecology following public comment on the Public Review Draft of Volume III.

[a] Restoration time frame is a MTCA-defined criterion.

BMP – best management practice

IC – institutional control

MTCA – Model Toxics Control Act

PCUL – preliminary cleanup level

TABLE 6-2. Summary of the Groundwater Remediation Alternatives Evaluation

Criteria	Alternative G-1 Sparging	Alternative G-2 Funnel and Gate	Alternative G-3 In-Situ Treatment
Alternative components	• Perform pilot testing in MW-56 area to determine effectiveness and determine design parameters • Install sparge wells (30 ft spacing assumed) highest priority area. Operate for 3 months, observe potential rebound for 1 month. Repeat two additional times. (Timing assumed.) • Expand air sparging system as needed to meet cleanup standards at the CPOC. • Operate as needed to attain PCULs consistently; assumed 3 years • Perform post-remediation performance and confirmational groundwater monitoring for 30 years. • Record an environmental covenant for the property	• Perform bench-scale testing to confirm effectiveness of treatment media and determine design parameters for full-scale implementation • Clear and grub construction areas • Demolish concrete pads within the construction areas for repurposing onsite or for offsite disposal • Excavate soil for installation of "gate" sections in East and West Mill Areas • Pre-trench "funnel" sections (sheet pile walls) to remove subsurface obstructions • Transport excavated soil from gate and funnel sections to Subtitle D landfill • Install sheet pile walls to depth of 40 ft in East and West Mill Areas (10-ft key-in to till layer) • Install temporary shoring (sheet piles) for reactive media installation in gate sections • Install five reactive media gates • Install groundwater monitoring wells for performance and confirmational monitoring • Perform post-construction performance and confirmational groundwater monitoring for 30 years • Record an environmental covenant for the property	• Perform bench- and pilot-scale testing to identify effective ISCO/ISCF reagents and determine design parameters for full-scale implementation • Install injection wells for reagent delivery (30-ft spacing between injection wells along treatment transects assumed) • Assume two reagents required for treatment of organics and metals • Assume three injection events per reagent per treatment area will be required to achieve PCULs • Perform process monitoring during each injection event to assess reagent injection concentrations, volumes, flow rates, radius of influence, etc. • Perform performance and confirmational groundwater monitoring for 5 years • Record an environmental covenant for the property
Protection of human health and the environment	**Yes -** Alternative will be protective of human health and the environment.	**Yes -** Alternative will be protective of human health and the environment.	**Yes -** Alternative will protective of human health and the environment.
Compliance with cleanup standards	**Yes -** Alternative is expected to comply with cleanup standards. This alternative will use air sparging to reduce contaminant concentrations below PCULs in conjunction with ICs to prevent potable uses of groundwater and restrict future actions that could reduce effectiveness of the remedy. Compliance will rely on long-term monitoring and ICs. Conditional POC required.	**Yes -** Alternative is expected to comply with cleanup standards. This alternative will use PRBs to reduce contaminant concentrations below PCULs in conjunction with ICs and monitoring as described in Alternative G-2. Maintenance of the PRB, and possible replacement would be required. Conditional POC required.	**Yes -** Alternative is expected to comply with cleanup standards. This alternative will use ISCO to reduce contaminant concentrations below PCULs in conjunction with ICs to prevent potable uses of groundwater. Compliance will rely on ICs. Standard POC.
Compliance with applicable state and federal regulations	**Yes**.	**Yes**.	**Yes.**
Provision for compliance monitoring	**Yes -** Alternative will include a provision for compliance monitoring.	**Yes -** Alternative will include a provision for compliance monitoring.	**Yes -** Alternative will include a provision for compliance monitoring.
Restoration time frame[a]	**No more than 10 years.**	**No more than 10 years.**	**No more than 10 years.**
Protectiveness	**Score = 7** Will use air sparging of upland groundwater to protect the groundwater to marine surface water/sediment pathway. Limited area action requires long-term monitoring.	**Score = 8** Will use *in situ* treatment of upland groundwater (PRBs) to protect the groundwater to marine surface water/sediment pathway. Limited area action requires long-term monitoring.	**Score = 9** Will use *in situ* treatment of upland groundwater (ISCO/ISCF) to protect the groundwater to marine surface water/sediment pathway. Full Upland Study Area actively addressed.
Permanence	**Score = 7** Would use active air sparging treatment to permanently reduce contaminant mass in selected locations where contaminants would otherwise have greatest likelihood of reaching marine environment at concentrations in excess of PCULs.	**Score = 8** Would use passive *in situ* groundwater treatment to permanently reduce contaminant mobility near the upland margin.	**Score = 9** Would use active *in situ* groundwater treatment to permanently reduce contaminant mass throughout the upland in locations where contaminants exceeded PCULs.

Criteria	Alternative G-1 Sparging	Alternative G-2 Funnel and Gate	Alternative G-3 In-Situ Treatment
Long-term effectiveness	**Score = 4** Would use active treatment in specified locations and would require long term monitoring.	**Score = 6** Would use passive *in situ* groundwater treatment to permanently reduce contaminant mobility near the upland margin. Long term monitoring and potential maintenance would be required.	**Score = 9** Would use active *in situ* groundwater treatment to permanently reduce contaminant mass throughout the upland in locations where contaminants exceeded PCULs.
Management of short-term risks	**Score = 8** Ranks higher than the other alternatives because the construction methods for air sparging will be less complicated than required for PRBs and ISCO/ISCF and will not involve the use of reactive media or industrial chemicals.	**Score = 5** The construction methods for PRB installation in an upland setting with relic subsurface structures will be more complicated than the methods required for air sparging.	**Score = 3** Would use large quantities of oxidants and/or other industrial chemicals for *in situ* groundwater treatment.
Technical and administrative implementability	**Score = 8** Ranks higher than the other alternatives because the construction methods for air sparging will be less complicated than methods required for PRBs and ISCO/ISCF.	**Score = 3** The construction methods for PRB installation in an upland setting with relic subsurface structures will be more complicated than the methods required for air sparging.	**Score = 2** Ranks lower than the other alternatives due to the technical challenges of working with large quantities of oxidants and/or other industrial chemicals.
Consideration of public concerns	**Score = 5** As determined by Ecology following public comment on the Public Review Draft of Volume III.	**Score = 5** As determined by Ecology following public comment on the Public Review Draft of Volume III.	**Score = 10** As determined by Ecology following public comment on the Public Review Draft of Volume III.

[a] Restoration time frame is the MTCA-defined criterion.
IC – institutional control
ISCF – *in situ* chemical fixation
ISCO – *in situ* chemical oxidation
MTCA – Model Toxics Control Act
PCULs – preliminary cleanup levels
PRB – permeable reactive barrier

TABLE 6-3. SUMMARY OF SEDIMENT REMEDIATION ALTERNATIVES EVALUATION

Criteria	Alternative S-1	Alternative S-2	Alternative S-3	Alternative S-4	Alternative S-5
Alternative Components	• Dredge/excavate log pond intertidal and dock landing (3.8 acres) • Apply ENR in remainder (47.8 acres)	• Dredge/excavate log pond intertidal and dock landing (3.8 acres) • Fill/apply ENR in berths (6.1 acres) • Apply ENR in remainder (41.7 acres)	• Dredge/excavate log pond intertidal and dock landing (3.8 acres) • Cap in log pond subtidal (5.7 acres) • Dredge under the mill dock (3.9 acres) • Fill and apply ENR in berths (6.1 acres) • Apply ENR in remainder (32.1 acres)	• Dredge/excavate entire log pond and dock landing (9.5 acres) • Fill/apply ENR in berths (6.1 acres) • Apply ENR in remainder (36 acres)	• Dredge/excavate all subareas (51.6 acres)
1. Compliance with MTCA Threshold Criteria					
Protection of human health and the environment	Yes. This alternative will protect human health and the environment through the attenuation of contaminant concentrations within the sediment depth of compliance. Monitoring and, if needed, maintenance will be implemented to ensure long-term protection.	Yes. See Alternative S-1. Filling and applying ENR in the berths will further enhance protection of remaining contaminated sediment.	Yes. See Alternative S-1. Capping subtidal log pond, dredging under the mill dock, and filling and application of ENR in the berths will further enhance protection of remaining contaminated sediment.	Yes. See Alternative S-1. Removal in the entire log pond and filling and applying ENR in the berths will further enhance protection of remaining contaminated sediment.	Yes. This alternative will protect human health and the environment through the removal of contaminated sediment in all SRSs.
Compliance with cleanup standards	Yes. This alternative is expected to comply with SMS and applicable PCULs identified for the sediment remediation area. This alternative will use ENR to attenuate contaminants and achieve PCULs.	Yes. See Alternative S-1. This alternative is expected to comply with SMS and applicable PCULs identified for the sediment remediation area.	See Alternative S-1. In addition, this alternative is expected to comply with SMS and applicable cleanup levels by capping of sediment from subtidal log pond and removal under the mill dock in areas with higher concentrations of COCs.	See Alternative S-1. In addition, this alternative is expected to comply with SMS and applicable cleanup levels by removal of sediment from subtidal log pond in areas with higher concentrations of COCs.	Yes. This alternative is expected to comply with SMS and applicable PCULs identified for the sediment remediation area. This alternative will use removal of contaminated sediments to achieve PCULs.
Compliance with applicable state and federal regulations	Yes. This alternative will comply with applicable federal and state regulations.	See Alternative S-1.	See Alternative S-1.	See Alternative S-1.	See Alternative S-1.
Provision for compliance monitoring	Yes. This alternative will include provisions for compliance monitoring and maintenance, if needed.	See Alternative S-1.	See Alternative S-1. Capped area will require a more robust long term monitoring program to verify protectiveness and permanence.	See Alternative S-1.	See Alternative S-1.
2. Compliance with Other MTCA and SMS Requirements (Ecology 2013c)					
Permanent solutions to the maximum extent practicable	Permanence will rely on proper application of ENR and maintenance, if needed. Limited area to be excavated/dredged will be permanently remediated.	Permanence will rely on proper application of ENR, design and placement of fill/ENR, and maintenance, if needed. Excavated/dredged subareas will be permanently remediated.	See Alternative S-2. Cap area will be monitored and maintained to ensure permanency.	See Alternative S-2.	Excavated/dredged subareas will be permanently remediated.
Restoration time frame[a]	The time frame for this alternative will be < 10 years.	See Alternative S-1.	See Alternative S-1.	See Alternative S-1.	See Alternative S-1.
Preference for most effective source control measures	Offsite contaminant sources will be addressed, to the extent practicable, through cleanup/source control actions by others. This criterion is therefore not applicable.	See Alternative S-1.	See Alternative S-1.	See Alternative S-1.	See Alternative S-1.
Issuance of SRZ	Not necessary. The alternative is expected to achieve applicable CULs within a time period ≤ 10 years.	See Alternative S-1.	See Alternative S-1.	See Alternative S-1.	See Alternative S-1.
Compliance with ICs	This alternative will not interfere with any existing IC compliance. No additional ICs are required.	See Alternative S-1.	See Alternative S-1 in terms of compliance with existing ICs. Additional ICs are required to protect cap.	See Alternative S-1.	See Alternative S-1.
Provisions for public review	Yes. The Cleanup Action Plan will include provisions for public review.	See Alternative S-1.	See Alternative S-1.	See Alternative S-1.	See Alternative S-1.
Provisions for periodic review	Periodic review by Ecology is anticipated	See Alternative S-1.	See Alternative S-1.	See Alternative S-1.	See Alternative S-1.
3. Disproportionate Cost Analysis Relative Benefits Ranking (scored from lowest [1] to highest [10])					
Protectiveness	Score = 6 Alternative will meet IAOs upon completion based on proper placement of ENR layer.	Score = 7 Alternative will meet IAOs upon completion based on proper placement of ENR layer. Alternative will be slightly more protective than Alternative S-1 because berths will be filled.	Score = 8 Level of protectiveness will be higher than Alternative S-2 due to cap in the subtidal long pond and dredging under the mill dock.	Score = 8 Same level of protectiveness is expected as in Alternative S-3.	Score = 10 Higher level of protectiveness is expected as a result of contaminated sediment removal in all SRSs.

Criteria	Alternative S-1	Alternative S-2	Alternative S-3	Alternative S-4	Alternative S-5
Permanence	Score = 6 Score is based on the potential need to replenish the ENR material.	Score = 7 Similar to Alternative S-1. Some incremental additional permanence will be associated with fill and ENR placement in the berths.	Score = 8 Achieves a permanent risk reduction (reduction in mass, toxicity, and mobility) in the areas by capping and dredging; other areas similar to Alternative S-2	Score = 8 Same level of permanence as in Alternative S-3. Achieves a permanent risk reduction (reduction in mass, toxicity and mobility) in the areas by dredging subtidal log pond; other areas are similar to Alternative S-2	Score = 9 Higher level of permanence will result from area-wide dredging.
Long-term effectiveness	Score = 4 Long-term effectiveness will depend on ENR performance and long-term maintenance.	Score = 6 Long-term effectiveness is higher than Alternative 1 due to fill/ENR in berths.	Score = 7 Long-term effectiveness is higher than Alternative S-2 due to capping in the log pond and dredging under the mill dock.	Score = 8 Total dredge area is slightly higher than Alternative S-3.	Score = 10 This alternative achieves the highest score because the maximum volume of contaminated sediment will be removed.
Management of short-term risks[b]	Score = 9 ENR represents the least intrusive remediation technology and will have the lowest risk to benthic habitat. ENR will also have the lowest risk of contaminant dispersion during implementation. Potential exposure of workers and the public to contaminated sediment will also be minimized. Remedial action is estimated to be completed in one construction season.	Score = 8 Same as Alternative S-1. Some redistribution of contaminated sediment from the berths during filling might occur, representing a short-term risk to adjacent sediment quality and biota. Remedial action is estimated to be completed in 1.5 construction seasons.	Score = 5 This alternative will include capping in the log pond (5.7 acres) and dredging under the mill dock (3.9 acres), , which will result in some incremental additional short-term impacts . Total dredge area is 7.7 acres. Dredging is the most intrusive of the remedial technologies and can generate dredging residuals that may have short-term impacts. Transfer, processing, staging, and transport of dredged materials also represents a possible risk to workers and the public. Remedial action is estimated to be completed in 2 construction seasons.	Score = 4 Similar to Alternative S-3 but has more dredging. Total dredge area is 9.5 acres. Remedial action is estimated to be completed in 2 construction seasons.	Score = 1 Total dredge area is 51.6 acres. Dredging is the most intrusive of the remedial technologies and can generate dredging residuals that may have short-term impacts. Transfer, processing, staging, and transport of dredged materials also represents a possible risk to workers and the public. Remedial action is estimated to be completed in 4 construction seasons.
Technical and administrative implementability	Score = 8 ENR can be readily implemented. Post placement monitoring would be required to ensure proper coverage and application.	Score = 7 ENR can be readily implemented (see Alternative S-1). Filling/ENR of the berths would be feasible because they consist of formerly dredged areas (depressions) that would contain fill placement without the need for perimeter or toe armoring. Administrative challenges could include coordination with DNR to place fill on state-owned tidelands.	Score = 4 Fill/ENR of the berth can be readily implemented. Capping requires additional administrative concurrence with the landowner but technically, can be readily implemented. Dredging under the dock is more intrusive and requires management of dredged materials that will require successful sediment dewatering, processing and final disposition. Dependent upon availability of disposal options. Administrative challenges could include coordination with DNR to place fill/cap on state-owned tidelands.	Score = 5 Similar to Alternative S-3 but has more dredging (additional 1.8 acres) but does not include capping. ENR and filling of the berth and approach can be readily implemented. More intrusive remediation and management of dredged materials will require successful sediment dewatering, processing and final disposition.	Score = 3 More intrusive remediation and management of large quantities of dredged materials will require large amounts of sediment dewatering, processing, and final disposition. Technical implementability will be governed by the availability of disposal options, which can periodically change.
Consideration of public concerns	Score = 1 As determined by Ecology following public comment on the Public Review Draft of Volume III.	Score = 2 As determined by Ecology following public comment on the Public Review Draft of Volume III.	Score = 4 As determined by Ecology following public comment on the Public Review Draft of Volume III.	Score = 6 As determined by Ecology following public comment on the Public Review Draft of Volume III.	Score = 10 As determined by Ecology following public comment on the Public Review Draft of Volume III.

[a] Restoration time frame is the MTCA-defined criterion.

[b] Construction duration was estimated by assuming the following production rates: Dredging in the log pond – 300 cy/day; Dredging/excavation elsewhere – 400 cy/day; ENR, cap, residual management layer placement – 400 cy/day; Fill – 500 cy/day.

CAP – cleanup action plan
CUL – cleanup level
cy – cubic yard
DNR – Washington State Department of Natural Resources
ENR – enhanced natural recovery
IAO – interim action objectives
IC – institutional control
MTCA – Model Toxics Control Act
SMS – Washington State Sediment Management Standards
SRS – sediment remediation subarea
SRZ – sediment recovery zone

TABLE 6-4. SMS FACTORS FOR EVALUATING SEDIMENT RESTORATION TIME FRAMES (WAC 173-204-570)

Criteria	Alternative S-1	Alternative S-2	Alternative S-3	Alternative S-4	Alternative S-5
Alternative Components	• Dredge/excavate log pond intertidal and dock landing • Apply ENR in remainder	• Dredge/excavate log pond intertidal and dock landing • Fill/apply ENR in berths • Apply ENR in remainder	• Dredge/excavate log pond intertidal and dock landing • Cap in log pond subtidal • Dredge under the mill dock • Fill and apply ENR in berths Apply ENR in remainder	• Dredge/excavate entire log pond and dock landing • Fill/apply ENR in berths • Apply ENR in remainder	• Dredge/excavate all subareas
Length of time estimated for the cleanup action to achieve the sediment cleanup standards once remedial construction is complete	Dredged/excavated areas (3.8 acres) will achieve cleanup standards once remedial construction is complete. The SRSs treated using ENR (47.8 acres) are expected to meet cleanup standards once applied material had been incorporated into the existing benthic substrate (1 to 3 years). Sediment PCULs should be met in all other SRSs upon completion of remedial construction (1 construction season).	Same as Alternative S-1 for SRSs dredge/excavated areas (3.8 acres) and the areas treated using ENR (41.7 acres). Fill/ENR berth areas (6.1 acre) will achieve cleanup standards once remedial construction is completed (estimated 1.5 construction season).	Same as Alternative S-1 for SRSs dredge/excavated areas (3.8 acres) and the areas treated using ENR (32.1 acre). Cap (5.7 acres), dredge under the mill dock (3.9 acres) and fill/ENR areas (6.1 acre) will achieve cleanup standards once remedial construction is completed (estimated 2 construction seasons).	Same as Alternative S-1 for SRSs dredge/excavated areas (3.8 acres) and the areas treated using ENR (36 acres). In addition, log pond subtidal (5.7 acres) and fill/ENR areas (6.1 acres) will achieve cleanup standards once remedial construction is completed (estimated 2 construction seasons).	All SRSs (51.6 acres) will achieve cleanup standards once remedial construction is completed (estimated 4 construction seasons).
Potential risks posed by the site to biological resources and human health	This alternative is expected to address both risks to biological resources and human health associated with current site conditions by complying with the threshold requirements.	Same as Alternative S-1.	Same as Alternative S-1.	Same as Alternative S-1.	Same as Alternative S-1.
Practicability of achieving the cleanup standards within a 10-year period	This alternative will likely achieve the cleanup standards in < 10 years.	Same as Alternative S-1.	Same as Alternative S-1.	Same as Alternative S-1.	Same as Alternative S-1.
Current use of the site, surrounding areas, and associated resources that are, or may be, affected by residual contamination	ENR is expected to reduce contaminant concentrations to levels that would not adversely impact aquatic resources. No current site uses or uses in the surrounding areas will be affected by post-remediation conditions. Current uses would be restricted during the remedial construction.	ENR is expected to reduce contaminant concentrations as described for Alternative S-1, and filling/ENR the berths will further isolate contaminants. No current site uses or uses in the surrounding areas will be affected by post-remediation conditions. Current uses would be restricted during the remedial construction.	Same as Alternative S-2. However, the capped subtidal log pond would be regulated through ICs and some current uses of this portion of the site may be restricted.	Same as Alternative S-2. This alternative will remove contaminated sediment within the subtidal log pond. It is unlikely that implementation of this alternative) would limit or impact current site uses.	Same as Alternative S-4. Contaminated sediment will be removed from all SRSs and there should be no limit or impact to current site uses.
Aquatic state land use classification(s) under WAC 332-30 of the lands encompassing the site or sediment cleanup unit	This alternative will not interfere with DNR general goals for state-owned aquatic lands. The overall remedial actions and site improvements should foster direct public use and access, including water-dependent uses, and help ensure environmental protection.	Filling/ENR of the berths on state-owned aquatic lands will need to be reviewed with DNR, but it is not anticipated that this will be incompatible with the agency's identified uses. The overall remedial actions and site improvements should foster direct public use and access, including water-dependent uses, and help ensure environmental protection.	Same as Alternative S-2. Capping of the subtidal log pond will need to be reviewed with DNR.	Similar to Alternative S-2. The implementation of dredging could inhibit access to state-owned aquatic lands for a brief period, but the final remedy should not conflict with current or future land use classifications.	The implementation of dredging could inhibit access to state-owned aquatic lands for a brief period, but the final remedy should not conflict with current or future land use classifications.
Potential future use of the site, surrounding areas, and associated resources that are, or may be, affected by residual contamination	Future aquatic-related uses in the vicinity are expected to be similar to the current uses.	Same as Alternative S-1.	Same as Alternative S-1. However, the capped subtidal log pond would be regulated through ICs, and some future uses of this portion of the site may be restricted.	Same as Alternative S-1.	Same as Alternative S-1.
Likely effectiveness of source control measures to reduce the time to achieve cleanup standards	Source control measures are not part of the sediment remediation alternatives. Source control actions are being implemented in the larger upland region outside of the Study Area. The alternatives for the in-water sediment remediation area do not rely on site-specific source control measures.	Same as Alternative S-1.	Same as Alternative S-1.	Same as Alternative S-1.	Same as Alternative S-1.

Criteria	Alternative S-1	Alternative S-2	Alternative S-3	Alternative S-4	Alternative S-5
Likely effectiveness and reliability of ICs	Mixing of the ENR material with underlying sediment is expected and no ICs are needed. Any impacts from small-vessel anchoring would likely be "self-healing." All ENR areas would be subtidal, so no control would be needed for beach users. Dredged/excavated areas do not need ICs because the contaminated sediment would have been removed through excavation or dredging.	See Alternative S-1. Fill/ENR berth areas will contain subtidal sediment, and ICs are not needed for permanence. Fill/ENR areas will self-heal after any disturbance.	Similar to Alternative S-2. However, ICs are needed to protect cap in the subtidal log pond.	Same as Alternative S-2.	ICs are not needed under this alternative because the contaminated sediment would have been removed through excavation or dredging.
Degree of, and ability to, control and monitor the migration of residual contamination	ENR performance will need to be monitored several times after the placement of the ENR material. Sediment transport modeling has demonstrated that ENR materials and sediment will be stable with the use of appropriately sized ENR materials. This alternative includes dredged/excavation areas (3.8 acres) will rely on the proper use of controls to ensure that residuals are not dispersed (some dredging residuals might need to be addressed).	See Alternative S-1. The monitoring of fill/ENR subarea would also be conducted.	Same as Alternative S-2. This alternative includes dredge/excavate log pond intertidal, dock landing and under the mill dock (7.7 acres). Capped area will require a more robust monitoring program to verify protectiveness and permanence.	Same as Alternative S-2. This alternative will involve the excavation and dredging of contaminated sediment in entire log pond and dock landing (9.5 acres).	This alternative will involve the excavation and dredging of contaminated sediment in all SRSs (51.6 acres). Dredging will rely on the proper use of controls to ensure that residuals are not dispersed (some dredging residuals may need to be addressed). Contamination will be removed from the site.
The degree to which natural recovery processes are expected to reduce contamination	MNR will not be part of this alternative. ENR includes natural recovery processes, and the deposition of sediment could potentially improve sediment conditions over time.	Same as Alternative S-1.	Same as Alternative S-1.	Same as Alternative S-1.	Same as Alternative S-1.

Note: Restoration time frame is a MTCA-defined criterion and does not refer to NRD-related actions.

DNR – Washington State Department of Natural Resources
ENR – enhanced natural recovery
IC – institutional control
MNR – monitored natural recovery
MTCA – Model Toxics Control Act
PCULs – preliminary cleanup levels
SRS – sediment remediation subarea
WAC – Washington Administrative Code

TABLE 6-5. DISPROPORTIONATE COST ANALYSIS FOR THE SOIL REMEDIATION ALTERNATIVES

Criteria	Criterion Weighting (%)	Alternative SL-1	Alternative SL-2	Alternative SL-3	Alternative SL-4	Alternative SL-5
		Cover	Consolidation with RELs	Consolidation	Excavation with RELs	Excavation
1. Compliance with MTCA threshold criteria	NA	Yes	Yes	Yes	Yes	Yes
2. Reasonable restoration time frame	NA	Yes	Yes	Yes	Yes	Yes
3. DCA relative benefits score						
Protectiveness	30%	8	6	9	7	10
Permanence	20%	5	6	7	8	9
Long-Term effectiveness	20%	6	7	8	8	10
Management of short-term risks	10%	9	8	7	6	5
Technical and administrative implementability	10%	9	9	9	6	6
Consideration of public concerns	10%	4	1	5	1	10
Total benefits score		**6.8**	**6.2**	**7.8**	**6.6**	**8.9**
4. Disproportionate cost analysis						
Estimated cost (+50%/-30%, rounded)	NA	$11,000,000	$7,400,000	$10,000,000	$28,000,000	$37,000,000
Ratio of cost to lowest-cost alternative	NA	1.5	1.0	1.4	3.8	5.0
Ratio of relative benefits to cost (total benefits/cost ($M) x 10	NA	6.2	8.4	7.8	2.4	2.4
Overall Ranking		**3rd**	**1st**	**2nd**	**T-4th**	**T-4th**

TABLE 6-6. DISPROPORTIONATE COST ANALYSIS FOR THE GROUNDWATER REMEDIATION ALTERNATIVES

Criteria	Criterion Weighting (%)	Alternative G-1	Alternative G-2	Alternative G-3
		Sparging	Funnel and Gate	In-Situ Treatment
1. Compliance with MTCA threshold criteria	NA	Yes	Yes	Yes
2. Reasonable restoration time frame	NA	Yes	Yes	Yes
3. DCA relative benefits score				
Protectiveness	30%	7	8	9
Permanence	20%	7	8	9
Long-Term effectiveness	20%	4	6	9
Management of short-term risks	10%	8	5	3
Technical and administrative implementability	10%	8	3	2
Consideration of public concerns	10%	5	5	10
Total benefits score		**6.4**	**6.5**	**7.8**
4. Disproportionate cost analysis				
Estimated cost (+50%/-30%, rounded)	NA	$5,700,000*	$23,000,000	$35,000,000
Ratio of cost to lowest-cost alternative	NA	1.0	4.0	6.1
Ratio of relative benefits to cost (total benefits/cost ($M))x10	NA	11.2	2.8	2.2
Overall Ranking		**1st**	**2nd**	**3rd**

* This assumes full implementation of sparging. Estimated cost range is $2,138,000 to $5,714,000 depending on whether the full system is needed to meet PCULs at the POC.

TABLE 6-7. DISPROPORTIONATE COST ANALYSIS FOR THE SEDIMENT REMEDIATION ALTERNATIVES

Criteria	Criterion Weighting (%)	Alternative S-1	Alternative S-2	Alternative S-3	Alternative S-4	Alternative S-5
1. Compliance with MTCA threshold criteria	NA	Yes	Yes	Yes	Yes	Yes
2. Reasonable restoration time frame	NA	Yes	Yes	Yes	Yes	Yes
3. DCA relative benefits score						
Protectiveness	30%	6	7	8	8	10
Permanence	20%	6	7	8	8	10
Long-Term effectiveness	20%	4	6	7	8	10
Management of short-term risks	10%	10	8	5	4	1
Technical and administrative implementability	10%	8	7	4	5	3
Consideration of public concerns	10%	1	2	4	6	10
Total benefits score		**5.7**	**6.4**	**6.7**	**7.1**	**8.4**
4. Disproportionate cost analysis						
Estimated cost (+50%/-30%, rounded)	NA	$9,953,000	$10,872,000	$15,213,000	$18,023,000	$55,343,000
Ratio of relative benefits to cost (total benefits/cost ($M) x 100	NA	57.3	58.9	44.0	39.4	15.2
Overall Ranking		**2nd**	**1st**	**3rd**	**4th**	**5th**

FIGURES

TITLE:

Site Map

LOCATION:

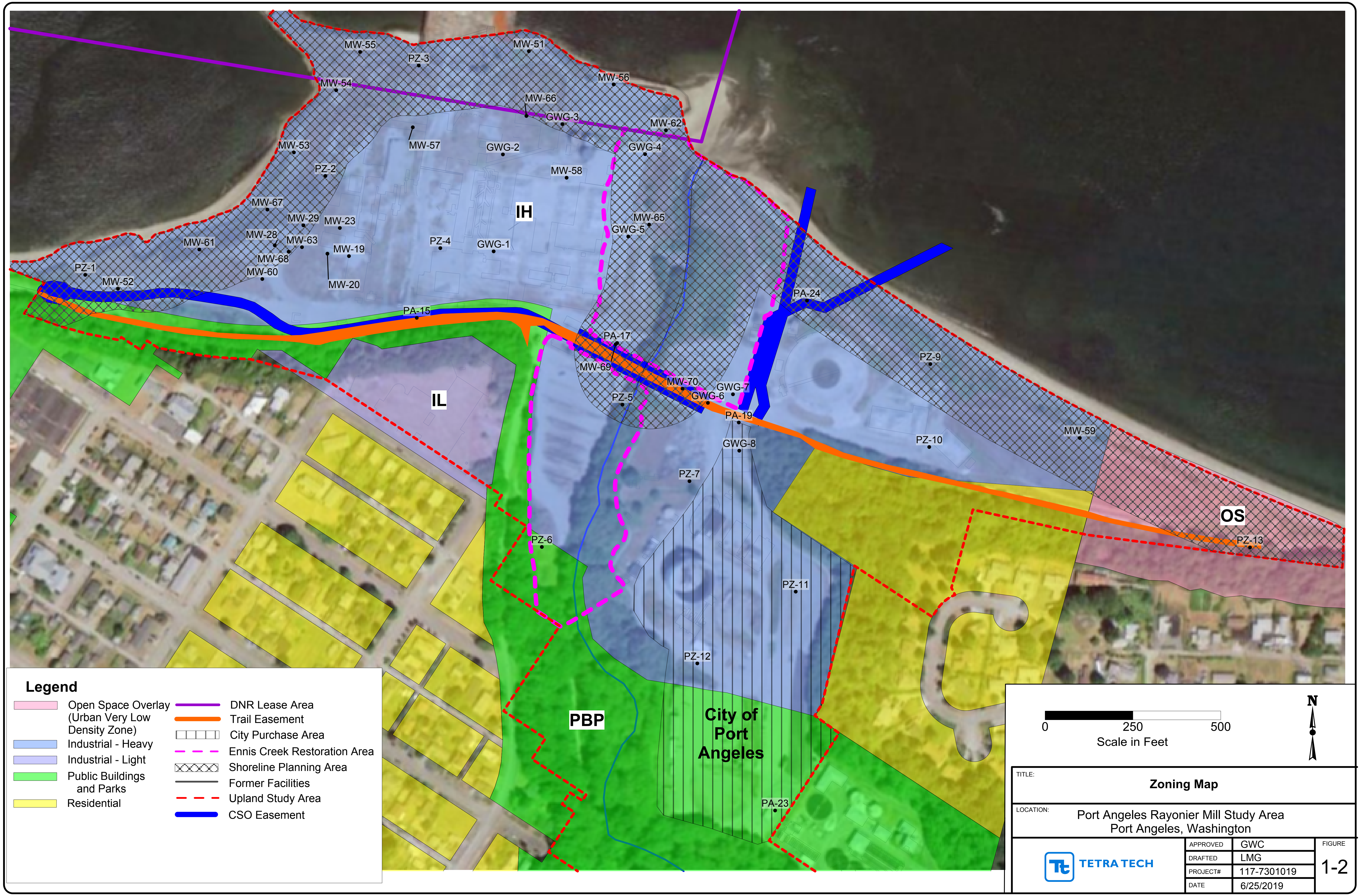
Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GC
DRAFTED	LMG
PROJECT#	117-7403019
DATE	6/27/2019

FIGURE **1-1**

P:\7304-RayonierAM\019 Port Angeles FS\GIS\MXDs\SiteMapFig1_1.mxd



MW-55
PZ-3
MW-51
MW-54
MW-56
MW-66
GWG-3
MW-62
MW-53
MW-57
GWG-2
GWG-4
PZ-2
MW-58
IH
MW-67
MW-29
MW-23
MW-65
GWG-5
MW-61
MW-28
MW-63
PZ-4
GWG-1
MW-19
MW-68
PZ-1
MW-60
MW-52
MW-20
PA-24
PA-15
PA-17
PZ-9
MW-69
IL
MW-70
GWG-7
GWG-6
PZ-5
PA-19
MW-59
PZ-10
GWG-8
PZ-7
OS
PZ-13
PZ-6
PZ-11
PZ-12
PBP
City of Port Angeles
PA-23
Legend
Open Space Overlay (Urban Very Low Density Zone)
Industrial - Heavy
Industrial - Light
Public Buildings and Parks
Residential
DNR Lease Area
Trail Easement
City Purchase Area
Ennis Creek Restoration Area
Shoreline Planning Area
Former Facilities
Upland Study Area
CSO Easement
0
250
500
Scale in Feet
N
TITLE:
Zoning Map
LOCATION:
Port Angeles Rayonier Mill Study Area
Port Angeles, Washington
TETRA TECH
APPROVED GWC
DRAFTED LMG
PROJECT# 117-7301019
DATE 6/25/2019
FIGURE
1-2

Prepared by mikey, 6/27/2019; W:\Projects\Rayonier PA Volume III\Data\GIS\Maps_and_Analysis\Volume_III_revised\TetraTech_Layout\6042a_Preferred alternatives applied to future use scenario 1_No InWater Remed_inline 8x11.mxd

Data sources: 0.5-foot 2016 imagery from DigitalGlobe and ESRI City of Port Angeles, Rayonier

Disclaimer: The locations of all features shown are approximate.

Windward environmental LLC

TITLE:	**Integrated Remediation and Restoration Overview**			
LOCATION:	**Rayonier Mill Study Area Port Angeles, Washington**			
TETRA TECH	APPROVED	APPROVED		FIGURE
	DRAFTED	M.Y.		**1-3**
	PROJECT#	194-9029		
	DATE	6/27/2019		

Prepared by mikey, 6/27/2019; W:\Projects\Rayonier PA Volume III\Data\GIS\Maps_and_Analysis\Volume_III_revised\TetraTech_Layout\6041a_Archaeological site map.mxd

Data sources: Archaeological data from Larsen Cultural Resource Assessment Report (1997); 0.5-foot 2016 imagery from DigitalGlobe and ESRI

Disclaimer: The locations of all features shown are approximate.

N

0 150 300 600

Feet

Windward environmental LLC

TITLE: **Archaeological Structures and Landmarks**

LOCATION: **Rayonier Mill Study Area**
Port Angeles, Washington

TETRA TECH

		FIGURE
APPROVED	APPROVED	2-1
DRAFTED	M.Y.	
PROJECT#	194-9029	
DATE	6/27/2019	

P:\ACAD\7304-019-RAYO\7304019008A.DWG

TITLE:	VIEW OF STUDY AREA LOOKING NORTHEAST (MARCH 2016)		
LOCATION:	Port Angeles Rayonier Mill Study Area Port Angeles, Washington		
TETRA TECH	APPROVED	GC	FIGURE
	DRAFTED	CP	2-2
	PROJECT#	117-7304019	
	DATE	6-25-19	

Legend

Data sources: Base data from "RAYO0903 _MILL_TOPO.dwg" (Northwestern Territories, Inc, 2000). Aerial photo from Google Earth.

- Pipeline Easement
- Trail Easement
- Ennis Creek Restoration Area
- Bulkhead
- Existing Structure
- Shoreline Protection Area
- City Purchase Area
- DNR Lease Area
- Upland Study Area Boundary
- Concrete Pad
- Concrete Rubble
- Rip rap
- Old Pilings

N

0 250 500 1,000

Feet

TITLE:

Current Study Area Conditions

LOCATION:

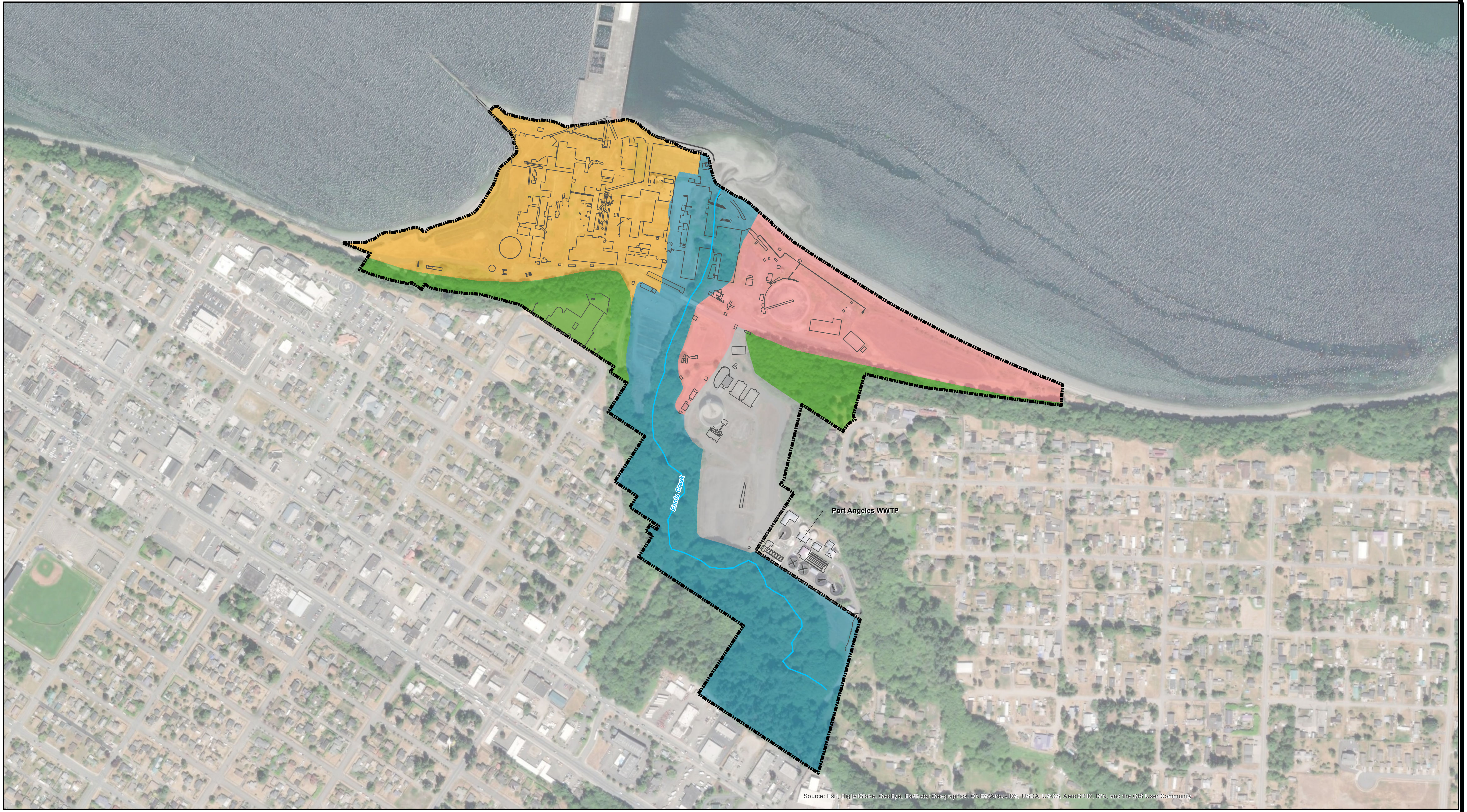
Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	LMG
DRAFTED	GC
PROJECT#	117-7304019
DATE	6/27/2019

FIGURE 2-3

Document Path: P:\7304-Rayonier\AM019 Port Angeles FS\GIS\MXDs\CurrentStudy_Fig2_3_Ver2.mxd



Data sources: Base data from "RAYO0903 _MILL_TOPO.dwg" (Northwestern Territories, Inc, 2000). Aerial photo from Google Earth.

Legend

- Upland Study Area Boundary
- Former Buildings and Structures

Land Use Area

- West Mill Area
- East Mill Area
- Marine Bluffs Area
- Ennis Creek Area
- City Purchase Area

N

0 250 500 1,000

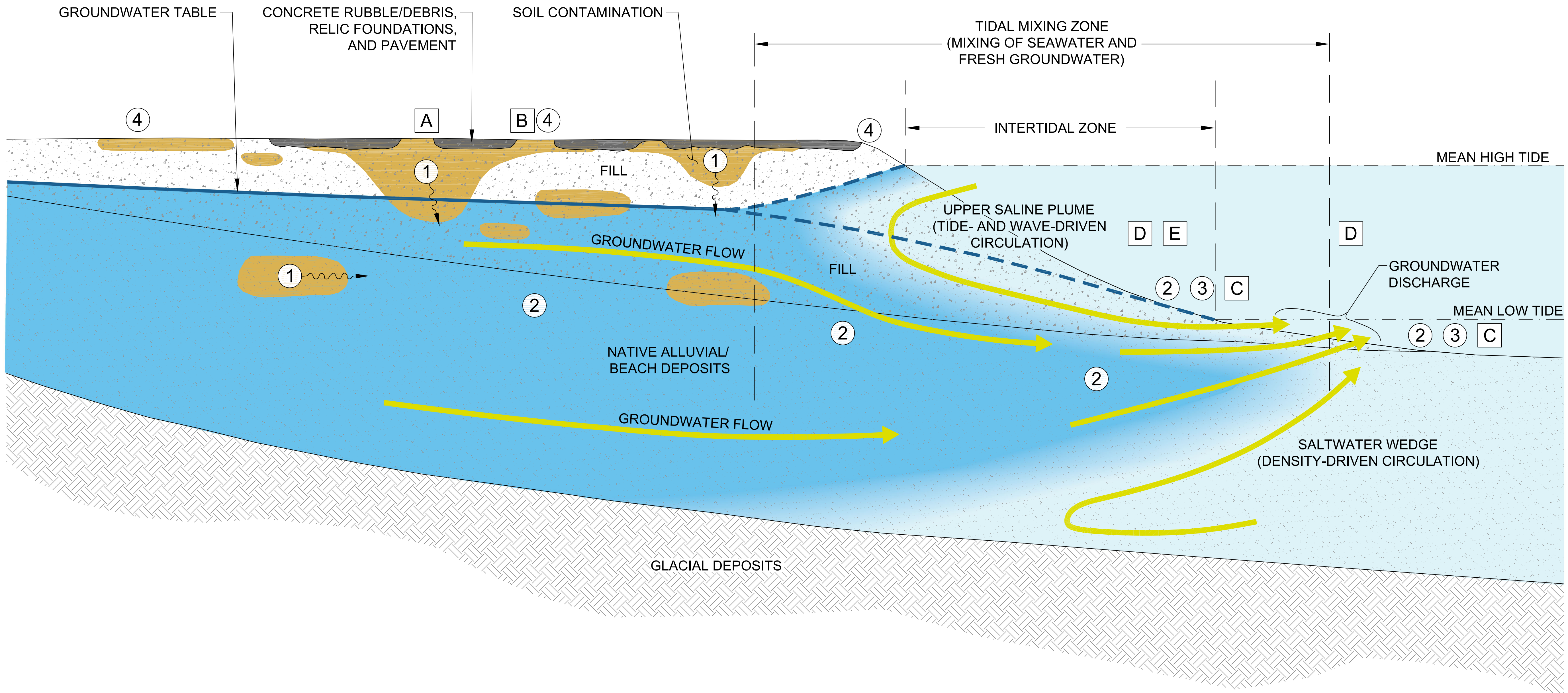
Feet

TITLE:	Land Use Areas
LOCATION:	Port Angeles Rayonier Mill Study Area Port Angeles, Washington

TETRA TECH

APPROVED	LMG	FIGURE
DRAFTED	GC	2-4
PROJECT#	117-7304019	
DATE	6/25/2019	

Document Path: P:\7304-RayonierAM019 Port Angeles FS\GIS\MXDs\LandUse_Fig2_4_rev.mxd



Potential Contaminant Transport Mechanisms

1. Leaching from soil to groundwater
2. Migration in groundwater and discharge of groundwater to marine surface water/sediment
3. Transport of sediments via scouring/currents
4. Erosion of contaminated soil/fill

Exposure Pathways of Potential Concern

- A Direct contact with soil by humans
- B Direct contact with soil by soil biota, plants, or wildlife; ingestion of biota or plants by wildlife
- C Direct contact with sediment or surface water by aquatic organisms
- D Ingestion of aquatic organisms by higher order species (humans/mammals, fish, birds, etc.) - food chain/bioaccumulation exposures
- E Direct contact with sediment and surface water by humans

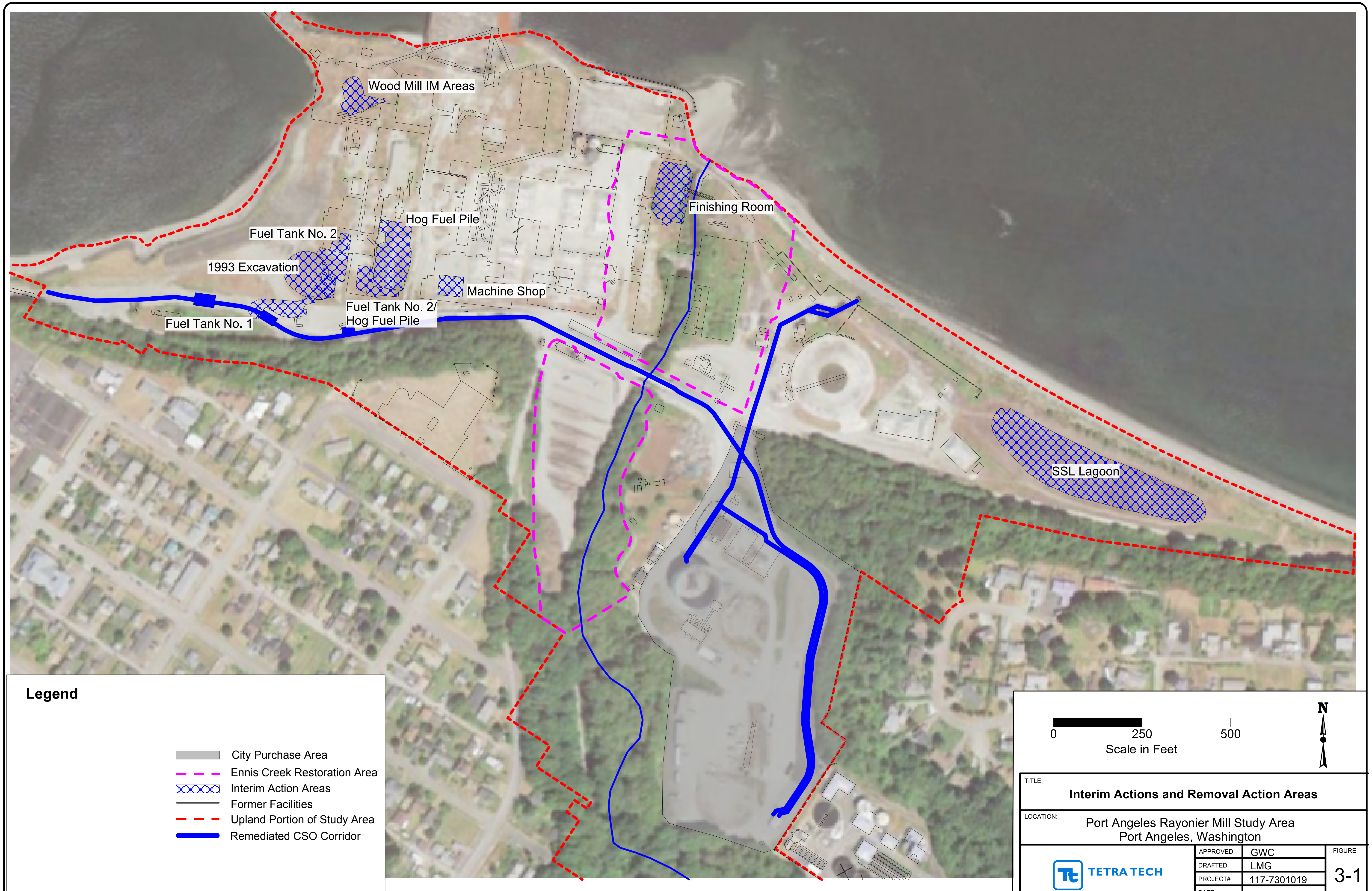
Disclaimer:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. and Windward cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and Windward, and will serve as the official record of this communication.

P:\ACAD\7304-019-RAYO\7304019009A.DWG

TITLE:	**CONCEPTUAL SITE MODEL**
LOCATION:	**Port Angeles Rayonier Mill Study Area** **Port Angeles, Washington**

TETRA TECH

APPROVED	GC	FIGURE
DRAFTED	CP	**2-5**
PROJECT#	117-7304019	
DATE	3-25-19	



TITLE:

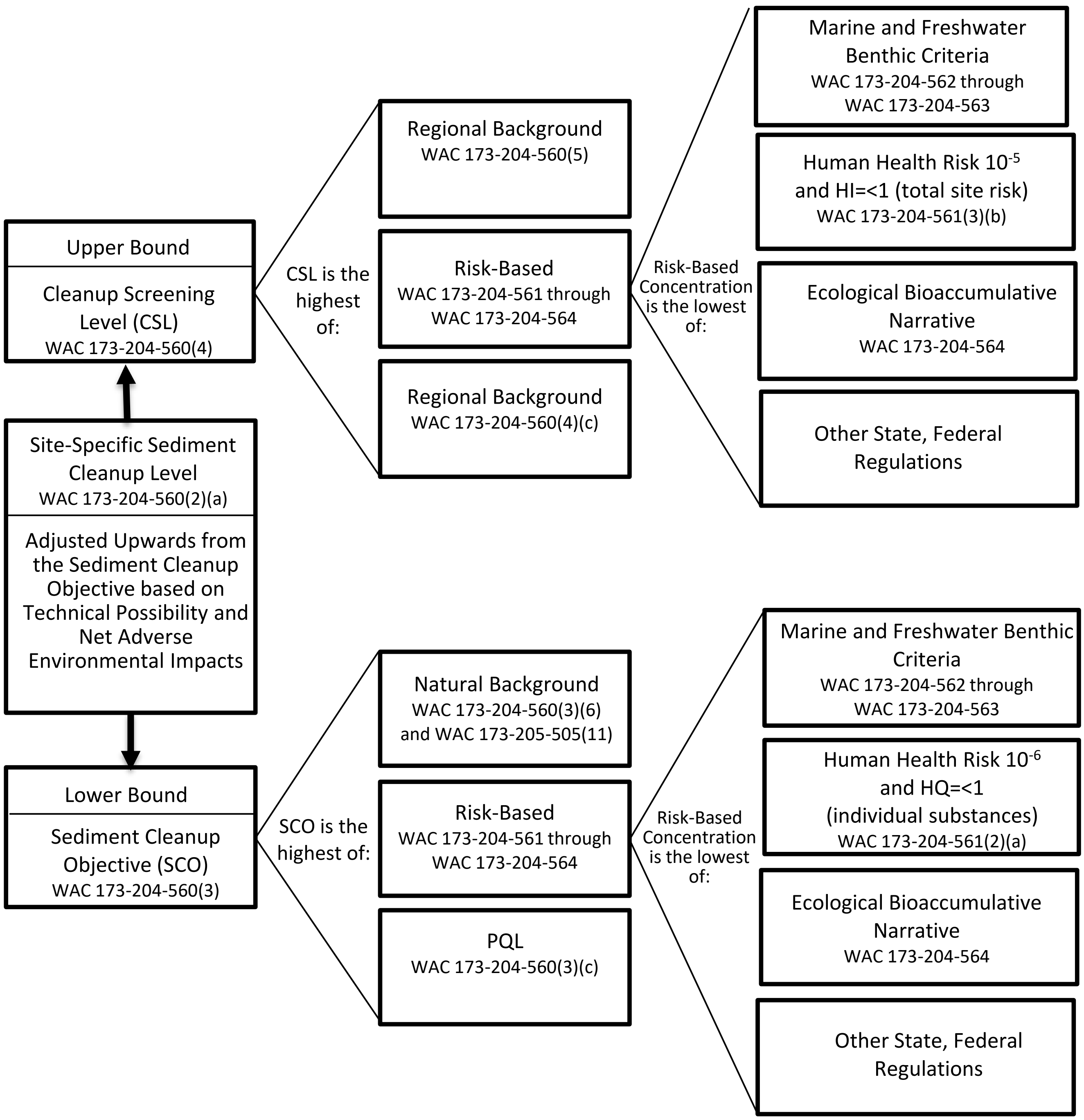
Interim Actions and Removal Action Areas

LOCATION:

Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC	FIGURE
DRAFTED	LMG	3-1
PROJECT#	117-7301019	
DATE	6/27/2019	

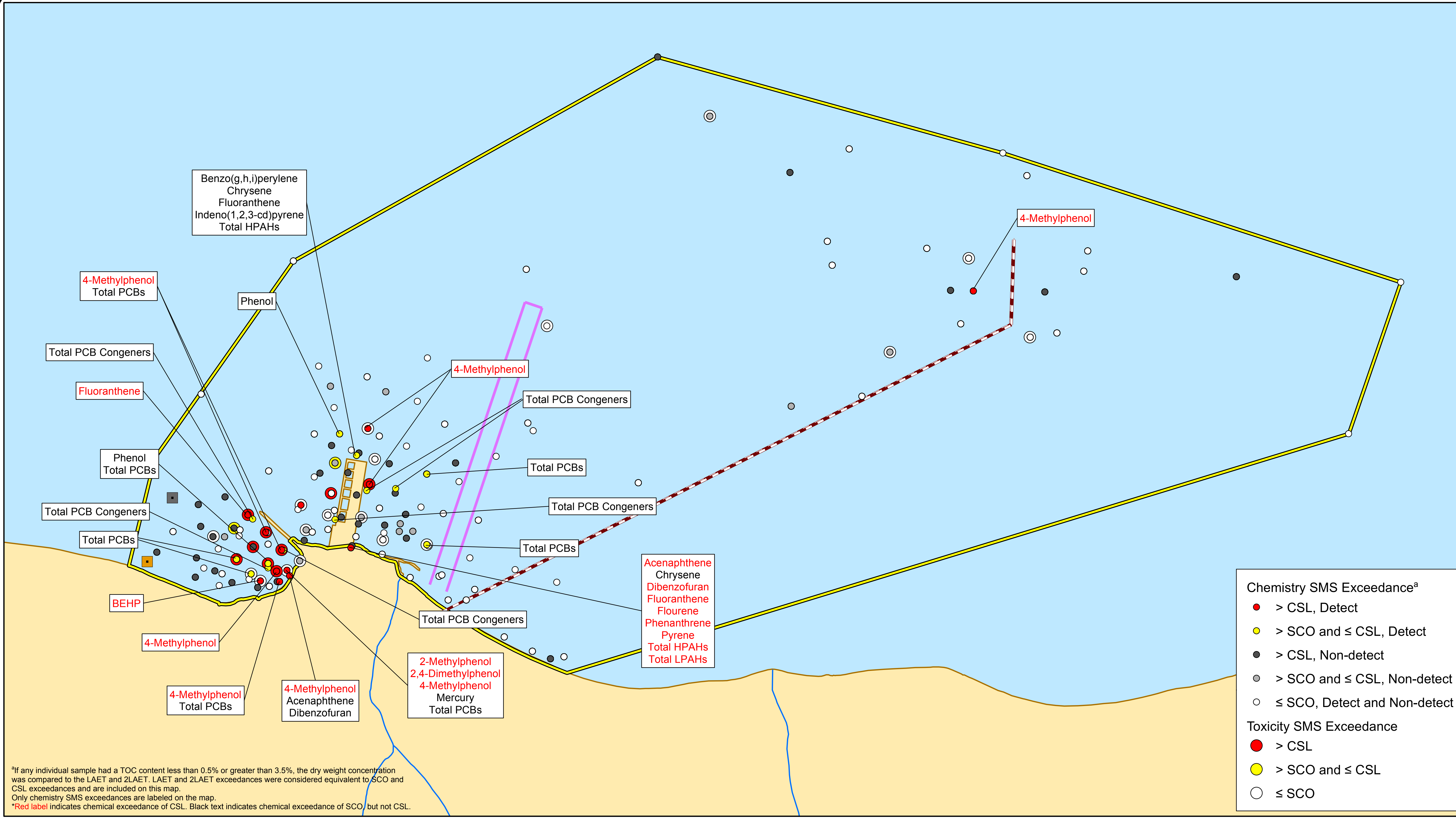


TITLE:	**Ecology's Two-Tiered Paradigm**
LOCATION:	**Rayonier Mill Study Area Port Angeles, Washington**

TETRA TECH

CHECKED:	GC	FIGURE:
DRAFTED:	PC	**3-2**
PROJ:	117-7304023	
DATE:	5-13-2019	

P:\7304-RayonierAM\023-Port Angeles FS (T&M)\Figures\Ecology Two-Tiered Paradigm



Disclaimer: The locations of all features shown are approximate.

N

0 1,000 2,000 4,000

Feet

Windward environmental LLC

TITLE: **SMS in Surface Sediment Samples from the Marine Study Area**

LOCATION: **Rayonier Mill Study Area Port Angeles, Washington**

TETRA TECH

APPROVED	App	FIGURE
DRAFTED	M.Y.	
PROJECT#	194-9029	3-3A
DATE	6/27/2019	

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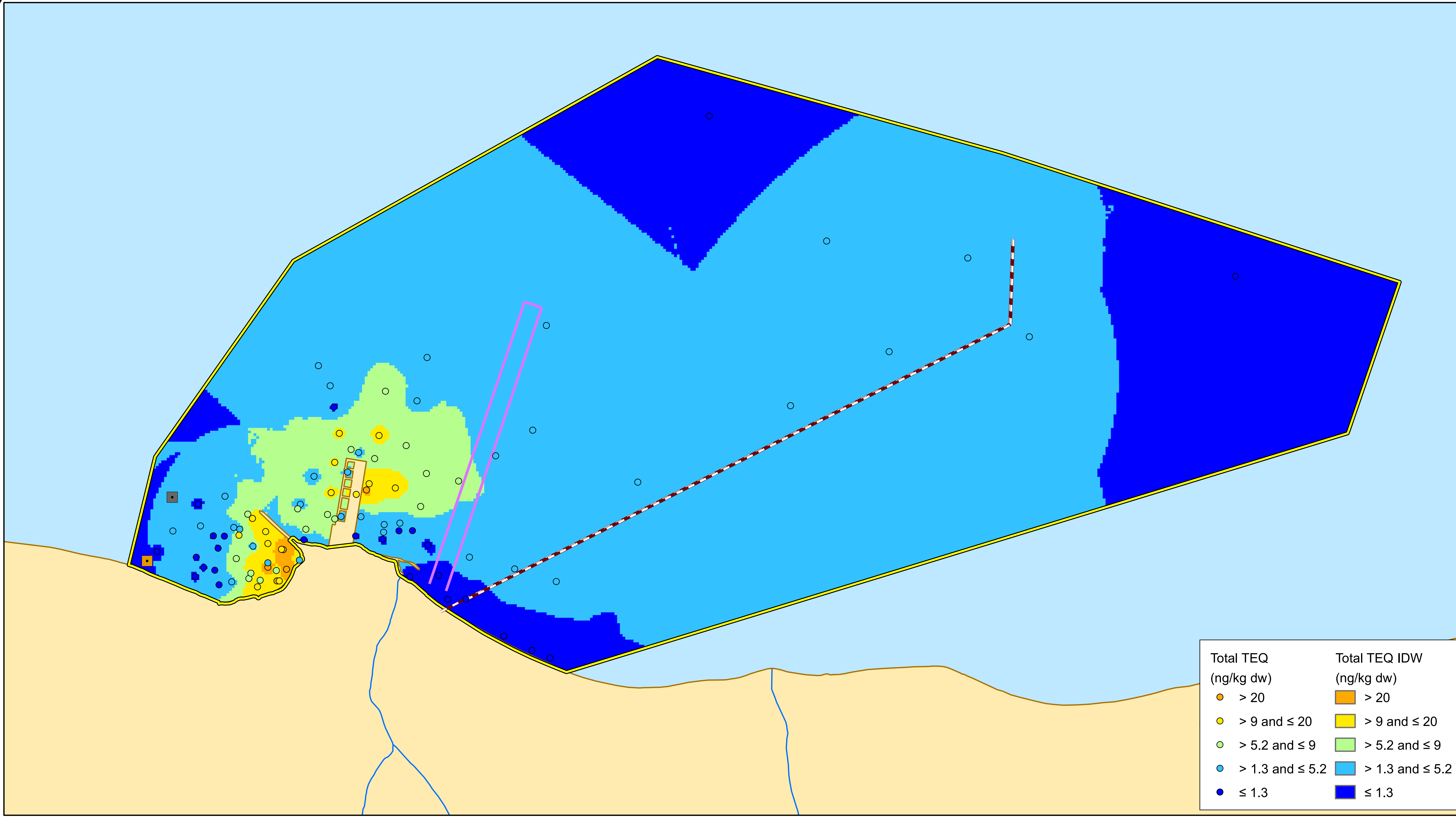

Disclaimer: The locations of all features shown are approximate.

N

0 1,000 2,000 4,000
Feet

Windward environmental LLC

TITLE: **Total TEQ in Surface Sediment Samples from the Marine Study Area**

LOCATION: **Rayonier Mill Study Area**
Port Angeles, Washington

TETRA TECH

APPROVED	App	FIGURE	
DRAFTED	M.Y.		
PROJECT#	194-9029	3-3B	
DATE	6/27/2019		

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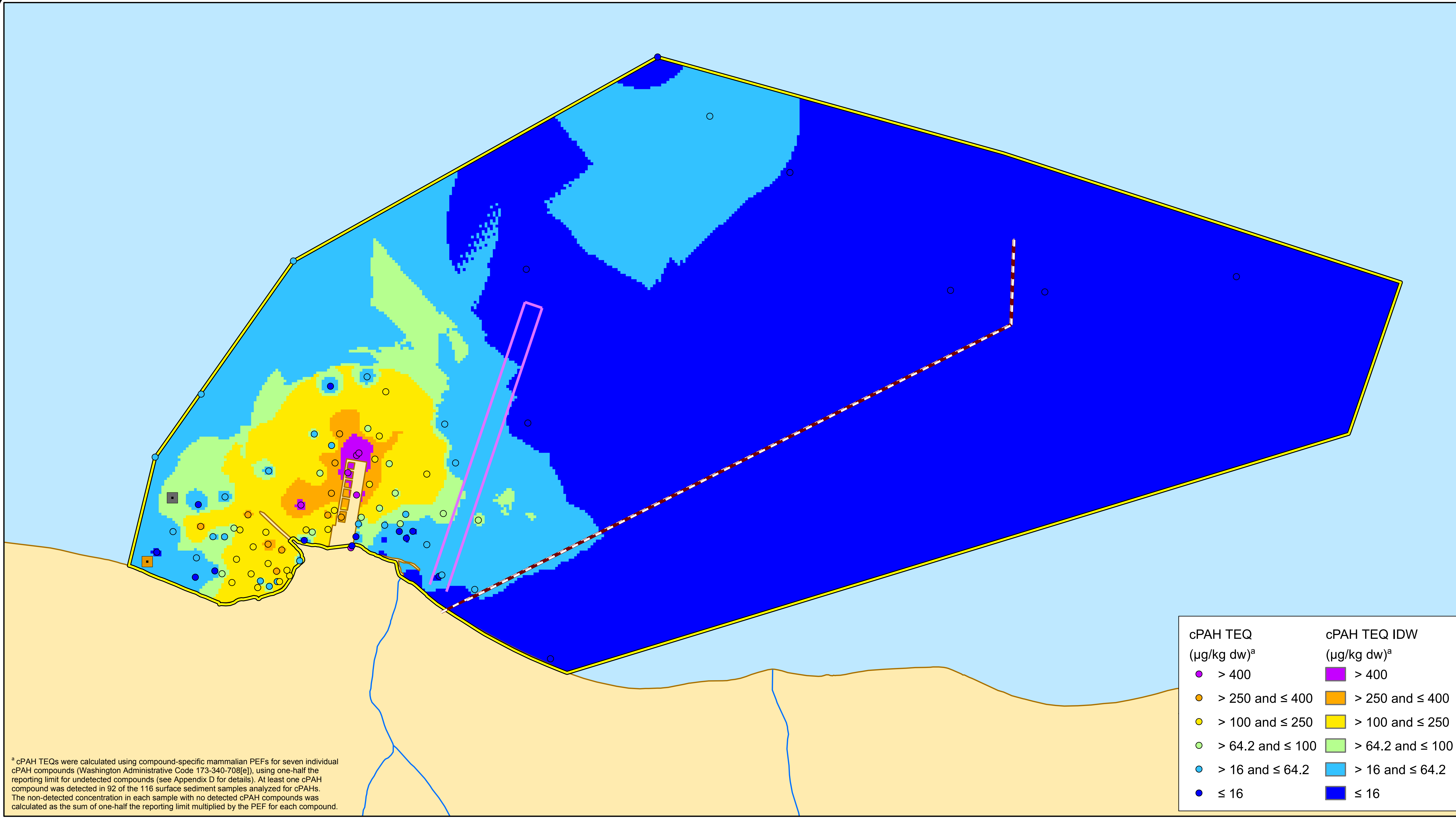

[a] cPAH TEQs were calculated using compound-specific mammalian PEFs for seven individual cPAH compounds (Washington Administrative Code 173-340-708[e]), using one-half the reporting limit for undetected compounds (see Appendix D for details). At least one cPAH compound was detected in 92 of the 116 surface sediment samples analyzed for cPAHs. The non-detected concentration in each sample with no detected cPAH compounds was calculated as the sum of one-half the reporting limit multiplied by the PEF for each compound.

Disclaimer: The locations of all features shown are approximate.

N

0 1,000 2,000 4,000
Feet

Windward environmental LLC

TITLE: **cPAH TEQ in Surface Sediment Samples from the Marine Study Area**

LOCATION: **Rayonier Mill Study Area**
Port Angeles, Washington

TETRA TECH

APPROVED	App	FIGURE
DRAFTED	M.Y.	
PROJECT#	194-9029	3-3C
DATE	6/27/2019	

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Data sources: 0.5-foot 2016 imagery from DigitalGlobe and ESRI

Disclaimer: The locations of all features shown are approximate.

N

0 150 300 600
Feet

Windward environmental LLC

TITLE: **Sediment Remediation Area and Subareas**

LOCATION: **Rayonier Mill Study Area**
Port Angeles, Washington

TETRA TECH

APPROVED	App	FIGURE
DRAFTED	M.Y.	**3-4**
PROJECT#	194-9029	
DATE	6/27/2019	

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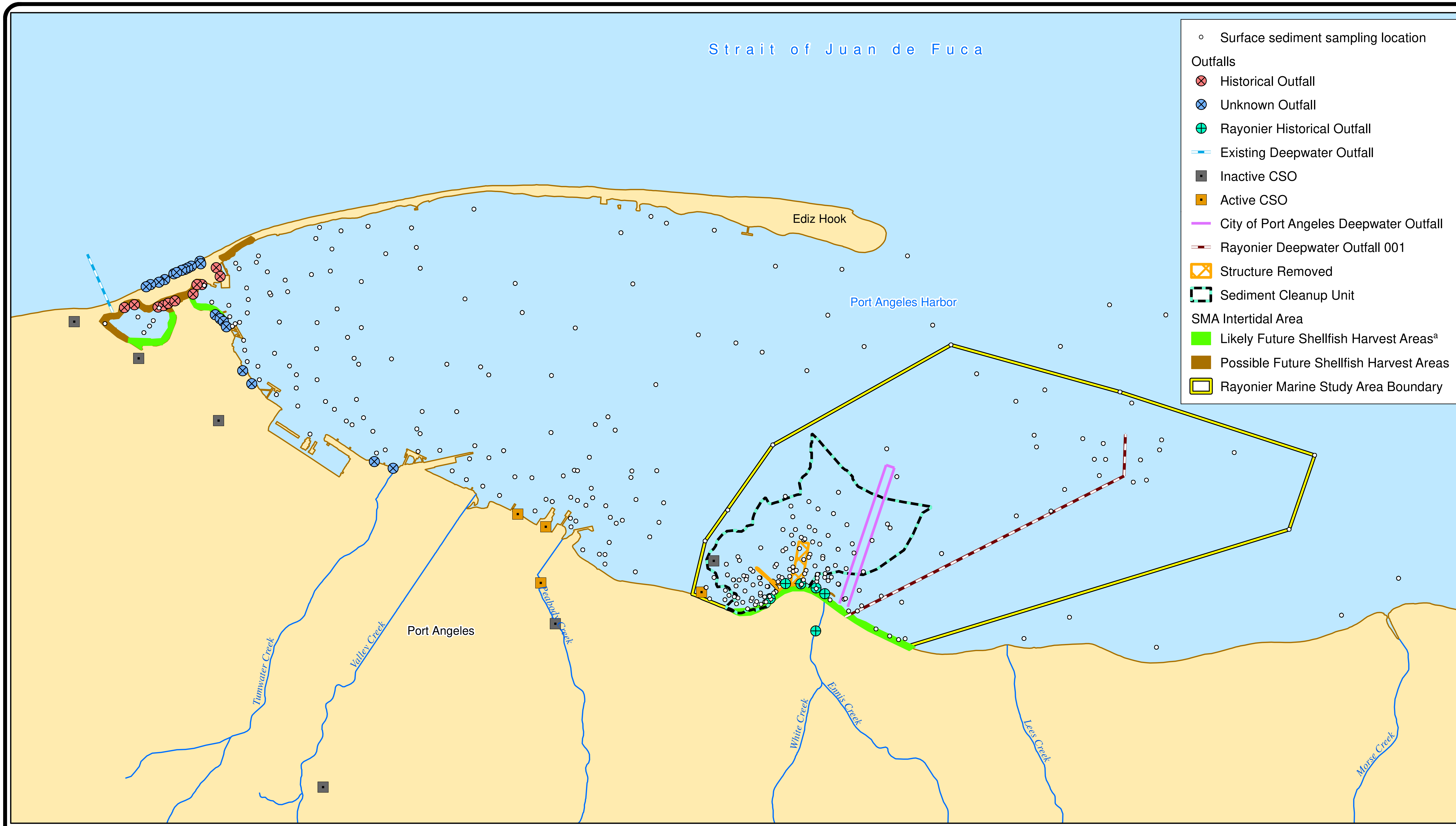


Disclaimer: The locations of all features shown are approximate.

[a]Ecology has designated sediment management areas (SMAs) within Port Angeles Harbor and near the former Mill (Ecology 2017b). Near the former mill, the SMA is limited to intertidal areas within the SCU where there is, or may be in the future, reasonable access to the shoreline for shellfish harvest by the public.

N

0 1,000 2,000 4,000
Feet

Windward environmental LLC

TITLE: **Sediment Cleanup Unit and Study Area Boundaries with Surface Sediment Sampling Locations from Port Angeles Harbor**

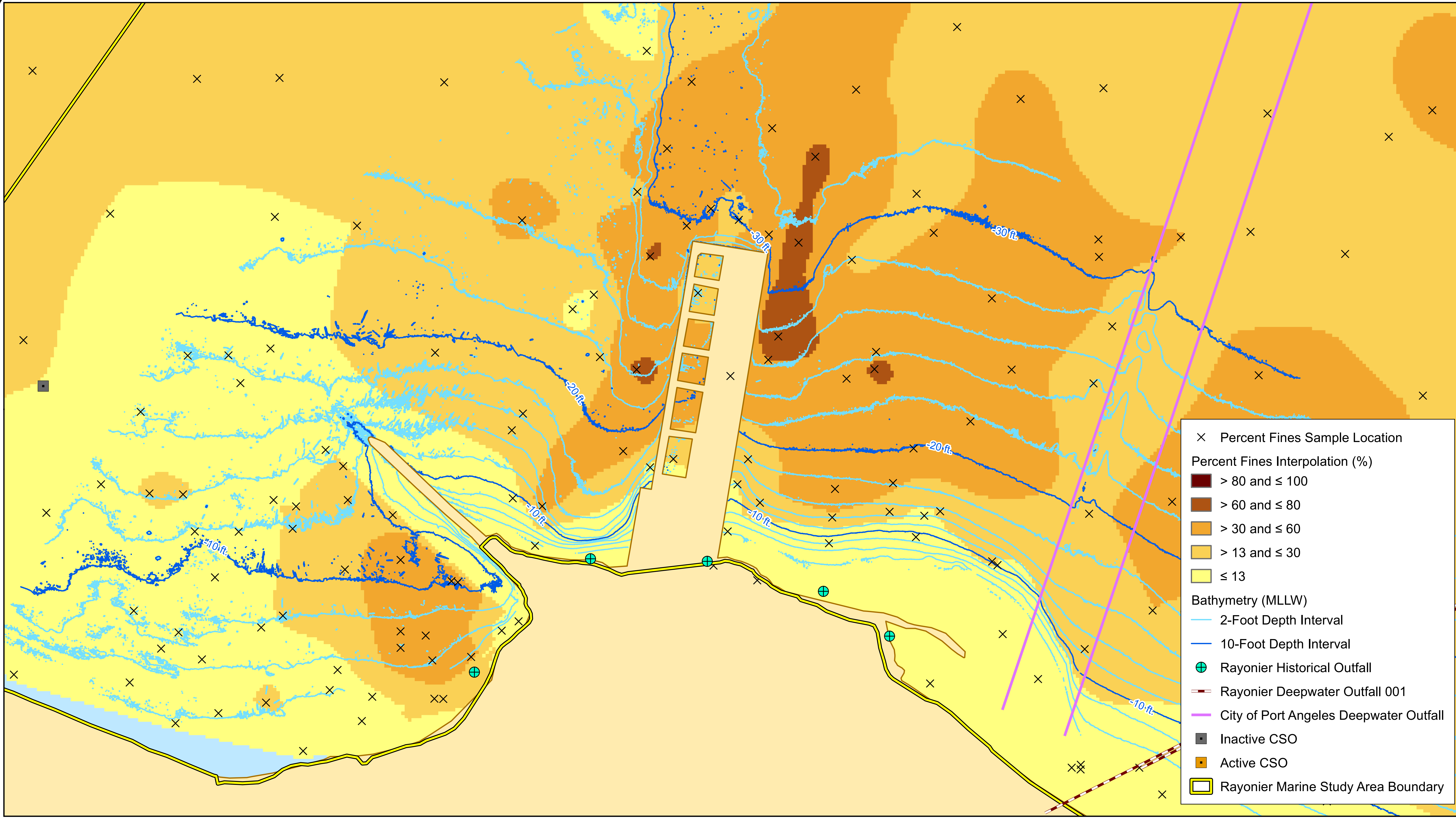
LOCATION: **Rayonier Mill Study Area**
Port Angeles, Washington

TETRA TECH

APPROVED	App
DRAFTED	M.Y.
PROJECT#	194-9029
DATE	6/28/2019

FIGURE **3-5**

W:\Projects\Rayonier PA Volume III\Data\GIS\Maps_and_Analysis\Volume_III_revised\TetraTech_Layout\6040c_Remediation and study area boundaries_V3.mxd



Data sources: Bathymetry (2014) from SEA Engineering
Grain size from STA and Windward dataset

Disclaimer: The locations of all features shown are approximate.

N

0 150 300 600
Feet

TITLE:
Bathymetry and Grain Size Distribution in Port Angeles Harbor

LOCATION:
Rayonier Mill Study Area
Port Angeles, Washington

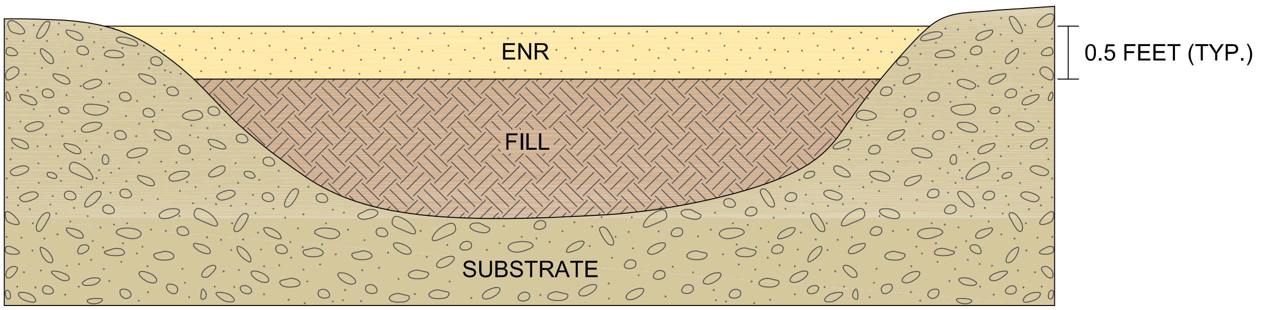
TETRA TECH

APPROVED	App
DRAFTED	M.Y.
PROJECT#	194-9029
DATE	6/27/2019

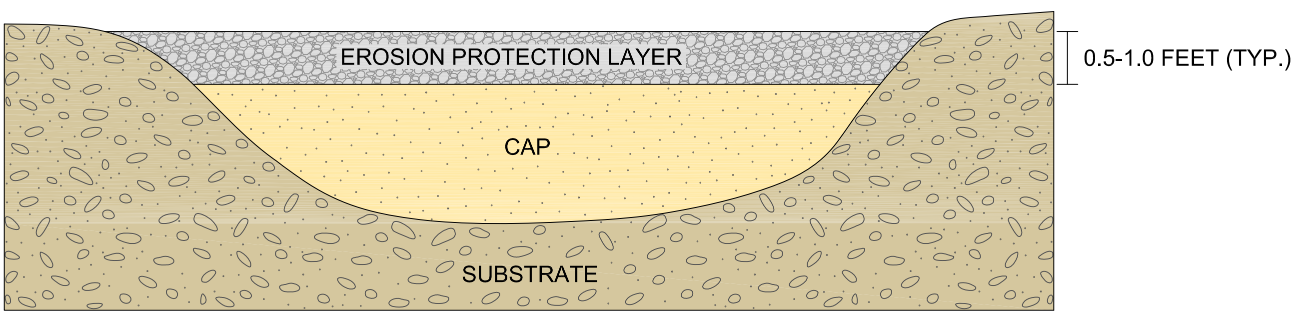
FIGURE
3-6

W:\Projects\Rayonier PA Volume III\Data\GIS\Maps_and_Analysis\Volume_III_revised\TetraTech_Layout\6054a_Bathymetry and sediment grain size distribution in Port Angeles Harbor.mxd

CLEAN FILL AND ENR (e.g., in Berth Areas)

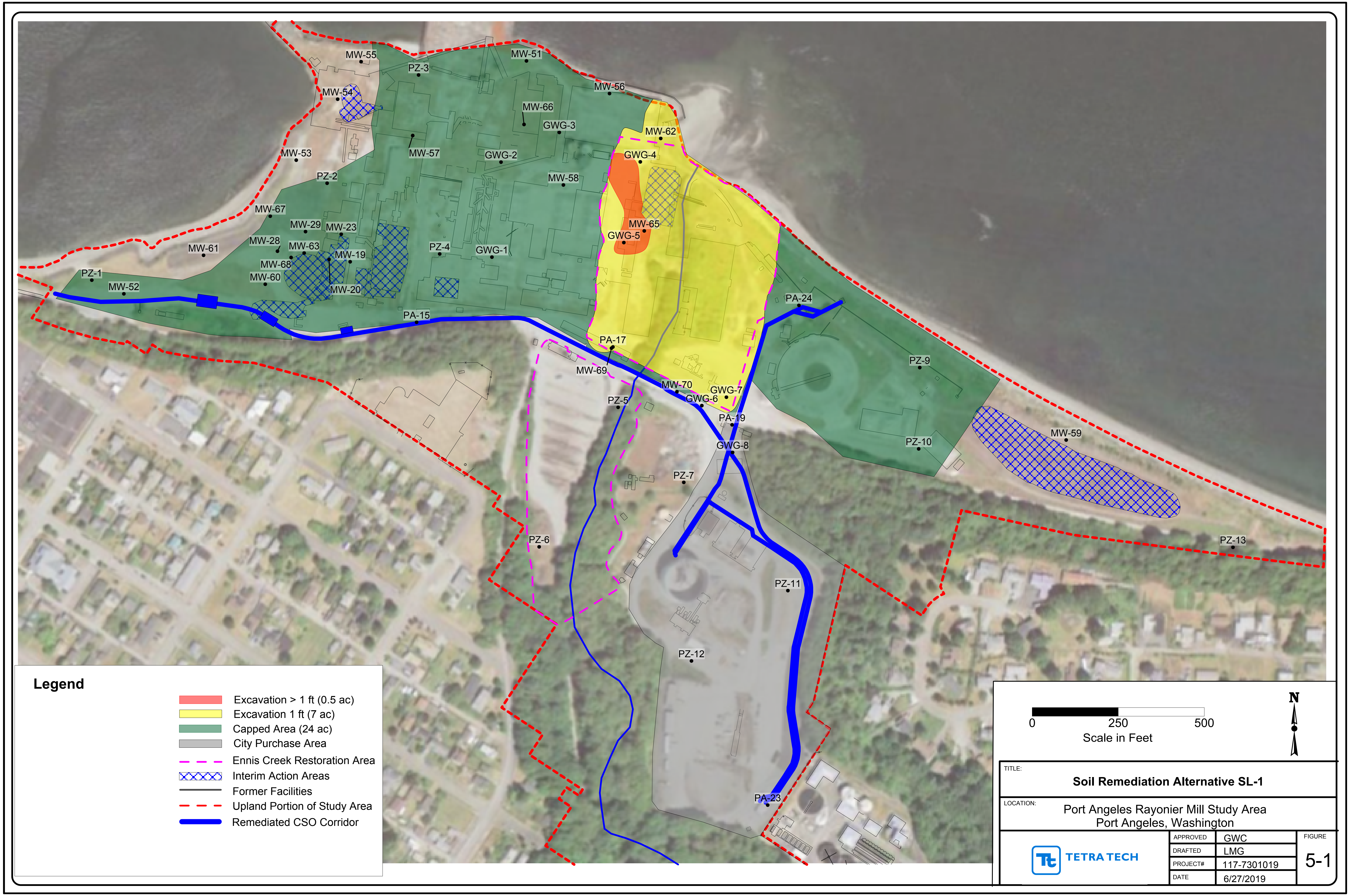


SEDIMENT CAP



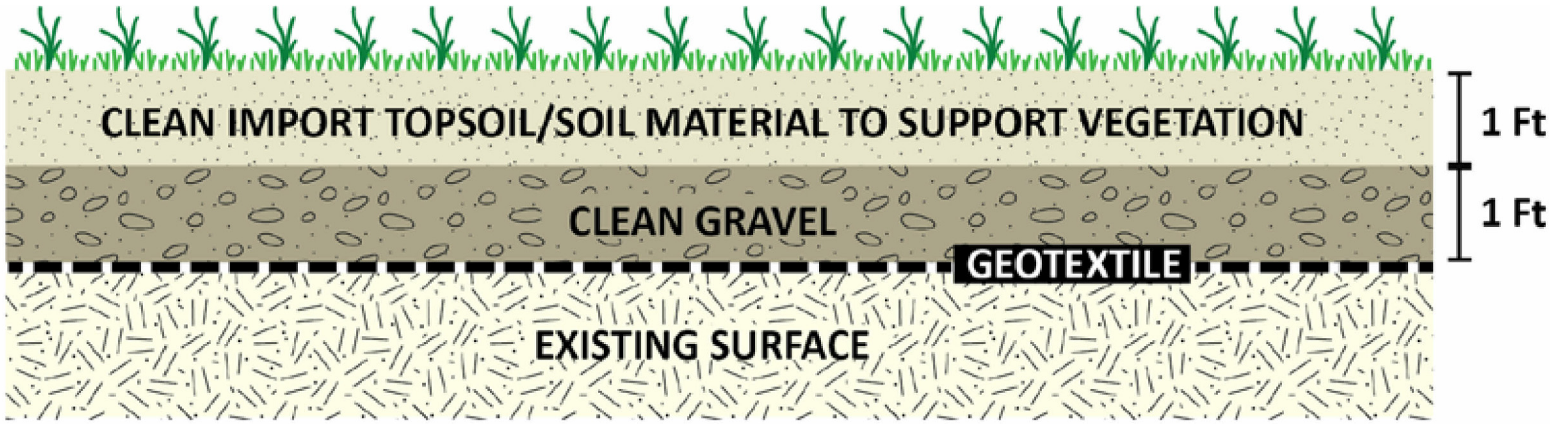
TITLE:	**CONCEPTUAL SCHEMATICS OF SEDIMENT CONTAINMENT**		
LOCATION:	**Rayonier Mill Study Area Port Angeles, Washington**		
TETRA TECH	APPROVED	GC	FIGURE
	DRAFTED	CP	**4-1**
	PROJECT#	117-7304023	
	DATE	3-25-19	

P:\ACAD\7304-023-PORT\7304023015A.DWG

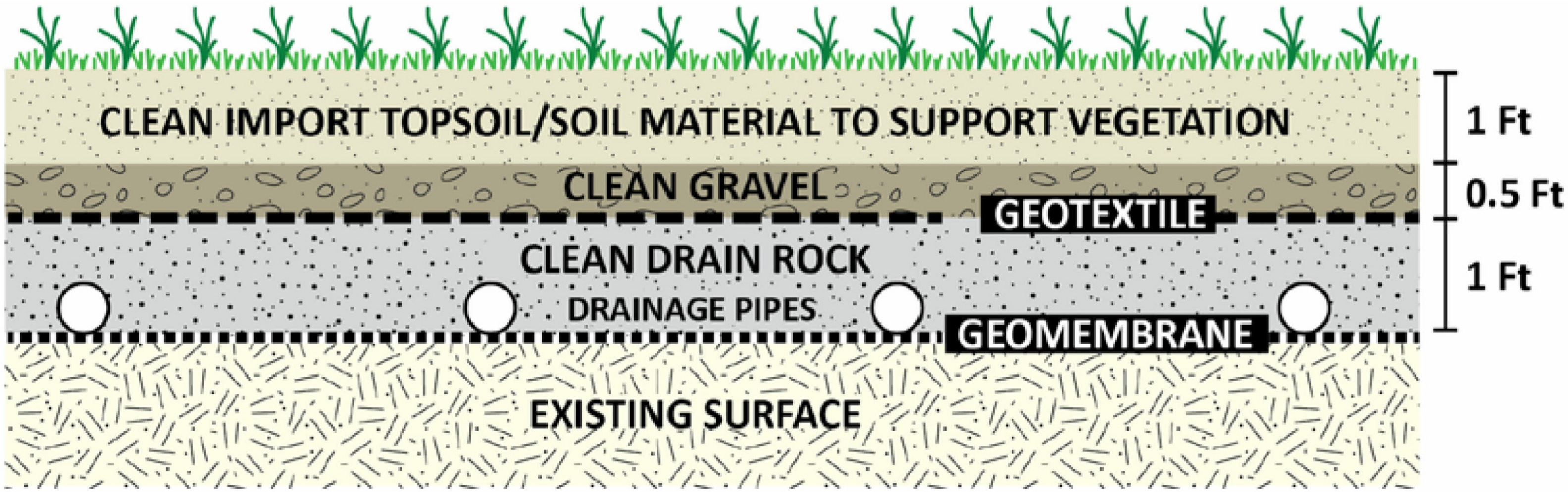

MW-55
PZ-3
MW-51
MW-54
MW-56
MW-66
GWG-3
MW-62
MW-53
MW-57
GWG-2
GWG-4
PZ-2
MW-58
MW-67
MW-29
MW-23
MW-65
GWG-5
MW-28
MW-63
PZ-4
GWG-1
MW-61
MW-19
MW-68
PZ-1
MW-60
MW-20
MW-52
PA-24
PA-15
PA-17
PZ-9
MW-69
MW-70
GWG-7
GWG-6
PZ-5
PA-19
PZ-10
MW-59
GWG-8
PZ-7
PZ-6
PZ-13
PZ-11
PZ-12
PA-23
Legend
Excavation > 1 ft (0.5 ac)
Excavation 1 ft (7 ac)
Capped Area (24 ac)
City Purchase Area
Ennis Creek Restoration Area
Interim Action Areas
Former Facilities
Upland Portion of Study Area
Remediated CSO Corridor
0
250
500
Scale in Feet
N
TITLE:
Soil Remediation Alternative SL-1
LOCATION:
Port Angeles Rayonier Mill Study Area
Port Angeles, Washington
TETRA TECH
APPROVED GWC
DRAFTED LMG
PROJECT# 117-7301019
DATE 6/27/2019
FIGURE
5-1

P:\ACAD\7304-019-RAYO\7304019007A.DWG

PERMEABLE SOIL COVER



LOW-PERMEABILITY SOIL CAP



TITLE:	SOIL ALTERNATIVE CAP DETAILS		
LOCATION:	Port Angeles Rayonier Mill Study Area Port Angeles, Washington		
TETRA TECH	APPROVED	GC	FIGURE
	DRAFTED	CP	5-2
	PROJECT#	117-7304019	
	DATE	3-25-19	

Legend

- Excavation > 1 ft (0.5 ac)
- Excavation 1 ft (10.2 ac)
- Capped Area (9.8 ac)
- City Purchase Area
- Ennis Creek Restoration Area
- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

0 250 500
Scale in Feet

N

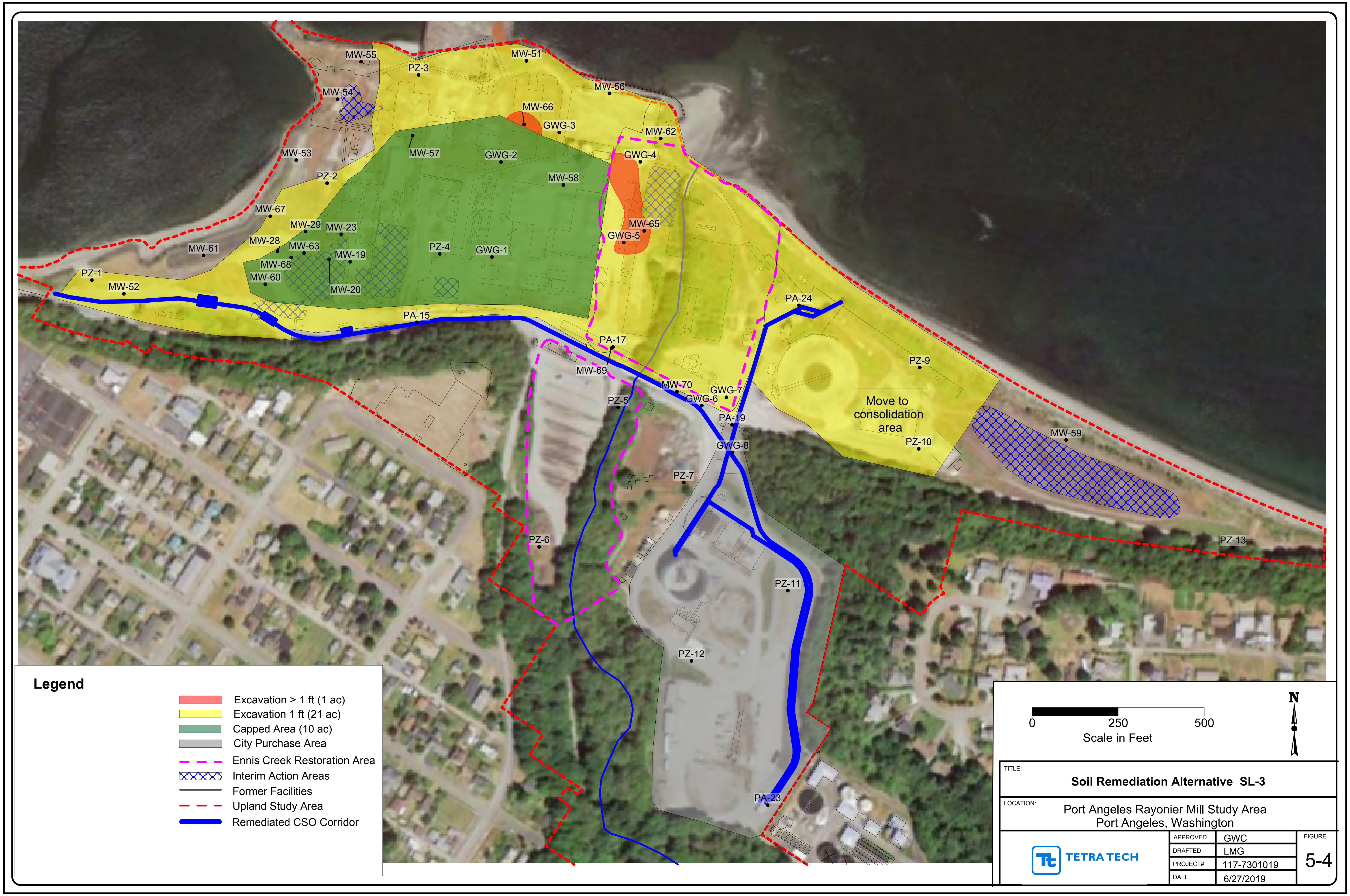
TITLE: **Soil Remediation Alternative SL-2**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

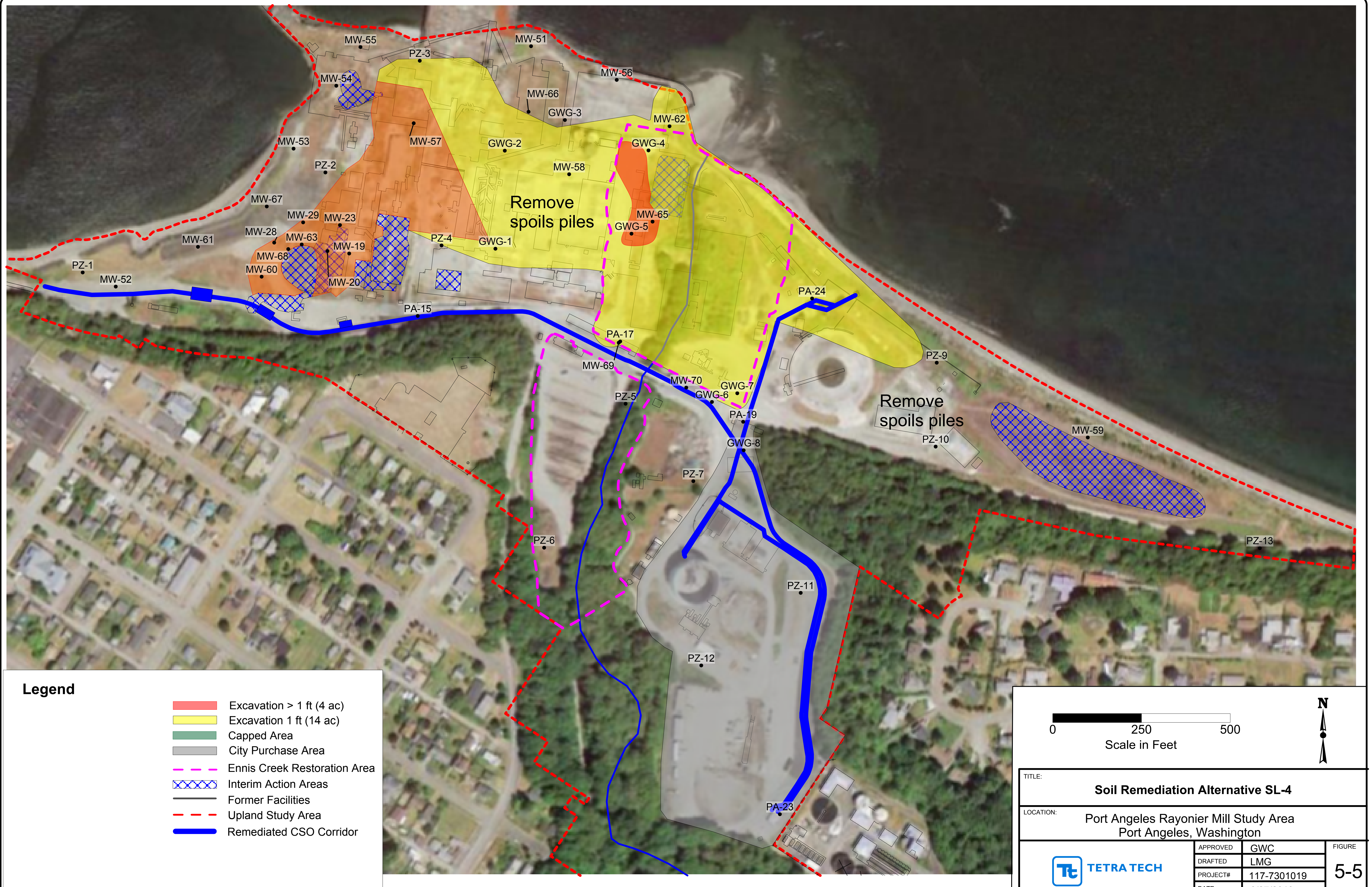
TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019

FIGURE 5-3



MW-55
PZ-3
MW-51
MW-54
MW-56
MW-66
GWG-3
MW-62
MW-53
MW-57
GWG-2
GWG-4
PZ-2
MW-58
MW-67
MW-65
MW-29
MW-23
MW-28
GWG-5
MW-61
MW-63
PZ-4
GWG-1
MW-19
MW-68
PZ-1
MW-60
MW-52
MW-20
PA-24
PA-15
PA-17
PZ-9
MW-69
MW-70
GWG-7
GWG-6
PZ-5
Move to consolidation area
PA-19
MW-59
PZ-10
GWG-8
PZ-7
PZ-6
PZ-13
PZ-11
PZ-12
PA-23
Legend
Excavation > 1 ft (1 ac)
Excavation 1 ft (21 ac)
Capped Area (10 ac)
City Purchase Area
Ennis Creek Restoration Area
Interim Action Areas
Former Facilities
Upland Study Area
Remediated CSO Corridor
0
250
500
Scale in Feet
N
TITLE:
Soil Remediation Alternative SL-3
LOCATION:
Port Angeles Rayonier Mill Study Area
Port Angeles, Washington
TETRA TECH
APPROVED
GWC
DRAFTED
LMG
PROJECT#
117-7301019
DATE
6/27/2019
FIGURE
5-4

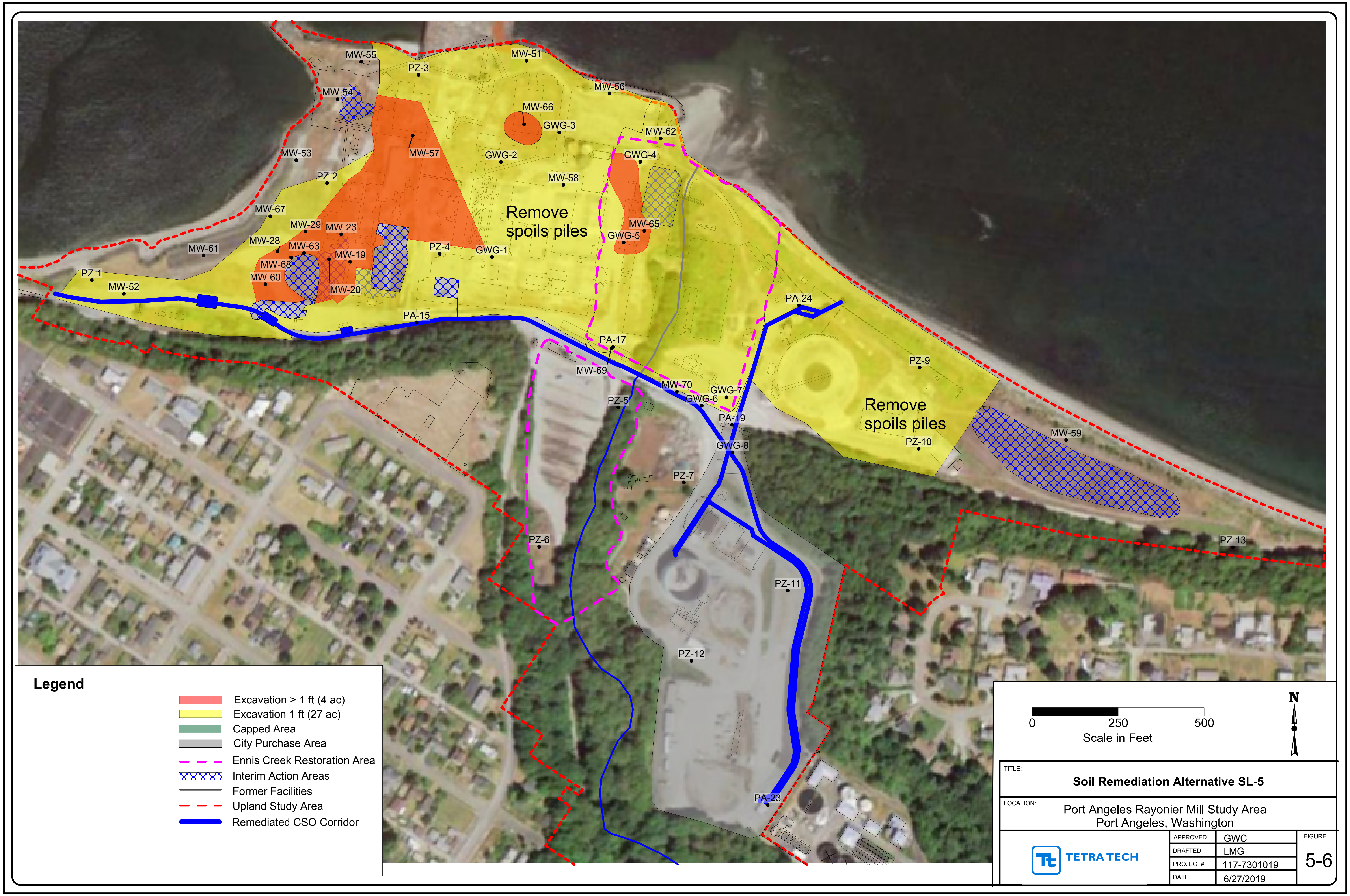


TITLE: **Soil Remediation Alternative SL-4**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC	FIGURE
DRAFTED	LMG	5-5
PROJECT#	117-7301019	
DATE	6/27/2019	


MW-55
PZ-3
MW-51
MW-56
MW-54
MW-66
GWG-3
MW-62
MW-57
GWG-2
GWG-4
MW-53
PZ-2
MW-58
Remove spoils piles
MW-67
MW-29
MW-23
MW-65
GWG-5
MW-28
MW-63
PZ-4
GWG-1
MW-61
MW-68
MW-19
PZ-1
MW-60
MW-20
MW-52
PA-24
PA-15
PA-17
PZ-9
MW-69
MW-70
GWG-7
GWG-6
PZ-5
Remove spoils piles
PA-19
MW-59
PZ-10
GWG-8
PZ-7
PZ-6
PZ-13
PZ-11
PZ-12
PA-23
Legend
Excavation > 1 ft (4 ac)
Excavation 1 ft (27 ac)
Capped Area
City Purchase Area
Ennis Creek Restoration Area
Interim Action Areas
Former Facilities
Upland Study Area
Remediated CSO Corridor
0
250
500
Scale in Feet
N
TITLE:
Soil Remediation Alternative SL-5
LOCATION:
Port Angeles Rayonier Mill Study Area
Port Angeles, Washington
TETRA TECH
APPROVED GWC
DRAFTED LMG
PROJECT# 117-7301019
DATE 6/27/2019
FIGURE
5-6


MW-55
MW-51
PZ-3
MW-54
MW-56
MW-66
GWG-3
MW-62
MW-53
MW-57
GWG-2
GWG-4
PZ-2
MW-58
MW-67
MW-29
MW-23
MW-65
MW-28
MW-63
GWG-5
MW-61
PZ-4
GWG-1
MW-19
MW-68
PZ-1
MW-60
MW-20
MW-52
PA-24
PA-15
PA-17
PZ-9
MW-69
MW-70
GWG-7
GWG-6
PZ-5
PA-19
MW-59
PZ-10
GWG-8
PZ-7
PZ-6
PZ-13
PZ-11
PZ-12
PA-23
Legend
Initial Sparging System
Additional Sparging Wells
City Purchase Area
Ennis Creek Restoration Area
Interim Action Areas
Former Facilities
Upland Study Area
Remediated CSO Corridor
0
250
500
Scale in Feet
N
TITLE:
Groundwater Remediation Alternative G-1
LOCATION:
Port Angeles Rayonier Mill Study Area
Port Angeles, Washington
TETRA TECH
APPROVED GWC
DRAFTED LMG
PROJECT# 117-7301019
DATE 6/28/2019
FIGURE
5-7

TITLE:

Groundwater Remediation Alternative G-2

LOCATION:

Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

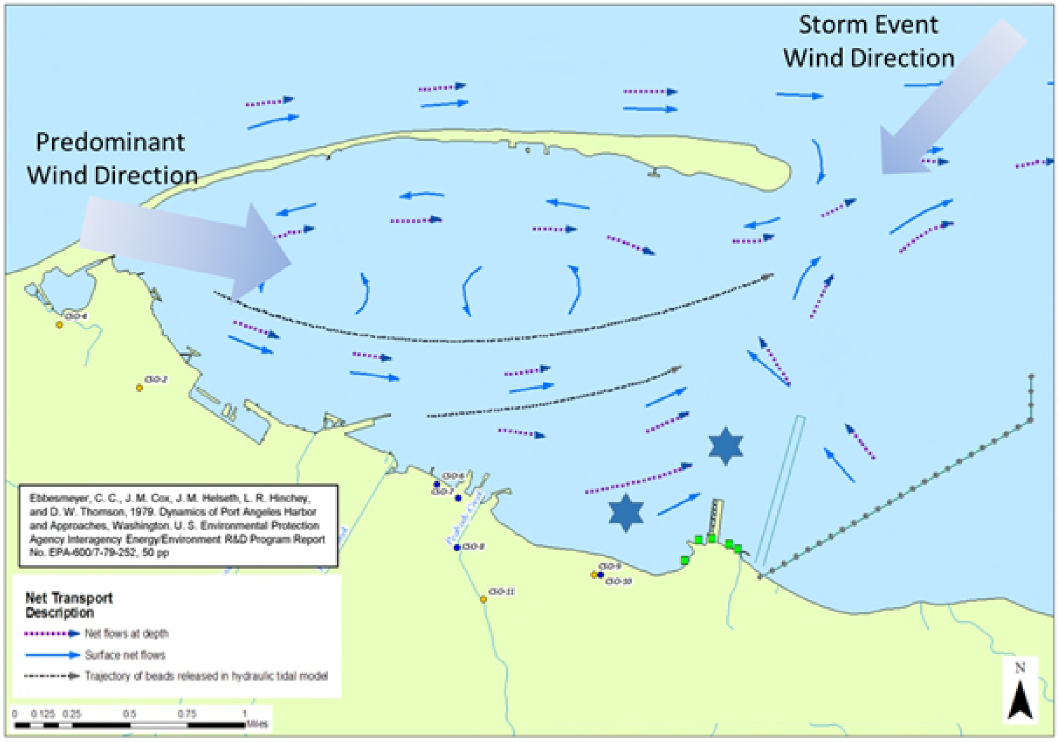
APPROVED	GWC	FIGURE
DRAFTED	LMG	5-8
PROJECT#	117-7301019	
DATE	6/27/2019	

TITLE: **Groundwater Remediation Alternative G-3**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC	FIGURE
DRAFTED	LMG	5-9
PROJECT#	117-7301019	
DATE	6/27/2019	



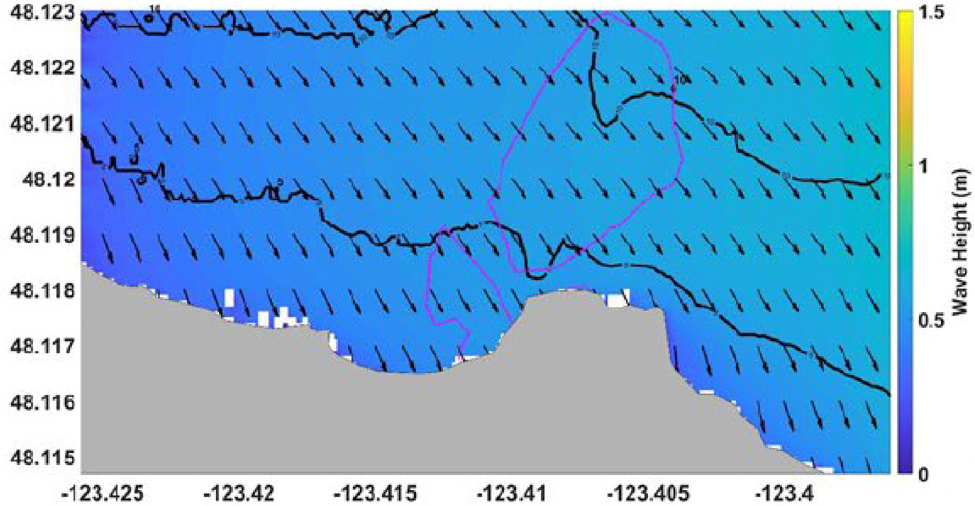
Study site with net circulation directions indicated (as presented by Ebbesmeyer et al., 1979). Blue stars indicate locations of current meters and water quality sondes deployed for the study and gray arrows indicate average (westerly; 292.5°) and storm (northeasterly; 67.5°) wind directions modeled during the study.

TITLE:	**Study Area Hydrodynamic Conditions**
LOCATION:	**Rayonier Mill Study Area Port Angeles, Washington**

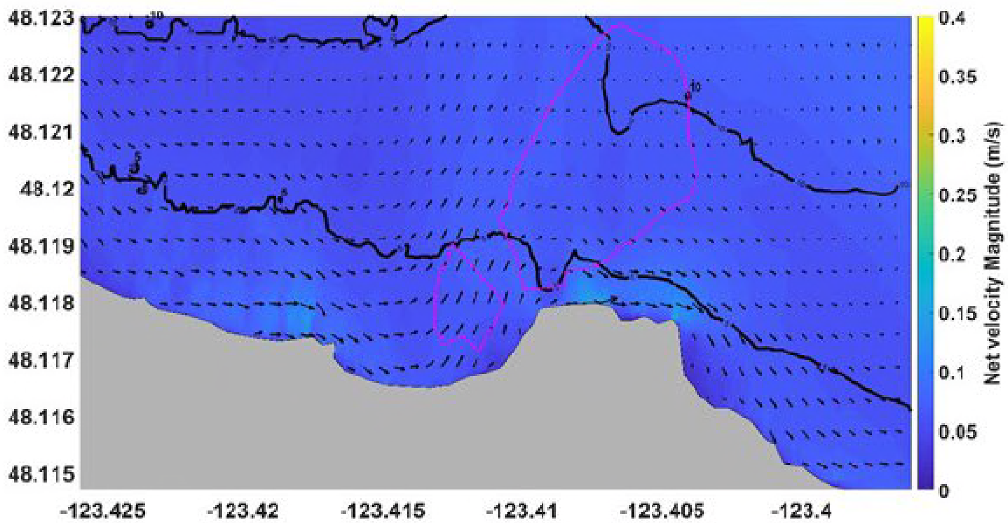
TETRA TECH

APPROVED		FIGURE
DRAFTED		5-10
PROJECT#		
DATE		

p:\Filename



Wave height due to a westerly 100-year storm. Wave directions are indicated with arrows. The regions designated for ENR are outlined in magenta.



Net circulation patterns due to a westerly 100-year storm. Current directions are indicated with arrows. The regions designated for ENR are outlined in magenta.

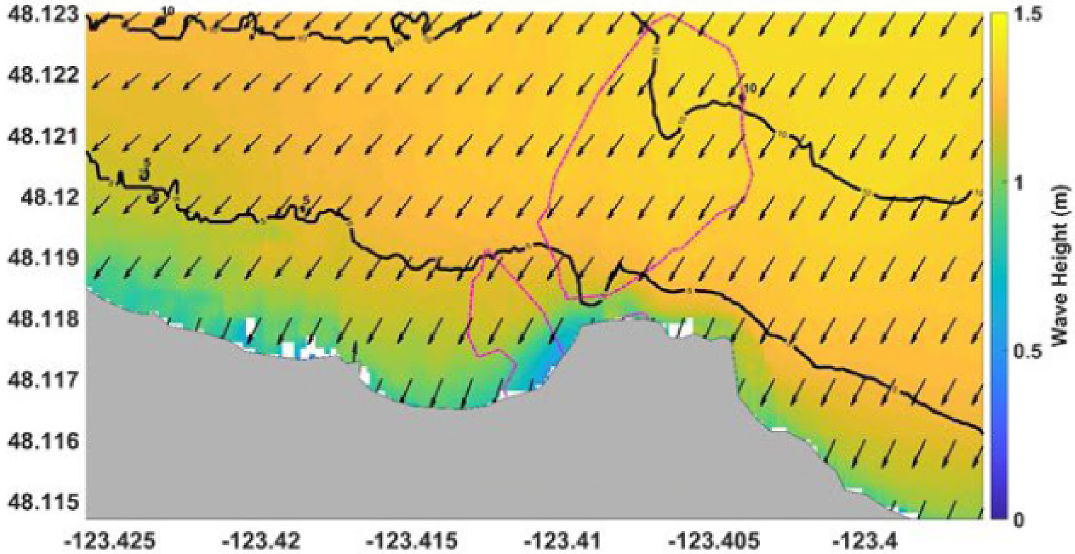
TITLE: **Westerly 100-Year Storm Conditions**

LOCATION: **Rayonier Mill Study Area Port Angeles, Washington**

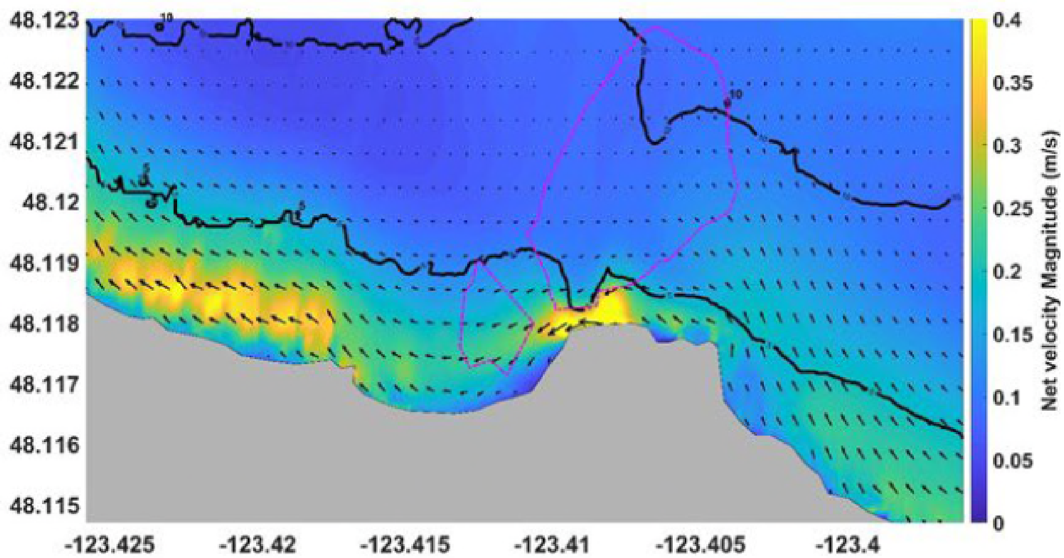
TETRA TECH

APPROVED		FIGURE
DRAFTED		5-11
PROJECT#		
DATE		

p:\Filename



Wave height due to a northeasterly 100-year storm. Wave directions are indicated with arrows. The regions designated for ENR are outlined in magenta.



Net circulation patterns due to a northeasterly 100-year storm. Current directions are indicated with arrows. The regions designated for ENR are outlined in magenta.

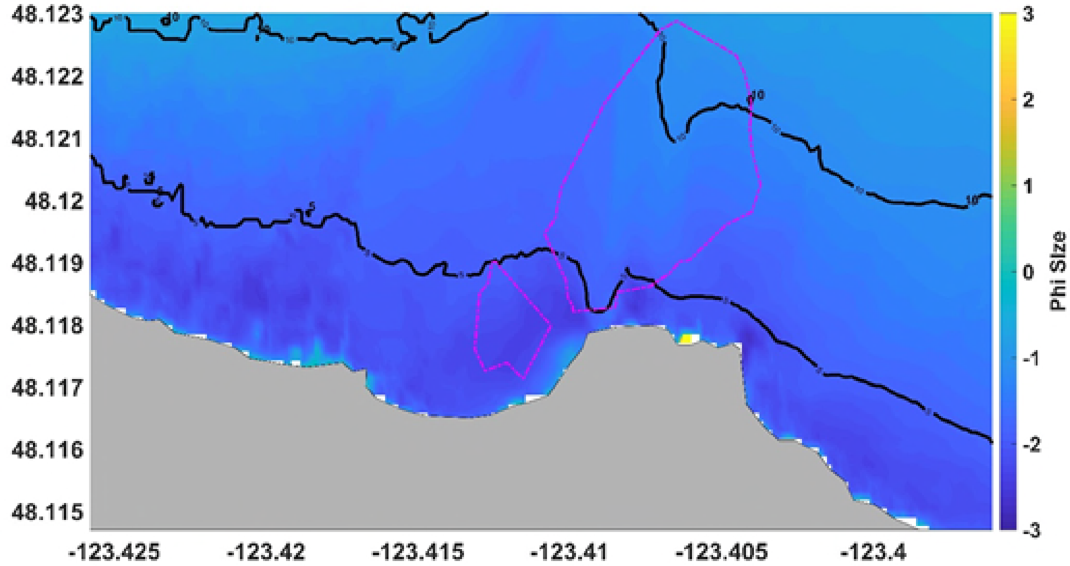
TITLE: **Northeasterly 100-Year Storm Conditions**

LOCATION: **Rayonier Mill Study Area Port Angeles, Washington**

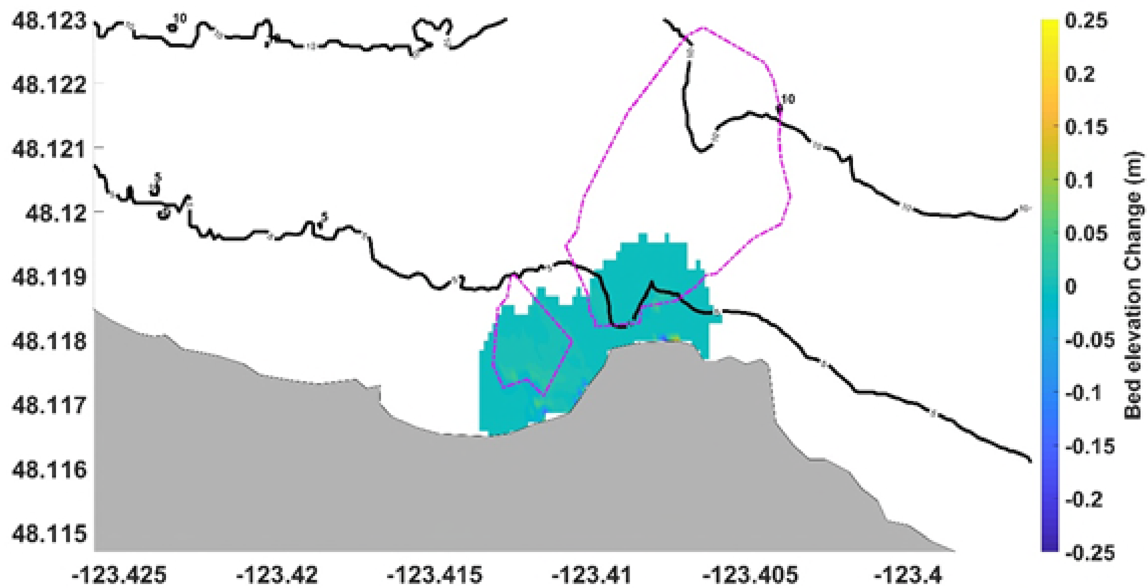
TETRA TECH

APPROVED		FIGURE	
DRAFTED			5-12
PROJECT#			
DATE			

p:\Filename



Range of Phi sizes that could be mobilized in ENR regions due to northeasterly 100–year storm conditions.



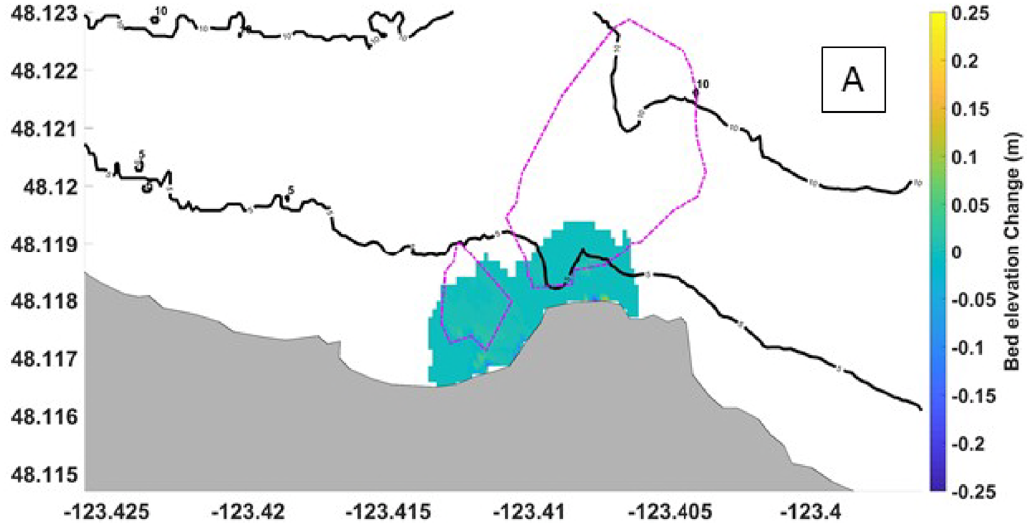
Potential Redistribution of ENR sediment in northeasterly 100–year storm conditions.

TITLE:	**Potential Redistribution and Stable Grain Size of ENR Sediment During Northeasterly 100-year Storm**
LOCATION:	**Rayonier Mill Study Area Port Angeles, Washington**

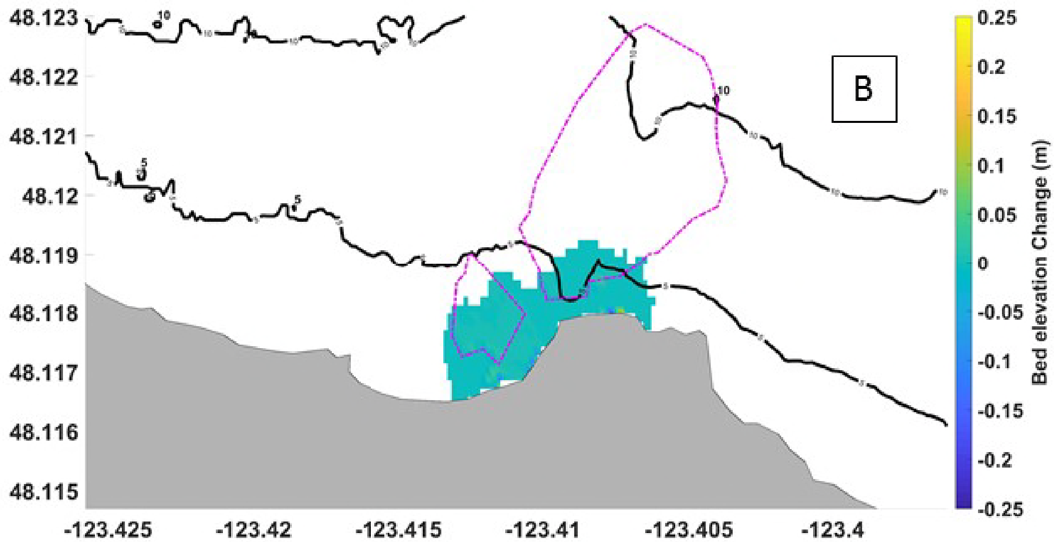
TETRA TECH

APPROVED		FIGURE
DRAFTED		5-13
PROJECT#		
DATE		

p:\Filename



Bed elevation change under the sea level rise scenario in 2050 due to a northeasterly 100-year storm.



Bed elevation change under the sea level rise scenario in 2100 due to a northeasterly 100-year storm.

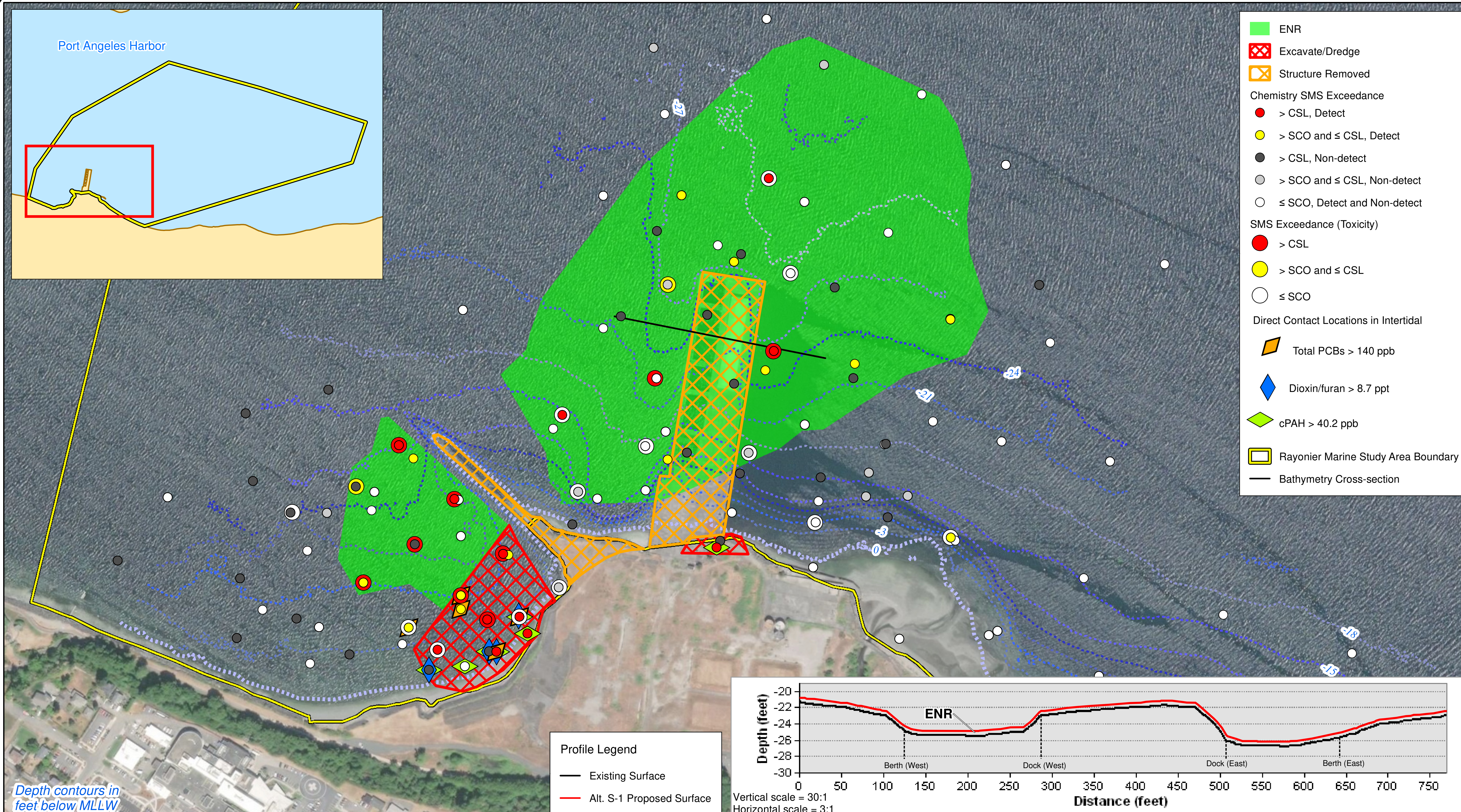
TITLE: **Potential Redistribution of ENR Sediment Due to Climate Change During Northeasterly 100-year Storm**

LOCATION: **Rayonier Mill Study Area Port Angeles, Washington**

TETRA TECH

APPROVED		FIGURE
DRAFTED		5-14
PROJECT#		
DATE		

p:\Filename



Data sources: 0.5-foot 2016 imagery from DigitalGlobe and ESRI
Bathymetry (2010) from Lower Elwah Klallam Tribe (LEKT)

Disclaimer: The locations of all features shown are approximate.

N

0 150 300 600
Feet

Windward environmental LLC

TITLE:
Sediment Remediation Alternative S-1

LOCATION:
Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	App	FIGURE
DRAFTED	M.Y.	5-15
PROJECT#	194-9029	
DATE	6/27/2019	

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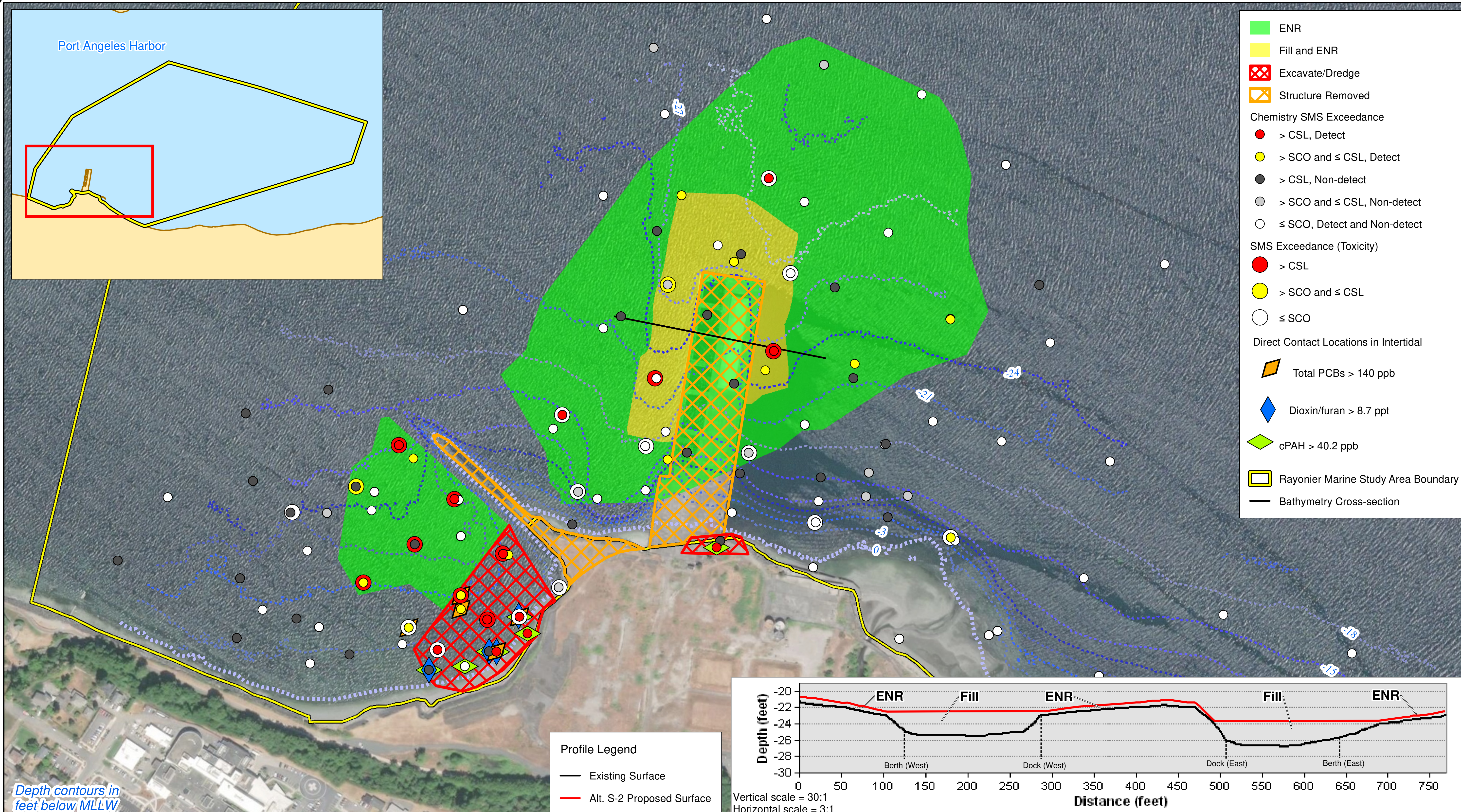


Data sources: 0.5-foot 2016 imagery from DigitalGlobe and ESRI
Bathymetry (2010) from Lower Elwha Klallam Tribe (LEKT)

Disclaimer: The locations of all features shown are approximate.

N

0 150 300 600
Feet

Windward environmental LLC

W:\Projects\Rayonier PA Volume III\Data\GIS\Maps_and_Analysis\Volume_III_revised\TetraTech_Layout\6714a_Sediment remediation alternative S2 revised with profile.mxd

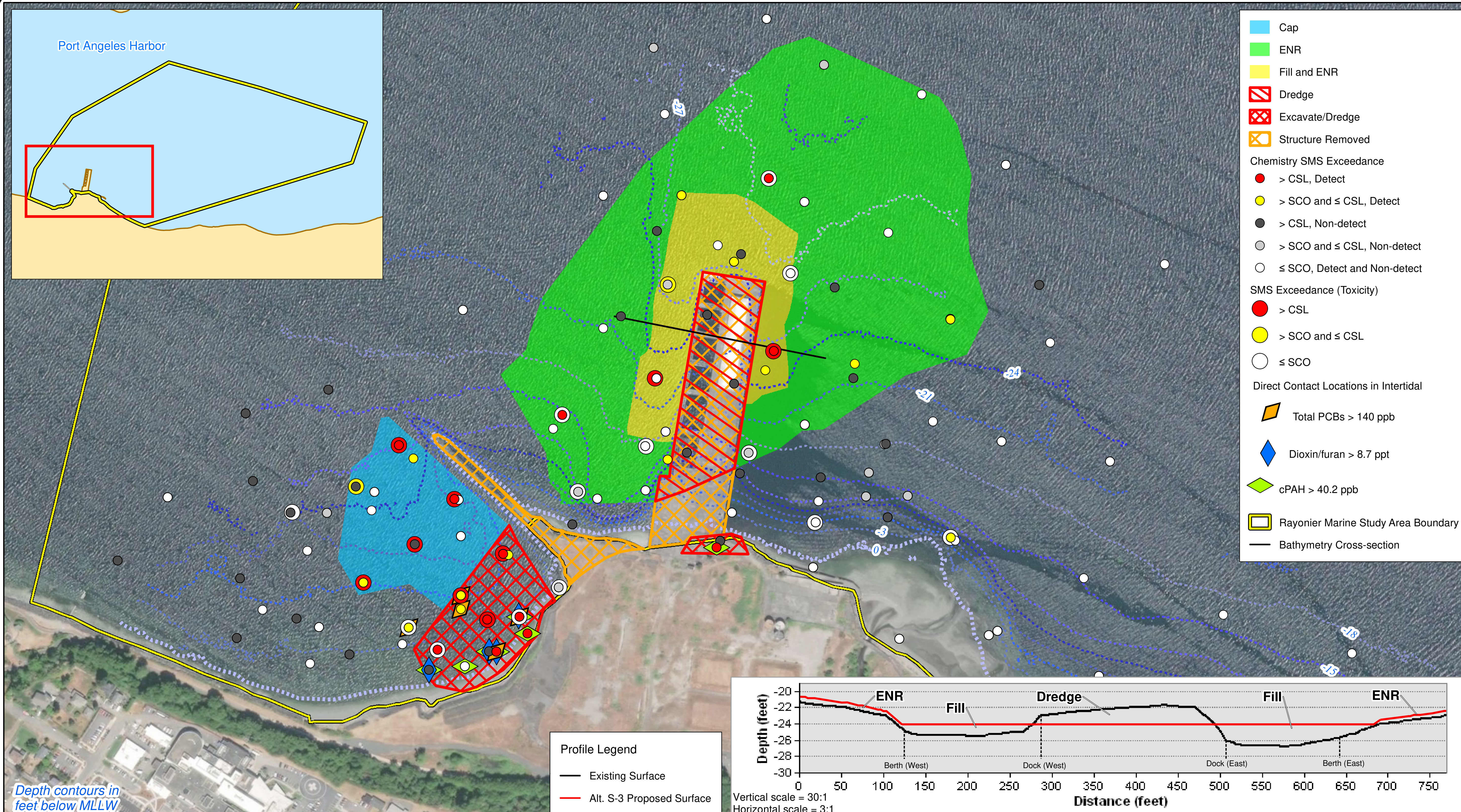
TITLE:
Sediment Remediation Alternative S-2

LOCATION:
Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	App
DRAFTED	M.Y.
PROJECT#	194-9029
DATE	6/27/2019

FIGURE
5-16



Data sources: 0.5-foot 2016 imagery from DigitalGlobe and ESRI
Bathymetry (2010) from Lower Elwah Klallam Tribe (LEKT)

Disclaimer: The locations of all features shown are approximate.

N

0 150 300 600
Feet

Windward environmental LLC

TITLE:
Sediment Remediation Alternative S-3

LOCATION:
Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	App	FIGURE
DRAFTED	M.Y.	5-17
PROJECT#	194-9029	
DATE	6/27/2019	

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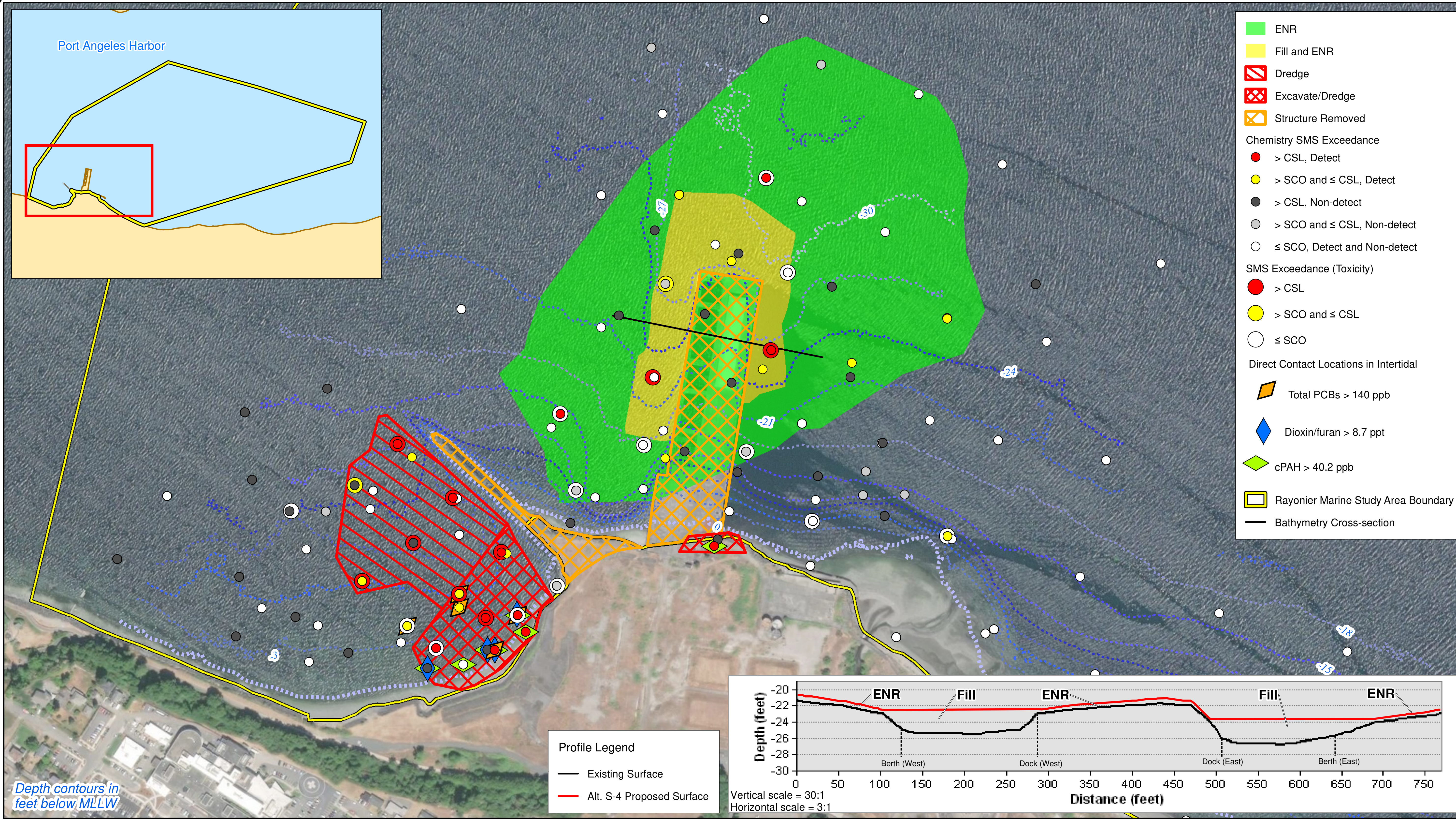

Data sources: 0.5-foot 2016 imagery from DigitalGlobe and ESRI
Bathymetry (2010) from Lower Elwah Klallam Tribe (LEKT)

Disclaimer: The locations of all features shown are approximate.

N

0 150 300 600
Feet

Windward environmental LLC

TITLE:
Sediment Remediation Alternative S-4

LOCATION:
Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	App	FIGURE
DRAFTED	M.Y.	5-18
PROJECT#	194-9029	
DATE	6/27/2019	

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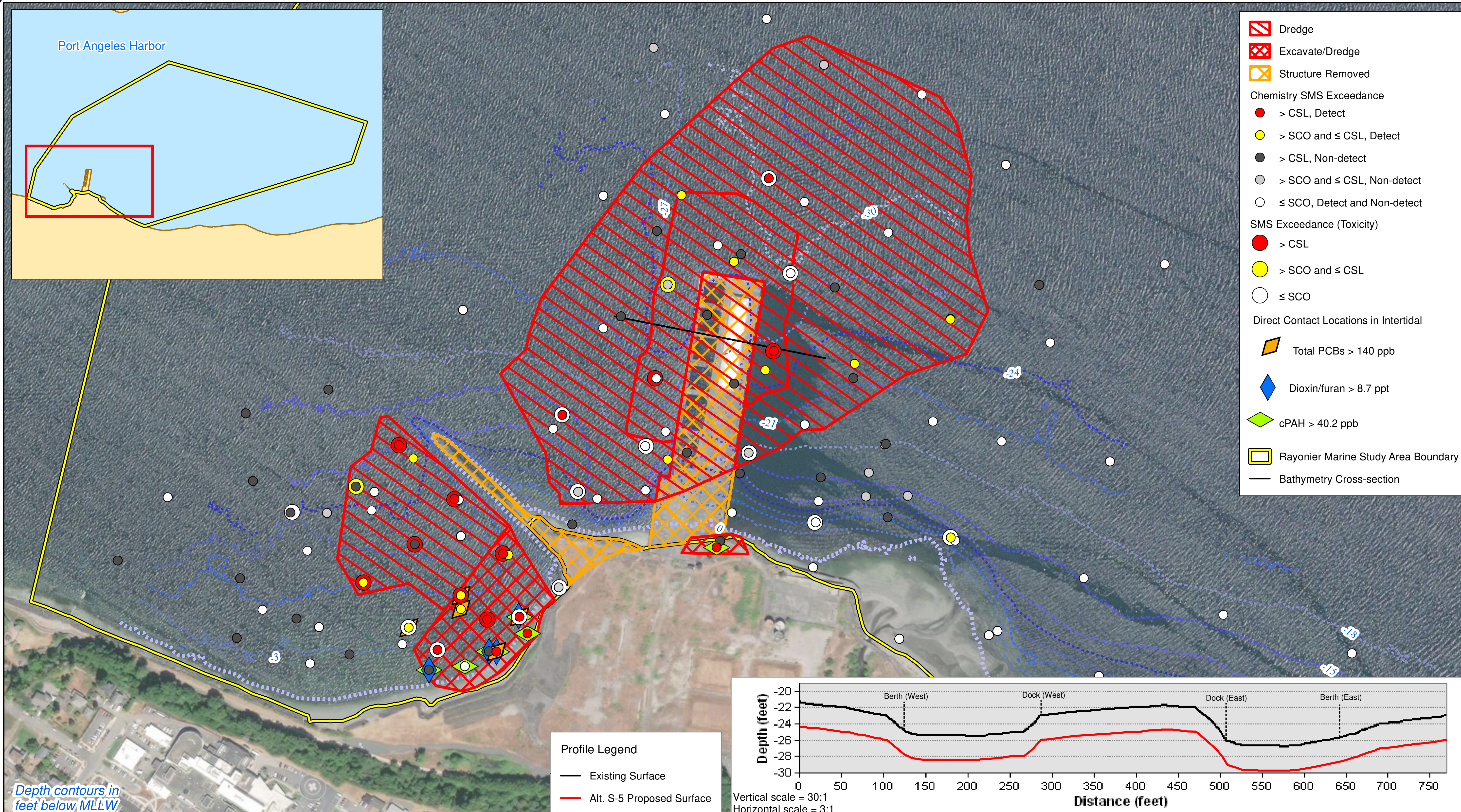

Data sources: 0.5-foot 2016 imagery from DigitalGlobe and ESRI
Bathymetry (2010) from Lower Elwah Klallam Tribe (LEKT)

Disclaimer: The locations of all features shown are approximate.

N

0 150 300 600
Feet

Windward environmental LLC

TITLE:
Sediment Remediation Alternative S-5

LOCATION:
Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	App	FIGURE
DRAFTED	M.Y.	5-19
PROJECT#	194-9029	
DATE	6/27/2019	

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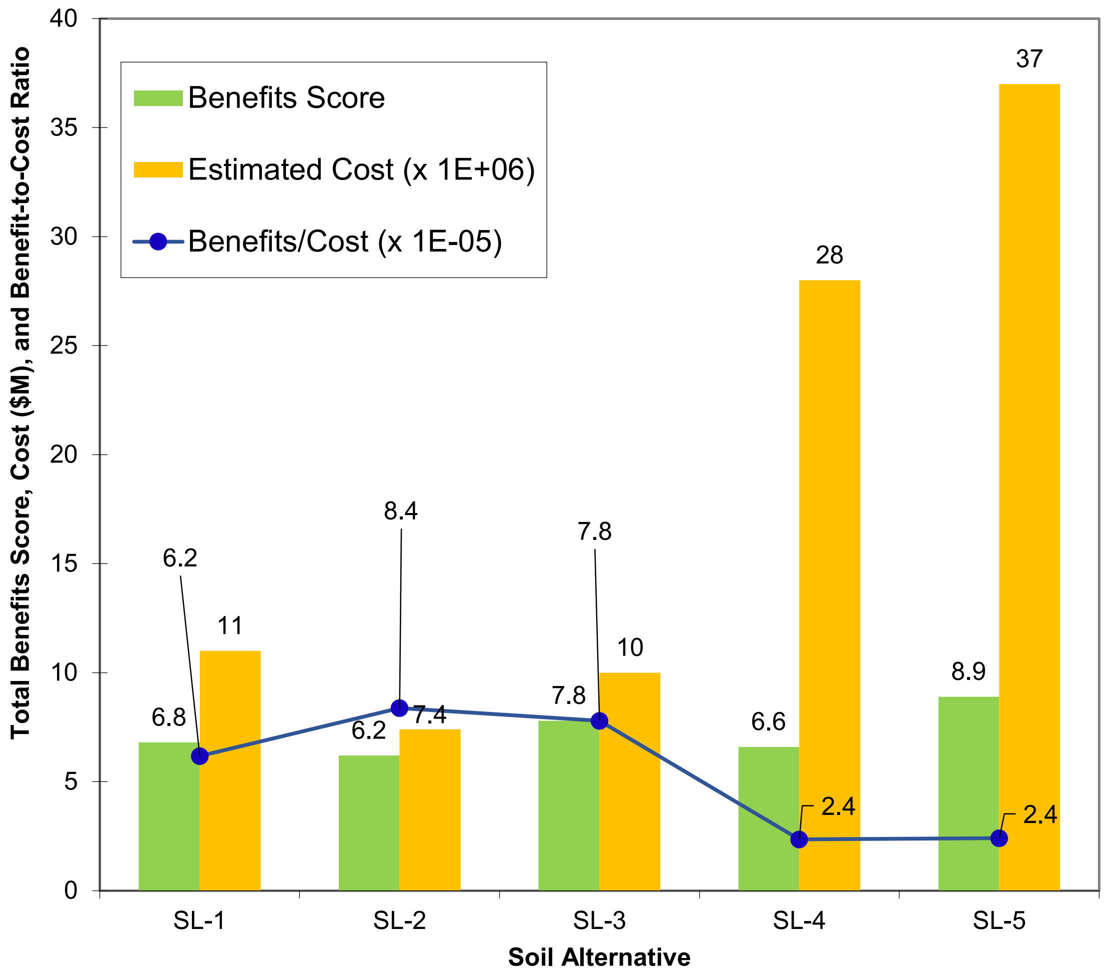
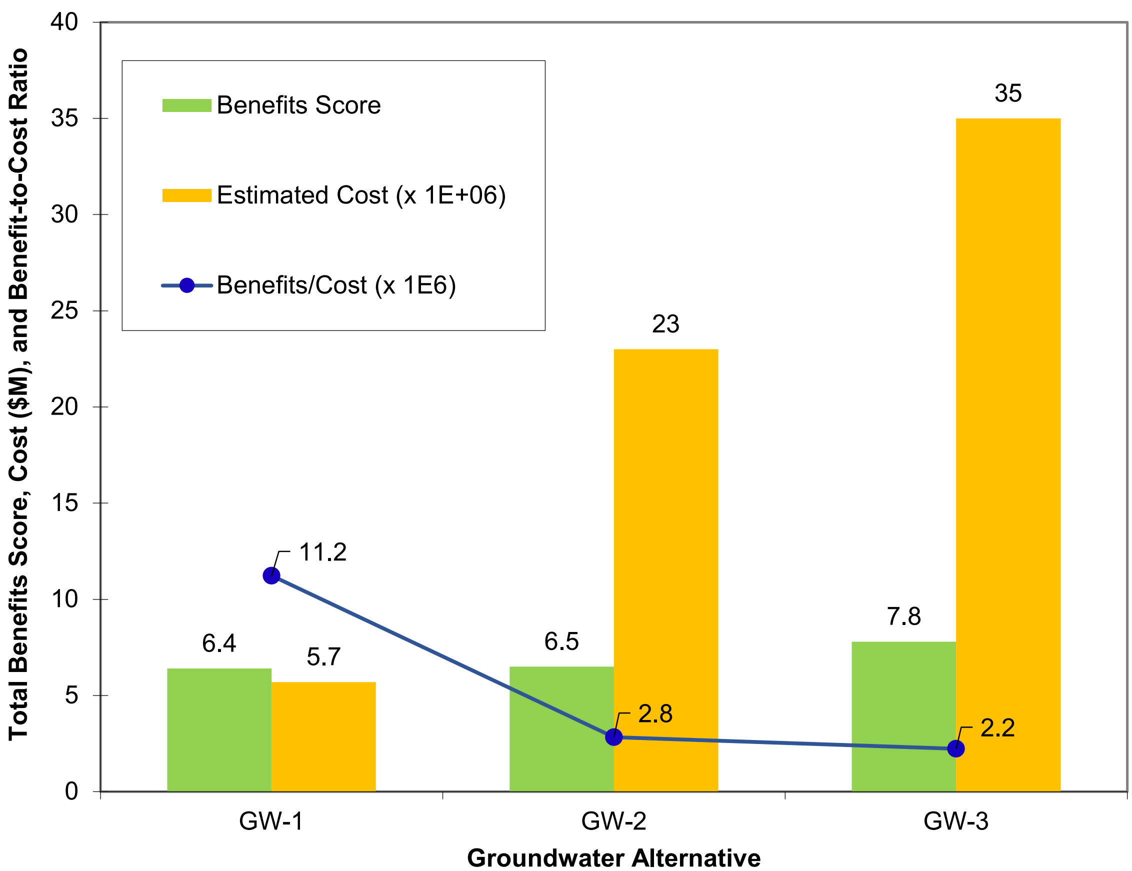


TITLE:	**Disproportionate Cost Analysis for the Soil Remediation Alternatives**
LOCATION:	**Rayonier Mill Study Area, Port Angeles, WA**

TETRA TECH

CHECKED:	GWC	FIGURE:
DRAFTED:	LMG	**6-1**
PROJ:	7304023	
DATE:	5/13/2021	

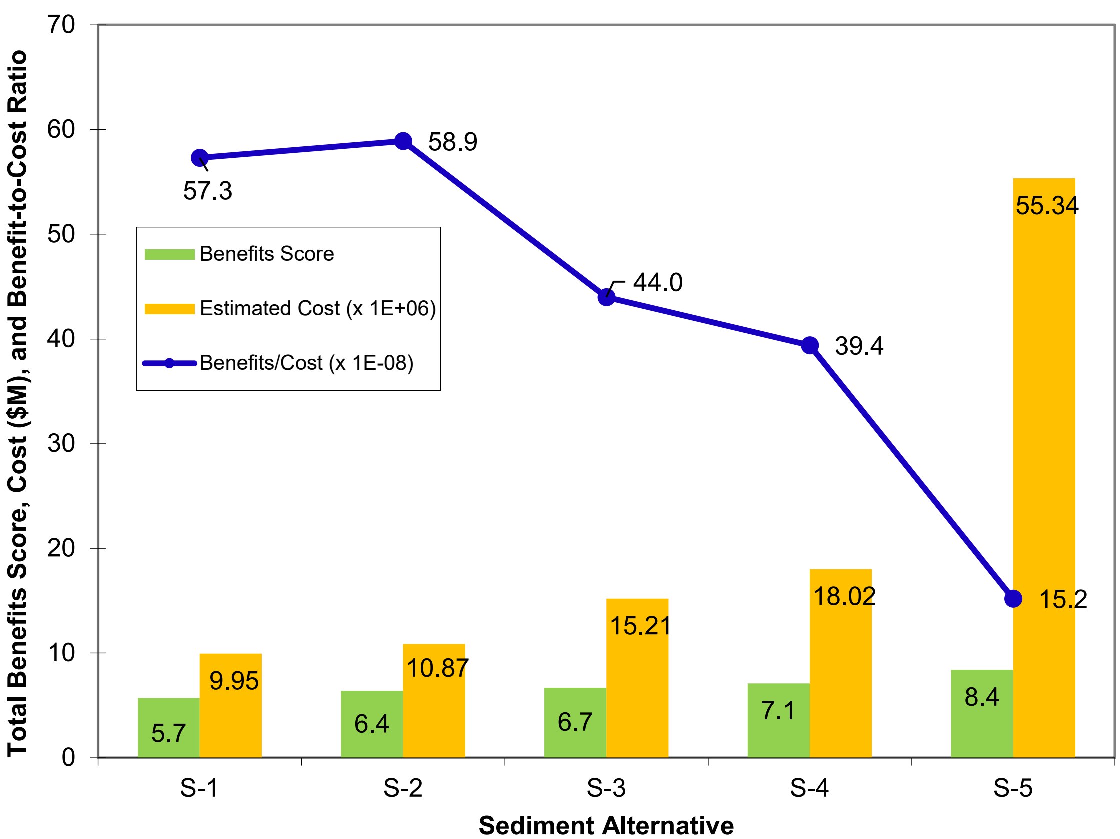


TITLE: **Disproportionate Cost Analysis for the Groundwater Remediation Alternatives**

LOCATION: **Rayonier Mill Study Area, Port Angeles, WA**

TETRA TECH

CHECKED:	GWC	FIGURE:	**6-2**
DRAFTED:	LMG		
PROJ:	7304023		
DATE:	5/13/2021		



TITLE:	**Disproportionate Cost Analysis for the Sediment Remediation Alternatives**
LOCATION:	**Rayonier Mill Study Area, Port Angeles, WA**

TETRA TECH

CHECKED:	GWC	FIGURE:
DRAFTED:	SO	**6-3**
PROJ:	7304023	
DATE:	5/13/2021	

APPENDIX A

INDICATOR HAZARDOUS SUBSTANCES AND PRELIMINARY CLEANUP LEVELS IN SOIL AND GROUNDWATER

TETRA TECH

MEMORANDUM

To:	Marian Abbett, Washington State Department of Ecology
From:	Gregory W. Council
CC:	Warren Snyder, Rayonier Advanced Materials; John Lang, EHS Support
Date:	July 1, 2019
Subject:	Port Angeles Site: Selection of Indicator Hazardous Substances, Preliminary Cleanup Levels, and Remediation Levels for Groundwater and Soil

1.0 INTRODUCTION

This memorandum describes the selection of indicator hazardous substances (IHSs) and preliminary cleanup levels (PCULs) for groundwater and soil at the former Rayonier mill site (Site) in Port Angeles, Washington. Selection of IHSs and identification of PCULs are done in accordance with the provisions of the Model Toxics Control Act (MTCA) regulations as presented in Chapter 173-340 of the Washington Administrative Code (WAC).

This memo also presents the derivation of soil remediation levels (RELs) protective of direct-contact exposure for an occasional site visitor/trespasser. These RELs may be used in select remedial alternatives to define (reduced) areas where active remedial measures are employed.

Industrial activities at the Site over a period of decades led to elevated concentrations of certain chemicals in soil, groundwater, and sediment. Rayonier A.M. Properties LLC (the company[1]),has been addressing contamination through a variety of investigation and remediation activities. In accordance with the 2010 Agreed Order DE 6815 with the Washington Department of Ecology (WDOE), the company commissioned an *Interim Action Report Volume I: Upland Data Summary Report (Volume I Report)* (GeoEngineers 2012). That report provided an initial identification of contaminants of potential concern (COPCs) for soil and groundwater along with screening levels. This memorandum updates that analysis to use current screening levels and to address comments provided by WDOE on selection of IHSs and PCULs provided in comments on two draft versions of the *Interim Action Report Volume III: Alternatives Evaluation (Volume III Report)* (Windward and GeoEngineers 2015; Tetra Tech 2018) and recent discussions with WDOE.

1.1 GROUNDWATER PROTECTION BASIS

As described in the *Volume I Report* and in accordance with MTCA (WAC 173-340-720), groundwater cleanup standards are based on protection of (1) marine surface water and (2) marine sediment. Groundwater is not classified as potable at this Site for purposes of defining cleanup standards because these conditions, as specified in the rule (WAC 173-340-720), apply:

- Groundwater is not a current source of drinking water (720(2)(a))

[1] Rayonier A.M. Properties LLC (formerly known as Rayonier Properties LLC) is the current owner of the property and is responsible for the project. In this document, "company" refers to Rayonier A.M. Properties LLC and its corporate predecessors.

- It is unlikely that contaminated groundwater will transport to groundwater that is a current or potential future source of drinking water (720(2)(c))
- There are known or projected points of entry into surface water (720(2)(d)(ii))
- Surface water is not a domestic water supply source (720(2)(d)(iii))
- Groundwater is sufficiently hydraulically connected to surface water that the groundwater is not practicable to use as a drinking water source (720(2)(d)(iv))

Therefore, Site-specific groundwater cleanup standards are set to protect the downgradient environment, namely marine surface water and marine sediment. This includes protection of aquatic life and protection of humans who may consume organisms from the marine environment.

For protection of marine surface water, the relevant standards are referenced in WAC 173-340-730. The standard Method B surface-water cleanup standards are used to define cleanup levels for Site groundwater. Surface-water PCULs are developed through consideration of several rule-specified sets of state and national water quality standards:

- Washington surface water quality standards for protection of marine aquatic life (acute and chronic) and human health (consumption of organism only) as listed in Table 240 of WAC 173-201A;
- National recommended water quality standards for protection of marine aquatic life (acute and chronic) and human health (consumption of organism only) as published under section 304 of the Clean Water Act; and
- The National Toxics Rule criteria applicable in Washington, as provided in Chapter 40 of the Code of Federal Regulations, Part 131 (standards provided for human health only).

For constituents that do not have a protective human-health based standard derived from one or more of the above sources, MTCA provides for use of risk-based calculations based on fish consumption (Equation 730-1 for non-carcinogens and Equation 730-2 for carcinogens).

For protection of marine sediment, equilibrium-partitioning calculations are made to define groundwater concentrations that will not lead to an exceedance of a sediment cleanup objective (SCO) for the Site, as defined in the 2018 draft V*olume III Report*. This is done using a two-phase (water-sediment) equilibrium partitioning equation, which can be derived from Equation 747-1 in WAC 173-740-747 for water-saturated conditions (air-filled porosity is zero and no dilution):

$$C_w = \frac{C_t \cdot UCF}{\left(K_d + \frac{\theta}{\rho_b}\right)}$$

In this equation, the water-filled (total) porosity (θ) is assumed to be 43% and the (dry) bulk density (ρ_b) is assumed to be 1.5 kilograms per liter (kg/L); these are default values for soil as listed in WAC 173-340-747. The unit conversion factor (*UCF*) is 1000 µg/mg. The partitioning (sorption) coefficient (K_d) varies by chemical and, for each organic chemical, is taken to be the product of the organic-carbon partitioning coefficient (K_{oc}) and the fraction of organic carbon in sediment (f_{oc}) which is assumed to be 3.3% based on the average of Site sediment organic-carbon measurements (Windward 2012, Table 2-13). Some SCOs are defined in units of mass (mg) of contaminant per mass (kg) of organic carbon. In these cases, the SCOs are multiplied by the average organic-carbon content (3.3%) to obtain a total sediment concentration (c_t) expressed as mass of contaminant per mass of (dry) sediment. This is the sediment concentration that is used to develop the protective pore-water concentration (c_w).

For a given contaminant, if the groundwater concentration determined to prevent exceedance of an SCO is lower than the concentration determined to meet all relevant marine-surface-water criteria, then the SCO-based groundwater concentration is taken to be the PCUL for Site groundwater; otherwise, the surface-water-based groundwater concentration is selected as the PCUL. In either case, the PCUL may be adjusted so that it is no greater than the natural background concentration in groundwater or the practical quantitation limit (PQL) for the contaminant.

The groundwater PCULs apply by default to all groundwater below the water table at any location impacted by Site activities; this is the standard groundwater point of compliance under MTCA. Conditional points of compliance near the locations of groundwater discharge to the marine environment may be proposed for one or more remediation alternatives as part of the *Volume III Report*. Conditional points of compliance are not discussed in this memorandum.

1.2 SOIL PROTECTION BASIS

Consistent with MTCA, PCULs for soil are defined in this memorandum for protection of:

- Human health by direct contact with contaminated Site soil (i.e., exposure via ingestion and/or dermal contact);
- Terrestrial ecological receptors; and
- Site groundwater by leaching.

For the direct-contact route, unrestricted-use standard Method B cleanup levels are defined in accordance with WAC 173-340-740. While portions of the Site qualify for treatment as industrial land, industrial use is not assumed for all parts of the Site and therefore unrestricted-use cleanup levels are used to define IHSs and set the most protective PCULs for consideration. Soil PCULs protective of direct contact apply by default to the upper 15 feet of soil at the Site (standard point of compliance).

A *Terrestrial Ecological Evaluation* (TEE) was conducted by Malcom Pirnie (2007) and later updated by GeoEngineers as part of the 2015 draft *Volume III Report*. The updated TEE identifies the contaminants that are ecological risk drivers for the Site and Site-specific concentrations that are protective of ecological receptors. WDOE provided comments on the TEE, noting that:

- Plants and soil biota should not be ruled out as potential future ecological receptors in the west mill area of the Site; and
- Petroleum hydrocarbons should be further considered as a potential ecological risk driver for the Site.

In this memorandum, the concentrations previously determined to be appropriate cleanup levels for protection of Site plants, soil biota, and wildlife are assumed to apply to all areas of the Site. Also, the WDOE-recommended ecological cleanup level of 200 milligrams per kilogram (mg/kg) for diesel-range petroleum hydrocarbons (as specified in Table 749-3 of the MTCA rules) is used in setting PCULs for soil. By default, the ecological PCULs apply to the upper 15 feet of soil at the Site (standard point of compliance).

In accordance with WAC 173-340-747, soil concentrations for groundwater protection are derived using the fixed-parameter three-phase partitioning model. This method defines unsaturated-zone and saturated-zone soil concentrations that ensure groundwater cleanup levels will not be exceeded due to leaching from contaminated soil. The groundwater PCULs derived in this memo are used as the basis for determining soil concentrations protective of groundwater and the downgradient marine environment. These PCULs apply throughout the Site (standard point of compliance): the unsaturated-zone leachability levels apply above the water table and the saturated-zone leachability levels apply at all depths below the water table.

As with groundwater, soil PCULs may be adjusted upward if needed to be no greater than natural background concentrations in soil (WDOE 1994) or PQLs.

Conditional points of compliance for soil (ecological criteria) consistent with the MTCA rules may also be considered when defining and comparing remediation alternatives, and RELs may be used to define where remediation technologies are applied in different remediation alternatives. Consideration of conditional points of compliance is not part of this memorandum. RELs based on protection of occasional Site visitors/trespassers are derived in Section 7 of this memorandum.

2.0 INDICATOR HAZARDOUS SUBSTANCES SELECTION OVERVIEW

Concentrations have been measured in Site soil and groundwater for over 200 chemicals. A database of concentration data was provided by the company. These validated data correspond to the data listed in Appendix E of the *Volume I Report*. The data reflect measured Site conditions between 1991 and 2011 at soil and groundwater sampling locations. Data from soil samples in areas where soil was subsequently removed as part of prior remedial actions are not included in the database, but data from excavation-sidewall and excavation-bottom confirmation samples are included.

When establishing cleanup requirements under MTCA, hazardous substances that contribute a small percentage of the overall threat to human health and the environment may be removed from consideration (WAC 173-340-703). The procedure used in this memorandum involves consideration of the seven factors identified in MTCA rules to develop a proposed list of indicator hazardous substances (IHSs) for WDOE's approval.

The hierarchy in the following procedure steps is sequential. If a chemical is determined in any step to not be an IHS for the Site, then this chemical is not considered in the subsequent steps.

2.1 STEP 1: PRE-SCREENING

In a few instances, concentrations are measured for constituents that are not considered to be toxic and are not regulated as hazardous substances. Such constituents include major ions in water (e.g. calcium, potassium, magnesium, and sodium), lignin, tannin, and coliforms. These substances are not considered in the screening process.

Also, in some cases, related chemicals are grouped together for the purposes of evaluating toxicity and risk. Rather than evaluating several chemicals individually, the concentrations for the chemicals may be combined into a total concentration or total toxic-equivalent (TEQ) concentration that can be compared to published standards. In these cases, only the total or TEQ concentration is used in the screening process.

2.2 STEP 2: THOROUGHNESS EVALUATION

Consistent with a MTCA-based IHS-selection process, thoroughness of testing is considered by evaluating whether sufficient data, of sufficient quality, are available to define whether each chemical represents a potential threat to human health or environment as a result of Site operations [WAC 173-340-703(2)(e)]. The significance of the thoroughness evaluation is ultimately tied to each chemical's association with historical Site operations. If the nature and extent of a chemical's presence at the Site is not reasonably affected by historical Site operations (and there has been no indication of actual site contamination) then there is no cause for concern about the thoroughness which that chemical has been evaluated at the Site.

Data for all chemicals analyzed at the site are reviewed to consider whether the spatial and temporal distribution of concentration data provide sufficient basis to evaluate whether or not the chemical presents a significant threat to human health and the environment. This review also includes consideration of whether artificially elevated analytical reporting limits prevent adequate comparison of concentration data with MTCA cleanup levels. This thoroughness review includes consideration of: (1) the number of samples analyzed, (2) the adequacy of analytical reporting limits, (3) the adequacy of the spatial distribution of samples across the site and in areas of specific operational interest, and (4) the adequacy of data in characterizing post-operations and/or post-remedy conditions at the Site.

If data are found not to be thorough, the chemical may not be eliminated due to lack of detections or detections below the PCUL in subsequent steps of this process unless the chemical is found not to be a Site-related chemical. If a chemical meets any of the following criteria, it is considered to be a Site-related chemical:

1) The chemical is known or reasonably suspected to have been associated with historical Site operations;
2) The chemical is a degradation by-product of a chemical known or reasonably suspected to have been associated with historical Site operations; consistent with a MTCA-based IHS-selection process, degradation byproducts of Site-related chemicals are also considered in this step [WAC 173-340-703(2)(g)].; or
3) The chemical is reasonably likely to demonstrate higher-than-normal concentrations as a result of Site-related changes to subsurface conditions.

Chemicals that are clearly not Site-related may be screened out at this step; however, to be conservative, chemicals were not removed from consideration due to lack of historical Site use in this thoroughness evaluation step. Lack of known or suspected historical site use was considered as a line of evidence in IHS screening associated with the review of detection frequency (Section 2.3) and toxicological characteristics (Section 2.4).

2.3 STEP 3: DETECTION FREQUENCY

Consistent with a MTCA-based IHS-selection process, frequency of detection is reviewed to consider whether each chemical represents a significant threat to human health or the environment [WAC 173-340-703(2)(f)]. The detection frequency of each chemical is tabulated and those chemicals that are never detected (and have been thoroughly tested) are screened from further consideration.

Chemicals analyzed in only a few samples, all with non-detect results, may be removed from further consideration as an IHS if the chemical is not associated with (or expected to be naturally present and affected by) historical Site operations.

2.4 STEP 4: TOXICOLOGICAL CHARACTERISTICS

Consistent with a MTCA-based IHS-selection process, the toxicological characteristics of each remaining chemical are next considered [WAC 173-340-703(2)(a)]. PCULs are developed in accordance with MTCA rules to define the most protective concentration for each chemical based on toxicity characteristics of the chemical. The PCULs represent threshold concentrations that define levels above which chemicals may present an unacceptable risk.

Once the protective PCUL is defined for a chemical, the measured concentrations for the chemical are compared to the PCUL. If the maximum measured concentration exceeds the PCUL, then the chemical is retained as a potential IHS and evaluated further. Otherwise the chemical is screened out as an IHS (unless it is a degradation byproduct of a potential IHS).

2.5 STEP 5: COMPARISON TO BACKGROUND

Consistent with a MTCA-based IHS-selection process, natural background concentrations [WAC 173-340-703(2)(d)] are considered next. If the toxicity-based PCUL for a chemical is less than the natural background concentration for that chemical, then the PCUL is revised to be the natural background concentration. A chemical may be screened out if it has never been detected above the natural background concentration.

2.6 STEP 6: CHEMICAL AND PHYSICAL CHARACTERISTICS

Consistent with a MTCA-based IHS-selection process, chemical and physical characteristics of each chemical are considered in the final screening step, particularly the mobility and persistence of individual chemicals [WAC 173-340-703(2)(b) and (c)]. A chemical that is by nature ephemeral, subject to rapid degradation, or highly unlikely to reach any reasonable exposure endpoint due to its nature may be eliminated from IHS consideration at this step.

In some cases, especially for groundwater, temporal data may show that a chemical was measured above the PCUL in the past and subsequently concentrations declined to below the PCUL at all measurement locations. As long as data are sufficient to show that the concentrations throughout the Site have likely declined to below the PCUL, the chemical can be screened out from IHS consideration at this step.

Another element considered during the chemical and physical characteristics review is similarity of spatial distribution with chemicals of similar (or greater) toxicity and persistence. If one of the similar chemicals consistently presents a much lower risk than the others – which may be quantified by a lower ratio of measured concentrations to the PCUL – then the lower-risk chemical may be eliminated in favor of using the similar higher-risk chemical as an IHS.

2.7 STEP 7: FINAL IHS SELECTION

After screening is complete, a preliminary set of groundwater and soil IHSs are defined, together with PCULs. Groundwater and soil contamination maps are then prepared to show where PCULs are exceeded at the Site. Evaluation of these maps allows a final elimination of IHSs that contribute a small percentage of the overall threat to human health and the environment, resulting in a more manageable set of IHSs that will still ensure protection of human health and the environment (WAC 173-340-703(1)).

Also, during this final IHS selection step, spatial relationships between the groundwater plumes and measured soil concentrations can be evaluated to make an empirical evaluation of leachability from soil consistent with WAC 173-340-747(3)(f).

3.0 GROUNDWATER IHS SCREENING

3.1 PRE-SCREENING

Six constituents measured in groundwater (calcium, magnesium, potassium, sodium, tannin/lignin, and total coliforms) are not regulated as hazardous substances and are therefore eliminated from IHS consideration.

Per MTCA rules, individual carcinogenic polycyclic aromatic hydrocarbons (cPAHs) are combined into a single TEQ concentration of benzo(a)pyrene for purposes of establishing a groundwater PCUL. Therefore, the seven individual cPAHs are not retained for IHS consideration nor is the total benzofluoranthene concentration that includes two of these individual cPAHs. Total cPAHs (expressed as benzo(a)pyrene TEQ concentration) is evaluated further as a potential IHS.

Likewise, polychlorinated dibenzo-*p*-dioxins and dibenzofurans (collectively called “dioxin” or “dioxin chemicals”) are regulated under MTCA using a TEQ approach with total concentrations expressed as 2,3,7,8-tetrachlorinated dibenzo-*p*-dioxin TEQ concentrations. The individual dioxin compounds and total homologue-group concentrations are not considered in the screening process. Dioxin (expressed as a TEQ total concentration) is evaluated further as a potential IHS.

Measurements for seven polychlorinated biphenyl (PCB) products (Aroclors) have been made at the Site for 145 groundwater samples. Three PCB products were never detected, two others were detected only once, and the other two were detected nine and ten times, respectively. Under MTCA, the total PCB concentration is used for evaluation of risk and compliance and specific PCB compounds or products are not considered in the screening process. Therefore, total PCBs are evaluated further as a potential IHS.

To facilitate comparison to PCULs, data for specific isomers of xylene were combined with total xylene data and individual isomers are not included in the screening. The single detection of m,p-cresol (total of two isomers) was assumed to represent the more toxic m-cresol while the non-detects were included with other data for both isomers (p-cresol is listed by its other name, 4-methylphenol, in the database); thus m,p-cresol data are not used in screening. Similarly, two 1991 measurements of 1,2-dichloroethene are assumed to be the more toxic cis-1,2-dichloroethene isomer. There are two measurements for "chlordane" (both non-detects) which match measurements for alpha-chlordane in the same samples; therefore, chlordane is not considered in the screening analysis, but isomers of chlordane are considered.

3.2 THOROUGHNESS OF TESTING

Groundwater testing at this Site has been thorough. **Table 1** summarizes the thoroughness evaluation for chemicals measured in groundwater samples. The database used for this evaluation contains measurements for all toxic chemicals and chemical classes that can reasonably be expected to be Site-related. For all constituents that are potentially Site-related, measurements have been made at wells and groundwater grab (GWG) locations throughout the Site and multiple measurements have been made at most wells over a time span of many years. Reporting limits have been reasonable PQLs for the time periods of data collection; in many cases the reporting levels have decreased over time as analytical methods have improved. State-of-the-art PQLs were used as reporting levels for the last several rounds of data collection in 2010-2011.

In **Table 1**, chemicals that have been measured fewer than thirty times or that have been measured at fewer than ten locations are identified as potentially not thoroughly tested. Only chemicals that are not Site-related are identified as being measured few times. Past investigations have been designed to preferentially evaluate areas of known or suspected impacts based on past operations.

No thoroughness issues are identified for further evaluation.

3.3 DETECTION FREQUENCY

Chemicals that have been measured at least thirty times at the Site at ten or more different locations spread throughout the Site but never detected are identified in **Table 2**. These chemicals are screened out as potential IHSs.

A few chemicals have fewer than thirty measurements which are all non-detects. In several cases, there is no reason to believe that there would be Site-related impacts for these chemicals, so the thoroughness test is not judged to be applicable and the chemicals are screened out. Details are provided in **Table 3**.

3.4 TOXICOLOGICAL CHARACTERISTICS

Per MTCA rules, surface-water PCULs (applicable to groundwater at this Site) are developed through consideration of several rule-specified sets of state and national water quality standards as summarized in Section 1.1. **Table 4** identifies these applicable standards for the chemicals that passed previous screening steps. For constituents that do not have a listed human-health based marine surface-water quality standard, and for manganese[2], the standard Method B formulae and assumptions (Equations 730-1 and 730-2) were used to develop human-health protective water concentrations based on fish consumption. If available, these Method B human-health criteria were taken directly from the Cleanup Levels and Risk Calculation (CLARC) data tables published by WDOE in July 2015. Otherwise they were calculated using the standard assumptions for Equations 730-1 and 730-2 with published data on toxicity and fish bioconcentration available from the web-based Risk Assessment Information System maintained by the Oak Ridge National Laboratory, or other appropriate sources (**Table 5**).

For the chemicals that passed initial screening and are also identified as IHSs in sediment (in the 2018 draft *Volume III Report*), a groundwater concentration protective of sediment is also calculated (**Table 6**) using the methodology described in Section 1.1.

Table 7 lists the chemicals that have never been detected above their toxicity-based PCULs. These chemicals are eliminated as potential IHSs.

3.5 COMPARISON TO BACKGROUND

The toxicity-based PCUL for arsenic is lower than the MTCA-specified natural background concentration of arsenic in groundwater: 5 µg/L. Therefore, the PCUL for arsenic is adjusted upward to 5 µg/L. No other chemical has an established natural background level in groundwater that is above the toxicity-based PCULs listed in **Table 4**.

3.6 CHEMICAL AND PHYSICAL CHARACTERISTICS

Table 8 lists chemicals that were detected above PCULs at some point in time but later declined to be strictly below PCULs and are judged to no longer be present above their PCULs at the Site. Pertinent details of the data for each of these chemicals are summarized in the table.

Several additional chemicals are screened out as potential IHSs based on chemical-specific characteristics and weight-of-evidence considerations. **Table 9** provides the rationales for screening these out as insignificant risk drivers, consistent with MTCA rules [WAC 173-340-703(2)(b) and (c)].

Table 10 shows the resulting list of nineteen groundwater IHSs that results from this screening process along with their PCULs. Note that the toxicity-based PCULs for a few IHSs have been adjusted upward to the PQLs (as achieved in the last rounds of sampling for the listed chemicals) as specified in MTCA rules.

In addition to the IHSs listed in the **Table 10**, field-measured pH will be used to evaluate MTCA compliance for groundwater. While pH is not a hazardous substance, it is a regulated water quality parameter in surface water. Per Chapter 173-201A of the Washington Administrative Code (WAC), Port Angeles Harbor is designated as “excellent quality” for aquatic life uses and the pH must be within the range of 7.0 to 8.5 for this use designation, unless the pH deviation is not caused by human actions.

[2] The surface-water PCUL for manganese was initially determined to be 100 µg/L based on the Clean Water Act value for human-health protection (fish ingestion). WDOE reviewed the basis for this value and determined that the 100 µg/L level is a recommended value without any health effects rationale. MTCA requires cleanup levels be set for the protection of human health and the environment and applicable state and federal laws must be considered. Recommendations that are not based on protection for health effects or environmental effects need not be adopted as cleanup levels. Therefore, the Clean Water Act value of 100 µg/L is not an applicable or relevant and appropriate requirement. WDOE recommended setting a PCUL based on Method B calculation.

4.0 SOIL IHS SCREENING

4.1 PRE-SCREENING

As with groundwater, calcium, magnesium, potassium, and sodium are not considered in soil IHS screening because these natural inorganic elements are not regulated as hazardous substances. Also, total TEQ concentrations are used to evaluate cPAHs and dioxin, and total PCB concentrations are used rather than individual PCB compounds or products (Aroclors). Therefore, the individual dioxin, cPAH, and PCB compounds, mixtures, and congener totals are not included in IHSs screening for soil except as contributing elements to their respective total TEQ concentrations. Total cPAHs (TEQ), dioxin (TEQ), and PCBs, are each retained as potential IHSs.

4.2 THOROUGHNESS OF TESTING

Soil testing at this Site has been thorough. **Table 11** summarizes the thoroughness evaluation for chemicals measured in soil samples. The database used for this evaluation contains measurements for all toxic chemicals and chemical classes that can reasonably be expected to be Site-related. For all key constituents, measurements have been made at many locations throughout the Site and at multiple depths. Reporting limits have been reasonable PQLs for the time periods of data collection; in many cases the reporting levels have decreased over time as analytical methods have improved. State-of-the-art PQLs were used as reporting levels for the latest data in the database (2010-2011).

In **Table 11**, chemicals that have been measured in fewer than thirty samples or at fewer than ten map locations are identified as potentially not thoroughly tested. Past investigations have been designed to preferentially evaluate areas of known or suspected impacts based on past operations.

No thoroughness issues are identified for further evaluation.

4.3 DETECTION FREQUENCY

Chemicals that have been measured at least thirty times in Site soil at ten or more different map locations spread throughout the Site but never detected are identified in **Table 12**. These chemicals are eliminated from consideration as potential soil IHSs.

A few chemicals have fewer than thirty measurements which are all non-detects. In several cases, there is no reason to believe that there would be Site-related impacts for these chemicals, so the thoroughness test is not judged to be applicable and the chemicals are screened out. Details are provided in **Table 13**.

4.4 TOXICOLOGICAL CHARACTERISTICS

For chemicals that pass the prior screening steps, the standard Method B risk equations and assumptions are used to define soil concentrations protective of human health by direct contact (incidental soil ingestion) for an unrestricted land use scenario (**Table 14**). These concentrations are taken directly from the WDOE CLARC data tables where available. For several chemicals, no Method B concentrations or toxicity values are listed in the CLARC tables (or the values are outdated), and appropriate values are calculated using toxicity data from other available sources (**Table 15**). In each of these cases the standard Method B exposure assumptions are used. For chemicals that have both cancer and noncancer values, the lower concentration is used as the concentration protective of direct contact by humans. For a few constituents that have no Method B concentrations listed in the CLARC tables, the MTCA Method A values are used as the concentrations protective of human health.

Soil concentrations protective of potential ecological receptors – including terrestrial wildlife, plants, and soil biota – have been defined in the 2007 TEE and the TEE update included in the 2015 draft *Volume III Report*. These concentrations are defined for three chemicals determined to be potential ecological risk drivers at the Site: antimony, zinc, and dioxin (TEQ) (**Table 14**). Based on TEE comments provided by WDOE, a fourth potential ecological risk driver has been added to the list: total diesel-range petroleum hydrocarbons. The WDOE-recommended protective concentration of 200 mg/kg (from Table 749-3 of the MTCA rules) is also included in **Table 14**.

For chemicals that pass the initial soil screening and are also identified as groundwater IHSs, equilibrium partitioning equations are used to define unsaturated-zone and saturated-zone soil (total) concentrations that are protective of groundwater (and therefore protective of the downgradient marine environment). The calculations, shown in **Table 16**, use the MTCA-specified Equation 747-1 and default assumptions.

Table 17 lists the chemicals that have never been detected above their toxicity-based PCULs. These chemicals are eliminated as potential IHSs.

4.5 COMPARISON TO BACKGROUND

Table 14 also shows the natural background concentrations for certain inorganic chemicals in Clallam County (WDOE, 1994). For arsenic, the natural background concentration (20 µg/kg) is taken from the MTCA rule tables. Arsenic, copper, manganese, mercury, nickel, and zinc have natural background concentrations greater than their respective toxicity-based PCULs. The final PCULs are therefore adjusted to be the natural background concentrations for these chemicals.

4.6 CHEMICAL AND PHYSICAL CHARACTERISTICS

Several additional chemicals are screened out as potential IHSs based on chemical-specific characteristics and weight-of-evidence considerations. **Table 18** provides the rationales for screening these out as insignificant risk drivers, consistent with MTCA rules.

After this screening, there are nineteen chemicals remaining as IHSs, as listed in **Table 19** along with their PCULs. Note that applicable soil PCULs are listed in **Table 19** for unrestricted-use direct contact, protection of terrestrial ecological receptors, and protection of groundwater above and below the water table. Different soil PCULs may apply for different areas and depths in remediation alternatives. Also note that the toxicity-based PCULs for a few IHSs have been adjusted upward to PQLs (as achieved in the last rounds of sampling for the listed chemicals) as specified in MTCA rules.

5.0 IHS REVIEW AND SELECTION

Plume maps were developed for all preliminary groundwater IHSs and for groundwater pH. While selection of IHSs, and remediation decisions generally, are not based on a single snapshot in time, plume maps require selecting one data point for each well for plotting purposes. For the groundwater plots in this memo, the last available measurement at each point is used to develop contour maps. In most cases, the last measurement was in the second quarter of 2011; however, for some wells and some parameters, only earlier data are available. Each plume was developed using kriging as the interpolation method with the Golden Software Surfer program and default variogram parameters. Interpolation was done using the log of concentration except for pH which is already a log-transformed value.

Maps were also prepared to show measured concentrations in soil relative to PCULs. In most cases, color-coded circles are used to indicate where different types of PCULs (direct contact, ecological, or leachability-based) are exceeded at sample points. In several cases, depth ranges are used to filter the data in a way that helps show the prevalence of contamination at different depth intervals relevant for MTCA compliance and for remedial strategies. These figures also show where prior interim actions were taken to remove soil from certain areas of the Site.

5.1 pH

Figure 1 shows the measured pH of Site groundwater. The posted pH values are those last measured in the field at monitoring wells or in GWG samples. While pH is not a hazardous substance, it is a regulated water quality parameter in surface water and the groundwater quality standards for this Site are taken to be those of the downgradient surface water. Per Chapter 173-201A of the Washington Administrative Code (WAC), Port Angeles Harbor is designated as “excellent quality” for aquatic life uses and the pH must be within the range of 7.0 to 8.5 for this use designation, unless the pH deviation is not caused by human actions. As evident in **Figure 1**, most of the Site groundwater has a pH slightly less than the allowable range (more acidic) – shown in a red shade (including several wells near the shoreline both east and west of Ennis Creek). This is true not only in the main process area west of Ennis Creek, where acids were used in the pulp-making process, but also in several wells in the southern (upgradient) areas of the Site where one would expect pH to be less affected by Site activities. The lowest measured pH shown (5.83) is at MW-70 east of Ennis Creek, relatively far from the main acid-using processes. All other pH measurements are 6.19 and greater. The spatial pattern of pH values less than 7.0 in groundwater does not suggest a Site process source.

High pH (basic) groundwater, greater than 8.5, is present in a few locations of the Site and is likely tied to release of ammonia (see Section 2.2) and possibly other high-pH chemicals used in the main process areas. The highest measured pH (11.44) was at MW-56 near the shoreline between the dock and the mouth of Ennis Creek.

Conclusion: pH is a groundwater IHS with a PCUL of between 7.0 and 8.5 for protection of surface-water aquatic life.

5.2 AMMONIA

Ammonia (expressed as un-ionized nitrogen) was elevated relative to its PCUL of 35 µg/L at a few locations, as shown in **Figure 2**. The three wells with elevated pH also had the highest levels of ammonia, which forms a basic solution in water. The ammonia concentration at MW-28 and MW-29 was between 287 and 373 µg/L, and the ammonia concentration at MW-56 (where pH was highest) was approximately 2,250 µg/L. Three wells along the shoreline adjacent to MW-56 (MW-51, MW-62, and PZ-3) had concentrations above 35 µg/L in November 2010 or February 2011, but the concentration in each of these wells had declined below 35 µg/L by May 2011. Slightly elevated ammonia concentrations (less than three times the PCUL) were measured at MW-20, MW-57 and MW-66. Ammonia was also elevated relative to the PCUL in three GWG samples collected in 2010. The data for **Figure 2** are the most recent measured (and calculated) concentrations of un-ionized ammonia nitrogen at each measurement location. For most locations, these measurements were made in the second quarter of 2011. GWG samples[3] were collected in 2010; these locations and other locations that do not have 2011 data are marked on the figure.

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[3] Note that GWG sample results were intended for screening only (GeoEngineers, 2012). However, the concentration results for many groundwater IHSs (including ammonia) were higher than typical monitoring-well concentrations. The results from GWG samples are used in this memo to develop conservative depictions of groundwater plumes. Consideration may be given to installing monitoring wells if (and where) the past GWG samples drive remediation decisions.

Conclusion: Ammonia is a groundwater IHS with a PCUL of 35 µg/L for protection of surface-water aquatic life. Ammonia is not a soil IHS; it was screened out because ammonia does not partition appreciably to soil (and thus no soil concentration data are available).

5.3 ARSENIC

Seven Site wells had arsenic concentrations greater than the 5.0 µg/L (natural background) PCUL in the second quarter of 2011. The greatest measured concentration in a well was 15.3 µg/L at MW-59 in the East Mill Area immediately north of the former Spent Sulfite Liquor (SSL) Lagoon. Arsenic was also elevated in three unfiltered GWG samples. An arsenic plume map developed from the last available concentration at each groundwater sample location is provided in **Figure 3**. Naturally-occurring arsenic can be mobilized (dissolved in groundwater or desorbed from soil) under geochemically reducing conditions, which are common throughout the Site (GeoEngineers, 2012).

Soil concentration maps in this memorandum are presented using posted circles that are color-coded based on the PCUL(s) that are exceeded, as explained in **Figure 4**. **Figure 5A** shows the measured arsenic concentrations in soil samples from the upper 2 feet of soil. In this depth horizon, there were several exceedances of the 20 mg/kg PCUL (natural background concentration) with most of the exceedances in the main process areas west of Ennis Creek; one sample in the City Purchase Area also exceeded 20 mg/kg. The industrial-use direct contact PCUL of 87.5 mg/kg is not exceeded in the City Purchase Area; this level is exceeded at four locations in the West Mill Area. The 20 mg/kg background-based PCUL is not exceeded in samples taken from depths greater than 2 feet (**Figures 5B and 5C**).

The highest arsenic soil concentrations, and most PCUL exceedances, are from the 1997 Expanded Site Investigation (ESI) (Ecology and Environment, 1998) and have potential quality-assurance issues (estimated flags due to lab duplicate or matrix spike results out of control limits; some biased high; many had low percentages of solids). Subsequent Remedial Investigation (RI) sampling in 2003 at the same or similar locations produced much lower concentrations (Integral, 2007). Soil sampling that occurred later than 2003 has also generally yielded much lower arsenic concentrations. No post-1997 sample has exceeded the industrial-use direct-contact PCUL of 87.5 mg/kg.

Empirical evidence of leachability was also considered by comparing locations where arsenic concentrations in soil are elevated (**Figure 5A**) to the arsenic plume in groundwater (**Figure 3**). There is no pattern that would suggest an ongoing source or sources of arsenic to groundwater. Rather, as stated above, it is likely that the arsenic plumes resulted from geochemically reducing conditions that mobilized the arsenic in soil. Note that the highest groundwater concentration measured (98 µg/L) was at GWG-1, but soil samples taken from that boring all had relatively low arsenic concentrations (< 4 mg/kg).

Conclusion: Arsenic is a groundwater IHS with a PCUL of 5 µg/L and a soil IHS with a PCUL of 20 mg/kg. Both PCULs are based on natural background. Based on an empirical demonstration, leachability is not a concern for arsenic. In industrial areas, the Method C direct-contact PCUL is 87.5 mg/kg.

5.4 COBALT

A full round of groundwater samples was analyzed for cobalt only once, in August 2010. For most wells both dissolved-fraction (i.e. filtered sample) cobalt and total (unfiltered) cobalt results were obtained. With one exception, the dissolved cobalt concentrations were all below the PCUL of 2.6 µg/L and it is the dissolved concentration that is important for assessing potential impacts to the marine environment because dissolved contaminants can seep with the groundwater toward the surface-water discharge locations along the shoreline. The exception was at PZ-11 where the measured dissolved concentration was 3.2 µg/L, only slightly greater than the PCUL (**Figure 6**). Where measured, the dissolved concentration of cobalt was typically much lower than total concentration of cobalt, implying that the cobalt in the total sample was largely immobile. At one other well, PZ-7, no dissolved concentration was determined, and the total cobalt concentration exceeded 2.6 µg/L. Both PZ-7 and PZ-11 are relatively far from the shoreline.

Note that cobalt is not listed in the CLARC database nor is there a surface-water standard listed among the federal and state regulations referenced in WAC 340-730, so the Method B (human-health for fish consumption) PCUL of 2.6 µg/L was calculated using a reference dose and fish bioconcentration factor obtained via the Risk Assessment Information System (RAIS) maintained online by Oak Ridge National Laboratory. The non-cancer reference dose, a Provisional Peer Reviewed-Toxicity Value (PPRTV) (EPA, 2008), includes an uncertainty factor of 3,000. The fish bioaccumulation factor (300 L/kg) is from a manual for RESRAD, a simulation program used to evaluate radionuclide transport and exposure (Yu et al., 2001).

Review of **Figure 6** and comparison to similar figures for other inorganics that are preliminary IHSs (e.g. arsenic, copper, manganese, and nickel) indicates that, relative to other IHSs, the threat of cobalt from groundwater contamination appears to be slight. Therefore, cobalt is eliminated as a groundwater IHS.

As shown on **Figure 7**, concentrations of cobalt in soil exceed the leachability-based PCULs (0.12 mg/kg and 2.3 mg/kg for saturated and unsaturated soil, respectively) that are premised on partitioning-theory modeling. **Figure 6**, however, clearly shows that cobalt is not present in the main portion of the Site at concentrations exceeding groundwater PCULs – the very PCULs that the leachability-based PCULs in soil are intended to protect. The lack of correlation between soil concentrations and nearby groundwater concentrations gives confidence that leaching to groundwater is not a significant issue for cobalt.

The unrestricted-use soil PCUL was calculated to be 24 mg/kg. This concentration was exceeded in eight of 250 samples. The maximum detection was an outlier: 84 mg/kg was measured at the GWG-5A borehole in the sample taken from 5 to 6.5 ft below ground surface (bgs). All other exceedances were between 24 mg/kg and 31 mg/kg – very close to the PCUL. Given that several other metals (e.g. arsenic, iron, lead, zinc) exceed their direct-contact PCULs by greater factors in far more samples covering the same general areas, cobalt is determined not to be a significant contributor to risk for soil. Remedial alternatives that address these other metals will also address cobalt in soil.

Conclusion: Based on a weight-of-evidence approach, cobalt is not an IHS for groundwater or soil.

5.5 COPPER

Most of the Site wells sampled in 2011 had measured concentrations of copper greater than the PCUL of 3.1 µg/L (**Figure 8**). The highest concentrations were at MW-68 (69 µg/L) and MW-56 (30 µg/L). Other wells with elevated copper were spread throughout the Site, and no spatial correlations indicative of an ongoing Site source are evident. The 3.1 µg/L PCUL is for protection of aquatic life. This PCUL is much lower than concentrations that would be protective of human health – for instance, the maximum contaminant level in drinking water is 1,300 µg/L.

Figure 9 shows the copper data from soil samples at all depths on one plot. It is evident from this figure that copper exceeded the background-based PCUL of 36 mg/kg in most soil samples (82%). This PCUL is for leaching to groundwater both above and below the water table. Moderately high concentrations (over ten times higher than background) were measured at several locations within the main process areas west of Ennis Creek. The highest copper concentrations were found within the upper 2 feet of soil (**Figure 9A**). However, most of the concentrations in the interval between 2 and 6 feet below ground surface (bgs) exceeded the background-based PCUL (**Figure 9B**), and there were several exceedances in deeper intervals (**Figures 9C and 9D**). The highest copper concentrations were from ESI sampling in 1997. The unrestricted-use direct contact PCUL (3,200 mg/kg) was exceeded only at one location in the former Pre-Fab Area just north of the City Purchase Area. This location was resampled for the RI and the result was much lower: 44 mg/kg.

The PCUL for leaching calculated by MTCA equation 747-1 would be well below background soil concentrations (**Table 16**). This implies that background soil is a potential leachability issue for the 3.1 µg/L groundwater PCUL. There is no apparent spatial relationship between the groundwater plume (**Figure 8**), and the highest soil concentrations measured at the Site (labeled in **Figure 9**). Based on this empirical demonstration, it does not appear that soil and groundwater concentrations are spatially correlated and therefore leaching is not used to set a PCUL for copper. Furthermore, using the background soil concentration of 36 mg/kg and equation 747-1 with default assumptions for the saturated zone, the groundwater concentration in equilibrium with background soil would be 1,620 µg/L.

Conclusion: Copper is an IHS for groundwater and the initial PCUL is 3.1 µg/L for protection of surface-water aquatic life. While no background concentration has been established for copper in groundwater, it is likely that the background concentration would be greater than 3.1 µg/L. Copper is not a soil IHS because the direct-contact PCUL was only exceeded in one sample which was resampled and determined to be below the PCUL, and because empirical analysis of soil and groundwater data shows that leachability is not a concern.

5.6 IRON

There are no listed federal or state surface-water standards for iron listed among the regulations cited in WAC 173-340-730. Therefore, the PCUL of 9,070 µg/L was calculated using the standard Method B formula for protection of human health by ingestion of fish. Iron was last measured in groundwater in 2002 and there were no wells at that time that had concentrations greater than this PCUL (**Figure 10**). However, there were some wells with elevated detection limits greater than the PCUL, including two wells that consistently had iron concentrations greater than the PCUL prior to 2002: PZ-4 in the digesters area of the West Mill Area and PZ-9 in the East Mill Area. Other than those two wells, exceedances of the iron PCUL were rare and limited to total (unfiltered) samples. Based on a full review of the data it can be concluded that iron was present above the PCUL in dissolved groundwater only at PZ-4 and PZ-9 and that the concentration was within approximately two times the PCUL at these two wells. Those wells are not near each other and no iron plume in groundwater can be drawn. Iron does not appear to be a significant contributor to risk for groundwater relative to other inorganic constituents such as arsenic, copper, manganese, and nickel.

Since groundwater is not a significant risk pathway for iron, and iron impacts in groundwater are quite limited, leachability from soil is not considered to be a primary risk driver. The unrestricted-use direct contact PCUL is 56,000 mg/kg (i.e. 5.6% iron by mass). There were eleven measurements above this PCUL out of 123 samples (**Figure 11**), all within the upper 3 inches of soil and all in the West Mill Area; these samples were all collected in 1997 as part of the ESI. Note that there is no industrial direct-contact (Method C) PCUL for iron because pure iron (100%) would not exceed the direct-contact threshold for this exposure scenario.

Conclusion: Iron is not a significant risk driver for groundwater and is therefore eliminated as a groundwater IHS. Iron is considered a soil IHS for unrestricted-use direct contact with a PCUL of 56,000 mg/kg.

5.7 LEAD

The groundwater PCUL for lead is 8.1 µg/L for protection of marine aquatic life. This PCUL has never been exceeded in dissolved samples at the Site. Lead concentrations did exceed 8.1 µg/L in total in GWG samples which did not have accompanying dissolved samples (**Figure 12**). Lead also exceeded the PCUL in total samples from a few wells but associated dissolved samples at those same wells did not exceed the PCUL and later samples from those wells did not exceed the PCUL. As a whole, the evidence indicates that dissolved groundwater concentrations at the Site do not exceed the PCUL.

Leachability from soil is not considered to be an important mechanism for lead migration since dissolved lead concentrations do not exceed the groundwater PCUL. Direct contact exposure is considered, with the unrestricted-use PCUL of 250 mg/kg and the industrial-use PCUL of 1,000 mg/kg taken from the Method A tables of MTCA. Twenty-five of 328 soil samples with lead results had concentrations that exceeded the unrestricted-use PCUL (**Figure 13**); several of these were from the 1997 ESI work and a few of those were later resampled with results below the PCUL.

Conclusion: Lead is not a groundwater IHS but is retained as a soil IHS for direct contact with an unrestricted-use PCUL of 250 mg/kg and an industrial-use PCUL of 1,000 mg/kg.

5.8 MANGANESE

The surface-water PCUL for manganese was initially determined to be 100 µg/L based on the Clean Water Act value for human-health protection (fish ingestion). Groundwater concentrations at most Site monitoring wells exceed 100 ug/L. WDOE reviewed the basis for this value and determined that the 100 µg/L level is a recommended value without any health effects rationale. MTCA requires cleanup levels be set for the protection of human health and the environment and applicable state and federal laws must be considered. However, recommendations that are not based on protection for health effects or environmental effects need not be adopted as cleanup levels. Therefore, the Clean Water Act value of 100 µg/L is not an applicable or relevant and appropriate requirement. WDOE recommended setting a PCUL based on Method B calculation. The Method B PCUL for protection of human health through fish consumption was calculated to be 910 µg/L (**Table 5**). This calculation uses the non-cancer reference dose listed in CLARC (which matches the current value in EPA's Integrated Risk Information System, IRIS) and a fish bioconcentration factor of 400 L/kg taken from RESRAD documentation (Yu et al., 2001).

The measured concentration of manganese in many Site monitoring wells was elevated relative to the PCUL of 910 µg/L (**Figure 14**). The occurrence of elevated manganese in groundwater may be largely due to reducing conditions in Site groundwater in many areas which can result in mobilization (dissolution or desorption) of naturally-occurring manganese in soil. The basaltic host rocks of the Olympic Peninsula are known to be rich in manganese deposits (e.g., Park, 1941; Green, 1945).

Manganese exceeded the unrestricted-use direct-contact PCUL of 11,200 mg/kg only in two samples (out of 270) near the former Auto Shop and Paint Shop (**Figure 15**); these two samples were from depths of 3 ft for one sample and 10 to 11.5 ft for the other. Based on the very limited number of exceedances and depth of these samples, manganese is determined to be an insignificant direct-contact risk at the Site.

As with a few other metals, use of the natural background soil concentration with the standard MTCA equilibrium calculation for leaching would suggest that background soil is a potential leachability concern. The 1,200 mg/kg background-based PCUL (for leachability) was exceeded at several locations throughout the Site, with a cluster of these exceedances west of the main process areas. Overall, the 90th percentile of manganese concentrations in Site soil is similar to the background concentration which is based on the 90th percentile of soil data throughout the Puget Sound area (WDOE, 1994). Furthermore, the manganese groundwater plume (**Figure 14**) does not correlate spatially with where soil concentrations were higher in manganese (**Figure 15**) suggesting that the manganese in groundwater is mobilized from manganese that naturally occurs in the soil.

Conclusion: Manganese is a groundwater IHS with a PCUL of 910 µg/L for protection of human health by fish consumption. Manganese is not a soil IHS.

5.9 MERCURY

The groundwater PCUL for mercury of 0.025 µg/L is taken from the Washington State surface-water criteria for protection of aquatic life. This PCUL is much lower than the Maximum Contaminant Level of 2 µg/L that would apply to drinking water for protection of human health, and this PCUL is also significantly lower than the federal Clean Water Act aquatic-life criterion of 0.94 µg/L.

Mercury was detected in only three wells in the second quarter of 2011 and exceeded the PCUL of 0.025 µg/L only at MW-56 (0.043 µg/L) and PZ-3 (0.036 µg/L). Mercury also exceeded the PCUL in two GWG samples. **Figure 16** shows that these that detections are somewhat spatially sporadic. All of the PCUL exceedances shown in **Figure 16** are from unfiltered samples thus representing total concentrations. Historical exceedances of the PCUL in dissolved samples have only occurred at two wells – MW-56 and MW-57. At each of these wells, dissolved concentrations were subsequently measured below the PCUL. While there could be some locations where dissolved mercury exceeds the PCUL, no plume can be drawn and the threat from mercury in groundwater appears to be very low compared with other metals such as copper and nickel which have more widespread impacts.

Mercury concentrations in soil samples for all depths are shown in **Figure 17**. Four locations in the West Mill Area exceeded the unrestricted-use (and industrial-use) direct-contact PCUL of 2 mg/kg (from MTCA Method A tables). These locations coincide with locations where other metals (e.g. arsenic, iron, lead) exceed their direct-contact PCULs. Since the other metals have more widespread exceedances and exceed their PCULs by greater factors, mercury is not a significant risk contributor to direct-contact risk.

Equilibrium calculations show that background soil concentrations would potentially leach concentrations that exceed the groundwater PCUL. Also, review of the soil and groundwater data (**Figures 16 and 17**) do not reveal an area where elevated mercury concentrations in soil are leading to PCUL exceedances in groundwater.

Conclusion: Mercury is not an IHS for groundwater or soil.

5.10 NICKEL

Of twenty-six wells sampled in the second quarter of 2011, four had nickel concentrations greater than the PCUL of 8.2 µg/L (for protection of marine aquatic life), and all of these concentrations were less than two times the PCUL. These wells (MW-55, MW-56, MW-57, and PZ-3) are in the northern portion of the West Mill area. Nickel was also elevated in four GWG samples – two on each side of Ennis Creek. A map showing the interpreted nickel plume is provided in **Figure 18**.

As with some other metals, the unsaturated-zone and saturated-zone soil concentrations that were calculated to be potential leachability concerns were below the natural background concentration of 38 mg/kg. This implies that even background soil could cause groundwater PCUL exceedances by leaching. **Figure 19** shows that soil samples throughout most of the site have exceeded the background nickel concentration. But the concentrations are all less than the concentration that would be an unrestricted-use direct-contact concern (**Table 14**) and there is no apparent spatial correlation between elevated soil concentrations and the groundwater plume that suggests an area of elevated nickel concentrations in soil that is acting as a source to groundwater.

Conclusion: Nickel is retained as an IHS in groundwater with a PCUL of 8.2 µg/L. Nickel is eliminated from the soil IHS list because there are no exceedances of direct-contact PCULs and the empirical evidence from soil and groundwater data do not suggest an ongoing source of nickel leaching to groundwater.

5.11 ZINC

Zinc concentrations in groundwater exceeded the PCUL of 81 µg/L (protection of marine aquatic life) at only four locations at last measurement (**Figure 20**) and three of those locations were total concentrations with no corresponding dissolved-fraction results. Several wells have had past exceedances of the zinc PCUL in one or two measurements, but no well has had consistent exceedances of the PCUL. It appears likely that dissolved zinc does not exceed the groundwater PCUL at the Site and, compared to other metals such as copper, arsenic, manganese, and nickel, zinc appears to contribute insignificant risk via groundwater migration.

Zinc concentrations in soil are depicted for different depth horizons in **Figures 21A, 21B, and 21C**. The 302 mg/kg PCUL is based on ecological risk and was exceeded for many shallow (upper 2 ft) samples in the main process area west of Ennis Creek, particularly near the former Acid Plant, Recovery Boiler, and Machine Room. One sample exceeded this PCUL in the horizon between 2 and 6 feet deep (**Figure 21B**) and no samples deeper than 6 ft exceeded the PCUL (**Figure 21C**).

Given that zinc in groundwater impacts appear to be minimal, leachability of zinc from soil is not considered to be a pathway of significant concern.

Conclusion: Zinc is not an IHS in groundwater. Zinc is an IHS in soil with a PCUL of 302 mg/kg for protection of terrestrial ecological receptors.

5.12 THALLIUM

Thallium was eliminated as a potential groundwater IHS during screening (**Table 8**). However, thallium is a potential IHS for soil by direct contact. The unrestricted-use PCUL is 0.8 mg/kg. Soil samples exceeded this PCUL at several locations in the West Mill Area and at two locations in the City Purchase Area (**Figure 22**). There have been no exceedances of the industrial direct-contact PCUL of 35 mg/kg.

Conclusion: Thallium is not an IHS in groundwater. Thallium is an IHS in soil with a PCUL of 0.8 mg/kg for unrestricted-use direct contact.

5.13 CARCINOGENIC POLYCYCLIC AROMATIC HYDROCARBONS

The PCUL for cPAHs in groundwater is based on the practical quantitation limits (PQLs) of the compounds that are used to calculate benzo(a)pyrene total toxic equivalent (TEQ) concentrations. That is because concentrations protective of surface water (human health by consumption of fish) and sediment were less than concentrations that can be accurately and reliably quantified by laboratories.

Five locations had cPAH concentrations above the PCUL in the last measurement: four wells and one GWG sample. The interpreted plume is depicted in **Figure 23**. The presence of these constituents is likely Site-related: cPAHs can form during combustion (e.g. hog-fuel burning) and are present in creosote-treated pilings that may have been used for foundations.

All of the shallow-soil cPAH soil samples exceeded the most restrictive PCUL of 0.015 mg/kg which is based on the PQL and is for leaching below the water table (**Figure 24A**). Most of these samples also exceeded the leachability standard that applies above the water table: 0.29 mg/kg (more likely to be applicable for shallow soil), and several exceeded the unrestricted-use direct-contact PCUL of 1 mg/kg. Though most of the shallow samples analyzed for cPAHs were collected in the main process area, there were two east of Ennis Creek and one west of the main process area that had relatively low concentrations. Most soil samples in deeper soils (**Figures 24B, 24C, and 24D**) did not exceed PCULs, but several did exceed the saturated-zone (PQL-based) PCUL.

The locations of highest cPAH concentrations in soil do not appear to be spatially correlated with the groundwater plume depicted in **Figure 23**, suggesting that ongoing leaching of cPAHs to soil may not be the main cause of cPAH groundwater impacts.

Conclusion: cPAHs are IHSs for groundwater and soil and have PCULs expressed as benzo(a)pyrene TEQ. The groundwater PCUL is the PQL (0.015 µg/L) and the unrestricted-use direct-contact soil PCUL is 1.0 mg/kg. The spatial pattern of soil and groundwater concentrations suggests that ongoing leaching from soil is not a significant issue.

5.14 ACENAPHTHENE

Figure 25 shows the acenaphthene concentrations in groundwater when last measured in 2003. The groundwater PCUL of 3.3 µg/L was determined to be protective of marine sediment (**Table 6**). This PCUL was exceeded at five locations in 2003. Acenaphthene is present in creosote which may have been used to treat foundation pilings at the Site.

Measured acenaphthene concentrations in soil are presented in **Figure 26** for all depths. The highest concentrations shown exceed the leachability standard that applies above the water table: 0.34 mg/kg. Some of these samples were taken from the upper 2 ft of soil and some were taken from longer intervals that begin in the upper 2 ft and end 5 ft bgs or deeper. Also shown are many locations where the saturated-zone leachability PCUL (0.017 mg/kg) was exceeded. The figure does not reflect the many non-detects that had elevated detection levels (0.32 to 3.0 mg/kg). Most of the acenaphthene data in soil are from 2003 and earlier (as are all the groundwater acenaphthene data). It is not clear whether elevated acenaphthene concentrations depicted in soil (**Figure 26**) could have led to the acenaphthene PCUL exceedances in groundwater (**Figure 25**). However, given that goal is to protect marine sediment which has a sediment cleanup objective of 0.53 mg/kg (**Table 6**) and only three soil measurements have exceeded that value (**Figure 26**) – all relatively far from the shoreline – it appears to be highly unlikely that leaching of acenaphthene from soil, followed by groundwater transport to the shoreline, followed by repartitioning onto marine sediment, would lead to an exceedance of the SCO.

Conclusion: Acenaphthene is an IHS for groundwater with a PCUL of 3.3 µg/L for protection of marine sediment. Acenaphthene is not a soil IHS.

5.15 PENTACHLOROPHENOL

In 2011 sampling, pentachlorophenol was detected at two wells in separate areas of the Site (**Figure 27**). At PA-19, one sample was measured at the PQL (which is the PCUL) of 0.25 µg/L and the duplicate of that sample had a result of 0.26 µg/L. A concentration of 0.89 µg/L was measured at MW-56. Pentachlorophenol impacts in groundwater appear to be limited in area compared to several other IHSs. Though its use at the Site is uncertain, pentachlorophenol was generally used as a wood preservative (possibly used in some pilings) and as a general insecticide/herbicide.

Pentachlorophenol exceeded its leachability-based PCUL of 0.01 mg/kg, which is also its PQL, in many of the Site soil samples (**Figure 28**). However, these exceedances do not line up spatially with where pentachlorophenol concentrations were elevated in groundwater (**Figure 27**).

There were five exceedances of the 2.5 mg/kg unrestricted-use direct-contact PCUL in the main process area west of Ennis Creek which were all in the upper 2 ft of soil (**Figure 28A**). As the depth increases, the number of pentachlorophenol detections decreases, as shown in **Figures 28B, 28C, and 28D**.

Conclusion: Pentachlorophenol is not a groundwater IHS. Pentachlorophenol is a soil IHS with a direct-contact PCUL of 2.5 mg/kg for unrestricted use.

5.16 BIS(2-ETHYLHEXYL)PHTHALATE

Detections of bis(2-ethylhexyl) phthalate (also known as BEHP) in groundwater have been sporadic in both space and time. BEHP is a common plasticizer that is ubiquitous in developed areas and can be introduced to samples unintentionally during sampling. **Figure 29** shows where detections were made in sampling during 2010-2011. For example, at MW-29, a concentration of 4.9 µg/L (which was the highest measured concentration at any well since 2001) was measured in August 2010, but measurements in November 2010, February 2011, and May 2011 were all non-detect. Only PZ-7 had more than one detection during this time period: it had two detections in 2010 and two non-detects in 2011. Based on lack of consistent detections, it does not appear that BEHP contributes a significant risk to the marine environment by groundwater.

BEHP soil concentrations are plotted in **Figure 30**. Except for one outlier, no soil concentrations exceeded the unrestricted-use PCUL of 71 mg/kg. Overall, concentrations were higher in the main process area of the West Mill Area, but these concentrations do not appear to be leading to elevated groundwater concentrations in this area (**Figure 29**).

Conclusion: Bis(2-ethylhexyl) phthalate is not an IHS for groundwater or soil.

5.17 PCBs

PCBs have been detected in fourteen of 144 groundwater samples. As with BEHP, detections have not been common at any individual well (**Figure 31**) suggesting that PCBs do not pose a significant risk to the marine environment via groundwater. Therefore, leachability from soil is also not a significant concern.

Figures 32A and 32B show total PCB concentrations in the upper 2 feet of soil and in deeper soil, respectively. PCB (total) concentrations exceeded the 0.5 mg/kg unrestricted-use direct-contact PCUL in shallow soil throughout the area of the former Machine Room (**Figure 32A**). Deeper exceedances of this PCUL were found near the edges of prior interim-action soil removals at the former Finishing Room and the former Hog Fuel Pile (**Figure 32B**).

Conclusion: PCBs are not a groundwater IHS. PCBs (total) are a soil IHS with a direct-contact PCUL of 0.5 mg/kg for unrestricted use.

5.18 DIOXIN

Dioxin was screened out as an IHS in groundwater (**Table 9**). Dioxin is commonly associated with pulp production.

Dioxin concentrations (expressed at total 2,3,7,8-tetrachlorinated dibenzo-*p*-dioxin TEQ concentrations) exceeded the 13 ng/kg PCUL for unrestricted-use direct contact in many shallow (upper 2 ft) soil samples from the Site. **Figure 33A** shows exceedances for the direct-contact PCUL (shaded red and pink) and the ecological PCUL (220 ng/kg, shaded orange). Higher dioxin concentrations appear to be correlated with Site operations, with higher concentrations generally in process areas, particularly west of Ennis Creek. With two exceptions, PCULs were not exceeded in deeper soil samples (**Figure 33B**).

Conclusion: Dioxin is not a groundwater IHS. Dioxin (TEQ) is a soil IHS with a direct-contact PCUL of 13 ng/kg for unrestricted use. The ecological PCUL is 220 ng/kg.

5.19 TPH

Petroleum fuels were stored and used at the Site. Petroleum hydrocarbons were screened out as IHSs for groundwater (**Tables 2, 3, 7, and 8**).

Diesel-range and heavy-oil-range total petroleum hydrocarbon (TPH) concentrations in soil are shown in **Figures 34 and 35**, respectively. The exceedances of PCULs, and the locations of samples generally, are concentrated around prior soil-removal interim actions which were largely targeted toward TPHs. The highest concentrations shown in these figures, which exceed the direct-contact PCUL (2000 mg/kg; unrestricted and industrial uses) were from various depths from 1 to 11.5 ft. **Figure 34** also shows where the ecological PCUL (200 mg/kg) is exceeded for diesel-range TPH.

Conclusion: TPH is not a groundwater IHS. TPH-Diesel is a soil IHS with an ecological PCUL of 200 mg/kg and a direct-contact PCUL of 2,000 mg/kg. TPH-Heavy-Oil is a soil IHS with a direct-contact PCUL of 2,000 mg/kg.

5.20 2,4,6-TRICHLOROPHENOL

MW-56 has had consistent detections of 2,4,6-trichlorophenol above the PCUL (**Figure 36**) with the most recent detection being 0.38 µg/L – slightly higher than the 0.28 µg/L PCUL. Four other wells have had one detection among multiple measurements. This constituent does not appear to pose a significant fraction of Site risk to the marine environment via groundwater migration.

2,4,6-trichlorophenol was screened out as a soil IHS (**Table 18**).

Conclusion: 2,4,6-trichlorophenol is not an IHS for groundwater or soil.

5.21 TRICHLOROETHENE AND DAUGHTER PRODUCTS

Trichloroethene (TCE) and its biodegradation products (cis-1,2-dichloroethene and vinyl chloride) were detected consistently at one well (MW-63) in 2010-2011 (**Figure 37**). These compounds were also detected at nearby MW-13 prior to its abandonment in the early 1990s. Detections at other wells have been rare and exceedances of PCULs even rarer. The groundwater data indicate that TCE impacts are isolated to the MW-63 area and that biodegradation of TCE is occurring.

TCE and its daughter products were screened out as IHSs in soil (**Tables 12 and 13**).

Conclusion: TCE, cis-1,2-dichloroehene, and vinyl chloride are not IHSs for groundwater or soil.

5.22 FINAL IHSs AND PCULs

Table 20 provides the final list of groundwater IHSs and PCULs that are used to develop remedial alternatives. Likewise, **Table 21** provides the final list of soil IHSs and PCULs that are used to develop remedial alternatives. Note that soil PCULs are provided for protection of unrestricted-use direct contact, industrial direct contact, and ecological receptors, as applicable.

6.0 REMEDIATION AREAS

Most of the groundwater at the Site either has a pH outside the PCUL range (**Figure 1**) or a copper concentration greater than the PCUL (**Figure 8**). Therefore, most Site groundwater is in the groundwater remediation area (**Figure 38**), defined as the area where one or more IHS does not meet its PCUL. Further evaluation of background water quality is warranted to assess whether the pH and copper conditions are entirely related to Site activities.

Likewise, a large portion of the Site (**Figure 39**) is within the soil remediation area where one or more soil PCULs are exceeded.

7.0 SOIL REMEDIATION LEVEL PROTECTIVE OF OCCASIONAL SITE VISITOR/TRESPASSER

The Method B unrestricted-use direct-contact PCULs for soil assume daily soil contact during adolescence (6 years) with a soil ingestion rate of 200 mg/d. This assumption is intended to represent a reasonable maximum exposure (RME) scenario for residential property occupants. However, residential development is not expected for the Site and the property owner (the company) intends to have appropriate site controls in place to limit site use. More realistic exposure scenarios are warranted that assume exposure frequencies of only a few days per year.

At the suggestion of WDOE, an exposure scenario was developed for an occasional Site visitor (trespasser) that visits the site 104 days per year (approximately twice per week) during adolescence.[4] MTCA Method B equations 740-1 and 740-2 were applied with this reduced exposure frequency to develop concentrations that would be protective of occasional Site visitors/trespassers for soil IHSs and would also be protective of terrestrial ecological receptors. These concentrations, which may be used as RELs in development of remediation alternatives, are provided in **Table 21**. Note that the arsenic REL is the same as the unrestricted-use PCUL because the calculated concentration for the visitor/trespasser exposure scenario was less than background. Also, the RELs for lead and TPH-heavy-oil are held at their unrestricted-use PCULs from Method A tables.

The Site area where one or more RELs are exceeded is depicted in **Figure 40**.

8.0 CONCLUSION

IHSs for soil and groundwater, along with associated PCULs, have been proposed through a detailed MTCA-compliant procedure described in this memorandum. The analysis presented herein uses current water-quality and toxicity information and addresses several comments made by WDOE on past drafts of the *Volume III Report*. The results are provided in **Table 20** for groundwater and **Table 21** for soil. **Table 21** also provides RELs protective of occasional Site visitors/trespassers that may be used in soil alternatives. These IHS lists, PCULs, and RELs, which are slightly different than those used previously, will be used in further development of the *Volume III Report* and in definition of the selected cleanup plan.

9.0 REFERENCES

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[4] This exposure frequency was suggested by WDOE and likely overestimates actual reasonable maximum exposures from occasional trespassers/visitors. Lower exposure frequencies (and therefore increased RELs) could also be supported with appropriate property use controls.

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Table 1. Thoroughness of Testing Summary - Groundwater

Analyte	Number of Measure-ments	Number of Locations	Adequate Reporting Limits	Sufficient Spatial Coverage	Adequate for Post-Operation	Thorough Testing
1,1,1,2-Tetrachloroethane	48	23	Yes	Yes	Yes	Yes
1,1,1-Trichloroethane	107	28	Yes	Yes	Yes	Yes
1,1,2,2-Tetrachloroethane	107	28	Yes	Yes	Yes	Yes
1,1,2-Trichloroethane	107	28	Yes	Yes	Yes	Yes
1,1-Dichloroethane	118	31	Yes	Yes	Yes	Yes
1,1-Dichloroethene	118	31	Yes	Yes	Yes	Yes
1,1-Dichloropropene	48	23	Yes	Yes	Yes	Yes
1,2,3-Trichlorobenzene	48	23	Yes	Yes	Yes	Yes
1,2,3-Trichloropropane	48	23	Yes	Yes	Yes	Yes
1,2,4-Trichlorobenzene	148	26	Yes	Yes	Yes	Yes
1,2,4-Trimethylbenzene	48	23	Yes	Yes	Yes	Yes
1,2-Dibromo-3-Chloropropane	85	19	Yes	Yes	Yes	Yes
1,2-Dibromoethane	48	23	Yes	Yes	Yes	Yes
1,2-Dichlorobenzene	108	21	Yes	Yes	Yes	Yes
1,2-Dichloroethane	151	36	Yes	Yes	Yes	Yes
1,2-Dichloropropane	107	28	Yes	Yes	Yes	Yes
1,3,5-Trimethylbenzene	48	23	Yes	Yes	Yes	Yes
1,3-Dichlorobenzene	108	21	Yes	Yes	Yes	Yes
1,3-Dichloropropane	48	23	Yes	Yes	Yes	Yes
1,4-Dichlorobenzene	134	31	Yes	Yes	Yes	Yes
2,2-Dichloropropane	48	23	Yes	Yes	Yes	Yes
2,4,5-Trichlorophenol	103	27	Yes	Yes	Yes	Yes
2,4,6-Trichlorophenol	175	45	Yes	Yes	Yes	Yes
2,4-Dichlorophenol	103	27	Yes	Yes	Yes	Yes
2,4-Dimethylphenol	103	27	Yes	Yes	Yes	Yes
2,4-Dinitrophenol	103	27	Yes	Yes	Yes	Yes
2,4-Dinitrotoluene	129	31	Yes	Yes	Yes	Yes
2,6-Dinitrotoluene	103	27	Yes	Yes	Yes	Yes
2-Butanone	107	28	Yes	Yes	Yes	Yes
2-Chloroethylvinylether	48	23	Yes	Yes	Yes	Yes
2-Chloronaphthalene	103	27	Yes	Yes	Yes	Yes
2-Chlorophenol	103	27	Yes	Yes	Yes	Yes
2-Chlorotoluene	48	23	Yes	Yes	Yes	Yes
2-Hexanone	107	28	Yes	Yes	Yes	Yes
2-Methylnaphthalene	83	25	Yes	Yes	Yes	Yes
2-Methylphenol	103	27	Yes	Yes	Yes	Yes
2-Nitroaniline	103	27	Yes	Yes	Yes	Yes
2-Nitrophenol	103	27	Yes	Yes	Yes	Yes
3,3'-Dichlorobenzidine	129	31	Yes	Yes	Yes	Yes
3-Nitroaniline	103	27	Yes	Yes	Yes	Yes
4,4'-DDD	112	33	Yes	Yes	Yes	Yes
4,4'-DDE	108	33	Yes	Yes	Yes	Yes
4,4'-DDT	107	33	Yes	Yes	Yes	Yes
4,6-Dinitro-2-methylphenol	103	27	Yes	Yes	Yes	Yes
4-Bromophenyl-phenylether	103	27	Yes	Yes	Yes	Yes
4-Chloro-3-methylphenol	103	27	Yes	Yes	Yes	Yes
4-Chloroaniline	103	27	Yes	Yes	Yes	Yes
4-Chlorophenyl-phenylether	103	27	Yes	Yes	Yes	Yes
4-Chlorotoluene	48	23	Yes	Yes	Yes	Yes
4-isopropyltoluene	86	27	Yes	Yes	Yes	Yes
4-Methyl-2-Pentanone	107	28	Yes	Yes	Yes	Yes
4-Methylphenol	79	26	Yes	Yes	Yes	Yes
4-Nitroaniline	103	27	Yes	Yes	Yes	Yes
4-Nitrophenol	103	27	Yes	Yes	Yes	Yes
Acenaphthene	110	27	Yes	Yes	Yes	Yes
Acenaphthylene	103	27	Yes	Yes	Yes	Yes
Acetone	109	29	Yes	Yes	Yes	Yes
Acrolein	44	22	Yes	Yes	Yes	Yes
Acrylonitrile	71	30	Yes	Yes	Yes	Yes
Aldrin	83	28	Yes	Yes	Yes	Yes
alpha-BHC	83	28	Yes	Yes	Yes	Yes
alpha-Chlordane	108	33	Yes	Yes	Yes	Yes
Aluminum	**7**	**7**	Yes	**No**	**No**	**No**
Ammonia-N (un-ionized)	160	43	Yes	Yes	Yes	Yes
Anthracene	102	27	Yes	Yes	Yes	Yes
Antimony	79	28	Yes	Yes	Yes	Yes
Arsenic	336	52	Yes	Yes	Yes	Yes
Barium	50	23	Yes	Yes	Yes	Yes
Benzene	109	29	Yes	Yes	Yes	Yes
Benzo(g,h,i)perylene	103	27	Yes	Yes	Yes	Yes
Benzoic acid	103	27	Yes	Yes	Yes	Yes
Benzyl alcohol	103	27	Yes	Yes	Yes	Yes
Beryllium	149	27	Yes	Yes	Yes	Yes
beta-BHC	83	28	Yes	Yes	Yes	Yes
Bis(2-chloro-1-methylethyl) ether	108	30	Yes	Yes	Yes	Yes
bis(2-Chloroethoxy)methane	103	27	Yes	Yes	Yes	Yes
bis(2-Chloroethyl)ether	129	31	Yes	Yes	Yes	Yes
bis(2-Chloroisopropyl)ether	**21**	20	Yes	Yes	**No**	**No**
bis(2-Ethylhexyl)phthalate	188	45	Yes	Yes	Yes	Yes
Bromobenzene	48	23	Yes	Yes	Yes	Yes
Bromochloromethane	48	23	Yes	Yes	Yes	Yes
Bromodichloromethane	107	28	Yes	Yes	Yes	Yes
Bromoform	107	28	Yes	Yes	Yes	Yes
Bromomethane	48	23	Yes	Yes	Yes	Yes
Butylbenzylphthalate	103	27	Yes	Yes	Yes	Yes
Cadmium	164	30	Yes	Yes	Yes	Yes
Carbazole	110	27	Yes	Yes	Yes	Yes
Carbon Disulfide	114	28	Yes	Yes	Yes	Yes
Carbon Tetrachloride	107	28	Yes	Yes	Yes	Yes
Chlorobenzene	107	28	Yes	Yes	Yes	Yes
Chloroethane	107	28	Yes	Yes	Yes	Yes
Chloroform	107	28	Yes	Yes	Yes	Yes
Chloromethane	107	28	Yes	Yes	Yes	Yes
Chromium	273	45	Yes	Yes	Yes	Yes
Chromium, Hexavalent	**4**	**4**	Yes	**No**	**No**	**No**
cis-1,2-Dichloroethene	99	30	Yes	Yes	Yes	Yes
cis-1,3-DICHLOROPROPENE	107	28	Yes	Yes	Yes	Yes
Cobalt	49	23	Yes	Yes	Yes	Yes
Copper	332	52	Yes	Yes	Yes	Yes
cPAH TEQ	179	45	Yes	Yes	Yes	Yes
delta-BHC	83	28	Yes	Yes	Yes	Yes
Diallate-Isomer 1	**21**	19	Yes	Yes	**No**	**No**
Dibenzofuran	82	26	Yes	Yes	Yes	Yes
Dibromochloromethane	107	28	Yes	Yes	Yes	Yes
Dibromoethane	46	23	Yes	Yes	Yes	Yes
Dieldrin	83	28	Yes	Yes	Yes	Yes
Diesel-range TPH	170	43	Yes	Yes	Yes	Yes
Diethylphthalate	103	27	Yes	Yes	Yes	Yes
Dimethylphthalate	103	27	Yes	Yes	Yes	Yes
Di-n-butylphthalate	103	27	Yes	Yes	Yes	Yes
Di-n-octylphthalate	103	27	Yes	Yes	Yes	Yes
Dioxin TEQ	69	40	Yes	Yes	Yes	Yes
Endosulfan I	83	28	Yes	Yes	Yes	Yes
Endosulfan II	83	28	Yes	Yes	Yes	Yes
Endosulfan Sulfate	83	28	Yes	Yes	Yes	Yes
Endrin	107	33	Yes	Yes	Yes	Yes
Endrin Aldehyde	107	33	Yes	Yes	Yes	Yes
Endrin Ketone	108	33	Yes	Yes	Yes	Yes
Ethyl Bromide	44	22	Yes	Yes	Yes	Yes
Ethylbenzene	109	29	Yes	Yes	Yes	Yes
Fluoranthene	110	27	Yes	Yes	Yes	Yes
Fluorene	109	27	Yes	Yes	Yes	Yes
gamma-BHC (Lindane)	83	28	Yes	Yes	Yes	Yes
gamma-Chlordane	81	28	Yes	Yes	Yes	Yes
Gasoline-range TPH	38	29	Yes	Yes	Yes	Yes
Heavy oil-range TPH	169	43	Yes	Yes	Yes	Yes
Heptachlor	108	33	Yes	Yes	Yes	Yes
Heptachlor Epoxide	83	28	Yes	Yes	Yes	Yes
Hexachlorobenzene	128	29	Yes	Yes	Yes	Yes
Hexachlorobutadiene	148	28	Yes	Yes	Yes	Yes
Hexachlorocyclopentadiene	103	27	Yes	Yes	Yes	Yes
Hexachloroethane	129	31	Yes	Yes	Yes	Yes
Iron	125	26	Yes	Yes	Yes	Yes
Isodrin	37	22	Yes	Yes	Yes	Yes
Isophorone	103	27	Yes	Yes	Yes	Yes
Isopropylbenzene	48	23	Yes	Yes	Yes	Yes
Lead	333	52	Yes	Yes	Yes	Yes
Manganese	181	49	Yes	Yes	Yes	Yes
m-Cresol	34	19	Yes	Yes	Yes	Yes
Mercury	210	49	Yes	Yes	Yes	Yes
Methoxychlor	83	28	Yes	Yes	Yes	Yes
Methyl iodide	48	23	Yes	Yes	Yes	Yes
Methylene chloride	114	28	Yes	Yes	Yes	Yes
Naphthalene	149	23	Yes	Yes	Yes	Yes
n-Butylbenzene	48	23	Yes	Yes	Yes	Yes
Nickel	329	52	Yes	Yes	Yes	Yes
Nitrobenzene	103	27	Yes	Yes	Yes	Yes
N-Nitroso-di-n-propylamine	129	31	Yes	Yes	Yes	Yes
N-Nitrosodiphenylamine	129	31	Yes	Yes	Yes	Yes
PCBs - Total	145	45	Yes	Yes	Yes	Yes
Pentachlorophenol	175	45	Yes	Yes	Yes	Yes
Phenanthrene	103	27	Yes	Yes	Yes	Yes
Phenol	103	27	Yes	Yes	Yes	Yes
Propylbenzene	48	23	Yes	Yes	Yes	Yes
Pyrene	162	40	Yes	Yes	Yes	Yes
Residual Range Organics	**1**	**1**	Yes	**No**	**No**	**No**
sec-Butylbenzene	48	23	Yes	Yes	Yes	Yes
Selenium	228	32	Yes	Yes	Yes	Yes
Silver	128	29	Yes	Yes	Yes	Yes
Styrene	107	28	Yes	Yes	Yes	Yes
tert-Butylbenzene	48	23	Yes	Yes	Yes	Yes
Tetrachloroethylene	145	34	Yes	Yes	Yes	Yes
Thallium	120	29	Yes	Yes	Yes	Yes
Toluene	116	29	Yes	Yes	Yes	Yes
Toxaphene	83	28	Yes	Yes	Yes	Yes
trans-1,2-Dichloroethene	118	31	Yes	Yes	Yes	Yes
trans-1,3-DICHLOROPROPENE	107	28	Yes	Yes	Yes	Yes
trans-1,4-DICHLORO-2-BUTENE	44	22	Yes	Yes	Yes	Yes
Trichloroethene	153	37	Yes	Yes	Yes	Yes
Trichlorofluoromethane	48	23	Yes	Yes	Yes	Yes
Trichlorotrifluoroethane	44	22	Yes	Yes	Yes	Yes
Vanadium	49	23	Yes	Yes	Yes	Yes
Vinyl Acetate	107	28	Yes	Yes	Yes	Yes
Vinyl chloride	153	37	Yes	Yes	Yes	Yes
Xylenes	109	27	Yes	Yes	Yes	Yes
Zinc	320	50	Yes	Yes	Yes	Yes

Table 2. Analytes Never Detected in Groundwater at the Site

Analyte	N	Analyte	N	Analyte	N
1,1,1,2-Tetrachloroethane	48	3-Nitroaniline	103	Dimethylphthalate	103
1,1,1-Trichloroethane	107	4,6-Dinitro-2-methylphenol	103	Di-n-octylphthalate	103
1,1,2,2-Tetrachloroethane	107	4-Bromophenyl-phenylether	103	Ethyl Bromide	44
1,1,2-Trichloroethane	107	4-Chloroaniline	103	gamma-Chlordane	81
1,1-Dichloroethene	118	4-Chlorophenyl-phenylether	103	Gasoline-range TPH	38
1,1-Dichloropropene	48	4-Chlorotoluene	48	Heptachlor Epoxide	83
1,2,3-Trichlorobenzene	48	4-Nitroaniline	103	Hexachlorobenzene	128
1,2,3-Trichloropropane	48	4-Nitrophenol	103	Hexachlorobutadiene	148
1,2,4-Trichlorobenzene	148	Acrolein	44	Hexachlorocyclopentadiene	103
1,2,4-Trimethylbenzene	48	Acrylonitrile	71	Hexachloroethane	129
1,2-Dibromo-3-Chloropropane	85	Aldrin	83	Isodrin	37
1,2-Dibromoethane	48	alpha-BHC	83	Isophorone	103
1,2-Dichlorobenzene	108	Benzyl alcohol	103	Isopropylbenzene	48
1,2-Dichloroethane	151	beta-BHC	83	Methyl iodide	48
1,2-Dichloropropane	107	Bis(2-chloro-1-methylethyl) ether	108	n-Butylbenzene	48
1,3,5-Trimethylbenzene	48	bis(2-Chloroethoxy)methane	103	Nitrobenzene	103
1,3-Dichlorobenzene	108	bis(2-Chloroethyl)ether	129	N-Nitroso-di-n-propylamine	129
1,3-Dichloropropane	48	Bromobenzene	48	N-Nitrosodiphenylamine	129
1,4-Dichlorobenzene	134	Bromochloromethane	48	Propylbenzene	48
2,2-Dichloropropane	48	Bromodichloromethane	107	sec-Butylbenzene	48
2,4-Dinitrophenol	103	Bromoform	107	tert-Butylbenzene	48
2,4-Dinitrotoluene	129	Bromomethane	48	Tetrachloroethylene	145
2,6-Dinitrotoluene	103	Carbon Tetrachloride	107	Toxaphene	83
2-Chloronaphthalene	103	Chlorobenzene	107	trans-1,2-Dichloroethene	118
2-Chlorotoluene	48	Chloroethane	107	trans-1,3-DICHLOROPROPENE	107
2-Hexanone	107	Chloroform	107	trans-1,4-DICHLORO-2-BUTENE	44
2-Methylnaphthalene	83	Chloromethane	107	Trichlorofluoromethane	48
2-Nitroaniline	103	cis-1,3-DICHLOROPROPENE	107	Trichlorotrifluoroethane	44
2-Nitrophenol	103	Dibromochloromethane	107	Vinyl Acetate	107
3,3'-Dichlorobenzidine	129	Dibromoethane	46		

N = Number of samples

Table 3. Analytes with Few Measurements, Not Detected in Groundwater, and Not Retained as Potential IHSs.

Analyte	N	Reason for Not Selecting as IHS
Chromium, Hexavalent	4	There is no known historical use of hexavalent chromium at the site, and it is not commonly associated with paper mill sites. Reducing conditions prevalent at the site are not conducive to the formation of hexavalent chromium. Even with a limited data set (4 samples), the consistency of non-detect results coupled with the lack of site-related chemical use forms the basis for removing hexavalent chromium from further consideration as an IHS.
bis(2-Chloroisopropyl)ether	21	There is no known historical use of bis(2-chloroisopropyl)ether at the site, and it is not commonly associated with paper mill sites. Even with a somewhat limited data set (21 samples), the consistency of non-detect results coupled with the lack of site-related chemical use forms the basis for removing bis(2-chloroisopropyl)ether from further consideration as an IHS.
Diallate-Isomer 1	21	There is no known historical use of diallate at the site, and it is not commonly associated with paper mill sites. Even with a somewhat limited data set (21 samples), the consistency of non-detect results coupled with the lack of site-related chemical use forms the basis for removing diallate from further consideration as an IHS.
Residual Range Organics	1	Residual range organics (carbon range C25-C36) is almost entirely quantified in the more-commonly analyzed heavy oil-range TPH (carbon range C20-C35). Heavy oil-range TPH will be retained for further consideration as an IHS, and the once-sampled (and not detected) residual range organics will be removed from further consideration as an IHS.

N = Number of samples

Table 4. Identification of Applicable Water Quality Standards and PCULs (µg/L) for IHS Screening

		Washington State Marine Surface Water Quality Standards			National Recommended Water Quality Criteria			National Toxics Rule -	MTCA Method B Risk Calculation			
Analyte	Max. Detected Conc.	Aquatic Life Acute	Aquatic Life Chronic	Human Health	Aquatic Life Acute	Aquatic Life Chronic	Human Health	Human Health	Non-Cancer	Cancer	Sediment Protective Conc.	Toxicity-Based PCUL
1,1-Dichloroethane	3.20E+00								7.36E+04	1.61E+02		1.61E+02
2,4,5-Trichlorophenol	7.90E+00						6.00E+02					6.00E+02
2,4,6-Trichlorophenol	7.70E+00			2.80E-01			2.80E+00	6.50E+00				2.80E-01
2,4-Dichlorophenol	3.90E+00			3.40E+01			6.00E+01	7.90E+02				3.40E+01
2,4-Dimethylphenol	5.60E+00			9.70E+01			3.00E+03				4.04E+03	9.70E+01
2-Butanone	1.00E+01								4.92E+05			4.92E+05
2-Chloroethylvinylether	5.00E+00											NC
2-Chlorophenol	1.40E-01			1.70E+01			8.00E+02					1.70E+01
2-Methylphenol	4.50E+00								1.21E+04		6.10E+00	6.10E+00
4,4'-DDD	9.80E-03			3.60E-05			1.20E-04	8.40E-04				3.60E-05
4,4'-DDE	2.90E-03			5.10E-05			1.80E-05	5.90E-04				1.80E-05
4,4'-DDT	7.90E-03			2.50E-05	1.30E-01	1.00E-03	3.00E-05	5.90E-04				2.50E-05
4-Chloro-3-methylphenol	9.50E-02			3.60E+01			2.00E+03					3.60E+01
4-isopropyltoluene	8.10E+00								1.04E+03			1.04E+03
4-Methyl-2-Pentanone	3.20E+00								6.10E+04			6.10E+04
4-Methylphenol	1.60E+01								2.93E+04		6.60E+01	6.60E+01
Acenaphthene	4.60E+01			1.10E+02			9.00E+01				3.30E+00	3.30E+00
Acenaphthylene	3.90E-01								2.87E+02			2.87E+02
Acetone	4.40E+01								7.38E+05			7.38E+05
alpha-Chlordane	1.60E-03				9.00E-02	4.00E-03	3.20E-04	5.90E-04				3.20E-04
Aluminum	1.04E+03								5.19E+03			5.19E+03
Ammonia-N (un-ionized)	7.23E+03	2.33E+02	3.50E+01									3.50E+01
Anthracene	2.10E+01			4.60E+03			4.00E+02	1.10E+05				4.00E+02
Antimony	2.47E+01			1.80E+02			6.40E+02	4.30E+03				1.80E+02
Arsenic	9.68E+01	6.90E+01	3.60E+01	1.00E+01	6.90E+01	3.60E+01	1.40E-01	1.40E-01			4.10E+02	1.40E-01
Barium	6.10E+03								1.30E+05			1.30E+05
Benzene	1.50E+00			1.60E+00			1.60E+01	7.10E+01				1.60E+00
Benzo(g,h,i)perylene	8.20E-01								7.07E+00		6.30E+00	6.30E+00
Benzoic acid	6.20E+01								3.28E+06			3.28E+06
Beryllium	1.80E-01								2.73E+02			2.73E+02
bis(2-Ethylhexyl)phthalate	3.50E+01			2.50E-01			3.70E-01	5.90E+00				2.50E-01
Butylbenzylphthalate	1.20E-01			5.80E-01			1.00E-01					1.00E-01
Cadmium	3.10E+02	4.20E+01	9.30E+00		3.30E+01	7.90E+00			4.05E+01		1.17E+02	7.90E+00
Carbazole	7.00E+00									1.91E+00		1.91E+00
Carbon Disulfide	2.00E+00								1.33E+04			1.33E+04
Chromium	3.20E+03								2.43E+05			2.43E+05
cis-1,2-Dichloroethene	9.30E+01								4.66E+02			4.66E+02
Cobalt	2.20E+02								2.59E+00			2.59E+00
Copper	6.98E+02	4.80E+00	3.10E+00		4.80E+00	3.10E+00			2.88E+03		1.57E+03	3.10E+00
cPAH TEQ	3.91E-01			2.10E-03			1.30E-04	3.11E-02			5.00E-04	1.30E-04
delta-BHC	2.40E-03								2.09E+00			2.09E+00
Dibenzofuran	5.40E+00								1.71E+00		1.60E+00	1.60E+00
Dieldrin	1.10E-03	7.10E-01	1.90E-03	6.10E-06	7.10E-01	1.90E-03	1.20E-06	1.40E-04				1.20E-06
Diesel-range TPH	3.00E+03								**5.00E+02**			5.00E+02
Diethylphthalate	1.10E+00			5.00E+03			6.00E+02	1.20E+05				6.00E+02
Di-n-butylphthalate	1.40E+00			5.10E+02			3.00E+01	1.20E+04				3.00E+01
Dioxin TEQ	6.78E-01			6.40E-08			5.10E-09	1.40E-08			5.20E-08	5.10E-09
Endosulfan I	7.20E-03			1.00E+01	3.40E-02	8.70E-03	3.00E+01					8.70E-03
Endosulfan II	3.60E-03			1.00E+01	3.40E-02	8.70E-03	4.00E+01					8.70E-03
Endosulfan Sulfate	2.10E-03			1.00E+01			4.00E+01					1.00E+01
Endrin	4.60E-03	3.70E-02	2.30E-03	3.50E-02	3.70E-02	2.30E-03	3.00E-02	8.10E-01				2.30E-03
Endrin Aldehyde	1.40E-01			3.50E-02			1.00E+00					3.50E-02
Endrin Ketone	2.80E-02											NC
Ethylbenzene	1.10E+00			2.70E+02			1.30E+02	2.90E+04				1.30E+02
Fluoranthene	2.00E+00			1.60E+01			2.00E+01	3.70E+02			3.30E+00	3.30E+00
Fluorene	7.40E+00			6.10E+02			7.00E+01	1.40E+04			3.00E+00	3.00E+00
gamma-BHC (Lindane)	6.10E-03	1.60E-01		1.70E+01	1.60E-01		4.40E+00	6.30E-02				6.30E-02
Heavy oil-range TPH	2.40E+02								**5.00E+02**			5.00E+02
Heptachlor	1.80E-03	5.30E-02	3.60E-03	1.00E-05	5.30E-02	3.60E-03	5.90E-06	2.10E-04				5.90E-06
Iron	1.02E+05								9.07E+03			9.07E+03
Lead	9.90E+02	2.10E+02	8.10E+00		2.10E+02	8.10E+00						8.10E+00
Manganese	1.39E+04						1.00E+02		9.10E+02			9.10E+02
m-Cresol	1.60E+01								1.42E+04			1.42E+04
Mercury	2.00E+00	1.80E+00	2.50E-02		1.80E+00	9.40E-01		1.50E-01			2.10E+00	2.50E-02
Methoxychlor	2.00E-03					3.00E-02	2.00E-02					2.00E-02
Methylene chloride	4.20E+01			2.50E+02			1.00E+03	1.60E+03				2.50E+02
Naphthalene	2.00E+01								4.94E+03			4.94E+03
Nickel	7.38E+02	7.40E+01	8.20E+00	1.90E+02	7.40E+01	8.20E+00	4.60E+03	4.60E+03				8.20E+00
PCBs - Total	1.80E+00					3.00E-02	6.40E-05	1.70E-04			9.80E-09	9.80E-09
Pentachlorophenol	8.30E+01	1.30E+01	7.90E+00	1.00E-01	1.30E+01	7.90E+00	4.00E-02	8.20E+00				4.00E-02
Phenanthrene	8.30E+00								3.10E+01		6.20E+00	6.20E+00
Phenol	8.00E+01			2.00E+05			3.00E+05	4.60E+06			3.40E+02	3.40E+02
Pyrene	4.30E+00			4.60E+02			3.00E+01	1.10E+04			1.50E+01	1.50E+01
Selenium	1.11E+03	2.90E+02	7.10E+01	4.80E+02	2.90E+02	7.10E+01	4.20E+03				1.13E+02	7.10E+01
Silver	8.50E+01	1.90E+00			1.90E+00				2.59E+04			1.90E+00
Styrene	2.00E-01								3.84E+04			3.84E+04
Thallium	4.00E-01			2.70E-01			4.70E-01	6.30E+00				2.70E-01
Toluene	4.90E+01			4.10E+02			5.20E+02	2.00E+05				4.10E+02
Trichloroethene	9.60E+00			8.60E-01			7.00E+00	8.10E+01				8.60E-01
Vanadium	9.50E+02								1.30E+04			1.30E+04
Vinyl chloride	3.40E+01			2.60E-01			1.60E+00	5.25E+02				2.60E-01
Xylenes	7.00E-01								3.51E+04			3.51E+04
Zinc	8.10E+02	9.00E+01	8.10E+01	2.90E+03	9.00E+01	8.10E+01	2.60E+04				1.24E+03	8.10E+01

All concentrations in µg/L

Bolded values are Method A Values for TPH in Groundwater (Table 720-1)

NC: Not calculated. Not listed in MTCA marine surface-water tables or referenced federal regulations. Screened out in subsequent step based on weight of evidece.

Table 5. Method B PCUL Calculations for Surface Water

Analyte	Non-Cancer Reference Dose mg/kg/d	Oral Cancer Slope Factor kg-d/mg	Fish Bio-concentration Factor	Protective Concentration Non-Cancer µg/L	Protective Concentration Cancer µg/L	Comment
1,1-Dichloroethane	2.00E-01	5.70E-03	7.05E+00	7.36E+04	1.61E+02	
2-Butanone	6.00E-01		3.16E+00	4.92E+05		
2-Methylphenol	5.00E-02		1.07E+01	1.21E+04		
4-isopropyltoluene	9.43E-02		2.36E+02	1.04E+03		RfDo from FDEP (2005)
4-Methyl-2-Pentanone	8.00E-02		3.40E+00	6.10E+04		
4-Methylphenol	1.00E-01		8.85E+00	2.93E+04		
Acenaphthalene	3.00E-02		2.71E+02	2.87E+02		RfDo is for surrogate: pyrene
Acetone	9.00E-01		3.16E+00	7.38E+05		
Aluminum	1.00E+00		5.00E+02	5.19E+03		
Barium	2.00E-01		4.00E+00	1.30E+05		
Benzo(g,h,i)perylene	3.00E-02		1.10E+04	7.07E+00		RfDo is for surrogate: pyrene
Benzoic acid	4.00E+00		3.16E+00	3.28E+06		
Carbazole		2.00E-02	1.70E+02		1.91E+00	Cancer slope factor from RAIS
Carbon disulfide	1.00E-01		1.95E+01	1.33E+04		
cis-1,2-Dichloroethylene	2.00E-03		1.11E+01	4.66E+02		
Cobalt	3.00E-04		3.00E+02	2.59E+00		RfDo from RAIS
delta-BHC	3.00E-04		3.72E+02	2.09E+00		RfDo is for gamma-BHC (Lindane)
Dibenzofuran	1.00E-03		1.52E+03	1.71E+00		
Iron	7.00E-01		2.00E+02	9.07E+03		
m-Cresol	5.00E-02		9.12E+00	1.42E+04		
Manganese	1.40E-01		4.00E+02	9.07E+02		
Naphthalene	2.00E-02		1.05E+01	4.94E+03		BCF from CLARC
Phenanthrene	3.00E-02		2.51E+03	3.10E+01		RfDo is for surrogate: pyrene
Styrene	2.00E-01		1.35E+01	3.84E+04		
Vanadium	5.00E-03		1.00E+00	1.30E+04		No BCF available; BCF assumed to be 1
Xylenes	2.00E-01		1.48E+01	3.51E+04		Highest BCF of xyelene isomers

RfDo = Non-Cancer reference dose; From CLARC tables except as noted

RAIS = Risk Assessment Information System, maintained by Oak Ridge National Laboratory

Fish bioconcentration factors (BCFs) taken from RAIS except as noted

Table 6. Calculation of Groundwater Concentrations Protective of Marine Sediment

	SCO (mg/kg OC)	SCO (mg/kg dw)	K_{oc} (L/kg)	K_d (L/kg)	Pore Water Conc. (µg/L)	Note
Benthic Protection						
Mercury		0.41		5.20E+01	7.8	Human-health criteria (below) controls
Acenaphthene	16	0.528	4.90E+03	1.62E+02	3.3	
Benzo(g,h,i)perylene	31	1.023	4.90E+03	1.62E+02	6.3	K_{oc} from EPI
Chrysene	110	3.63	3.98E+05	1.31E+04	0.28	TEQ is 0.0028; human-health for cPAH TEQ controls
Dibenzofuran	15	0.495	9.16E+03	3.02E+02	1.6	K_{oc} from EPI
Fluoranthene	160	5.28	4.91E+04	1.62E+03	3.3	
Fluorene	23	0.759	7.71E+03	2.54E+02	3.0	
Indeno(1,2,3-cd)pyrene	34	1.122	3.47E+06	1.15E+05	0.0098	TEQ is 0.00098; human-health for cPAH TEQ controls
Phenanthrene	100	3.3	1.60E+04	5.28E+02	6.2	K_{oc} from EPI
Pyrene	1,000	33	6.80E+04	2.24E+03	15	
PCBs - Total	12	0.396	3.09E+05	1.02E+04	0.039	Human-health criteria (below) controls
2-Methylphenol		0.063	3.07E+02	1.01E+01	6.1	K_{oc} from EPI
2,4-Dimethylphenol		29	2.09E+02	6.90E+00	4037	
4-Methylphenol		0.67	3.00E+02	9.91E+00	66	K_{oc} from EPI
Phenol		0.42	2.88E+01	9.50E-01	340	
Human-Health Protection						
Arsenic		12		2.90E+01	410	
Cadmium		0.82		6.70E+00	117	
Copper		35		2.20E+01	1570	
Selenium		0.6		5.00E+00	113	
Zinc		77		6.20E+01	1236	
Mercury		0.11		5.20E+01	2.1	
Alpha-BHC		0.0013		1.76E+03	7.39E-04	
cPAH TEQ		0.016	9.69E+05	3.20E+04	0.00050	Koc for benzo(a)pyrene
PCBs - Total		1.00E-07	3.09E+05	1.02E+04	9.81E-09	
Dioxin TEQ		1.20E-06	6.95E+05	2.29E+04	5.23E-08	K_{oc} for HxCDD mixture, from EPI

SCO = Sediment Cleanup Objective

mg/kg OC = concentrations in mass of contaminant per mass of orgnic carbon

mg/kg dw = concentrations in mass of contaminant per mass of sediment (dry weight)

K_{oc} = organic-carbon partition coefficient; taken from CLARC data tables except as noted

K_d = soil-water partition coefficient; taken from CLARC data tables or calculated as K_{oc} x f_{oc}

f_{oc} = fraction of organic content in sediment (0.033)

EPI = EPA Estimation Programs Interface Suite

Table 7. Chemicals That Never Exceed Groundwater PCULs

Analyte	PCUL (µg/L)	Max. Conc. (µg/L)	Percent Detects	N
1,1,-Dichloroethane	161	3.2	6.8%	118
2,4,5-Trichlorophenol	600	7.9	1.9%	103
2,4-Dichlorophenol	34	3.9	1.9%	103
2,4-Dimethylphenol	97	5.6	3.9%	103
2-Butanone	492000	10	3.7%	107
2-Chlorophenol	17	0.14	2.9%	103
2-Methylphenol	6.1	4.5	5.8%	103
4-Chloro-3-methylphenol	36	0.095	4.9%	103
4-isopropyltoluene	1038	8.1	3.5%	86
4-Methyl-2-Pentanone	61000	3.2	1.9%	107
4-Methylphenol	66	16	5.1%	79
Acenaphthylene	287	0.39	9.7%	103
Acetone	738000	44	23.9%	109
Anthracene	400	21	23.5%	102
Antimony	180	24.7	31.6%	79
Barium	130000	6100	100.0%	50
Benzene	1.6	1.5	7.3%	109
Benzo(g,h,i)perylene	6.3	0.82	10.7%	103
Benzoic acid	3280000	62	3.9%	103
Beryllium	273	0.18	8.7%	149
Carbon disulfide	13300	2	7.9%	114
Chromium	243000	3200	54.6%	273
delta-BHC	2.09	0.0024	3.6%	83
Diethylphthalate	600	1.1	20.4%	103
Di-n-butylphthalate	30	1.4	25.2%	103
Endosulfan I	0.0087	0.0072	1.2%	83
Endosulfan II	0.0087	0.0036	6.0%	83
Endosulfan Sulfate	10	0.0021	1.2%	83
Ethylbenzene	130	1.1	4.6%	109
Fluoranthene	3.3	2	28.2%	110
gamma-BHC (Lindane)	0.063	0.0061	1.2%	83
Heavy oil-range TPH	500	240	1.2%	169
m-Cresol	14200	16	5.9%	34
Methoxychlor	0.02	0.002	1.2%	83
Methylene chloride	250	42	7.0%	114
Naphthalene	4938	20	19.5%	149
Phenol	442	80	19.4%	103
Pyrene	15	4.3	37.0%	162
Styrene	38400	0.2	0.9%	107
Toluene	410	49	13.8%	116
Vanadium	13000	950	93.9%	49
Xylenes	35100	0.7	3.7%	109

N = Number of measurements

Table 8. Chemicals That Have Been Historically Detected above PCULs in Groundwater but Have Since Declined below PCULs

Analyte	PCUL (µg/L)	Max. Conc. (µg/L)	Percent Detected	N	Comments/Details
2-Chloroethylvinylether	NC	5.00E+00	4.2%	48	Two detections were estimated at the PQL at locations PZ-10 and PZ-12 in 1997 but were not detected at those same locations in subsequent monitoring events. There is no known historical use of 2-chloroethylvinylether at the site, and it is not commonly associated with paper mill sites. On this basis, 2-chloroethylvinylether was removed from further consideration as an IHS.
4,4'-DDD	3.60E-05	9.80E-03	8.0%	112	All detections were in a single sampling event in June 2003; all wells with detection were subsequently non-detect for multiple events in 2010-2011. There is no known historical use of 4,4'-DDD or associated pesticides at the site. On this basis, 4,4'-DDD was removed from further consideration as an IHS.
4,4'-DDE	1.80E-05	2.90E-03	3.7%	108	4,4'-DDE was detected at four wells in June 2003. 4,4'-DDE was not detected at these wells or any other wells in three events in 2010-2011. There is no known historical use of 4,4'-DDE or associated pesticides at the site. On this basis, 4,4'-DDE was removed from further consideration as an IHS.
4,4'-DDT	2.50E-05	7.90E-03	4.7%	107	4,4'-DDT was detected at five wells in June 2003. 4,4'-DDT was not detected at these wells or any other wells in three events in 2010-2011. There is no known historical use of 4,4'-DDT or associated pesticides at the site. On this basis, 4,4'-DDT was removed from further consideration as an IHS.
alpha-Chlordane	3.20E-04	1.60E-03	4.6%	108	Alpha-chlordane was detected at five wells in June 2003. alpha-chlordane was not detected at these wells or any other wells in three events in 2010-2011. There is no known historical use of alpha-chlordane or associated pesticides at the site. On this basis, alpha-chlordane was removed from further consideration as an IHS.
Cadmium	7.90E+00	3.10E+02	37.2%	164	Twice measured above PCUL in 164 measurements: (1) At PA-19, concentration was reported as 310 µg/L (unfiltered sample) upon first measurement in 2009; subsequent measurements in 2010-2011 were less than 4 µg/L; the initial measurement is anomalous. (2) At PZ-10, the total (unfiltered) concentration in 2001 was 10 µg/L; the dissolved (filtered) result for the same sample was less than 2 µg/L; subsequent measurements in 2003 and 2010 were 3.1 µg/L and lower (total and dissolved). Cadmium does not exceed the PCUL in groundwater.
Carbazole	1.91E+00	7.00E+00	10.9%	110	Measured above PCUL four times at two locations: (1) At MW-23, detected below the PCUL in 1997 (1.8 µg/L) then above the PCUL in 2001 (4.6 µg/L); subsequent measurements at this well in 2001, 2002, and 2003 were less than 1 µg/L. (2) At PZ-3, measured between 6.7 µg/L and 7 µg/L in three events in 1997; four subsequent measurements at this well in 2001 - 2003 were less than 1 µg/L. Exceedances of the PCUL were limited to pre-2002 for carbazole.
Dibenzofuran	1.60E+00	5.40E+00	6.1%	82	Twice measured above the PCUL in 82 measurements: (1) At MW-23, the concentration was above the PCUL in 1997 (2 µg/L); three subsequent measurements at this well in 2001-2002 showed declining concentrations below the PCUL (1.4, 1.3, and <1 µg/L in succession). (2) At MW-54 the concentration was 5.4 µg/L in February 2001; subsequent measurements at this well in August 2001 and December 2002 were non-detects (<1 µg/L). Exceedances of the PCUL were limited to pre-2002 for dibenzofuran.
Dieldrin	1.20E-06	1.10E-03	2.4%	83	Dieldrin was detected below the PQL at two wells in 2003 (MW-58 and PZ-10). Dieldrin was not detected at these two wells (or any other well) in 2010. There is no known historical use of dieldrin at the site. On this basis, dieldrin was removed from further consideration as an IHS.
Diesel-range TPH	5.00E+02	3.00E+03	5.9%	170	TPH-Diesel was measured above the PCUL twice: (1) At PA-19, the concentration was reported as 3,000 µg/L on August 21, 2009; TPH-diesel was not detected at this well in five subsequent measurements in 2010-2011 (detection limits ranging from 100 to 260 µg/L). (2) At PZ-9, the concentration was 440 µg/L (below the PCUL) in February 1997 and 840 µg/L (above the PCUL) in August 1997; five subsequent measurements at this well in 2001-2010 were all non-detects (detection limits between 100 and 260 µg/L). None of the wells downgradient of known TPH-diesel releases have had detections above the PCUL. This information is sufficient to conclude that TPH-diesel does not exceed the PCUL at the site.
Endrin	2.30E-03	4.60E-03	2.8%	107	Endrin was detected (below the PQL) at three wells in 2003 (MW-59, MW-70 and PZ-3). Endrin was not detected at two of these wells when sampled again in 2010. There is no endrin result for MW-70 in 2010; the estimated 2003 result for this well was 0.0029 µg/L -- below the PQL and very close to the protective concentration. There is no known historical use of endrin at the site. On this basis, endrin was removed from further consideration as an IHS.
Endrin Aldehyde	3.50E-02	1.40E-01	6.5%	107	Endrin aldehyde was detected above the PCUL once -- at MW-56 in June 2003. Three subsequent measurements at this well in 2010-2011 were non-detect for endrin aldehyde (<0.0017 µg/L). Endrin aldehyde is a breakdown product of endrin. There is no known historical use of endrin at the site. On this basis, endrin aldehyde was removed from further consideration as an IHS.
Endrin Ketone	NC	2.80E-02	2.8%	108	Endrin ketone was detected (below the PQL) at three locations in June 2003. Multiple subsequent measurements at each of these wells in 2010-2011 were non-detect for endrin ketone. Endrin ketone is a breakdown product of endrin. There is no known historical use of endrin at the site. On this basis, endrin ketone was removed from further consideration as an IHS.
Fluorene	3.00E+00	7.40E+00	22.0%	109	Measured above PCUL four times at two locations: (1) At MW-54, detected above the PCUL in February 2001 (7.4 µg/L) then below the PCUL in four subsequent measurements in 2001-2003 (1.2, <0.1, and <0.0026 sequentially). (2) At PZ-3, measured between 3.1 µg/L and 4.2 µg/L in three events in 1997; four subsequent measurements at this well in 2001 - 2003 were less than 1 µg/L. Exceedances of the PCUL were limited to pre-2002 for fluorene.
Heptachlor	5.90E-06	1.80E-03	2.8%	108	Heptachlor was detected at three wells in June 2003. heptachlor was not detected at these wells or any other wells in three events in 2010-2011. There is no known historical use of heptachlor at the site. On this basis, heptachlor was removed from further consideration as an IHS.
Phenanthrene	6.20E+00	8.30E+00	20.4%	103	Measured once above PCUL in 103 measurements: At MW-54, concentration was 8.3 µg/L in February 2001; subsequent measurements in August 2001 (1.8 µg/L) ,December 2002 (<0.1 µg/L), and June 2003 (0.015 µg/L, estimated) were below the PCUL. Exceedances of the PCUL were limited to pre-2002 for phenanthrene.
Selenium	7.10E+01	1.11E+03	31.6%	228	Seven (of 228) measurements at five wells were above the PCUL; six of these were unfiltered samples: (1) At PA-19, the first measurement in 2009 was 1,110 µg/L in an unfiltered sample (anomaly); subsequent sampling at this well in 2010 yielded non detects (<0.5 µg/L) in filtered and unfiltered samples. (2) At PZ-9, two sampling events in 1997 yielded results of 80 µg/L and 300 µg/L in unfiltered samples; six subsequent sampling events in 2001-2010 yielded results below the PCUL for all samples, with the maximum reported concentration of 0.9 µg/L during that time. (3) At MW-54, initial sampling in February 2001 yielded results of 200 µg/L in the unfiltered sample and 100 µg/L in the filtered sample; in August of 2001 the results declined below the PCUL (20 µg/L unfiiltered and <40 µg/L filtered); in three subsequent sampling events between 2002 and 2010 selenium was not detected. (4) At PZ-11, the initial result in February 1997 was 80 µg/L in an unfiltered sample - slightly greater than the PCUL; subsequent sampling over six events from August 1997 through August 2010 yielded results uniformly below the PCUL. (5) At PZ-4, the initial result in February 1997 was 80 µg/L in an unfiltered sample - slightly greater than the PCUL; subsequent sampling over six events from August 1997 through August 2010 yielded results uniformly below the PCUL. Selenium declined to levels below the PCUL at all groundwater locations.
Silver	1.90E+00	8.50E+01	24.2%	128	Only one measurement has yielded a concentration above the PCUL: the initial measurement at PA-19 in 2009 (85 µg/L). In August 2010 filtered and unfiltered samples at this well were non-detect for silver (<0.2 µg/L). The initial PA-19 concentration appears to be an anomaly. Silver does not exceed the PCUL in groundwater.
Thallium	2.70E-01	4.00E-01	16.7%	120	One thallium measurement has been above the PCUL: the unfiltered (total) concentration at PZ-6 in August 2010 was 0.4 µg/L. The filtered (dissolved) concentration for this same sample was less than the PCUL (0.2 µg/L). The dissolved concentration is most relevant for protection of downgradient surface water and the dissolved concentration has not exceeded the PCUL.

N = Number of samples

NC: Not calculated. Not listed in MTCA marine surface-water tables or referenced federal regulations. For purposes of screening here, PCUL is assumed to be the PQL.

Table 9. Final Screening of Groundwater IHSs

Analyte	PCUL (µg/L)	Max. Conc. (µg/L)	Percent Detected	N	Reason for Not Selecting as IHS
Aluminum	5.19E+03	1.04E+03	100.0%	7	Never detected above PCUL in seven measurements. Despite few measurements, it is unlikely that aluminum would be important for overall site risk relative to other inorganic IHSs.
Butylbenzylphthalate	1.00E-01	1.20E-01	1.0%	103	One detection at PZ-11 in 2003 (last measurement); that detection was only slightly above the PCUL and was below the PQL in use at that time. There is no known historic use of butylbenzylphthalate at the site.
Dioxin TEQ	5.10E-09	6.78E-01	82.6%	69	Detections of dioxin in Site groundwater were shown to be associated with suspended solids in samples (GeoEngineers 2012). Dissolved (mobile) groundwater is relevant for protection of the downgradient marine environment. See Section 6.3.2 and Figures 24A-24D of the *Volume I Report (* GeoEngineers 2012) for more details and analysis of correlation between dioxin concentration and suspended solids concentration.

N: Number of samples

Table 10. Groundwater IHSs and PCULs after Screening

IHS	PCUL (µg/L)	Basis
2,4,6-Trichlorophenol	0.28	Human Health
Acenaphthene	3.3	Sediment
Ammonia-N (un-ionized)	35	Aquatic Life
Arsenic	5	Natural Background
bis(2-Ethylhexyl)phthalate	0.25	Human Health
cis-1,2-Dichloroethene	466	Human Health
Cobalt	2.59	Human Health
Copper	3.1	Aquatic Life
cPAH TEQ	0.015	PQL
Iron	9070	Human Health
Lead	8.1	Aquatic Life
Manganese	910	Human Health
Mercury	0.025	Aquatic Life
Nickel	8.2	Aquatic Life
PCBs - Total	0.01	PQL
Pentachlorophenol	0.25	PQL
Trichloroethene	0.86	Human Health
Vinyl chloride	0.26	Human Health
Zinc	81	Aquatic Life

Table 11. Thoroughness of Testing Summary - Soil

Analyte	Number of Measure-ments	Number of Locations	Adequate Reporting Limits	Sufficient Spatial Coverage	Adequate for Post-Operation	Thorough Testing
1,1,1-Trichloroethane	141	97	Yes	Yes	Yes	Yes
1,1,2,2-Tetrachloroethane	141	97	Yes	Yes	Yes	Yes
1,1,2-Trichloroethane	141	97	Yes	Yes	Yes	Yes
1,1-Dichloroethane	142	98	Yes	Yes	Yes	Yes
1,1-Dichloroethene	142	98	Yes	Yes	Yes	Yes
1,2,4-Trichlorobenzene	153	100	Yes	Yes	Yes	Yes
1,2-Dichlorobenzene	153	100	Yes	Yes	Yes	Yes
1,2-Dichloroethane	144	99	Yes	Yes	Yes	Yes
1,2-Dichloroethene	123	79	Yes	Yes	Yes	Yes
1,2-Dichloropropane	141	97	Yes	Yes	Yes	Yes
1,3-Dichlorobenzene	153	100	Yes	Yes	Yes	Yes
1,4-Dichlorobenzene	243	129	Yes	Yes	Yes	Yes
1-Methylnaphthalene	47	46	Yes	Yes	Yes	Yes
2,4,5-Trichlorophenol	153	100	Yes	Yes	Yes	Yes
2,4,6-Trichlorophenol	420	135	Yes	Yes	Yes	Yes
2,4-Dichlorophenol	153	100	Yes	Yes	Yes	Yes
2,4-Dimethylphenol	153	100	Yes	Yes	Yes	Yes
2,4-Dinitrophenol	150	99	Yes	Yes	Yes	Yes
2,4-Dinitrotoluene	248	130	Yes	Yes	Yes	Yes
2,6-Dinitrotoluene	153	100	Yes	Yes	Yes	Yes
2-Butanone	144	99	Yes	Yes	Yes	Yes
2-Chloronaphthalene	153	100	Yes	Yes	Yes	Yes
2-Chlorophenol	153	100	Yes	Yes	Yes	Yes
2-Hexanone	92	69	Yes	Yes	Yes	Yes
2-Methylnaphthalene	210	151	Yes	Yes	Yes	Yes
2-Methylphenol	153	100	Yes	Yes	Yes	Yes
2-Nitroaniline	153	100	Yes	Yes	Yes	Yes
2-Nitrophenol	153	100	Yes	Yes	Yes	Yes
3,3'-Dichlorobenzidine	243	125	Yes	Yes	Yes	Yes
3-Nitroaniline	152	99	Yes	Yes	Yes	Yes
4,4'-DDD	180	96	Yes	Yes	Yes	Yes
4,4'-DDE	180	96	Yes	Yes	Yes	Yes
4,4'-DDT	180	96	Yes	Yes	Yes	Yes
4,6-Dinitro-2-methylphenol	153	100	Yes	Yes	Yes	Yes
4-Bromophenyl-phenylether	152	99	Yes	Yes	Yes	Yes
4-Chloro-3-methylphenol	153	100	Yes	Yes	Yes	Yes
4-Chloroaniline	153	100	Yes	Yes	Yes	Yes
4-Chlorophenyl-phenylether	153	100	Yes	Yes	Yes	Yes
4-Methyl-2-Pentanone	98	74	Yes	Yes	Yes	Yes
4-Methylphenol	154	101	Yes	Yes	Yes	Yes
4-Nitroaniline	153	100	Yes	Yes	Yes	Yes
4-Nitrophenol	153	100	Yes	Yes	Yes	Yes
Acenaphthene	210	152	Yes	Yes	Yes	Yes
Acenaphthylene	209	151	Yes	Yes	Yes	Yes
Acetone	142	98	Yes	Yes	Yes	Yes
Acrylonitrile	**2**	**1**	Yes	**No**	**No**	**No**
Aldrin	180	96	Yes	Yes	Yes	Yes
alpha-BHC	179	95	Yes	Yes	Yes	Yes
alpha-Chlordane	179	95	Yes	Yes	Yes	Yes
Aluminum	123	79	Yes	Yes	Yes	Yes
Anthracene	209	151	Yes	Yes	Yes	Yes
Antimony	237	134	Yes	Yes	Yes	Yes
Arsenic	296	159	Yes	Yes	Yes	Yes
Barium	268	154	Yes	Yes	Yes	Yes
Benzene	145	100	Yes	Yes	Yes	Yes
Benzo(g,h,i)perylene	201	144	Yes	Yes	Yes	Yes
Benzyl alcohol	**29**	24	Yes	Yes	**No**	**No**
Beryllium	123	79	Yes	Yes	Yes	Yes
beta-BHC	180	96	Yes	Yes	Yes	Yes
Bis(2-chloro-1-methylethyl) ether	219	109	Yes	Yes	Yes	Yes
bis(2-Chloroethoxy)methane	123	78	Yes	Yes	Yes	Yes
bis(2-Chloroethyl)ether	246	128	Yes	Yes	Yes	Yes
bis(2-Chloroisopropyl)ether	**29**	24	Yes	Yes	**No**	**No**
bis(2-Ethylhexyl)phthalate	255	129	Yes	Yes	Yes	Yes
Bromodichloromethane	141	97	Yes	Yes	Yes	Yes
Bromoform	141	97	Yes	Yes	Yes	Yes
Bromomethane	123	79	Yes	Yes	Yes	Yes
Butylbenzylphthalate	148	95	Yes	Yes	Yes	Yes
Cadmium	268	154	Yes	Yes	Yes	Yes
Carbazole	153	100	Yes	Yes	Yes	Yes
Carbon Disulfide	141	97	Yes	Yes	Yes	Yes
Carbon Tetrachloride	141	97	Yes	Yes	Yes	Yes
Chlorobenzene	141	97	Yes	Yes	Yes	Yes

Analyte	Number of Measure-ments	Number of Locations	Adequate Reporting Limits	Sufficient Spatial Coverage	Adequate for Post-Operation	Thorough Testing
Chloroethane	141	97	Yes	Yes	Yes	Yes
Chloroform	141	97	Yes	Yes	Yes	Yes
Chloromethane	141	97	Yes	Yes	Yes	Yes
Chromium	266	154	Yes	Yes	Yes	Yes
Chrysene	327	183	Yes	Yes	Yes	Yes
cis-1,2-Dichloroethene	**19**	19	Yes	Yes	**No**	**No**
cis-1,3-DICHLOROPROPENE	141	97	Yes	Yes	Yes	Yes
Cobalt	250	138	Yes	Yes	Yes	Yes
Copper	272	142	Yes	Yes	Yes	Yes
cPAH TEQ	332	188	Yes	Yes	Yes	Yes
delta-BHC	179	95	Yes	Yes	Yes	Yes
Dibenzofuran	163	106	Yes	Yes	Yes	Yes
Dibromochloromethane	141	97	Yes	Yes	Yes	Yes
Dieldrin	180	96	Yes	Yes	Yes	Yes
Diesel-range TPH	267	169	Yes	Yes	Yes	Yes
Diethylphthalate	153	100	Yes	Yes	Yes	Yes
Dimethylphthalate	153	100	Yes	Yes	Yes	Yes
Di-n-butylphthalate	152	99	Yes	Yes	Yes	Yes
Di-n-octylphthalate	146	94	Yes	Yes	Yes	Yes
Dioxin TEQ	126	72	Yes	Yes	Yes	Yes
Endosulfan I	179	95	Yes	Yes	Yes	Yes
Endosulfan II	180	96	Yes	Yes	Yes	Yes
Endosulfan Sulfate	180	96	Yes	Yes	Yes	Yes
Endrin	180	96	Yes	Yes	Yes	Yes
Endrin Aldehyde	179	95	Yes	Yes	Yes	Yes
Endrin Ketone	180	96	Yes	Yes	Yes	Yes
Ethylbenzene	145	100	Yes	Yes	Yes	Yes
Fluoranthene	209	151	Yes	Yes	Yes	Yes
Fluorene	211	152	Yes	Yes	Yes	Yes
Fuel oil-range TPH	60	55	Yes	Yes	Yes	Yes
gamma-BHC (Lindane)	179	95	Yes	Yes	Yes	Yes
gamma-Chlordane	180	96	Yes	Yes	Yes	Yes
Gasoline-range TPH	**24**	**9**	Yes	**No**	**No**	**No**
Heavy oil-range TPH	312	216	Yes	Yes	Yes	Yes
Heptachlor	179	95	Yes	Yes	Yes	Yes
Heptachlor Epoxide	179	95	Yes	Yes	Yes	Yes
Hexachlorobenzene	203	109	Yes	Yes	Yes	Yes
Hexachlorobutadiene	159	100	Yes	Yes	Yes	Yes
Hexachlorocyclopentadiene	152	99	Yes	Yes	Yes	Yes
Hexachloroethane	248	130	Yes	Yes	Yes	Yes
Iron	123	79	Yes	Yes	Yes	Yes
Isophorone	153	100	Yes	Yes	Yes	Yes
Lead	328	173	Yes	Yes	Yes	Yes
Manganese	270	142	Yes	Yes	Yes	Yes
Mercury	288	159	Yes	Yes	Yes	Yes
Methoxychlor	179	95	Yes	Yes	Yes	Yes
Methylene chloride	159	97	Yes	Yes	Yes	Yes
MTBE	**1**	**1**	Yes	**No**	**No**	**No**
Naphthalene	211	153	Yes	Yes	Yes	Yes
Nickel	272	142	Yes	Yes	Yes	Yes
Nitrobenzene	153	100	Yes	Yes	Yes	Yes
N-Nitroso-di-n-propylamine	247	129	Yes	Yes	Yes	Yes
N-Nitrosodiphenylamine	248	130	Yes	Yes	Yes	Yes
PCBs - Total	468	317	Yes	Yes	Yes	Yes
Pentachlorophenol	266	134	Yes	Yes	Yes	Yes
Phenanthrene	209	151	Yes	Yes	Yes	Yes
Phenol	154	101	Yes	Yes	Yes	Yes
Pyrene	324	185	Yes	Yes	Yes	Yes
Selenium	268	154	Yes	Yes	Yes	Yes
Silver	268	154	Yes	Yes	Yes	Yes
Styrene	141	97	Yes	Yes	Yes	Yes
Tetrachloroethylene	147	101	Yes	Yes	Yes	Yes
Thallium	250	138	Yes	Yes	Yes	Yes
Toluene	145	100	Yes	Yes	Yes	Yes
Toxaphene	175	91	Yes	Yes	Yes	Yes
trans-1,2-Dichloroethene	**19**	19	Yes	Yes	**No**	**No**
trans-1,3-DICHLOROPROPENE	141	97	Yes	Yes	Yes	Yes
Trichloroethene	144	99	Yes	Yes	Yes	Yes
Vanadium	252	138	Yes	Yes	Yes	Yes
Vinyl Acetate	**18**	18	Yes	Yes	**No**	**No**
Vinyl chloride	126	81	Yes	Yes	Yes	Yes
Xylenes	126	82	Yes	Yes	Yes	Yes
Zinc	270	142	Yes	Yes	Yes	Yes

Table 12. Analytes Thoroughly Tested and Never Detected in Soil at the Site

Analyte	N	Analyte	N
1,1,1-Trichloroethane	141	4-Chloroaniline	153
1,1,2,2-Tetrachloroethane	141	4-Chlorophenyl-phenylether	153
1,1,2-Trichloroethane	141	4-Nitroaniline	153
1,1-Dichloroethane	142	Bis(2-chloro-1-methylethyl) ether	219
1,1-Dichloroethene	142	bis(2-Chloroethoxy)methane	123
1,2,4-Trichlorobenzene	153	bis(2-Chloroethyl)ether	246
1,2-Dichloroethane	144	Bromodichloromethane	141
1,2-Dichloroethene	123	Bromoform	141
1,2-Dichloropropane	141	Bromomethane	123
1,3-Dichlorobenzene	153	Carbon Tetrachloride	141
2,4,5-Trichlorophenol	153	Chlorobenzene	141
2,4-Dimethylphenol	153	Chloroethane	141
2,4-Dinitrophenol	150	Chloromethane	141
2,4-Dinitrotoluene	248	cis-1,3-DICHLOROPROPENE	141
2,6-Dinitrotoluene	153	Dibromochloromethane	141
2-Chloronaphthalene	153	Hexachlorocyclopentadiene	152
2-Chlorophenol	153	Hexachloroethane	248
2-Methylphenol	153	Nitrobenzene	153
2-Nitroaniline	153	N-Nitroso-di-n-propylamine	247
2-Nitrophenol	153	N-Nitrosodiphenylamine	248
3,3'-Dichlorobenzidine	243	Tetrachloroethylene	147
3-Nitroaniline	152	Toxaphene	175
4,6-Dinitro-2-methylphenol	153	trans-1,3-DICHLOROPROPENE	141
4-Bromophenyl-phenylether	152	Trichloroethene	144
4-Chloro-3-methylphenol	153	Vinyl chloride	126

N = Number of samples

Table 13. Analytes Measured at Few Locations, Not Detected in Soil, and Not Retained as Potential IHSs.

Analyte	N	Reason for Not Selecting as IHS
Acrylonitrile	2	There is no known historical use of acrylonitrile at the site, and it is not commonly associated with paper mill sites. Even with a limited data set (2 samples), the consistency of non-detect results coupled with the lack of site-related chemical use forms the basis for removing acrylonitrile from further consideration as an IHS.
bis(2-Chloroisopropyl)ether	29	There is no known historical use of bis(2-chloroisopropyl)ether at the site, and it is not commonly associated with paper mill sites. Even with a limited data set (29 samples), the consistency of non-detect results coupled with the lack of site-related chemical use forms the basis for removing bis(2-chloroisopropyl)ether from further consideration as an IHS.
cis-1,2-Dichloroethene	19	There have been no detections of cis-1,2-dichloroethene, trans-1,2-dichloroethene, or 1,2-dichloroethene (unspecified); taken tgether, testing has been thorough. Also, there have been no detections of parent trichloroethylene or daughter vinyl chloride in soil.
MTBE	1	Not detected in the single sample anaylzed. Not a significant constituent of interest in soil because gasoline-related constituents are all screened out as potential IHSs in soil and groundwater.
trans-1,2-Dichloroethene	19	There have been no detections of cis-1,2-dichloroethene, trans-1,2-dichloroethene, or 1,2-dichloroethene (unspecified); taken tgether, testing has been thorough. Also, there have been no detections of parent trichloroethylene or daughter vinyl chloride in soil.
Vinyl Acetate	18	There is no known historical use of vinyl acetate at the site, and it is not commonly associated with paper mill sites. Even with a limited data set (18 samples), the consistency of non-detect results coupled with the lack of site-related chemical use forms the basis for removing vinyl acetate from further consideration as an IHS.

N = Number of samples

Table 14. Soil PCUL Development

Analyte	Maximum Detection	Direct Contact, Unrestricted Noncancer	Cancer	Method A	Terrestrial Ecology	Ground-water protect	Toxicity-Based PCUL	Natural Background	PQL	Updated PCUL
1,2-Dichlorobenzene	2.20E-01	7.20E+03					7.20E+03			7.20E+03
1,4-Dichlorobenzene	3.00E-02	5.60E+03	1.85E+02				1.85E+02			1.85E+02
1-Methylnaphthalene	1.70E+00	5.60E+03	3.45E+01				3.45E+01			3.45E+01
2,4,6-Trichlorophenol	1.30E-02	8.00E+01	9.09E+01			1.9E-04	1.87E-04			1.87E-04
2,4-Dichlorophenol	8.20E-01	2.40E+02					2.40E+02			2.40E+02
2-Butanone	3.10E+00	4.80E+04					4.80E+04			4.80E+04
2-Hexanone	1.10E-02	4.00E+02					4.00E+02			4.00E+02
2-Methylnaphthalene	1.10E+00	3.20E+02					3.20E+02			3.20E+02
4,4'-DDD	3.80E-03		4.17E+00				4.17E+00			4.17E+00
4,4'-DDE	3.40E-02		2.94E+00				2.94E+00			2.94E+00
4,4'-DDT	4.60E-02	4.00E+01	2.94E+00				2.94E+00			2.94E+00
4-Methyl-2-Pentanone	1.10E-02	6.40E+03					6.40E+03			6.40E+03
4-Methylphenol	2.10E+00	8.00E+03					8.00E+03			8.00E+03
4-Nitrophenol	1.10E-01	6.40E+02					6.40E+02			6.40E+02
Acenaphthene	1.90E+00	4.80E+03				1.7E-02	1.70E-02			1.70E-02
Acenaphthylene	3.00E-01	2.40E+03					2.40E+03			2.40E+03
Acetone	1.00E+01	7.20E+04					7.20E+04			7.20E+04
Aldrin	2.20E-02	2.40E+00	5.88E-02				5.88E-02			5.88E-02
alpha-BHC	3.90E-04	6.40E+02	1.59E-01				1.59E-01			1.59E-01
alpha-Chlordane	1.30E-02	4.00E+01	2.86E+00				2.86E+00			2.86E+00
Aluminum	3.23E+04	8.00E+04					8.00E+04	3.30E+04		8.00E+04
Anthracene	6.10E+00	2.40E+04					2.40E+04			2.40E+04
Antimony	9.40E+01	3.20E+01			5.00E+00		5.00E+00			5.00E+00
Arsenic	2.60E+02	2.40E+01	6.67E-01			1.5E-01	1.50E-01	2.00E+01		2.00E+01
Barium	8.26E+02	1.60E+04					1.60E+04			1.60E+04
Benzene	1.90E-03	3.20E+02	1.82E+01				1.82E+01			1.82E+01
Benzo(g,h,i)perylene	1.20E+00	2.40E+03					2.40E+03			2.40E+03
Benzyl alcohol	7.00E-02	8.00E+03					8.00E+03			8.00E+03
Beryllium	5.60E-01	1.60E+02					1.60E+02	6.10E-01		1.60E+02
beta-BHC	2.30E-01		5.56E-01				5.56E-01			5.56E-01
bis(2-Ethylhexyl)phthalate	1.80E+03	1.60E+03	7.14E+01			2.8E-02	2.80E-02			2.80E-02
Butylbenzylphthalate	2.60E-01	1.60E+04	5.26E+02				5.26E+02			5.26E+02
Cadmium	1.40E+02	8.00E+01					8.00E+01	7.70E-01		8.00E+01
Carbazole	1.30E+00		5.00E+01				5.00E+01			5.00E+01
Carbon Disulfide	4.60E-02	8.00E+03					8.00E+03			8.00E+03
Chloroform	6.50E-02	8.00E+02	3.23E+01				3.23E+01			3.23E+01
Chromium	3.57E+02	1.20E+05					1.20E+05	4.80E+01		1.20E+05
Chrysene	6.80E+00		1.37E+02				1.37E+02			1.37E+02
Cobalt	8.40E+01	2.40E+01				1.2E-01	1.17E-01			1.17E-01
Copper	9.37E+03	3.20E+03				6.9E-02	6.90E-02	3.60E+01		3.60E+01
cPAH TEQ	4.94E+00		1.00E+00			1.5E-02	1.50E-02		1.50E-02	1.50E-02
delta-BHC	2.20E-03	2.40E+01					2.40E+01			2.40E+01
Dibenzofuran	1.10E+00	8.00E+01					8.00E+01			8.00E+01
Dieldrin	1.70E-02	4.00E+00	6.25E-02				6.25E-02			6.25E-02
Diesel-range TPH	3.90E+04			2.00E+03	2.00E+02		2.00E+02			2.00E+02
Diethylphthalate	2.70E+00	6.40E+04					6.40E+04			6.40E+04
Dimethylphthalate	1.10E+00	8.00E+03					8.00E+03			8.00E+03
Di-n-butylphthalate	7.60E-01	8.00E+03					8.00E+03			8.00E+03
Di-n-octylphthalate	2.20E+01	8.00E+02					8.00E+02			8.00E+02
Dioxin TEQ	3.05E-03	9.30E-05	1.28E-05		2.20E-04		1.28E-05	5.20E-06		1.28E-05
Endosulfan I	9.80E-03	4.80E+02					4.80E+02			4.80E+02
Endosulfan II	2.00E-02	4.80E+02					4.80E+02			4.80E+02
Endosulfan Sulfate	1.80E-02									NC
Endrin	2.10E-02	2.40E+01					2.40E+01			2.40E+01
Endrin Aldehyde	3.20E-02									NC
Endrin Ketone	5.70E-02									NC
Ethylbenzene	2.90E-01	8.00E+03					8.00E+03			8.00E+03
Fluoranthene	6.70E+00	3.20E+03					3.20E+03			3.20E+03
Fluorene	1.90E+00	3.20E+03					3.20E+03			3.20E+03
Fuel oil-range TPH	1.40E+03			2.00E+03			2.00E+03			2.00E+03
gamma-BHC (Lindane)	4.30E-02	2.40E+01	9.09E-01				9.09E-01			9.09E-01
gamma-Chlordane	1.60E-02	4.00E+01	2.86E+00				2.86E+00			2.86E+00
Gasoline-range TPH	2.30E+01			3.00E+01	1.00E+02		3.00E+01			3.00E+01
Heavy oil-range TPH	2.50E+04			2.00E+03			2.00E+03			2.00E+03
Heptachlor	3.00E-02	4.00E+01	2.22E-01				2.22E-01			2.22E-01
Heptachlor Epoxide	3.70E-02	1.04E+00	1.10E-01				1.10E-01			1.10E-01
Hexachlorobenzene	4.10E-02	6.40E+01	6.25E-01				6.25E-01			6.25E-01
Hexachlorobutadiene	1.10E-01	8.00E+01	1.28E+01				1.28E+01			1.28E+01
Iron	2.64E+05	5.60E+04					5.60E+04	3.60E+04		5.60E+04
Isophorone	6.20E-01	1.60E+04	1.05E+03				1.05E+03			1.05E+03
Lead	8.61E+03			2.50E+02		8.1E+01	8.10E+01	1.70E+01		8.10E+01
Manganese	1.41E+04	1.12E+04				5.9E+01	5.90E+01	1.20E+03		1.20E+03
Mercury	6.60E+00					1.3E-03	1.30E-03	7.00E-02		7.00E-02
Methoxychlor	4.80E-02	4.00E+02					4.00E+02			4.00E+02
Methylene chloride	1.50E+00	4.80E+02	5.00E+02				4.80E+02			4.80E+02
Naphthalene	2.30E+00	1.60E+03					1.60E+03			1.60E+03
Nickel	5.72E+02	1.60E+03				5.4E-01	5.40E-01	3.80E+01		3.80E+01
PCBs - Total	4.80E+00		5.00E-01			3.1E-03	3.09E-03		4.00E-03	4.00E-03
Pentachlorophenol	1.50E+01	4.00E+02	2.50E+00			1.7E-04	1.70E-04		1.00E-02	1.00E-02
Phenanthrene	8.00E+00	2.40E+03					2.40E+03			2.40E+03
Phenol	5.30E-01	2.40E+04					2.40E+04			2.40E+04
Pyrene	1.40E+04	2.40E+03					2.40E+03			2.40E+03
Selenium	5.40E+00	4.00E+02					4.00E+02			4.00E+02
Silver	4.88E+01	4.00E+02					4.00E+02			4.00E+02
Styrene	1.20E-03	1.60E+04					1.60E+04			1.60E+04
Thallium	7.00E+00	8.00E-01					8.00E-01			8.00E-01
Toluene	3.50E+00	6.40E+03					6.40E+03			6.40E+03
Vanadium	1.40E+03	4.00E+02					4.00E+02			4.00E+02
Xylenes	7.40E-02	1.60E+04					1.60E+04			1.60E+04
Zinc	2.94E+03	2.40E+04			3.02E+02	5.0E+00	5.00E+00	8.50E+01		8.50E+01

Notes:

All concentrations in mg/kg.

Human-health criteria for TPH ranges, mercury, and lead are taken from Method A tables.

Congener dimethyl terephthalate used for human-health criteria for dimethylphthalate.

NC = Not Calculated for this chemical; screened out in final screening.

Table 15. Method B PCUL Calculations for Soil

Analyte	Non-Cancer Reference Dose mg/kg/d	Protective Concentration - Non-Cancer mg/kg	Carcionogenic Potency Factor kg-d/mg	Protective Concentration - Cancer mg/kg	Toxicity Source
Cobalt	3.00E-04	2.40E+01			RAIS
Carbazole			2.00E-02	5.00E+01	RAIS
benzo(a)pyrene			1.00E+00	1.00E+00	Updated IRIS Value
2-Hexanone	5.00E-03	4.00E+02			IRIS
4-Nitrophenol	8.00E-03	6.40E+02			FDEP 2005
Acenaphthylene	3.00E-02	2.40E+03			Surrogate: pyrene
Benzo(g,h,i)perylene	3.00E-02	2.40E+03			Surrogate: pyrene
delta-BHC	3.00E-04	2.40E+01			Surrogate: gamma-BHC (Lindane)
Phenanthrene	3.00E-02	2.40E+03			Surrogate: pyrene

Table 16. Calculation of Soil Concentrations Protective of Groundwater by Leaching

Analyte	Ground-water PCUL (ug/L)	K_{oc} (L/kg)	K_d (L/kg)	Henry's Law Constant	Protection via Leaching (mg/kg) Unsaturated Zone	Saturated Zone	Note
2,4,6-Trichlorophenol	0.28	3.81E+02	3.81E-01	3.19E-04	3.3E-03	1.9E-04	
Acenaphthene	3.3	4.90E+03	4.90E+00	6.36E-03	3.4E-01	1.7E-02	
Ammonia-N (un-ionized)	35				---	---	Does not parition to soil appreciably
Arsenic	5		2.90E+01		2.9E+00	1.5E-01	
bis(2-Ethylhexyl)phthalate	0.25	1.11E+05	1.11E+02	4.18E-06	5.6E-01	2.8E-02	
Cobalt	2.59		4.50E+01		2.3E+00	1.2E-01	Kd from RAIS
Copper	3.1		2.20E+01		1.4E+00	6.9E-02	
cPAH TEQ	0.015	9.69E+05	9.69E+02	4.63E-05	2.9E-01	1.5E-02	K_{oc} is for benzo(a)pyrene
Iron	9070		2.50E+01		4.6E+03	2.3E+02	Kd from RAIS
Lead	8.1		1.00E+04		1.6E+03	8.1E+01	
Manganese	910		6.50E+01		1.2E+03	5.9E+01	Kd from RAIS
Mercury	0.025		5.20E+01	4.70E-01	2.6E-02	1.3E-03	
Nickel	8.2		6.50E+01		1.1E+01	5.4E-01	
PCBs - Total	0.01	3.09E+05	3.09E+02		6.2E-02	3.1E-03	
Pentachlorophenol	0.25	4.10E+02	4.10E-01	1.00E-06	3.1E-03	1.7E-04	pH-dependant leaching; conservative value used
Zinc	81		6.20E+01	1.11E+00	1.0E+02	5.0E+00	

K_{oc} = organic-carbon partition coefficient; taken from CLARC data tables except as noted

K_d = soil-water partition coefficient; taken from CLARC data tables or calculated as K_{oc} x f_{oc}

f_{oc} = fraction of organic content in sediment (0.001)

RAIS = Risk Assessment Information System, maintained by Oak Ridge National Laboratory

Table 17. Chemicals That Never Exceed the PCUL

Analyte	PCUL (mg/kg)	Max. Conc. (mg/kg)	Percent Detects	N	Analyte	PCUL (mg/kg)	Max. Conc. (mg/kg)	Percent Detects	N
1,2-Dichlorobenzene	7200	0.22	0.7%	153	delta-BHC	24	0.0022	0.6%	179
1,4-Dichlorobenzene	185	0.03	5.8%	243	Dibenzofuran	80	1.1	19.0%	163
1-Methylnaphthalene	34.5	1.7	19.1%	47	Dieldrin	0.0625	0.017	10.0%	180
2,4-Dichlorophenol	240	0.82	2.6%	153	Diethylphthalate	64000	2.7	11.1%	153
2-Butanone	48000	3.1	6.9%	144	Dimethylphthalate	8000	1.1	22.2%	153
2-Hexanone	400	0.011	1.1%	92	Di-n-butylphthalate	8000	0.76	11.8%	152
2-Methylnaphthalene	320	1.1	19.0%	210	Di-n-octylphthalate	800	22	2.7%	146
4,4'-DDD	4.17	0.0038	3.3%	180	Endosulfan I	480	0.0098	11.7%	179
4,4'-DDE	2.941	0.034	17.2%	180	Endosulfan II	480	0.02	2.8%	180
4,4'-DDT	2.941	0.046	19.4%	180	Endrin	24	0.021	4.4%	180
4-Methyl-2-Pentanone	6400	0.011	1.0%	98	Ethylbenzene	8000	0.29	2.8%	145
4-Methylphenol	8000	2.1	11.7%	154	Fluoranthene	3200	6.7	52.2%	209
4-Nitrophenol	640	0.11	0.7%	153	Fluorene	3200	1.9	21.3%	211
Acenaphthalene	2400	0.3	7.2%	209	Fuel oil-range TPH	2000	1400	10.0%	60
Acetone	72000	10	23.9%	142	gamma-BHC (Lindane)	0.909	0.043	3.9%	179
Aldrin	0.0588	0.022	13.9%	180	gamma-Chlordane	2.86	0.016	16.1%	180
alpha-BHC	0.159	0.00039	2.8%	179	Heptachlor	0.22	0.03	7.8%	179
alpha-Chlordane	2.86	0.013	6.1%	179	Heptachlor Epoxide	0.110	0.037	17.9%	179
Aluminum	80000	32300	100.0%	123	Hexachlorobenzene	0.625	0.041	1.5%	203
Anthracene	24000	6.1	33.0%	209	Hexachlorobutadiene	12.821	0.11	1.9%	159
Barium	16000	826	100.0%	268	Isophorone	1053	0.62	0.7%	153
Benzene	18.2	0.0019	0.7%	145	Methoxychlor	400	0.048	3.4%	179
Benzo(g,h,i)perylene	2400.0	1.2	25.9%	201	Methylene chloride	480	1.5	9.4%	159
Benzyl alcohol	8000	0.07	6.9%	29	Naphthalene	1600.0	2.3	23.2%	211
Beryllium	160	0.56	90.2%	123	Phenanthrene	2400.0	8	56.0%	209
beta-BHC	0.556	0.23	31.1%	180	Phenol	24000	0.53	5.8%	154
Butylbenzylphthalate	526	0.26	2.7%	148	Selenium	400	5.4	11.2%	268
Carbazole	50	1.3	18.3%	153	Silver	400	48.8	63.4%	268
Carbon Disulfide	8000	0.046	6.4%	141	Styrene	16000	0.0012	0.7%	141
Chloroform	32.3	0.065	2.1%	141	Toluene	6400	3.5	13.1%	145
Chromium	120000	357	99.2%	266	Xylenes	16000	0.074	7.1%	270
Chrysene	137	6.8	47.4%	327					

N = Number of measurements

Table 18. Final Screening of Soil IHSs

Analyte	PCUL (mg/kg)	Max Conc. (mg/kg)	N	Percent Detects	Reason for Not Selecting as IHS
2,4,6-trichlorophenol	0.000187	0.013	420	0.2%	Detected only once in 420 measurements, in a field duplicate. The normal sample for that duplicate was ND (<0.0069). Screened out as being consistently < PQL.
Antimony	5	94	237	33.8%	Of 80 detections; two exceed the human-health concentration and nine exceed ecological concentration (all of these exceedances are estimated concentrations). All but one sample with a PCUL exceedance also has an exceedance for the zinc ecological criterion. Zonc exceeds its PCUL for far more samples; therefore zinc is better IHS.
Cadmium	80	140	268	51.9%	Only one of 267 measurements above the PCUL. Not a significant contributor to risk.
Endosulfan Sulfate	NC	0.018	180	13.3%	Sum of endosulfans & endosulfan sulfate never detected above PCUL for endosulfan.
Endrin Aldehyde	NC	0.032	179	2.8%	Sum of enrdrin and transofrmation products (aldehyde & ketone) always much less than endrin PCUL.
Endrin Ketone	NC	0.057	180	14.4%	Sum of enrdrin and transofrmation products (aldehyde & ketone) always much less than endrin PCUL.
Gasoline-range TPH	30	23	24	25.0%	Though measured fewer than 30 times, concentrations never exceed the most stringent PCUL for TPH-gasoline. Measurments indicate that TPH impacts at the site are predminantly in the diesel and heavy-oil range. Gasoline-range TPH is therefore screened out as a relatively low potential contributor to risk.
Pyrene	2400	14000	324	52.2%	Only detection above PCUL appears to be anamoly; others <= 10 mg/kg. Not a significant contributor to Site risk.
Vanadium	2	1400	252	100.0%	Only one of 252 measurements over protective concentration of 400; that sample had field duplicate of 53.2 mg/kg.

N = Number of samples

NC = Not Calculated for this chemical.

Table 19. Soil IHSs and PCULs after Screening

IHS	PCULs (mg/kg) Direct Contact Unrestricted	Terrestrial Ecological Receptors	Protection of Groundwater Unsaturated	Protection of Groundwater Saturated	Note
Acenaphthene			0.34	0.017	
Arsenic	20		20	20	PCULs are Natural Background
bis(2-Ethylhexyl)phthalate	71		0.56	0.028	
Cobalt	24		2.3	0.12	
Copper	3200		36	36	Groundwater-Protection PCULs are Natural Background
cPAH TEC	1.0		0.29	0.015	
Diesel-range TPH	2000	200			
Dioxin TEQ	0.000013	0.00022			
Heavy oil-range TPH	2000				
Iron	56000		36000	36000	Groundwater-Protection PCULs are Natural Background
Lead	250		1620	81	Saturated Groundwater-Protection PCUL is Natural Background
Manganese	11200		1200	1200	Groundwater-Protection PCULs are Natural Background
Mercury	2		0.07	0.07	Groundwater-Protection PCULs are Natural Background
Nickel			38	38	Groundwater-Protection PCULs are Natural Background
PCBs - Total	0.5		0.062	0.004	Saturated Groundwater-Protection PCUL is PQL
Pentachlorophenol	2.5		0.01	0.01	Groundwater-Protection PCULs are PQL
Thallium	0.8				
Zinc		302	101	85	Saturated Groundwater-Protection PCUL is Natural Background

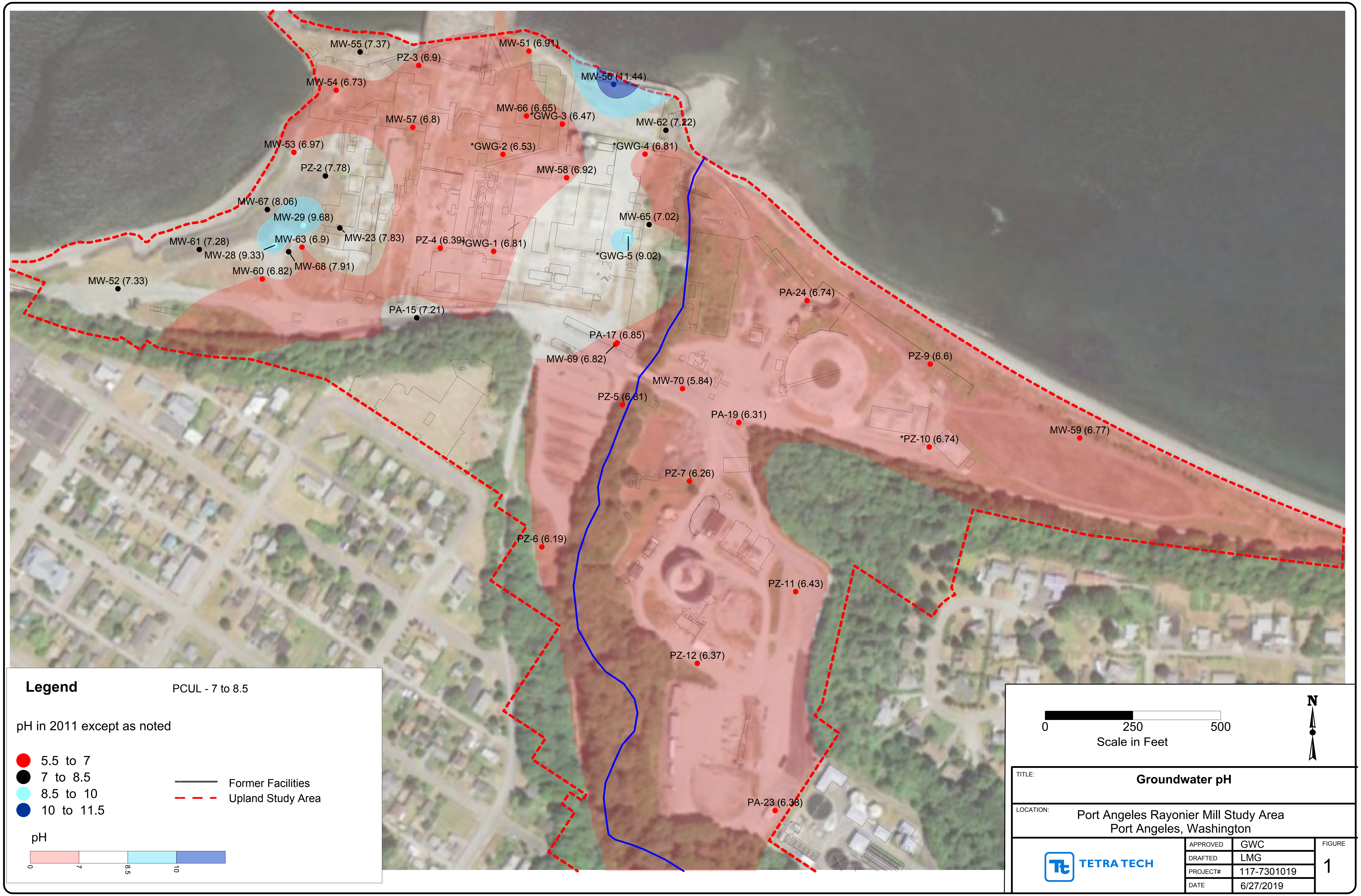
TABLE 20. GROUNDWATER INDICATOR HAZARDOUS SUBSTANCES AND PRELIMINARY CLEANUP LEVELS

IHS	PCUL	Basis
pH	7.0 – 8.5	Protection of marine surface water aquatic life
Ammonia (un-ionized) (µg/L)	35	Protection of marine surface water aquatic life
Arsenic (µg/L)	5	Natural background
Copper (µg/L)	3.1	Protection of marine surface water aquatic life
Manganese (µg/L)	910	Protection of marine surface water – human health
Nickel (µg/L)	8.2	Protection of marine surface water aquatic life
cPAHs (TEQ) (µg/L)	0.015	PQL
Acenaphthene (µg/L)	3.3	Protection of marine sediment

TABLE 21. SOIL INDICATOR HAZARDOUS SUBSTANCES, PRELIMINARY CLEANUP LEVELS, AND POTENTIAL REMEDIATION LEVELS

IHS	Unrestricted Use PCUL (mg/kg)	Industrial Use PCUL (mg/kg)	Ecological PCUL (mg/kg)	Potential REL * (mg/kg)
Arsenic	20	87.5		20
Iron	56,000			180,000
Lead	250	1,000		250
Zinc	24,000		302	302
Thallium	0.8	35		2.5
cPAHs TEQ	1.0	18		2.4
Pentachlorophenol	2.5	328		6.1
Dioxin TEQ	0.000013	0.0017	0.00022	0.000040
PCBs - Total	0.5	65.6		1.2
TPH-Diesel range	2,000	2,000	200	200
TPH-Heavy oil range	2,000	2,000		2,000

*The Potential RELs listed are protective of human health for occasional visitors/trespassers and are protective of terrestrial ecological receptors (Appendix A). These RELs may be used to define where certain remedial technologies are applied in remedial alternatives.



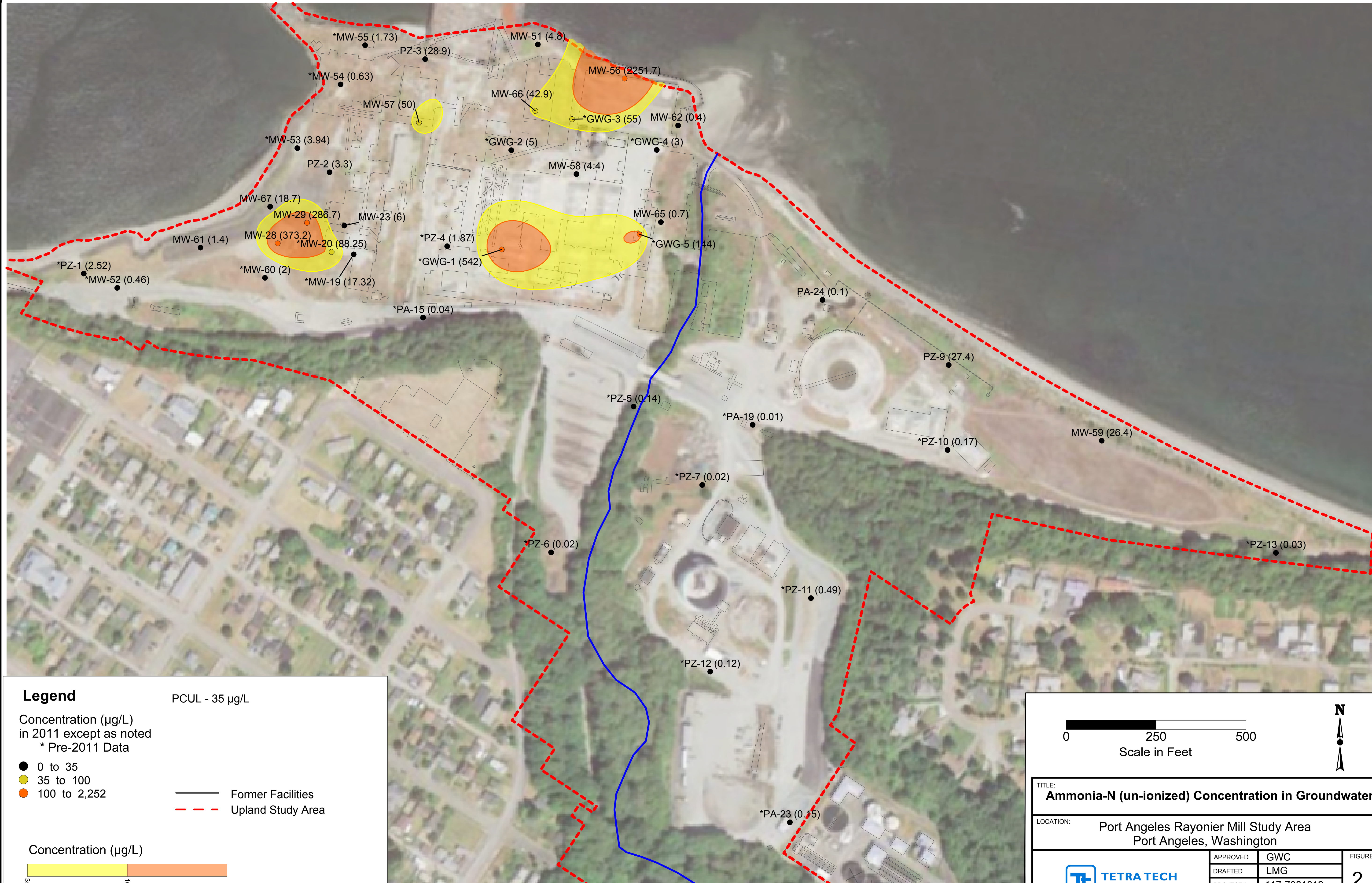
TITLE: Groundwater pH

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019

FIGURE 1



Legend

PCUL - 35 µg/L

Concentration (µg/L)
in 2011 except as noted
* Pre-2011 Data

- 0 to 35
- 35 to 100
- 100 to 2,252

Former Facilities
Upland Study Area

Concentration (µg/L)

35 100

0 250 500
Scale in Feet

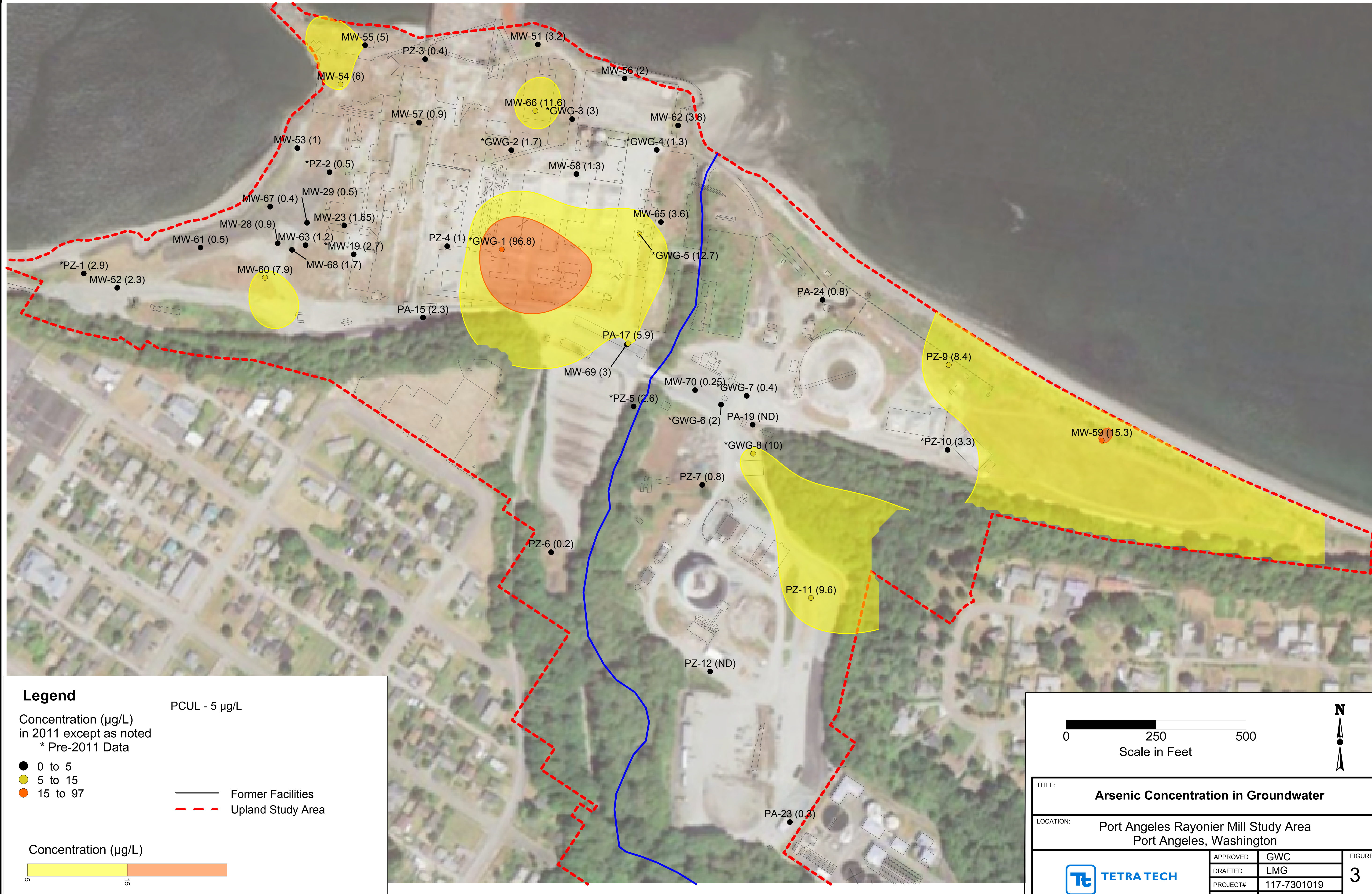
N

TITLE:
Ammonia-N (un-ionized) Concentration in Groundwater

LOCATION:
Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC	FIGURE
DRAFTED	LMG	2
PROJECT#	117-7301019	
DATE	6/27/2019	



TITLE:

Arsenic Concentration in Groundwater

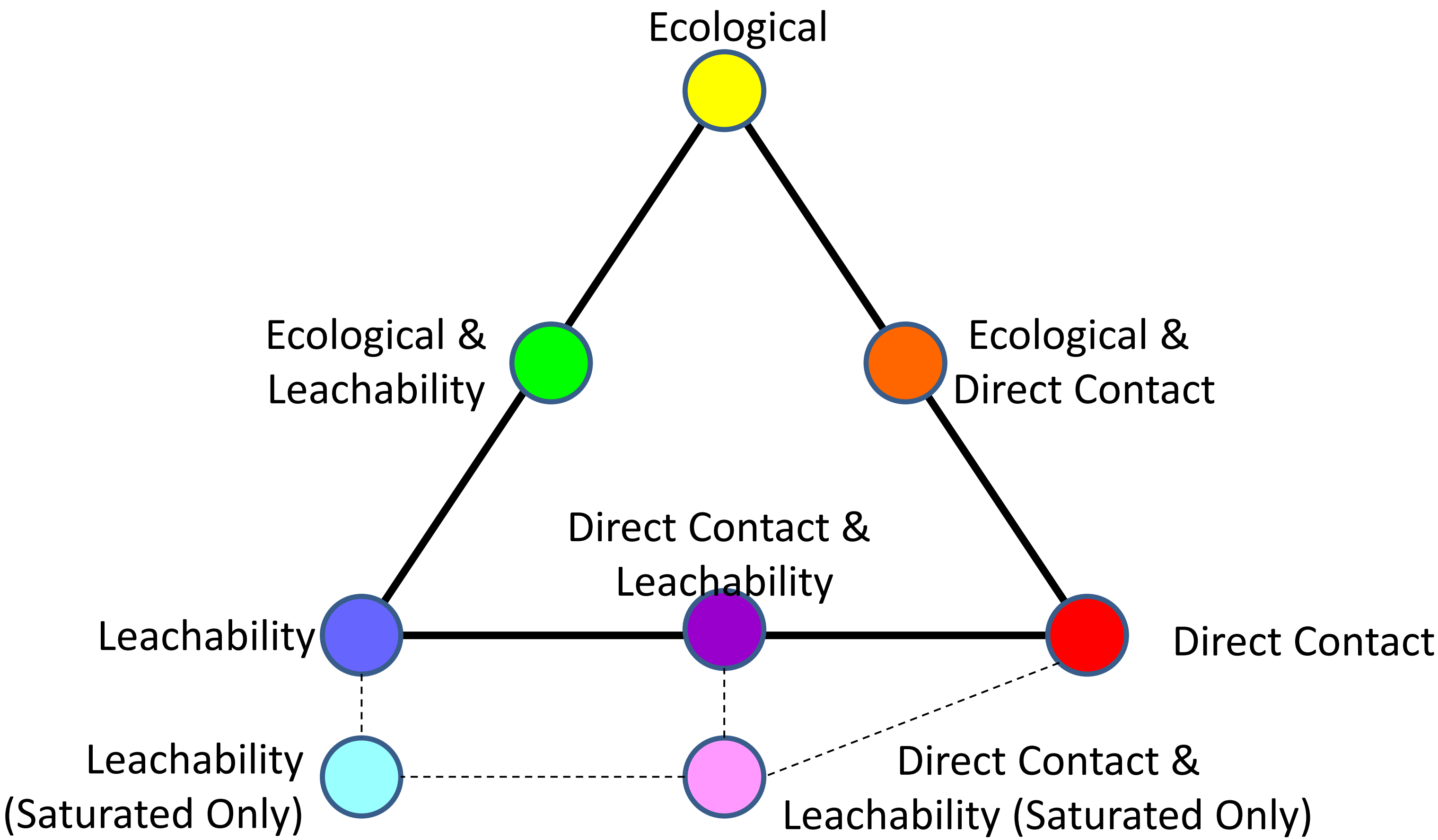
LOCATION:

Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019

FIGURE
3



TITLE: **COLOR CODES FOR SOIL PCUL EXCEEDANCES**

LOCATION: **Port Angeles Rayonier Mill Study Area**
Port Angeles, Washington

TETRA TECH

APPROVED	GC	FIGURE
DRAFTED	LMG	4
PROJECT#	117-7304024	
DATE	4/12/2019	

Legend

Concentration (mg/kg)

- 0 to 20
- 20 to 260

PCUL/Leachability - 20 mg/kg
PCUL/Direct - 20 mg/kg
(Background)

- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

TITLE:	Arsenic Concentration in Soil (0-2 ft)
LOCATION:	Port Angeles Rayonier Mill Study Area, Port Angeles, Washington
APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019
FIGURE	5A

TETRA TECH

TITLE: **Arsenic Concentration in Soil (2-6 ft)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019

FIGURE 5B


Legend
PCUL/Leachability - 20 mg/kg
PCUL/Direct - 20 mg/kg
(Background)
Concentration (ng/kg)
0 to 20
20 to 88
88 to 260
Interim Action Areas
Former Facilities
Upland Study Area
Remediated CSO Corridor
0
250
500
Scale in Feet
N
TITLE:
Arsenic Concentration in Soil
(>6 ft)
LOCATION:
Port Angeles Rayonier Mill Study Area
Port Angeles, Washington
TETRA TECH
APPROVED
GWC
DRAFTED
LMG
PROJECT#
117-7301019
DATE
6/27/2019
FIGURE
5C

TITLE: **Cobalt Concentration in Groundwater**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019
FIGURE	6

Legend

Concentration (mg/kg)

- 0 to 0.12
- 0.12 to 2.3
- 2.3 to 24
- 24 to 100

PCUL/Leachability Sat. - 0.12 mg/kg
PCUL/Leachability Unsat. - 2.3 mg/kg
PCUL/Direct - 24 mg/kg

- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

0 250 500
Scale in Feet

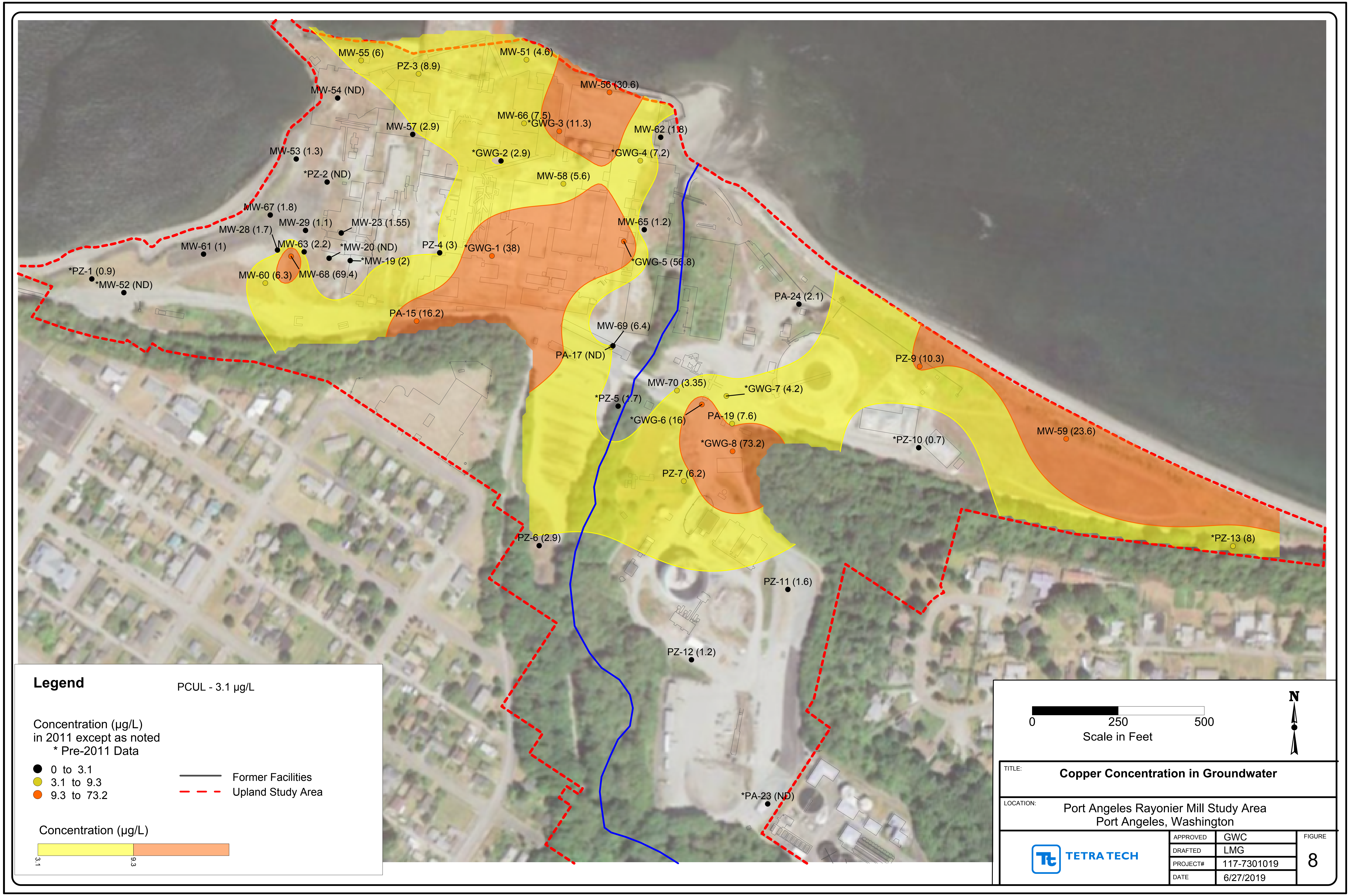
N

TITLE: **Cobalt Concentration in Soil (All Depths)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC	FIGURE	7
DRAFTED	LMG		
PROJECT#	117-7301019		
DATE	6/27/2019		



MW-55 (6)
PZ-3 (8.9)
MW-51 (4.6)
MW-54 (ND)
MW-56 (30.6)
MW-66 (7.5)
*GWG-3 (11.3)
MW-57 (2.9)
MW-62 (1.8)
MW-53 (1.3)
*GWG-2 (2.9)
*GWG-4 (7.2)
*PZ-2 (ND)
MW-58 (5.6)
MW-67 (1.8)
MW-29 (1.1)
MW-23 (1.55)
MW-65 (1.2)
MW-28 (1.7)
MW-63 (2.2)
*MW-20 (ND)
PZ-4 (3)
*GWG-1 (38)
MW-61 (1)
*MW-19 (2)
*GWG-5 (56.8)
*PZ-1 (0.9)
MW-60 (6.3)
MW-68 (69.4)
*MW-52 (ND)
PA-24 (2.1)
PA-15 (16.2)
MW-69 (6.4)
PA-17 (ND)
PZ-9 (10.3)
MW-70 (3.35)
*GWG-7 (4.2)
*PZ-5 (1.7)
*GWG-6 (16)
PA-19 (7.6)
MW-59 (23.6)
*PZ-10 (0.7)
*GWG-8 (73.2)
PZ-7 (6.2)
PZ-6 (2.9)
*PZ-13 (8)
PZ-11 (1.6)
PZ-12 (1.2)
*PA-23 (ND)
Legend
PCUL - 3.1 µg/L
Concentration (µg/L)
in 2011 except as noted
* Pre-2011 Data
0 to 3.1
3.1 to 9.3
9.3 to 73.2
Former Facilities
Upland Study Area
Concentration (µg/L)
3.1
9.3
0
250
500
Scale in Feet
N
TITLE:
Copper Concentration in Groundwater
LOCATION:
Port Angeles Rayonier Mill Study Area
Port Angeles, Washington
TETRA TECH
APPROVED GWC
DRAFTED LMG
PROJECT# 117-7301019
DATE 6/27/2019
FIGURE
8

Legend

Concentration (mg/kg)
- 0 to 36
- 36 to 3200
- 3200 to 9400

PCUL/Leachability Sat. - 36 mg/kg (Background)
PCUL/Direct - 3200 mg/kg

- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

0 250 500
Scale in Feet

N

TITLE: **Copper Concentration in Soil (All Depths)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019
FIGURE	9

Legend

PCUL/Leachability Sat. - 36 mg/kg (Background)
PCUL/Direct - 3200 mg/kg

Concentration (mg/kg)

- 0 to 36
- 36 to 3200
- 3200 to 9400

- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

0 250 500
Scale in Feet

N

TITLE: **Copper Concentration in Soil (0-2 ft)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019

FIGURE 9A

TITLE:	Copper Concentration in Soil (2-6 ft)
LOCATION:	Port Angeles Rayonier Mill Study Area Port Angeles, Washington
APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019
FIGURE	9B

TETRA TECH


Legend
Concentration (mg/kg)
0 to 36
36 to 3200
3200 to 9400
PCUL/Leachability Sat. - 36 mg/kg (Background)
PCUL/Direct - 3200 mg/kg
Interim Action Areas
Former Facilities
Upland Study Area
Remediated CSO Corridor
0
250
500
Scale in Feet
N
TITLE:
Copper Concentration in Soil (6-15 ft)
LOCATION:
Port Angeles Rayonier Mill Study Area
Port Angeles, Washington
TETRA TECH
APPROVED GWC
DRAFTED LMG
PROJECT# 117-7301019
DATE 6/27/2019
FIGURE 9C

TITLE: Copper Concentration in Soil (>15 ft)

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019
FIGURE	9D

TITLE:
Iron Concentration in Groundwater

LOCATION:
Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019

FIGURE 10

Legend

PCUL/Leachability Sat. - 36,000 mg/kg
PCUL/Direct - 56,000 mg/kg

Concentration (mg/kg)

- 0 to 36,000
- 36,000 to 56,000
- 56,000 to 200,000

- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

0 250 500
Scale in Feet

N

TITLE: **Iron Concentration in Soil (All Depths)**

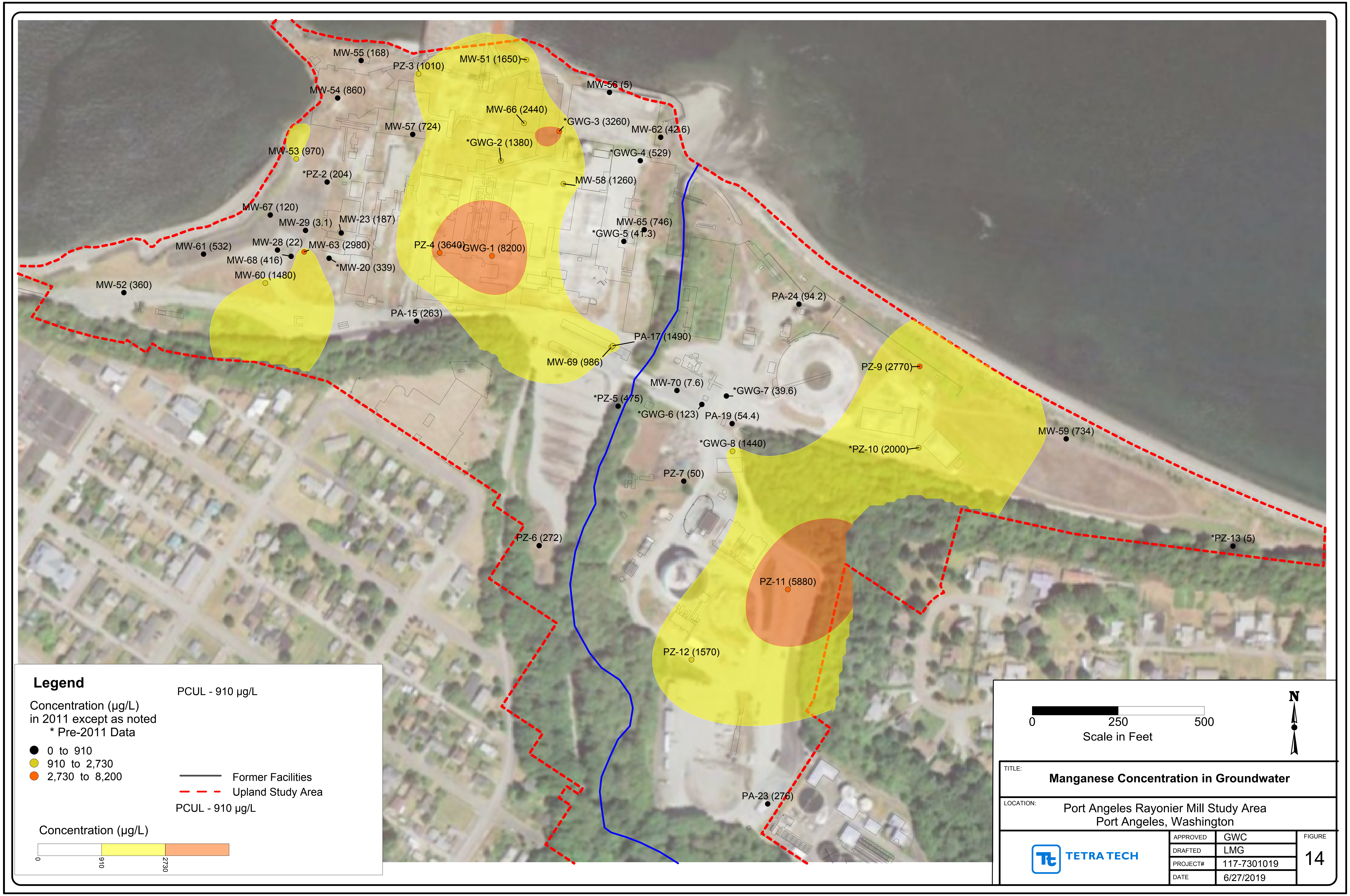
LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC	FIGURE	
DRAFTED	LMG		11
PROJECT#	117-7301019		
DATE	6/27/2019		


*MW-55 (10 U)
MW-51 (1)
PZ-3 (1 U)
MW-56 (1)
*MW-54 (10 U)
#MW-66 (0.8)
#GWG-3 (9)
MW-57 (1 U)
MW-62 (1 U)
MW-53 (1 U)
#GWG-2 (1)
#GWG-4 (3)
*FR-1 (1 U)
#PZ-2 (1 U)
*MW-58 (0.1)
#MW-67 (0.2)
MW-23 (1 U)
MW-29 (1 U)
#MW-65 (0.3)
#GWG-5 (51)
#MW-61 (1 U)
MW-28 (1)
#MW-68 (0.2)
MW-63 (1 U)
PZ-4 (1 U)
*PZ-1 (1 U)
*MW-52 (0.02 U)
#MW-60 (4.2)
*#MW-20 (20 U)
*MW-19 (1 U)
#GWG-1 (7)
PA-24 (1 U)
#PA-15 (1 U)
#PA-17 (0.1 U)
#MW-69 (1.6)
#GWG-7 (1 U)
PZ-9 (1)
PZ-5 (1 U)
#MW-70 (0.1 U)
#GWG-6 (1)
PA-19 (1 U)
PZ-10 (1 U)
MW-59 (1 U)
#GWG-8 (9)
*PZ-7 (0.13)
PZ-6 (1 U)
*#PZ-13 (20 U)
PZ-11 (1 U)
PZ-12 (1 U)
#PA-23 (1 U)
Legend
PCUL - 8.1 µg/L
Dissolved Concentration (µg/L)
in 2011 except as noted
* Pre-2011 Data
# Total (Unfiltered)
Concentration
Non Detect DL > 8.1
Non Detect DL < 8.1
8.1 to 100
Historic Lead > PCUL
Dissolved or Total
Former Facilities
Upland Study Area
0
250
500
Scale in Feet
N
TITLE:
Lead Concentration in Groundwater
LOCATION:
Port Angeles Rayonier Mill Study Area
Port Angeles, Washington
TETRA TECH
APPROVED GWC
DRAFTED LMG
PROJECT# 117-7301019
DATE 6/27/2019
FIGURE
12

7310
2060
8610
Legend
Concentration (mg/kg)
0 to 81
81 to 250
250 to 1,620
1,620 to 10,000
PCUL/Leachability Sat. - 81 mg/kg (Background)
PCUL/Direct - 250 mg/kg
PCUL/Leachability Unsat. - 1620 mg/kg
Interim Action Areas
Former Facilities
Upland Study Area
Remediated CSO Corridor
0 250 500
Scale in Feet
N
TITLE:
Lead Concentration in Soil (All Depths)
LOCATION:
Port Angeles Rayonier Mill Study Area
Port Angeles, Washington
TETRA TECH
APPROVED GWC
DRAFTED LMG
PROJECT# 117-7301019
DATE 6/27/2019
FIGURE 13


MW-55 (168)
PZ-3 (1010)
MW-51 (1650)
MW-56 (5)
MW-54 (860)
MW-66 (2440)
*GWG-3 (3260)
MW-62 (42.6)
MW-57 (724)
*GWG-2 (1380)
*GWG-4 (529)
MW-53 (970)
*PZ-2 (204)
MW-58 (1260)
MW-67 (120)
MW-29 (3.1)
MW-23 (187)
MW-65 (746)
*GWG-5 (41.3)
MW-61 (532)
MW-28 (22)
MW-63 (2980)
PZ-4 (3640)
GWG-1 (8200)
MW-68 (416)
*MW-20 (339)
MW-60 (1480)
MW-52 (360)
PA-24 (94.2)
PA-15 (263)
PA-17 (1490)
MW-69 (986)
PZ-9 (2770)
MW-70 (7.6)
*GWG-7 (39.6)
*PZ-5 (475)
*GWG-6 (123)
PA-19 (54.4)
MW-59 (734)
*GWG-8 (1440)
*PZ-10 (2000)
PZ-7 (50)
PZ-6 (272)
*PZ-13 (5)
PZ-11 (5880)
PZ-12 (1570)
PA-23 (276)
Legend
Concentration (µg/L)
in 2011 except as noted
* Pre-2011 Data
0 to 910
910 to 2,730
2,730 to 8,200
PCUL - 910 µg/L
Former Facilities
Upland Study Area
PCUL - 910 µg/L
Concentration (µg/L)
0
910
2730
0
250
500
Scale in Feet
N
TITLE:
Manganese Concentration in Groundwater
LOCATION:
Port Angeles Rayonier Mill Study Area
Port Angeles, Washington
TETRA TECH
APPROVED GWC
DRAFTED LMG
PROJECT# 117-7301019
DATE 6/27/2019
FIGURE
14

Legend

Concentration (mg/kg)

- 0 to 1200
- 1200 to 11200
- 11200 to 14100

PCUL/Leachability Sat. - 1200 mg/kg (Background)

PCUL/Direct - 11,200 mg/kg

- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

0 250 500

Scale in Feet

N

TITLE:	**Manganese Concentration in Soil (All Depths)**
LOCATION:	Port Angeles Rayonier Mill Study Area Port Angeles, Washington

TETRA TECH

APPROVED	GWC	FIGURE
DRAFTED	LMG	15
PROJECT#	117-7301019	
DATE	6/27/2019	

TITLE: **Mercury Concentration in Groundwater**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC	FIGURE
DRAFTED	LMG	16
PROJECT#	117-7301019	
DATE	6/27/2019	

Legend

Concentration (mg/kg)

- 0 to 0.07
- 0.07 to 2
- 2 to 7

PCUL/Leachability Sat. - 0.07 mg/kg (Background)
PCUL/Direct - 2 mg/kg (Method A)

- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

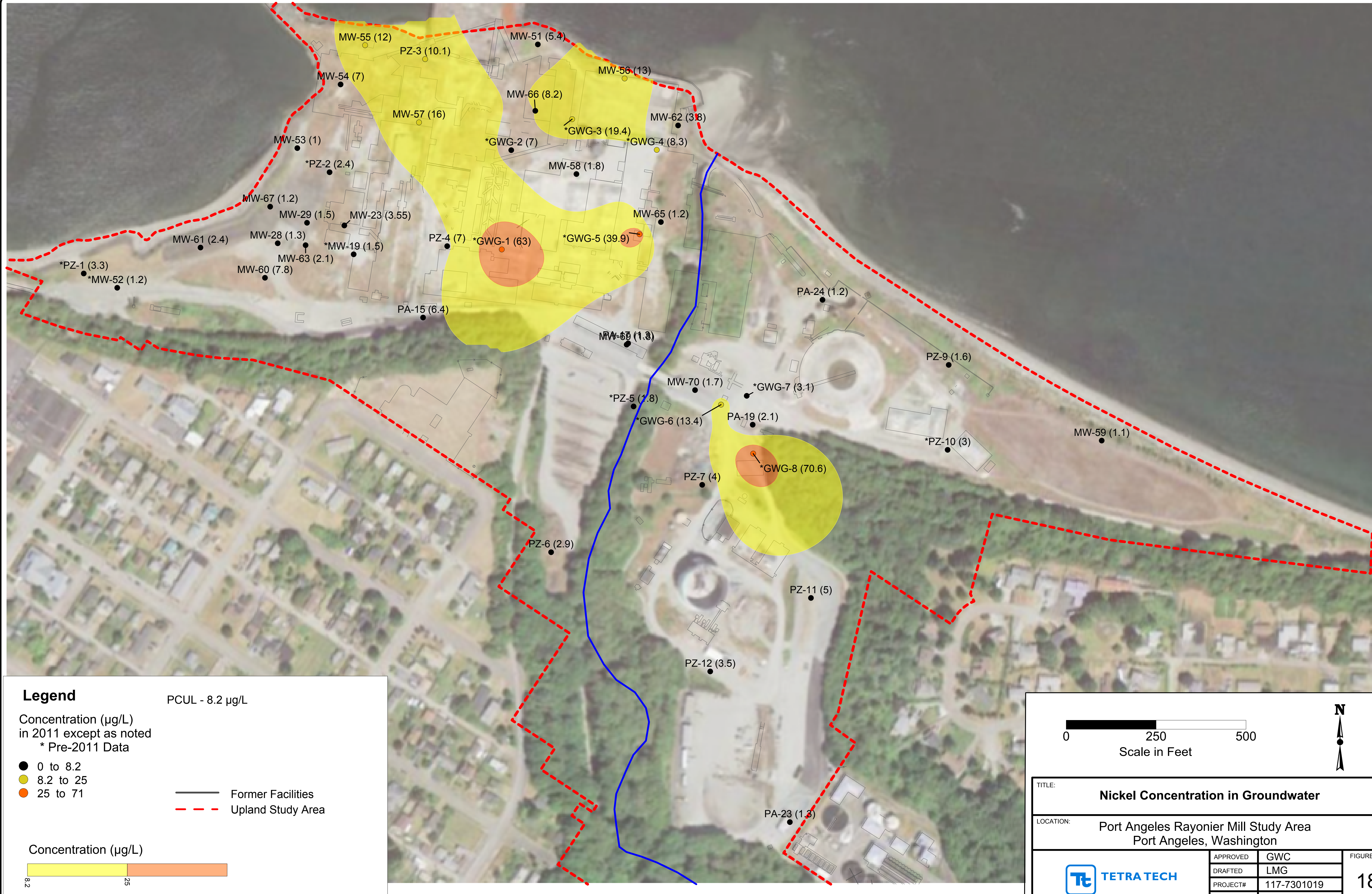
0 250 500
Scale in Feet

N

TITLE:	Mercury Concentration in Soil (All Depths)
LOCATION:	Port Angeles Rayonier Mill Study Area Port Angeles, Washington

TETRA TECH

APPROVED	GWC	FIGURE
DRAFTED	LMG	17
PROJECT#	117-7301019	
DATE	6/27/2019	



TITLE: **Nickel Concentration in Groundwater**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019

FIGURE 18

Legend

PCUL/Leachability Sat. -38 mg/kg (Background)

Concentration (mg/kg)

- 0 to 38
- 38 to 600

- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

0 250 500
Scale in Feet

N

TITLE: **Nickel Concentration in Soil (All Depths)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019

FIGURE 19


#MW-55 (40 U)
PZ-3 (4 U)
MW-51 (6)
MW-56 (6)
#MW-54 (40 U)
MW-57 (115)
#MW-66 (27)
#GWG-3 (22)
MW-62 (4 U)
MW-53 (4 U)
#GWG-2 (12)
#GWG-4 (37)
#PZ-2 (4 U)
MW-58 (4 U)
#MW-67 (4 U)
MW-23 (4 U)
MW-29 (4 U)
#MW-65 (4 U)
#GWG-5 (134)
#MW-61 (4 U)
MW-28 (4 U)
PZ-4 (4 U)
#GWG-1 (86)
*#MW-19 (38)
#MW-60 (70)
#MW-52 (5)
*#MW-20 (4 U)
#MW-68 (17)
MW-63 (4 U)
#PA-15 (4 U)
PA-24 (4 U)
#PA-17 (4 U)
#MW-69 (4 U)
PZ-9 (20)
#MW-70 (4 U)
#GWG-7 (4)
PZ-5 (4 U)
PA-19 (50)
#GWG-6 (20)
#GWG-8 (81)
PZ-10 (4 U)
MW-59 (4 U)
#PZ-7 (153)
PZ-6 (4 U)
*#PZ-13 (5 U)
PZ-11 (4)
PZ-12 (4 U)
#PA-23 (4 U)
Legend
PCUL - 81 µg/L
Concentration (µg/L)
in 2010/11 except as noted
* Pre-2010 Data
#Total Zinc
0 to 81
81 to 1,000
Historic Zinc > PCUL
Former Facilities
Upland Study Area
0
250
500
Scale in Feet
N
TITLE:
Zinc Concentration in Groundwater
LOCATION:
Port Angeles Rayonier Mill Study Area
Port Angeles, Washington
TETRA TECH
APPROVED GWC
DRAFTED LMG
PROJECT# 117-7301019
DATE 6/27/2019
FIGURE
20

TITLE: **Zinc Concentration in Soil (0-2 ft)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC	FIGURE	
DRAFTED	LMG	21A	
PROJECT#	117-7301019		
DATE	6/27/2019		

TITLE: **Zinc Concentration in Soil (2-6 ft)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019

FIGURE 21B

TITLE: **Zinc Concentration in Soil (>6 ft)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC	FIGURE
DRAFTED	LMG	21C
PROJECT#	117-7301019	
DATE	6/27/2019	

Legend

PCUL/Direct - 0.8 mg/kg

Concentration (mg/kg)

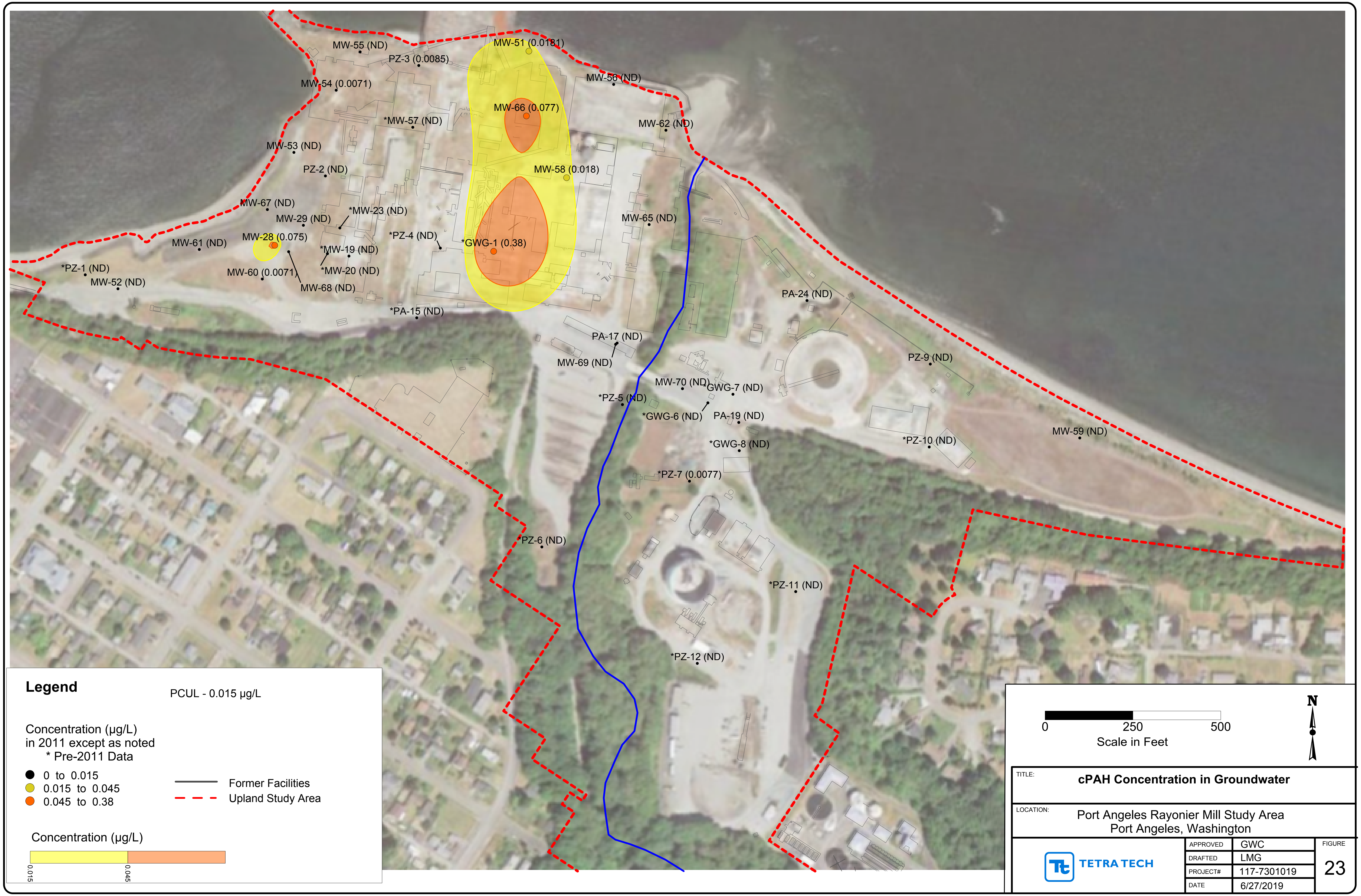
- Non Detect > 0.8
- Non Detect < 0.8
- 0.8 to 10

- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

0 250 500
Scale in Feet

N

TITLE:	**Thallium Concentration in Soil (All Depths)**		
LOCATION:	Port Angeles Rayonier Mill Study Area Port Angeles, Washington		
TETRA TECH	APPROVED	GWC	FIGURE
	DRAFTED	LMG	22
	PROJECT#	117-7301019	
	DATE	6/27/2019	


MW-55 (ND)
PZ-3 (0.0085)
MW-51 (0.0181)
MW-54 (0.0071)
MW-56 (ND)
MW-66 (0.077)
*MW-57 (ND)
MW-62 (ND)
MW-53 (ND)
PZ-2 (ND)
MW-58 (0.018)
MW-67 (ND)
*MW-23 (ND)
MW-29 (ND)
MW-65 (ND)
MW-28 (0.075)
*PZ-4 (ND)
MW-61 (ND)
*GWG-1 (0.38)
*MW-19 (ND)
*PZ-1 (ND)
*MW-20 (ND)
MW-60 (0.0071)
MW-52 (ND)
MW-68 (ND)
PA-24 (ND)
*PA-15 (ND)
PA-17 (ND)
PZ-9 (ND)
MW-69 (ND)
MW-70 (ND)
GWG-7 (ND)
*PZ-5 (ND)
*GWG-6 (ND)
PA-19 (ND)
MW-59 (ND)
*PZ-10 (ND)
*GWG-8 (ND)
*PZ-7 (0.0077)
*PZ-6 (ND)
*PZ-11 (ND)
*PZ-12 (ND)
Legend
PCUL - 0.015 µg/L
Concentration (µg/L)
in 2011 except as noted
* Pre-2011 Data
0 to 0.015
0.015 to 0.045
0.045 to 0.38
Former Facilities
Upland Study Area
Concentration (µg/L)
0.015
0.045
0
250
500
Scale in Feet
N
TITLE:
cPAH Concentration in Groundwater
LOCATION:
Port Angeles Rayonier Mill Study Area
Port Angeles, Washington
TETRA TECH
APPROVED GWC
DRAFTED LMG
PROJECT# 117-7301019
DATE 6/27/2019
FIGURE
23


3.47
4.94
1.10
1.09
1.45
1.91
1.21
Legend
PCUL/Leachability Sat. -0.015 mg/kg(PQL)
PCUL/Leachability Unsat. - 0.29 mg/kg
PCUL/Direct - 1 mg/kg
Concentration (mg/kg)
0 to 0.015
0.015 to 0.29
0.29 to 1
1 to 5
Interim Action Areas
Former Facilities
Upland Study Area
Remediated CSO Corridor
0 250 500
Scale in Feet
N
TITLE:
cPAH Concentration in Soil
(0-2 ft)
LOCATION:
Port Angeles Rayonier Mill Study Area
Port Angeles, Washington
TETRA TECH
APPROVED GWC
DRAFTED LMG
PROJECT# 117-7301019
DATE 6/27/2019
FIGURE
24A

Legend

PCUL/Leachability Sat. -0.015 mg/kg(PQL)
PCUL/Leachability Unsat. - 0.29 mg/kg
PCUL/Direct - 1 mg/kg

Concentration (mg/kg)

- 0 to 0.015
- 0.015 to 0.29
- 0.29 to 1
- 1 to 5

- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

TITLE:	cPAH Concentration in Soil (2-6 ft)
LOCATION:	Port Angeles Rayonier Mill Study Area Port Angeles, Washington
APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019
FIGURE	24B

TETRA TECH

Legend

PCUL/Leachability Sat. -0.015 mg/kg(PQL)
PCUL/Leachability Unsat. - 0.29 mg/kg
PCUL/Direct - 1 mg/kg

Concentration (mg/kg)

- 0 to 0.015
- 0.015 to 0.29
- 0.29 to 1
- 1 to 5

- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

0 250 500
Scale in Feet

N

TITLE:	cPAH Concentration in Soil (6-15 ft)		
LOCATION:	Port Angeles Rayonier Mill Study Area Port Angeles, Washington		
TETRA TECH	APPROVED	GWC	FIGURE
	DRAFTED	LMG	24C
	PROJECT#	117-7301019	
	DATE	6/27/2019	

Legend

PCUL/Leachability Sat. -0.015 mg/kg(PQL)
PCUL/Leachability Unsat. - 0.29 mg/kg
PCUL/Direct - 1 mg/kg

Concentration (mg/kg)

- 0 to 0.015
- 0.015 to 0.29
- 0.29 to 1
- 1 to 5

- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

0 250 500
Scale in Feet

N

TITLE: **cPAH Concentration in Soil (> 15 ft)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019
FIGURE	24D

TITLE:	Antimony Concentration in Soil (All Depths)		
LOCATION:	Port Angeles Rayonier Mill Study Area Port Angeles, Washington		
TETRA TECH	APPROVED	GWC	FIGURE
	DRAFTED	LMG	25
	PROJECT#	117-7301019	
	DATE	6/27/2019	

TITLE: **Acenapthene Concentration in Soil (All Depths)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC	FIGURE
DRAFTED	LMG	26
PROJECT#	117-7301019	
DATE	6/27/2019	

Legend

PCUL/Leachability Sat. - 0.017 mg/kg
PCUL/Leachability Unsat. - 0.34 mg/kg

Concentration (mg/kg)

- 0 to 0.017
- 0.017 to 0.34
- 0.34 to 1.9

- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

0 250 500
Scale in Feet

N

TITLE: **Acenapthene Concentration in Soil (0-2 ft)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019

FIGURE 26A

TITLE: **Pentachlorophenol Concentration in Groundwater**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC	FIGURE
DRAFTED	LMG	27
PROJECT#	117-7301019	
DATE	6/27/2019	


4.3
5.3
15
7.1
3.9
Legend
PCUL/Leachability - 0.01 mg/kg(PQL)
PCUL/Direct - 2.5 mg/kg
Concentration (mg/kg)
0 to 0.01
0.01 to 2.5
2.5 to 15
Interim Action Areas
Former Facilities
Upland Study Area
Remediated CSO Corridor
0
250
500
Scale in Feet
N
TITLE:
Pentachlorophenol Concentration in Soil
(All Depths)
LOCATION:
Port Angeles Rayonier Mill Study Area
Port Angeles, Washington
TETRA TECH
APPROVED GWC
DRAFTED LMG
PROJECT# 117-7301019
DATE 6/27/2019
FIGURE
28

TITLE: **Pentachlorophenol Concentration in Soil (0-2 ft)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019

FIGURE 28A

TITLE: **Pentachlorophenol Concentration in Soil (2-6 ft)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019

FIGURE 28B

TITLE: **Pentachlorophenol Concentration in Soil (6-15 ft)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019
FIGURE	28C

Legend

PCUL/Leachability - 0.01 mg/kg(PQL)
PCUL/Direct - 2.5 mg/kg

Concentration (mg/kg)

- 0 to 0.01
- 0.01 to 2.5
- 2.5 to 15
- Not detected; detection limit between 0.01 and 2.5 mg/kg

- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

0 250 500
Scale in Feet

N

TITLE: **Pentachlorophenol Concentration in Soil (>15 ft)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019

FIGURE 28D

TITLE: **Bis(2-ethylhexyl)phthalate Concentration in Groundwater**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC	FIGURE	29
DRAFTED	LMG		
PROJECT#	117-7301019		
DATE	6/27/2019		

Legend

Concentration (mg/kg)

- 0 to 0.028
- 0.028 to 0.56
- 0.56 to 71
- 71 to 2000

PCUL/Leachability Sat. - 0.028 mg/kg
PCUL/Leachability Unsat. - 0.56 mg/kg
PCUL/Direct - 71 mg/kg

- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

TITLE:	bis(2-Ethylhexyl)phthalate Concentration in Soil (All Depths)
LOCATION:	Port Angeles Rayonier Mill Study Area Port Angeles, Washington
APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019
FIGURE	30

TETRA TECH

TITLE:

Total PCB Concentration in Groundwater

LOCATION:

Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC	FIGURE
DRAFTED	LMG	31
PROJECT#	117-7301019	
DATE	6/27/2019	

Legend

Concentration (mg/kg)

- 0 to 0.004
- 0.004 to 0.062
- 0.062 to 0.5
- 0.5 to 4.8

PCUL/Leachability Sat. -0.004 mg/kg
PCUL/Leachability Unsat. - 0.062 mg/kg
PCUL/Direct - 0.5 mg/kg

- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

0 250 500
Scale in Feet

N

TITLE: **PCB Concentration in Soil (0-2 ft)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC	FIGURE	
DRAFTED	LMG	32A	
PROJECT#	117-7301019		
DATE	6/27/2019		

Legend

PCUL/Leachability Sat. -0.004 mg/kg
PCUL/Leachability Unsat. - 0.062 mg/kg
PCUL/Direct - 0.5 mg/kg

Concentration (mg/kg)

- 0 to 0.004
- 0.004 to 0.062
- 0.062 to 0.5
- 0.5 to 4.8

- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

0 250 500
Scale in Feet

N

TITLE: **PCB Concentration in Soil (> 2 ft)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019

FIGURE 32B

TITLE: **Dioxin Concentration in Soil (0-2 ft)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019

FIGURE 33A

Legend

PCUL/Direct - 13 ng/kg
PCUL/Eco - 220 ng/kg

Concentration (ng/kg)

- 0 to 13
- 13 to 40
- 40 to 220
- 220 to 3100

- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

0 250 500
Scale in Feet

N

TITLE: **Dioxin Concentration in Soil (>2 ft)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019

FIGURE 33B

Legend

PCUL/Eco - 200 mg/kg
PCUL/Direct - 2000 mg/kg

Concentration (mg/kg)
- 0 to 200
- 200 to 2000
- 2000 to 39000

- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

0 250 500
Scale in Feet

N

TITLE: **Diesel-range TPH Concentration in Soil (All Depths)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC	FIGURE
DRAFTED	LMG	34
PROJECT#	117-7301019	
DATE	6/27/2019	

TITLE: **Heavy-oil-range TPH Concentration in Soil (All Depths)**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC	FIGURE
DRAFTED	LMG	35
PROJECT#	117-7301019	
DATE	6/27/2019	

Legend

PCUL - 0.28 µg/L

Concentration (µg/L)
in 2011 except as noted
* Pre-2011 Data

- Non-Detects
- Detections

Historic 2,4,6-TCP > ND

Former Facilities

Upland Study Area

TITLE: **2,4,6-Trichlorophenol Concentration in Groundwater**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/26/2019

FIGURE 36

Legend

Maximum TCE Concentration (µg/L) in 2010-2011

- Non Detect
- Detection
- 0.2 to 100

TCE PCUL - 0.86 µg/L

- Historic TCE,cis-DCE or VC > ND
- Former Facilities
- Upland Study Area

0 250 500
Scale in Feet

N

TITLE: **TCE Concentration in Groundwater**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	6/27/2019

FIGURE 37

Legend

- Area Exceeding at Least One Groundwater PCUL
- City Purchase Area
- Ennis Creek Restoration Area
- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

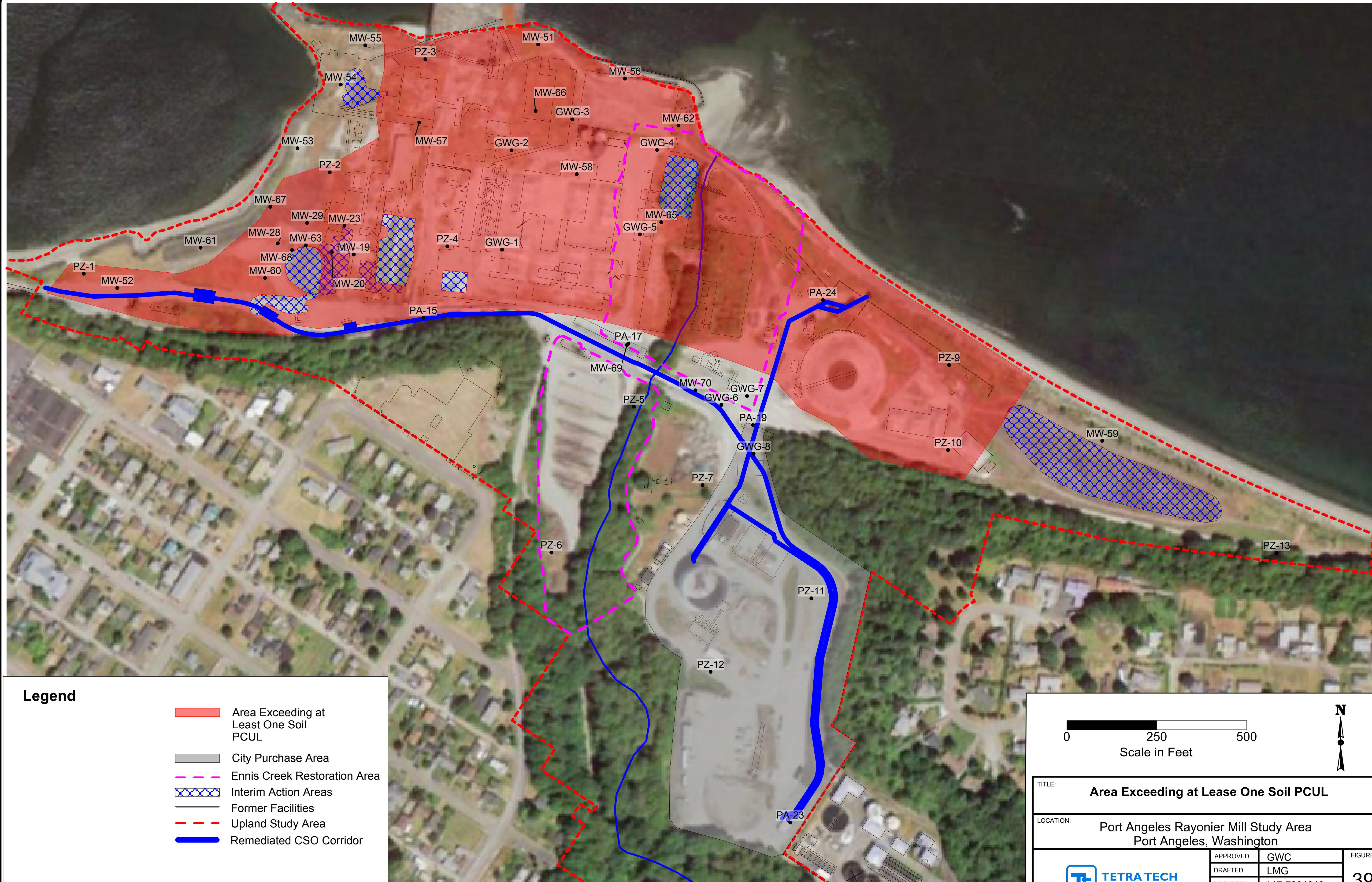
TITLE: **Area Exceeding at Least One Groundwater PCUL**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC
DRAFTED	LMG
PROJECT#	117-7301019
DATE	4/30/2019

FIGURE 38



Legend

- Area Exceeding at Least One Soil PCUL
- City Purchase Area
- Ennis Creek Restoration Area
- Interim Action Areas
- Former Facilities
- Upland Study Area
- Remediated CSO Corridor

0 250 500
Scale in Feet

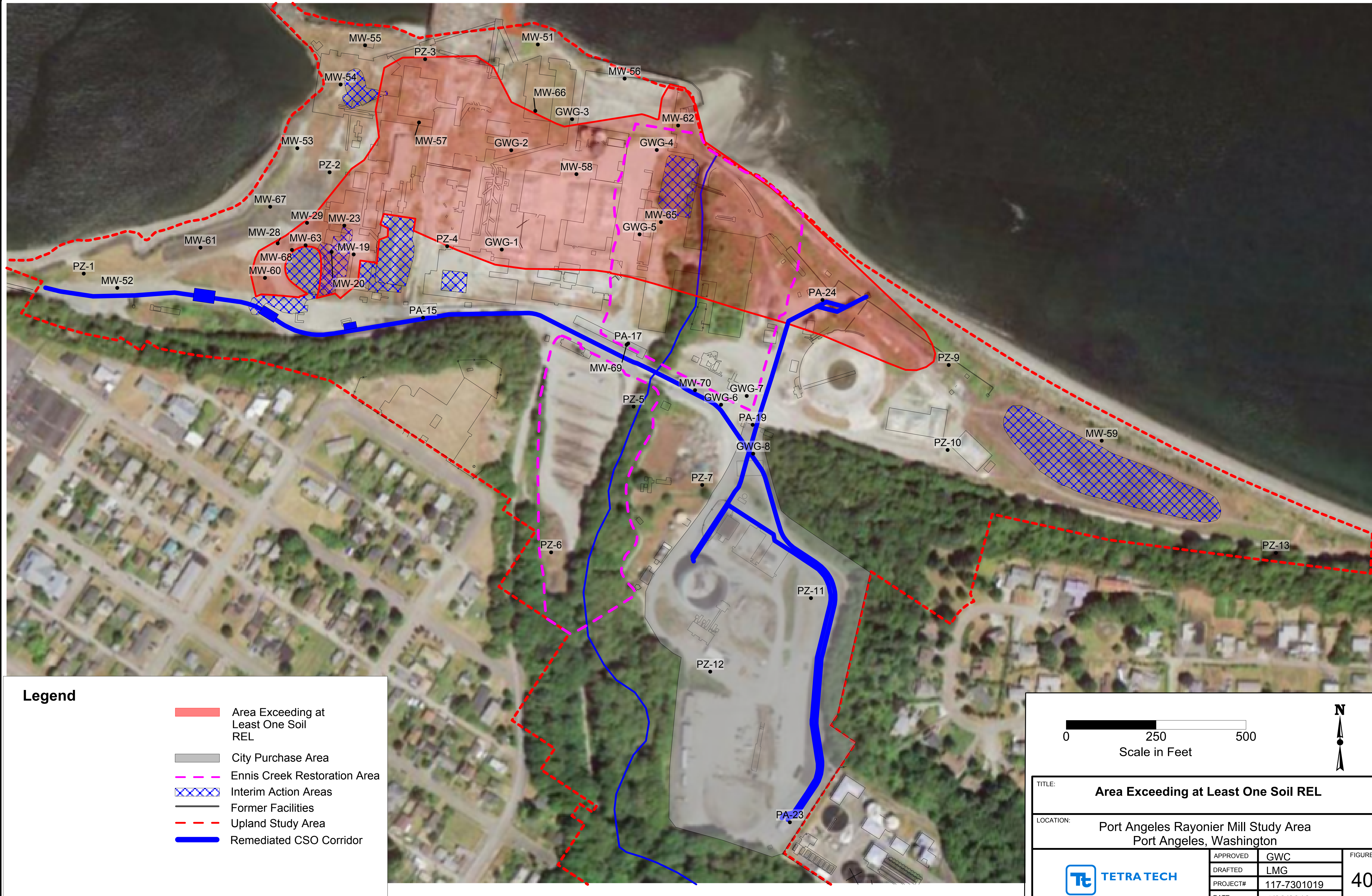
N

TITLE: **Area Exceeding at Lease One Soil PCUL**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC	FIGURE
DRAFTED	LMG	39
PROJECT#	117-7301019	
DATE	4/30/2019	



TITLE: **Area Exceeding at Least One Soil REL**

LOCATION: Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

TETRA TECH

APPROVED	GWC	FIGURE
DRAFTED	LMG	40
PROJECT#	117-7301019	
DATE	4/30/2019	

APPENDIX B

UPDATES TO THE TERRESTRIAL ECOLOGICAL EVALUATION

MEMORANDUM

To:	Marian Abbett, Washington State Department of Ecology
From:	Gregory W. Council
CC:	Warren Snyder, Rayonier Advanced Materials; John Lang, EHS Support
Date:	May 17, 2019
Subject:	Port Angeles Site: Terrestrial Ecological Evaluation

This memorandum presents the soil concentrations protective of terrestrial biota at the former Rayonier mill site (Site) in Port Angeles, Washington. Selection of these soil concentrations is made in accordance with the provisions of the Model Toxics Control Act (MTCA) regulations as presented in Chapter 173-340 of the Washington Administrative Code (WAC).

A *Terrestrial Ecological Evaluation* (TEE) was conducted by Malcom Pirnie in 2007 and updated in 2013 by GeoEngineers. The GeoEngineers TEE Update Technical Memorandum (dated July 12, 2013) was submitted as Appendix A-2 of the 2015 Agency Review Draft of the *Volume III Report*. The GeoEngineers TEE Update memorandum is included in its original form in this appendix to the Public Review Draft of the *Volume III Report*.

The 2013 TEE Update identifies three contaminants that are ecological risk drivers for the Site (dioxin, antimony, and zinc) and derives Site-specific concentrations of these contaminants that are protective of ecological receptors.

The Washington Department of Ecology (WDOE) provided comments on the TEE Update, noting that:

- Plants and soil biota should not be ruled out as potential future ecological receptors in the west mill area of the Site; and
- Petroleum hydrocarbons should be further considered as a potential ecological risk driver for the Site.

The company[1] has agreed to address WDOE's comments as follows:

(1) The concentrations determined to be appropriate cleanup levels for protection of Site plants, soil biota, and wildlife are assumed to apply to all areas of the Site (including the west mill).

(2) The WDOE-recommended ecological cleanup level of 200 mg/kg for diesel-range petroleum hydrocarbons (as specified in Table 749-3 of the MTCA rules) is used in setting cleanup levels for soil.

[1] Rayonier A.M. Properties LLC (formerly known as Rayonier Properties LLC) is the current owner of the property and is responsible for the project. In this document, "company" refers to Rayonier A.M. Properties LLC and its corporate predecessors.

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Thus, the soil concentrations protective of terrestrial ecological receptors – to be applied throughout the Site – are:

Contaminant	TEE Cleanup Level
Dioxin	220 ng/kg
Antimony	5 mg/kg
Zinc	302 mg/kg
Total Petroleum Hydrocarbons – Diesel Range	200 mg/kg

INTRODUCTION

This Terrestrial Ecological Evaluation (TEE) Update Technical Memorandum has been prepared for the upland portion of the Port Angeles Rayonier Mill Study Area. The scope of the present TEE effort consisted of updating the 2007 TEE report (Malcolm Pirnie, 2007) by addressing previous review comments as necessary on an earlier (2005) version the TEE report, and updating the list of constituents of potential ecological concern (COPECs) and site-specific indicator soil concentrations (ISCs) presented in the 2007 TEE report.

The updates to the 2007 TEE address the four main concerns identified in the previous review comments from Ecology and other reviewers, which are summarized as follows:

- Outdated toxicity equivalency factors (TEFs) were used to evaluate individual dioxin and furan congeners.
- Potential bioaccumulation in predators was underestimated by the methodology used to derive earthworm bioaccumulation factors (BAFs).
- Risks to higher-order predators such as the peregrine falcon, bald eagle, or river otter should be evaluated, as these species may have greater exposures than the Model Toxics Control Act (MTCA) default predator species evaluated in the 2007 TEE.
- Exposure point concentrations (EPCs) and risk calculations should be calculated using data from surface soil samples, which appear to have higher constituent concentrations than deeper soil.

Additional tasks performed in updating the 2007 TEE include:

- Conducted site reconnaissance to evaluate and summarize the current ecological baseline conditions and update the 2002 ground cover survey performed by Malcolm Pirnie (2007).
- Added soil data to the TEE chemical database. Soil data added include data collected by Rayonier during the 2010-2011 Supplemental Upland Investigation in the West Mill, East Mill, Ennis Creek, and City Purchase Areas, and by the City of Port Angeles (City) in 2011 in the City Purchase Area.
- Recalculated EPCs and reevaluated ecological risk.

UPDATED PROBLEM FORMULATION

As defined in MTCA (Washington Administrative Code [WAC] 173-340-7493[2]), the problem formulation step of the TEE defines the focus of the TEE and includes a description of the TEE purpose, a description of the problem being evaluated, and a plan for analyzing and characterizing potential risks. The problem formulation presented in the 2007 TEE report included the following sections (Malcolm Pirnie, 2007):

- Ecosystem Potentially at Risk.
- Current and Future Land Use.
- Chemicals of Potential Ecological Concern.

- Ecotoxicological Effects.
- Conceptual Site Model.
- Ecological Receptors of Concern.
- Evaluation Methods and Endpoints.

This technical memorandum includes updates to the descriptions of the ecosystem potentially at risk and the current and future land use, as well as an updated identification of COPECs.

Ecosystem Potentially at Risk

This section includes the results of the February 22, 2013 site reconnaissance conducted by GeoEngineers. The purpose of the reconnaissance was to confirm current on-the-ground ecological baseline conditions and to update (as necessary) the 2002 ground cover survey that was included in the 2007 TEE. Results of the survey are summarized below. Table 1 presents the habitat conditions observed during the February 2013 site reconnaissance. Updated ecological exposure areas are shown in Figure 1.

During the site visit, we documented the current habitat conditions in the areas originally identified and mapped in 2002 (Table A-2 and Figure A-3 in Malcolm Pirnie, 2007). In general, we observed little change in habitat conditions in the northern portion of the mill property other than anticipated vegetation establishment and development. Habitat conditions in the northern portion are degraded (as they were in 2002); however, some vegetation does exist in this area. We observed that the City's Combined Sewer Overflow (CSO) project had impacted the existing habitat conditions in the southern portions of the property. As a result of the CSO project, habitat conditions in the southern portion of the property were heavily degraded, and there was a reduction in vegetation cover that was available for wildlife during the 2002 survey. The City plans to restore areas where habitat conditions have been degraded by the CSO project. It is anticipated that an increase in vegetative cover will occur over time in these areas.

Current and Future Land Use

Under MTCA, the goals of the TEE differ based on current and future land use (WAC 173-340-7490). For unrestricted land use, the goal of the TEE is the protection of plants, soil biota, and wildlife; for industrial land use, the goal of the TEE is the protection of wildlife.

The 2007 TEE assumed current and future industrial land use for the West Mill Area and unrestricted land use for the remainder of the property, which was defined in the 2007 TEE as the East Mill, Marine Bluffs, and Ennis Creek Areas. This TEE Update slightly modifies these ecological exposure areas by separating the City Purchase Area from the East Mill Area (Figure 1). The reason for defining the City Purchase Area as a separate area is that the current and anticipated future land use of this area is industrial, while the anticipated future land use in the remainder of the East Mill Area is unrestricted. The current land use in the West Mill Area is industrial based on the present zoning and character of this area.

Based on the above, the ecological goals of the interim action for each ecological exposure area are as follows:

- West Mill Area: The ecological goal of the interim action is the protection of wildlife because the habitat conditions, land use, and zoning in the West Mill Area are consistent with the MTCA rationale for evaluating only wildlife exposure at industrial sites. According to Ecology's February 12, 2001 Concise Explanatory Statement for the 2001 amendments to MTCA (Ecology Publication No. 01-09-043): The underlying rationale (for the categorical exemption found at WAC 173-340-7490[3][c]) is that the properties that qualify for the exemption represent areas of land specifically designated for uses that may preclude growing plants and obviate the value of functions provided by soil biota. As noted in Table 1, the only vegetation types currently present at the West Mill Area are grasses and forbs that commonly occur in heavily disturbed areas. In addition, large portions of the area are covered by pavement or concrete rubble and the area was heavily disturbed by the CSO project at the time of the February 2013 site reconnaissance.
- East Mill Area, Marine Bluffs Area, and Ennis Creek/Estuary Area: The ecological goal of the interim action is the protection of plants, soil biota, and wildlife because habitat conditions and anticipated future land use in these areas are consistent with MTCA criteria for unrestricted land use.
- City Purchase Area: The ecological goal of the interim action is the protection of wildlife due to the habitat conditions and the current and anticipated future industrial land use in this area.

Chemicals of Potential Ecological Concern

Updating the PA Mill TEE Soil Data Set

The 2007 TEE included data from soil samples collected by the United States Environmental Protection Agency (USEPA) during the 1997 Expanded Site Investigation (E&E, 1998) and soil samples collected by Rayonier during the 2003 Upland Remedial Investigation (RI; Integral, 2007). This TEE Update also includes soil samples collected by Rayonier during the 2010-2011 Supplemental Upland Investigation (GeoEngineers, 2012) and samples collected by the City in 2011 in the City Purchase Area (Farallon, 2011).

The 2007 TEE divided the mill property into four exposure areas: West Mill, East Mill, Marine Bluffs, and Ennis Creek. This TEE Update evaluates the City Purchase Area as a separate exposure area. The City Purchase Area was included as part of the East Mill Area in the 2007 TEE.

To support the data evaluations described below, soil samples were identified as being in the 0 to 6 inch, 0 to 6 feet, and/or 0 to 15 feet depth intervals (depths referenced to ground surface at time of sampling). Samples were assigned to one or more of these groups using the midpoint of the sample depth range. For example, if a sample was collected from a depth of 4 to 7 feet below ground surface (bgs), its midpoint was defined as 5.5 feet bgs, and the sample was assigned to the 0 to 6 feet group and the 0 to 15 feet group.

The 0 to 6 feet and 0 to 15 feet groups are consistent with the 2007 TEE. However, the 2007 TEE only evaluated the 0 to 6 inch group for the West Mill Area.

During planning of the 2003 Upland RI, it was noted that anomalously high soil metals concentrations were detected in a number of samples collected in 1997. The sampling locations with the anomalous metals results were resampled during the 2003 RI, because the metals concentrations in the 1997 soil samples were so high that the samples were suspected to contain small pieces of scrap metal. The 2003 soil samples were analyzed only for the individual metals that were considered suspect in the original 1997 samples. The 2007 TEE included only the 2003 metals results for the suspect sampling locations. This TEE Update includes the 2003 metals results and the 1997 metals results (minus the anomalous values) for each suspect location. The table below lists the original (anomalous) metals results and the 2003 resample results that replaced the original results in the TEE database.

Exposure Area	Sample Location	Metal	1997 Original Concentration (mg/kg)	2003 Resample Concentration (mg/kg)
West Mill	AP03	Lead	7,310	147
West Mill	DB02	Lead	2,060	374
West Mill	GB08	Lead	8,610	31.1
West Mill	MR03	Lead	813	227
West Mill	RB01	Arsenic	250	4.7
East Mill	PF02	Copper	9,370	43.6
City Purchase	BY02	Arsenic	27.5	0.7

Updating the PA Mill TEE COPEC Tables

COPECs were identified for the West Mill, East Mill, Marine Bluffs, Ennis Creek, and City Purchase Areas following the procedure outlined in the 2007 TEE. COPECs were identified based on the ecological goals for each area: protection of plants, soil biota, and wildlife for the East Mill, Marine Bluffs and Ennis Creek Areas, and protection of wildlife for the West Mill and City Purchase Areas.

Preliminary COPECs were identified by comparing the maximum detected concentration in the 0 to 15 feet depth interval from each exposure area to the MTCA default ISCs in MTCA Table 749-3. A constituent was identified as a preliminary COPEC if the maximum detected concentration was greater than the lowest available ISC, and, in the case of metals, also greater than the natural background concentration of the constituent (if available). The background metals concentrations used were either Puget Sound 90th percentile values (Ecology, 1994) or Western Washington or Puget Sound 90th percentile values derived in Appendix F of the 2007 TEE.

Final COPECs were selected from the list of preliminary COPECs by comparing the reasonable maximum EPC (defined as the lesser of the maximum detected concentration and the 95% upper confidence limit on the arithmetic mean [95% UCL]) of each preliminary COPEC to the appropriate MTCA default ISC for each exposure area (see Tables 2 through 10). This was done for the 0 to 15 feet bgs and 0 to 6 feet bgs depth intervals. A constituent was identified as a final COPEC if the EPC was greater than an applicable ISC and natural background, or if the EPC was greater than background and no ISC was available for a particular receptor group. The methodology for calculating EPCs is described in the next section.

USEPA soil screening levels (SSLs; source: http://www.epa.gov/ecotox/ecossl/) and the dioxin/furan ISC for soil biota of 5E+06 ng/kg (derived in the 2007 TEE) were used as ISCs in cases where a default MTCA ISC was not available. The following USEPA SSLs were used to identify final COPECs:

- Soil biota: antimony (78 mg/kg), barium (330 mg/kg), and manganese (450 mg/kg).
- Wildlife: antimony (0.27 mg/kg), barium (2,000 mg/kg), cobalt (120 mg/kg), silver (4.2 mg/kg), and vanadium (7.8 mg/kg).

Tables 2 through 10 present the final COPECs for each exposure area. For this TEE Update, final COPECs are identified by exposure area and receptor group. For example, in the East Mill Area, lead is identified as a COPEC for plants in the 0 to 6 feet bgs interval, but lead is not identified as a COPEC for soil biota or wildlife (see Table 5).

Table 11 summarizes the final COPECs for each exposure area, receptor group, and depth interval. The final COPECs for Upland Study Area soils are total polychlorinated biphenyls (PCBs), dioxins/furans, total petroleum hydrocarbons (TPH), antimony, chromium, copper, lead, manganese, mercury, nickel, silver, and zinc. These COPECs were carried forward in the evaluation of potential ecological risk.

ECOLOGICAL RISK EVALUATION

The risk evaluation portion of the 2007 TEE included an exposure analysis, toxicity analysis, and a discussion of natural background metals concentrations. For this TEE Update, the following elements of the exposure analysis were reviewed and updated:

- EPCs for soil.
- Calculation of site-specific earthworm BAFs.

Exposure Analysis

EPCs for Soil

A reasonable maximum EPC for a particular COPEC in a particular environmental medium (such as soil) is a conservative estimate of the COPEC concentration to which potential receptors (such as terrestrial plants and animals) may be routinely exposed. The reasonable maximum EPCs (hereafter referred to simply as EPCs) used in this TEE Update were derived for up to three soil depth intervals in each exposure area. Potential risks to ecological receptors are assessed by assuming the potential receptors are exposed to COPECs at the EPC.

Soil EPCs were recalculated for this TEE Update because of the addition of chemical analytical data for soil samples collected in 2010 and 2011 in the West Mill, East Mill, Ennis Creek, and City Purchase Areas. The EPCs were used to identify COPECs and to assess potential risks to ecological receptors; they were selected as the lesser of the maximum detected concentration and the 95% UCL. The 95% UCL represents the value below which the true arithmetic mean is expected to fall with 95% certainty. The 95% UCL values were calculated using USEPA ProUCL® version 4.1.00 software.

Soil EPCs for total PCBs, dioxins/furans, TPH, and various metals are presented in Tables 2 through 10. Soil EPCs for individual dioxin and furan congeners are presented in Tables 14 through 23.

Exposure Parameters

In both the 2007 TEE and this TEE Update, site-specific plant uptake coefficients (K_{plant}) and earthworm BAFs were multiplied by soil EPC values (derived as described above) to estimate plant and earthworm COPEC concentrations that may result from exposure of plants and earthworms to COPECs in soil. The K_{plant} and earthworm BAF values were derived using co-located soil, plant, and earthworm tissue samples, and were calculated on a sample-by-sample basis. The K_{plant} and earthworm BAF values used in the 2007 TEE and this TEE Update are the average values calculated for each COPEC.

The 2007 TEE derived site-specific K_{plant} values by collecting and analyzing co-located soil and plant samples at eight locations across the Upland Study Area. The samples and method used to calculate K_{plant} values in this TEE Update were the same as those used in the 2007 TEE. Consequently, the K_{plant} values derived in both TEE analyses are the same. Table 12 presents the calculation of site-specific K_{plant} values for the eight co-located sample pairs; this table is included to allow verification of the K_{plant} values used in both TEEs.

Similar to the K_{plant} values, site-specific earthworm BAFs were derived in the 2007 TEE by collecting and analyzing co-located soil and earthworm samples at eight locations. As part of the derivation, the 2007 TEE used the Acid Insoluble Residue (AIR) method to correct the laboratory-reported, whole-earthworm chemical concentrations to tissue-only concentrations. The stated rationale for using the AIR method was that residual soil remained in the gut of the earthworms after the worms were allowed to depurate for 48 hours, and that this residual soil would result in an overestimate of the BAF values. The AIR method was developed by Stafford and McGrath (1986) to eliminate the contribution from soil in the earthworm gut. However, the AIR method formula used to estimate earthworm tissue-only concentrations resulted in negative concentration values that were assumed to be zero in the 2007 TEE (equivalent to an assumption of no bioaccumulation). In other words, the AIR method may have caused the estimates of earthworm BAFs to be biased low, thereby underestimating potential ecological risks.

Site-specific earthworm BAFs were calculated in this TEE Update without using the AIR method, due to concerns that the method may underestimate bioaccumulation-related risks. Table 13 presents the site-specific earthworm BAFs calculated without using the AIR method; for comparison, the 2007 TEE BAFs calculated using the AIR method also are included in Table 13. As shown in this table, the updated site-specific earthworm BAFs are generally higher than the 2007 TEE BAFs.

UPDATED RESULTS AND CONCLUSIONS

The Results and Conclusions section of the 2007 TEE included an evaluation of potential threats to wildlife, plants, and soil biota, an uncertainty analysis, and conclusions. This section updates the 2007 TEE results and conclusions based on the additional soil data collected since 2007 and revisions to the site-specific earthworm BAF estimates.

Potential Risks to Wildlife

Potential risks to wildlife were evaluated by calculating hazard quotients (HQs) for wildlife exposure to individual COPECs. HQs were calculated for individual wildlife receptors (shrew, vole, robin, and goose) in each ecological exposure area by dividing the COPEC EPC by the appropriate site-specific ISC for wildlife. Site-specific ISCs for wildlife were calculated using the methodology outlined in the 2007 TEE. The only difference between the ISCs calculated in 2007 and those used in this TEE Update is that the new ISC values were calculated using the updated earthworm BAFs discussed above.

The site-specific dioxin/furan congener ISCs for wildlife incorporate the site-specific earthworm BAFs and the most recent mammal and bird toxicity equivalency factors (TEFs). The mammal TEFs were obtained from Van den Berg et al. (2006) and the bird TEFs were obtained from Van den Berg et al. (1998). Dioxin and furan HQs were calculated for individual congeners. However, to be consistent with the MTCA approach for evaluating mixtures of dioxin and furan congeners (WAC 173-340-708[8][d]), the HQs for individual congers were summed to derive a 2,3,7,8-TCDD toxic equivalent quotient (TEQ; similar to an HQ) for the entire mixture.

Tables 14 through 23 present the calculation of HQs for wildlife exposure to soil in the five ecological exposure areas and various depth intervals (0 to 6 inches, 0 to 6 feet, and/or 0 to 15 feet, as applicable in each exposure area). An HQ greater than 1 indicates that the potential risk posed by an individual COPEC exceeds the MTCA standard for acceptable risk.

HQs are greater than 1 in the West Mill Area only. Soil in the East Mill, Marine Bluffs, Ennis Creek, and City Purchase Areas is not expected to pose a risk to wildlife, as the maximum HQ for each of these areas is less than 1.

The chromium soil EPCs for the Ennis Creek Area that were used to evaluate risks to wildlife (see Tables 20 and 21) were calculated after removing an outlier result of 307 mg/kg (sample location RS20; sample depth of 0 to 3 inches) from the 0 to 15 feet and 0 to 6 feet data sets. The 307 mg/kg chromium result was identified as an outlier by using the ProUCL® version 4.1.00 statistical analysis program to perform the Dixon's Outlier Test and to prepare Box plots and Q-Q plots. These three statistical methods each identified the 307 mg/kg result as an outlier, indicating that this isolated result is not representative of chromium concentrations in the Ennis Creek Area. Potential ecological risks to wildlife from chromium in the Ennis Creek Area were initially evaluated with the outlier sample retained in the soil data sets. The maximum chromium HQs associated with the 0 to 15 feet and 0 to 6 feet data sets before the 307 mg/kg result was removed are both 1. Removing the 307 mg/kg outlier result yields maximum chromium HQs of 0.5. Accordingly, evaluation of the soil data sets with and without the chromium outlier result indicates that chromium is not expected to pose a potential risk to wildlife in the Ennis Creek Area.

In the West Mill Area, dioxins/furans, antimony, and zinc are the only COPECs with HQs that exceed the MTCA acceptable standard of 1, as follows:

- **Dioxins/furans:** The maximum dioxin/furan HQs in the West Mill Area by depth interval are 2 (shrew at 0 to 15 feet), 2 (shrew at 0 to 6 feet), and 3 (vole at 0 to 6 inches). These values indicate that dioxins/furans in soil at each of the three depth intervals may pose a potential risk to shrews and voles.

- **Antimony:** The maximum antimony HQs in the West Mill Area by depth interval are 1 (vole at 0 to 15 feet), 1 (vole at 0 to 6 feet), and 2 (vole at 0 to 6 inches). These values indicate that antimony in soil at the 0 to 6 inch depth interval may pose a potential risk to voles. Since the antimony HQs for the 0 to 15 feet and 0 to 6 feet depth intervals don't exceed 1, the antimony in soil at these depth intervals does not pose a potential unacceptable risk to wildlife.
- **Zinc:** The maximum zinc HQs in the West Mill Area by depth interval are 1 (robin at 0 to 6 feet) and 2 (robin at 0 to 6 inches). These values indicate that zinc in soil at the 0 to 6 inch depth interval may pose a potential risk to robins. Since the zinc HQ for the 0 to 6 feet depth interval doesn't exceed 1, the zinc in soil at this depth interval does not pose a potential unacceptable risk to wildlife. Zinc was not identified as a COPEC for the 0 to 15 feet depth interval.

Potential Risks to Plants

The 2007 TEE used two approaches to evaluate potential ecological risks to plants in the East Mill, Marine Bluffs, and Ennis Creek Areas.

The first approach compared COPEC concentrations detected in plant tissue samples obtained at the mill property to plant tissue thresholds developed for the 2007 TEE. According to the 2007 TEE: …*results show the concentrations of COPECs measured in plant tissue samples from the three exposure areas were below the excessive or toxic thresholds*. The first approach was not updated for this technical memorandum because no additional plant tissue samples have been collected and analyzed since the 2007 TEE was prepared.

The second approach multiplied soil EPCs for each COPEC by site-specific and chemical-specific K_{plant} values to estimate reasonable maximum plant tissue concentrations in each exposure area. These estimated plant tissue concentrations were then compared to the plant tissue thresholds for each COPEC (Table 24). The second approach was updated because new COPECs were identified and new EPCs were calculated for the TEE Update. The updated results show that the estimated reasonable maximum plant tissue concentrations do not exceed the excessive or toxic thresholds. These results are consistent with the 2007 TEE results.

During the TEE Update, dioxins/furans and TPH were identified as plant COPECs because they met one or more of the criteria for COPECs. Specifically, the EPC for dioxins/furans is greater than the Washington state background concentration of 5.2 ng/kg, and MTCA does not provide an ISC protective of plants for either dioxins/furans or TPH. Dioxins/furans were also identified as a plant COPEC in the 2007 TEE. Although identified as a COPEC, dioxins/furans present in soil in the East Mill, Marine Bluffs, and Ennis Creek Areas are unlikely to pose a potential risk to plants, because, as noted in the 2007 TEE, dioxins/furans have a negligible potential to be absorbed into plants and exert a toxic effect due to their lipophilic nature.

Recent research has shown that crude oil concentrations in soil as high as 10,000 mg/kg have no significant impact on plant survival or health (API, 1997). Other numerical standards for TPH in the U.S. based on protection of plants range from 2,000 to 10,000 mg/kg (Efroymnson et al., 2004). The Canadian Council of Ministers of the Environment enacted TPH values for "ecological soil contact" ranging from 130 to 3,300 mg/kg (CCME, 2000), although these values are not specific to plants. Therefore, the relatively low soil diesel- and heavy oil-range TPH concentrations detected in the East Mill, Marine Bluffs, and Ennis Creek Areas are unlikely to pose an unacceptable risk to plants. Total TPH concentrations (sum of diesel- and heavy-oil range) in these three ecological exposure areas range from 258 to 1,048 mg/kg.

Consistent with the conclusions of the 2007 TEE, the two approaches for evaluating risks to plants suggest that soil COPECs do not pose unacceptable risks to plants in the East Mill, Marine Bluffs, and Ennis Creek Areas.

Potential Risks to Soil Biota

The 2007 TEE evaluated potential ecological risks to soil biota in the East Mill, Marine Bluffs, and Ennis Creek Areas using two approaches.

The first approach compared COPEC concentrations in earthworm tissue samples obtained at the mill property to earthworm tissue "no effects levels" developed in the 2007 TEE. The 2007 TEE concluded that: …*results show the concentrations of COPECs measured in earthworm tissue samples are below the no effects levels*. The first approach was not updated for this technical memorandum because no additional earthworm tissue samples have been collected and analyzed. However, based on a review of the source paper (Ma, 1982), it appears that the earthworm tissue no effects level of 130 mg/kg derived for copper is a soil concentration, not an earthworm tissue concentration. Following the same approach used in the 2007 TEE to derive the tissue no effects levels, the earthworm tissue no effects level for copper should be 70 mg/kg. This new value does not change the conclusions of the 2007 TEE.

The second approach multiplied soil EPCs for each COPEC by site-specific and chemical-specific earthworm BAF values to estimate reasonable maximum earthworm tissue concentrations in each exposure area. These estimated earthworm tissue concentrations were then compared to the earthworm tissue no effects levels for each COPEC (Table 25). The second approach was updated because new COPECs were identified and new EPCs and earthworm BAFs were calculated for the TEE Update. The updated results indicate that the estimated earthworm tissue concentrations are below the no effects levels derived in the 2007 TEE. These results are consistent with the 2007 TEE results.

The chromium soil EPCs for the Ennis Creek Area that were used in the second approach (see Table 25) were calculated after removing an outlier result of 307 mg/kg (sample location RS20; sample depth of 0 to 3 inches) from the 0 to 15 feet and 0 to 6 feet data sets. The 307 mg/kg chromium result was identified as an outlier by using the ProUCL® version 4.1.00 statistical analysis program to perform the Dixon's Outlier Test and to prepare Box plots and Q-Q plots. These three statistical methods each identified the 307 mg/kg result as an outlier, indicating that this isolated result is not representative of chromium concentrations in the Ennis Creek Area. Potential ecological risks to soil biota from chromium in the Ennis Creek Area were initially evaluated with the outlier sample retained in the soil data set. Estimated reasonable maximum earthworm tissue concentrations before the 307 mg/kg result was removed are approximately 30 mg/kg, which exceeds the earthworm tissue no effects level of 16 mg/kg. Removing the 307 mg/kg result yields estimated reasonable maximum earthworm tissue concentrations of approximately 12 mg/kg, which is below the 16 mg/kg no effects level. Accordingly, evaluation of the soil data set without the outlier chromium result indicates that chromium is not expected to pose a potential risk to soil biota in the Ennis Creek Area.

TPH was not identified as a COPEC in the 2007 TEE, and the rationale for excluding TPH was not provided in the 2007 TEE. As shown in Tables 7 and 8, diesel-range and heavy oil-range TPH were identified as soil biota COPECs in the Ennis Creek Area. Based on the soil EPCs and the ISCs for soil biota shown in Tables 7 and 8, the HQs associated with soil biota exposure to diesel- and heavy oil-range TPH in the Ennis Creek Area are 1 and 4, respectively.

GeoEngineers' recent project experience at other sites with aged petroleum contamination in soil suggests that in many cases, diesel- and heavy oil-range TPH concentrations significantly higher than the 200 mg/kg MTCA default diesel-range ISC for soil biota likely do not pose unacceptable risks to soil biota. According to Ecology's February 12, 2001 Concise Explanatory Statement for the 2001 amendments to MTCA (Ecology Publication No. 01-09-043), the studies Ecology evaluated to select the diesel-range ISC for soil biota were limited to studies of fresh petroleum product. The diesel- and heavy oil-range TPH contamination in the Ennis Creek Area is at least 22 years old, and may be as much as 76 years old. As part of the remedial investigation and feasibility study for the Irondale Iron and Steel Plant in Port Hadlock-Irondale, Washington, Ecology conducted soil bioassays in accordance with "Earthworm Bioassay Protocol for Soil Toxicity Screening" (Ecology Publication No. 96-327) to evaluate the toxicity of aged diesel- and heavy oil-range TPH (90 to 100 years old) to soil biota. Based on a set of serial dilutions, Ecology derived a combined diesel- plus heavy oil-range TPH soil screening level of 5,200 mg/kg for soil biota. This combined TPH screening level is approximately five times greater than the sum of the diesel- and heavy-oil soil EPCs for the Ennis Creek Area. In addition, at Rayonier's Former Sekiu Log Sorting Yard Site in Sekiu, Washington, soil bioassays showed that concentrations of aged Bunker C (at least 50 years old) as high as 11,000 mg/kg in site soil are not harmful to soil biota. This comparison of Ennis Creek Area soil data to the Irondale soil screening level and the Sekiu soil bioassay results suggests that the MTCA Method B soil cleanup level for diesel- and heavy oil-range TPH of 2,000 mg/kg is likely protective of soil biota in the Ennis Creek Area.

Consistent with the conclusions of the 2007 TEE, the two approaches for evaluating risks to soil biota suggest that soil COPECs do not pose unacceptable risks to soil biota in the East Mill, Marine Bluffs, and Ennis Creek Areas.

Evaluating Potential Risks to Higher-Order Receptors

A number of reviewers of the 2007 TEE commented on the need to evaluate risk to higher-order predators such as the peregrine falcon, bald eagle, or river otter. The reviewers suspected that higher-order predators were likely to have greater exposures to bioaccumulative COPECs than the MTCA default predator species evaluated in the 2007 TEE.

We addressed the concerns of the reviewers by comparing the updated EPCs for dioxins/furans in soil within each exposure area (West Mill, East Mill, City Purchase, Ennis Creek, and Marine Bluffs Areas) to bioaccumulation-based screening levels that were modeled for a red-tailed hawk. Dioxins/furans were selected for this evaluation rather than PCBs or mercury, because potential risks to the red-tailed hawk associated with exposure to dioxins/furans are expected to be greater than those associated with exposure to PCBs and mercury, due to the greater toxicity and larger overall geographic footprint of dioxin/furan contamination. The red-tailed hawk is a higher-order predator that is more likely to forage at the mill property than other higher-order receptors, and thus represents the greatest potential for ecological exposure and risk to higher-order predators in the Upland Study Area.

The results of the red-tailed hawk dioxin/furan exposure model are presented in Table 26. As shown in this table, potential risks to the red-tailed hawk from dioxins/furans in the five ecological exposure areas are below the MTCA standard for acceptable risk; calculated HQs range from 0.00075 (City Purchase Area, 0 to 6 feet and 0 to 15 feet) to 0.025 (West Mill Area, 0 to 6 inches).

The red-tailed hawk is a more appropriate higher-order receptor to evaluate for the terrestrial ecosystem of the Upland Study Area than the river otter, bald eagle, or peregrine falcon because:

- River otters live and forage almost exclusively in aquatic and riverine environments. Consequently, the river otter would be more representative of a higher-order aquatic receptor, since its exposure would occur primarily along the nearshore marine areas of the Study Area or within the estuary and freshwater habitat of Ennis Creek.
- Bald eagles also are less likely than the red-tailed hawk to forage on terrestrial organisms that may be present in the Upland Study Area, because bald eagles are opportunistic in their foraging behavior, which varies throughout the season and from region to region. They are highly dependent on the movement and abundance of their prey, which includes fish (salmon) and migratory waterfowl in addition to terrestrial wildlife.
- Peregrine falcons primarily nest in rocky outcrops and cliffs in the natural environment, or on buildings or bridges in the built environment. This type of nesting habitat does not exist in the Study Area. Additionally, peregrine falcons would be more likely to forage for waterfowl or other migratory birds in the nearshore portions of the Study Area, and would be less likely to forage within the upland (terrestrial) portions, which represent better foraging habitat for the red-tailed hawk.

SUMMARY

This TEE Update evaluated potential ecological risks from exposure to soil COPECs in the five areas of the Upland Study Area: the West Mill, East Mill, Marine Bluffs, Ennis Creek, and City Purchase Areas. The West Mill and City Purchase Areas are primarily zoned heavy industrial; current land use in these areas is consistent with this zoning, and the areas provide little habitat of any ecological value. The Marine Bluffs and Ennis Creek Areas are relatively undisturbed and provide moderate-quality habitat for ecological receptors. The majority of the East Mill Area has limited habitat value; however, native grasses and dunes in the eastern and shoreline portions of this area constitute high-quality habitat.

Based on land use and MTCA requirements, the ecological goals of the interim action are:

- West Mill and City Purchase Areas: protection of wildlife.
- Marine Bluffs, Ennis Creek, and East Mill Areas: protection of plants, soil biota, and wildlife.

Potential ecological risks in the five ecological exposure areas were evaluated relative to these goals.

Plants

Potential risks to terrestrial plants from exposure to COPECs in soil were evaluated using ISC values protective of plants and tissue-based toxicity thresholds for plants that were derived in the 2007 TEE. Consistent with the conclusions of the 2007 TEE, the results of this TEE Update suggest that existing COPEC concentrations in soil in the Upland Study Area do not pose unacceptable risks to terrestrial plants.

Soil Biota

Potential risks to soil biota from exposure to COPECs in soil were evaluated using tissue-based no effects levels for earthworms that were derived in the 2007 TEE. Consistent with the conclusions of the 2007 TEE, the results of this TEE Update suggest that existing COPEC concentrations in soil in the Upland Study Area do not pose unacceptable risks to soil biota.

Wildlife

Potential risks to terrestrial wildlife from exposure to COPECs in soil were evaluated using site-specific K_{plant} values and earthworm BAFs to calculate site-specific ISCs for four target receptors: the shrew, vole, robin, and goose. HQs were then calculated by dividing exposure area-specific and COPEC-specific EPCs by the site-specific ISCs for the target receptors in the five ecological exposure areas. The calculated HQs were greater than 1 for shrews and voles in the West Mill Area, and less than 1 in the other four areas. These values indicate that COPECs in West Mill Area soil pose a potential risk to shrews and voles. The HQ values less than 1 in the East Mill, Ennis Creek, Marine Bluffs, and City Purchase Areas indicate that soil COPECs in these other areas do not pose unacceptable risks to terrestrial wildlife.

The ecological risk drivers in the West Mill Area are dioxins/furans, antimony, and zinc, as follows:

- **Dioxins/furans:** The maximum dioxin/furan HQs in the West Mill Area by depth interval are 2 (shrew at 0 to 15 feet), 2 (shrew at 0 to 6 feet), and 3 (shrew and vole at 0 to 6 inches). These values indicate that dioxins/furans in soil at each of the three depth intervals may pose a potential risk to shrews and voles.
- **Antimony:** The maximum antimony HQs in the West Mill Area by depth interval are 1 (vole at 0 to 15 feet), 1 (vole at 0 to 6 feet), and 2 (vole at 0 to 6 inches). These values indicate that antimony in soil at the 0 to 6 inch depth interval may pose a potential risk to voles. Since the antimony HQs for the 0 to 15 feet and 0 to 6 feet depth intervals don't exceed 1, the antimony in soil at these depth intervals does not pose an unacceptable risk to wildlife.
- **Zinc:** The maximum zinc HQs in the West Mill Area by depth interval are 1 (robin at 0 to 6 feet) and 2 (robin at 0 to 6 inches). These values indicate that zinc in soil at the 0 to 6 inch depth interval may pose a potential risk to robins. Since the zinc HQ for the 0 to 6 feet depth interval doesn't exceed 1, the zinc in soil at this depth interval does not pose an unacceptable risk to wildlife. Zinc was not identified as a COPEC for the 0 to 15 feet depth interval.

The 2007 TEE includes an Uncertainty Analysis section that details major areas of uncertainty in the ecological evaluation. Because this TEE Update was generally completed following the same methodology, most of the 2007 TEE uncertainty discussion is also applicable to this update. One particular area of discussion in the 2007 TEE is the use of the 0 to 6 inch depth interval to evaluate risks to wildlife in the West Mill Area. While COPEC concentrations are generally higher in the 0 to 6 inch depth interval relative to the 0 to 6 feet and 0 to 15 feet depth intervals, the assumption that wildlife receptors are exposed exclusively to soil in the 0 to 6 inch depth interval is unrealistic, and likely overestimates potential wildlife exposure. As noted in the 2007 TEE, wildlife receptors can be directly exposed to COPECs in soil deeper than 6 inches bgs, and are indirectly exposed to COPECs through the ingestion of plants and soil biota that can accumulate COPECs from soil deeper than 6 inches bgs. Antimony and zinc are only identified as ecological risk drivers based on wildlife exposure to soil in the 0 to 6 inch depth interval (based on estimated HQs of 2); the wildlife HQ for both of these metals drops to an acceptable level of 1 when evaluating the 0 to 6 feet depth interval, which is the MTCA conditional point of compliance for terrestrial ecological evaluations.

Indicator Soil Concentrations for Ecological Risk Drivers

As noted above, dioxins/furans, antimony, and zinc were identified as ecological risk drivers for the West Mill Area based on wildlife exposure to soil in this area. The site-specific ISCs that caused each of these COPECs to be identified as a risk driver are summarized in the table below:

COPEC	Receptor(s)	ISC
Dioxins/Furans	Shrew, Vole	220 ng/kg, 259 ng/kg
Antimony	Vole	5 mg/kg
Zinc	Robin	302 mg/kg

The antimony and zinc ISCs were selected from the wildlife ISCs presented in Tables 14 through 23. The dioxins/furans ISCs were derived separately because Tables 14 through 23 only include ISCs for individual dioxin and furan congeners. Dioxins/furans ISCs were derived for each target receptor with HQs greater than 1 (shrew and vole). We used the ratios of individual dioxin and furan congeners in each exposure area (West Mill, East Mill, Marine Bluffs, Ennis Creek, and City Purchase Areas) to calculate 2,3,7,8-TCDD toxic equivalent concentrations that are protective of shrews and voles. This methodology assumes that the ratios of individual congeners based on the EPCs in Tables 14 through 23 reflected the ratios of individual congeners throughout each exposure area. The table above presents the lowest (most conservative) ISC protective of shrews and voles as calculated for each exposure area and each applicable depth interval (0 to 6 inches, 0 to 6 feet, and 0 to 15 feet).

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Table 1

PA Mill Ecological Exposure Areas

Port Angeles Mill Study Area

Port Angeles, Washington

Exposure Area	Photograph of Observed Conditions	Habitat Characteristics	Relative Habitat Value	Potential or Observed Wildlife Use/Condition	Notes/Comments
West Mill Area		Very little vegetation other than grasses and forbs that commonly occur in heavily disturbed areas. Large areas covered in pavement or rubble. Heavily disturbed by the ongoing CSO project.	Low	■ Some use by shore birds. ■ Killdeer were observed in large numbers in the areas covered by rubble. ■ Canada geese were observed in areas dominated by grass.	Wetland conditions exist within the Log Yard Habitat Area.
East Mill Area		Western and southern portions have been heavily impacted by the ongoing CSO project and provide little habitat structure. The lagoon area is relatively undisturbed and dominated by grasses and forbs.	Low	■ Passerine bird species in the lagoon area. ■ Wetland conditions within the East Roll Storage Habitat Area.	Large areas disturbed by the ongoing CSO project.
Marine Bluffs Area		Forested habitat dominated by red alder and some native conifers.	Moderate	■ Small mammals. ■ Nesting and perch habitat for coastal species (e.g. bald eagle).	Areas of mass wasting.

Exposure Area	Photograph of Observed Conditions	Habitat Characteristics	Relative Habitat Value	Potential or Observed Wildlife Use/Condition	Notes/Comments
Ennis Creek/ Estuary Area		Well-developed riparian habitat, particularly in the southern portion of the site where the typical native trees dominate the forest canopy and sub-canopy. The riparian habitat in the northern portion of the site is heavily degraded and has been impacted by the ongoing CSO project.	High	■ Observed belted kingfisher, dipper and other woodland bird species. ■ Bald eagle nest is located in an off-site forested habitat contiguous with the Ennis Creek Area. ■ Aquatic habitat for resident and anadromous fish species. ■ Small mammals.	CSO project has impacted the Ennis Creek Area at the location of the new elevated force main crossing of the creek.
CSO Project Area (includes City Purchase Area)		Heavily disturbed due to ongoing construction project	Very low	■ Heavily disturbed. ■ Very little anticipated wildlife use.	
Dune Habitat		Dune habitat, consisting of grasses, shrubs and small trees parallels the shoreline.	Moderate	■ Coastal passerine and shorebird habitat.	Abuts high value intertidal beach habitat.

Table 2

West Mill Area (0-15 feet) - COPEC Screen

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	Concentrations			Indicator Soil Concentration[1]	Background	
	Maximum	95%UCL	EPC	Wildlife	Value	Reference
Polychlorinated Biphenyls (PCBs) (µg/kg)						
Total PCBs	4,800	262	262	650	--	--
Dioxin & Furans (ng/kg)						
TEC Bird	1,901	267.1	267.1	2	5.2	Ecology 2010
TEC Mammal	3,047	395.8	395.8	2	5.2	Ecology 2010
Total Petroleum Hydrocarbons (mg/kg)						
Gasoline Range	23	11.66	11.66	5,000	--	--
Diesel Range	39,000	2,117	2,117	6,000	--	--
Heavy Oil Range	25,000	1,641	1,641	6,000	--	--
Fuel Oil Range	1,400	90.26	90.26	6,000	--	--
Metals (mg/kg)						
Antimony	94	5.599	5.599	0.27	3.12	From MP 2007 TEE
Arsenic	260	13.44	13.44	102	20	MTCA Method A
Barium	826	125.5	125.5	2,000	703.8	From MP 2007 TEE
Cadmium	140	4.979	4.979	14	1	Ecology 1994
Chromium	357	57.57	57.57	67	48	Ecology 1994
Cobalt	84	12.38	12.38	120	32.13	From MP 2007 TEE
Copper	1,590	219.6	219.6	217	36	Ecology 1994
Lead	1,140	153.5	153.5	118	24	Ecology 1994
Manganese	14,100	1314	1,314	1,500	1,200	Ecology 1994
Mercury	6.6	0.418	0.418	0.4	0.07	Ecology 1994
Nickel	572	56.97	56.97	980	48	Ecology 1994
Selenium	5.4	0.548	0.548	0.3	2	From MP 2007 TEE
Silver	48.8	2.273	2.273	4.2	0.24	From MP 2007 TEE
Thallium	7	0.408	0.408	--	4.53	From MP 2007 TEE
Vanadium	1,400	107.6	107.6	7.8	296.6	From MP 2007 TEE
Zinc	2,940	357.8	357.8	360	85	Ecology 1994

Notes:

[1] Indicator soil concentrations are generally from MTCA Table 749-3. Additional soil screening values were obtained from EPA ecological soil screening level documents or were derived for the 2007 TEE (see text for details).

Yellow shading indicates EPC is greater than background value (if available) and Indicator Soil Concentration from MTCA Table 749-3.

EPC = exposure point concentration

COPEC = Contaminant of Potential Ecological Concern

mg/kg = micrograms per kilogram

N/A = not applicable

ng/kg = nanograms per kilogram

TEC = toxic equivalency concentration

TEE = terrestrial ecological evaluation

µg/kg = microliters per kilogram

UCL = upper confidence limit

Table 3

West Mill Area (0-6 feet) - COPEC Screen

Port Angeles Mill Study Area
Port Angeles, Washington

Analyte	Concentrations			Indicator Soil Concentration[1]	Background	
	Maximum	95%UCL	EPC	Wildlife	Value	Reference
Polychlorinated Biphenyls (µg/kg)						
Total PCBs	4,800	248	248	650	--	--
Dioxin & Furans (ng/kg)						
TEC Bird	1,901	295	295	2	5.2	Ecology 2010
TEC Mammal	3,047	438	438	2	5.2	Ecology 2010
Total Petroleum Hydrocarbons (mg/kg)						
Gasoline Range	23	12.29	12.29	5,000	--	--
Diesel Range	1,500	291.5	291.5	6,000	--	--
Heavy Oil Range	3,600	644.3	644.3	6,000	--	--
Fuel Oil Range	85	85	85	6,000	--	--
Metals (mg/kg)						
Antimony	94	6.252	6.252	0.27	3.12	From MP 2007 TEE
Arsenic	260	22.82	22.82	102	20	MTCA Method A
Barium	826	142.4	142.4	2,000	703.8	From MP 2007 TEE
Cadmium	140	6.16	6.16	14	1	Ecology 1994
Chromium	357	63.98	63.98	67	48	Ecology 1994
Cobalt	84	12.51	12.51	120	32.13	From MP 2007 TEE
Copper	1,590	243.4	243.4	217	36	Ecology 1994
Lead	1,140	167	167	118	24	Ecology 1994
Manganese	14,100	1,457	1,457	1,500	1,200	Ecology 1994
Mercury	6.6	0.425	0.425	0.4	0.07	Ecology 1994
Nickel	572	60.11	60.11	980	48	Ecology 1994
Selenium	5.4	0.593	0.593	0.3	2	From MP 2007 TEE
Silver	48.8	2.717	2.717	4.2	0.24	From MP 2007 TEE
Thallium	7	0.445	0.445	--	4.53	From MP 2007 TEE
Vanadium	1,400	115	115	7.8	296.6	From MP 2007 TEE
Zinc	2,940	399.8	399.8	360	85	Ecology 1994

Notes:

[1] Indicator soil concentrations are generally from MTCA Table 749-3. Additional soil screening values were obtained from EPA ecological soil screening level documents or were derived for the 2007 TEE (see text for details).

Yellow shading indicates EPC is greater than background value (if available) and Indicator Soil Concentration from MTCA Table 749-3.

EPC = exposure point concentration

COPEC = Contaminant of Potential Ecological Concern

mg/kg = micrograms per kilogram

N/A = not applicable

ng/kg = nanograms per kilogram

TEC = toxic equivalency concentration

TEE = terrestrial ecological evaluation

µg/kg = microliters per kilogram

UCL = upper confidence limit

Table 4

East Mill Area (0-15 feet) - COPEC Screen

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	Concentrations			Indicator Soil Concentration[1]			Background	
	Maximum	95%UCL	EPC	Plants	Soil Biota	Wildlife	Value	Reference
Polychlorinated Biphenyls (µg/kg)								
Total PCBs	N/A	N/A	N/A	40,000	--	650	--	--
Dioxin & Furans (ng/kg)								
TEC Bird	58.86	44.06	44.06	--	5,000	2	5.2	Ecology 2010
TEC Mammal	73.22	52.21	52.21	--	5,000	2	5.2	Ecology 2010
Total Petroleum Hydrocarbons (mg/kg)								
Gasoline Range	N/A	N/A	N/A	--	100	5,000	--	--
Diesel Range	58	N/A	58	--	200	6,000	--	--
Heavy Oil Range	200	206.5	200	--	200	6,000	--	--
Fuel Oil Range	N/A	N/A	N/A	--	200	6,000	--	--
Metals (mg/kg)								
Antimony	1.87	0.286	0.286	5	78	0.27	3.12	From MP 2007 TEE
Arsenic	9.7	4.306	4.306	10	60	102	20	MTCA Method A
Barium	224	89.19	89.19	500	330	2,000	703.8	From MP 2007 TEE
Cadmium	0.88	0.439	0.439	4	20	14	1	Ecology 1994
Chromium	63.8	44.63	44.63	42	42	67	48	Ecology 1994
Cobalt	20.1	14.23	14.23	20	--	120	32.13	From MP 2007 TEE
Copper	161	68.69	68.69	100	50	217	36	Ecology 1994
Lead	126	42.17	42.17	50	500	118	24	Ecology 1994
Manganese	1760	665.6	665.6	1,100	450	1,500	1,200	Ecology 1994
Mercury	0.15	0.0702	0.0702	0.3	0.1	0.4	0.07	Ecology 1994
Nickel	64.7	43.85	43.85	30	200	980	48	Ecology 1994
Selenium	0.4	0.292	0.292	1	70	0.3	2	From MP 2007 TEE
Silver	42.3	18.26	18.26	2	--	4.2	0.24	From MP 2007 TEE
Thallium	0.035	0.035	0.035	1	--	--	4.53	From MP 2007 TEE
Vanadium	100	75.29	75.29	2	--	7.8	296.6	From MP 2007 TEE
Zinc	309	85.74	85.74	86	200	360	85	Ecology 1994

Notes:

[1] Indicator soil concentrations are generally from MTCA Table 749-3. Additional soil screening values were obtained from EPA ecological soil screening level documents or were derived for the 2007 TEE (see text for details).

Yellow shading indicates EPC is greater than background value (if available) and Indicator Soil Concentration from MTCA Table 749-3.

Green shading indicates EPC is greater than background value (if available) and no Indicator Soil Concentration is available in MTCA Table 749-3.

EPC = exposure point concentration

COPEC = Contaminant of Potential Ecological Concern

mg/kg = micrograms per kilogram

N/A = not applicable

ng/kg = nanograms per kilogram

TEC = toxic equivalency concentration

TEE = terrestrial ecological evaluation

µg/kg = microliters per kilogram

UCL = upper confidence limit

Table 5

East Mill Area (0-6 feet) - COPEC Screen

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	Concentrations			Indicator Soil Concentration[1]			Background	
	Maximum	95%UCL	EPC	Plants	Soil Biota	Wildlife	Value	Reference
Polychlorinated Biphenyls (µg/kg)								
Total PCBs	N/A	N/A	N/A	40,000	--	650	--	--
Dioxin & Furans (ng/kg)								
TEC Bird	58.86	44.06	44.06	--	5,000	2	5.2	Ecology 2010
TEC Mammal	73.22	52.21	52.21	--	5,000	2	5.2	Ecology 2010
Total Petroleum Hydrocarbons (mg/kg)								
Gasoline Range	N/A	N/A	N/A	--	100	5,000	--	--
Diesel Range	58	N/A	58	--	200	6,000	--	--
Heavy Oil Range	200	291.9	200	--	200	6,000	--	--
Fuel Oil Range	N/A	N/A	N/A	--	200	6,000	--	--
Metals (mg/kg)								
Antimony	1.87	0.353	0.353	5	78	0.27	3.12	From MP 2007 TEE
Arsenic	6.6	4.082	4.082	10	60	102	20	MTCA Method A
Barium	224	92.5	92.5	500	330	2,000	703.8	From MP 2007 TEE
Cadmium	0.88	0.471	0.471	4	20	14	1	Ecology 1994
Chromium	63.8	43.22	43.22	42	42	67	48	Ecology 1994
Cobalt	20.1	14.05	14.05	20	--	120	32.13	From MP 2007 TEE
Copper	161	73.6	73.6	100	50	217	36	Ecology 1994
Lead	126	53.19	53.19	50	500	118	24	Ecology 1994
Manganese	1,760	966.9	966.9	1,100	450	1,500	1,200	Ecology 1994
Mercury	0.15	0.0755	0.0755	0.3	0.1	0.4	0.07	Ecology 1994
Nickel	64.7	43.9	43.9	30	200	980	48	Ecology 1994
Selenium	0.4	0.4	0.4	1	70	0.3	2	From MP 2007 TEE
Silver	42.3	23.64	23.64	2	--	4.2	0.24	From MP 2007 TEE
Thallium	0.035	0.035	0.035	1	--	--	4.53	From MP 2007 TEE
Vanadium	99	74.21	74.21	2	--	7.8	296.6	From MP 2007 TEE
Zinc	309	92.56	92.56	86	200	360	85	Ecology 1994

Notes:

[1] Indicator soil concentrations are generally from MTCA Table 749-3. Additional soil screening values were obtained from EPA ecological soil screening level documents or were derived for the 2007 TEE (see text for details).

Yellow shading indicates EPC is greater than background value (if available) and Indicator Soil Concentration from MTCA Table 749-3.

Green shading indicates EPC is greater than background value (if available) and no Indicator Soil Concentration is available in MTCA Table 749-3.

EPC = exposure point concentration

COPEC = Contaminant of Potential Ecological Concern

mg/kg = micrograms per kilogram

N/A = not applicable

ng/kg = nanograms per kilogram

TEC = toxic equivalency concentration

TEE = terrestrial ecological evaluation

µg/kg = microliters per kilogram

UCL = upper confidence limit

Table 6

Marine Bluffs Area (0-6 feet) - COPEC Screen

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	Concentrations			Indicator Soil Concentration[1]			Background	
	Maximum	95%UCL	EPC	Plants	Soil Biota	Wildlife	Value	Reference
Polychlorinated Biphenyls (µg/kg)								
Total PCBs	0.021	N/A	0.021	40,000	--	650	--	--
Dioxin & Furans (ng/kg)								
TEC Bird	50.97	31.56	31.56	--	5,000	2	5.2	Ecology 2010
TEC Mammal	47.43	34.6	34.6	--	5,000	2	5.2	Ecology 2010
Total Petroleum Hydrocarbons (mg/kg)								
Gasoline Range	N/A	N/A	N/A	--	100	5,000	--	--
Diesel Range	N/A	N/A	N/A	--	200	6,000	--	--
Heavy Oil Range	N/A	N/A	N/A	--	200	6,000	--	--
Fuel Oil Range	N/A	N/A	N/A	--	200	6,000	--	--
Metals (mg/kg)								
Antimony	0.13	0.129	0.129	5	78	0.27	3.12	From MP 2007 TEE
Arsenic	3.2	2.865	2.865	10	60	102	20	MTCA Method A
Barium	51.5	48.48	48.48	500	330	2,000	703.8	From MP 2007 TEE
Cadmium	0.18	0.165	0.165	4	20	14	1	Ecology 1994
Chromium	30.5	28.23	28.23	42	42	67	48	Ecology 1994
Cobalt	8.4	7.771	7.771	20	--	120	32.13	From MP 2007 TEE
Copper	22.9	21.37	21.37	100	50	217	36	Ecology 1994
Lead	17.3	14.1	14.1	50	500	118	24	Ecology 1994
Manganese	402	354.7	354.7	1,100	450	1,500	1,200	Ecology 1994
Mercury	0.1	0.0757	0.0757	0.3	0.1	0.4	0.07	Ecology 1994
Nickel	33.9	32.46	32.46	30	200	980	48	Ecology 1994
Selenium	N/A	N/A	N/A	1	70	0.3	2	From MP 2007 TEE
Silver	0.05	0.0474	0.0474	2	--	4.2	0.24	From MP 2007 TEE
Thallium	0.086	0.0646	0.0646	1	--	--	4.53	From MP 2007 TEE
Vanadium	56.4	56.19	56.19	2	--	7.8	296.6	From MP 2007 TEE
Zinc	65	54.81	54.81	86	200	360	85	Ecology 1994

Notes:

[1] Indicator soil concentrations are generally from MTCA Table 749-3. Additional soil screening values were obtained from EPA ecological soil screening level documents or were derived for the 2007 TEE (see text for details).

Yellow shading indicates EPC is greater than background value (if available) and Indicator Soil Concentration from MTCA Table 749-3.

Green shading indicates EPC is greater than background value (if available) and no Indicator Soil Concentration is available in MTCA Table 749-3.

EPC = exposure point concentration

COPEC = Contaminant of Potential Ecological Concern

mg/kg = micrograms per kilogram

N/A = not applicable

ng/kg = nanograms per kilogram

TEC = toxic equivalency concentration

TEE = terrestrial ecological evaluation

µg/kg = microliters per kilogram

UCL = upper confidence limit

Table 7

Ennis Creek/Estuary Area (0-15 feet) - COPEC Screen

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	Concentrations			Indicator Soil Concentration[1]			Background	
	Maximum	95%UCL	EPC	Plants	Soil Biota	Wildlife	Value	Reference
Polychlorinated Biphenyls (µg/kg)								
Total PCBs	1,600	101	101	40,000	--	650	--	--
Dioxin & Furans (ng/kg)								
TEC Bird	190	97.46	97.46	--	5000	2	5.2	Ecology 2010
TEC Mammal	118.9	61.06	61.06	--	5000	2	5.2	Ecology 2010
Total Petroleum Hydrocarbons (mg/kg)								
Gasoline Range	N/A	N/A	N/A	--	100	5,000	--	--
Diesel Range	1,300	248.1	248.1	--	200	6,000	--	--
Heavy Oil Range	6,600	779.6	779.6	--	200	6,000	--	--
Fuel Oil Range	N/A	N/A	N/A	--	200	6,000	--	--
Metals (mg/kg)								
Antimony	0.32	0.175	0.175	5	78	0.27	3.12	From MP 2007 TEE
Arsenic	13.3	5.714	5.714	10	60	102	20	MTCA Method A
Barium	115	81.14	81.14	500	330	2,000	703.8	From MP 2007 TEE
Cadmium	1	0.447	0.447	4	20	14	1	Ecology 1994
Chromium	307	138.1	138.1	42	42	67	48	Ecology 1994
Cobalt	25.7	17.31	17.31	20	--	120	32.13	From MP 2007 TEE
Copper	178	102.4	102.4	100	50	217	36	Ecology 1994
Lead	276	122.3	122.3	50	500	118	24	Ecology 1994
Manganese	649	559.1	559.1	1100	450	1,500	1,200	Ecology 1994
Mercury	0.54	0.291	0.291	0.3	0.1	0.4	0.07	Ecology 1994
Nickel	65.9	51.67	51.67	30	200	980	48	Ecology 1994
Selenium	1.2	0.746	0.746	1	70	0.3	2	From MP 2007 TEE
Silver	1.4	0.333	0.333	2	--	4.2	0.24	From MP 2007 TEE
Thallium	0.076	0.0644	0.0644	1	--	--	4.53	From MP 2007 TEE
Vanadium	121	95.5	95.5	2	--	7.8	296.6	From MP 2007 TEE
Zinc	200	111.7	111.7	86	200	360	85	Ecology 1994

Notes:

[1] Indicator soil concentrations are generally from MTCA Table 749-3. Additional soil screening values were obtained from EPA ecological soil screening level documents or were derived for the 2007 TEE (see text for details).

Yellow shading indicates EPC is greater than background value (if available) and Indicator Soil Concentration from MTCA Table 749-3.

Green shading indicates EPC is greater than background value (if available) and no Indicator Soil Concentration is available in MTCA Table 749-3.

EPC = exposure point concentration

COPEC = Contaminant of Potential Ecological Concern

mg/kg = micrograms per kilogram

N/A = not applicable

ng/kg = nanograms per kilogram

TEC = toxic equivalency concentration

TEE = terrestrial ecological evaluation

µg/kg = microliters per kilogram

UCL = upper confidence limit

Table 8

Ennis Creek/Estuary Area (0-6 feet) - COPEC Screen

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	Concentrations			Indicator Soil Concentration[1]			Background	
	Maximum	95%UCL	EPC	Plants	Soil Biota	Wildlife	Value	Reference
Polychlorinated Biphenyls (µg/kg)								
Total PCBs	1600	108	108	40000	--	650	--	--
Dioxin & Furans (ng/kg)								
TEC Bird	190	106.4	106.4	--	5000	2	5.2	Ecology 2010
TEC Mammal	118.9	66.63	66.63	--	5000	2	5.2	Ecology 2010
Total Petroleum Hydrocarbons (mg/kg)								
Gasoline Range	N/A	N/A	N/A	--	100	5000	--	--
Diesel Range	1300	258.9	258.9	--	200	6000	--	--
Heavy Oil Range	6600	789.3	789.3	--	200	6000	--	--
Fuel Oil Range	N/A	N/A	N/A	--	200	6000	--	--
Metals (mg/kg)								
Antimony	0.32	0.18	0.18	5	78	0.27	3.12	From MP 2007 TEE
Arsenic	13.3	5.915	5.915	10	60	102	20	MTCA Method A
Barium	107	77.73	77.73	500	330	2000	703.8	From MP 2007 TEE
Cadmium	1	0.624	0.624	4	20	14	1	Ecology 1994
Chromium	307	144.3	144.3	42	42	67	48	Ecology 1994
Cobalt	25.7	16.77	16.77	20	--	120	32.13	From MP 2007 TEE
Copper	178	105.1	105.1	100	50	217	36	Ecology 1994
Lead	276	129.4	129.4	50	500	118	24	Ecology 1994
Manganese	649	553.6	553.6	1100	450	1500	1200	Ecology 1994
Mercury	0.54	0.307	0.307	0.3	0.1	0.4	0.07	Ecology 1994
Nickel	65.9	50.94	50.94	30	200	980	48	Ecology 1994
Selenium	1.2	0.754	0.754	1	70	0.3	2	From MP 2007 TEE
Silver	1.4	0.364	0.364	2	--	4.2	0.24	From MP 2007 TEE
Thallium	0.076	0.0653	0.0653	1	--	--	4.53	From MP 2007 TEE
Vanadium	121	94.66	94.66	2	--	7.8	296.6	From MP 2007 TEE
Zinc	200	116.1	116.1	86	200	360	85	Ecology 1994

Notes:

[1] Indicator soil concentrations are generally from MTCA Table 749-3. Additional soil screening values were obtained from EPA ecological soil screening level documents or were derived for the 2007 TEE (see text for details).

Yellow shading indicates EPC is greater than background value (if available) and Indicator Soil Concentration from MTCA Table 749-3.

Green shading indicates EPC is greater than background value (if available) and no Indicator Soil Concentration is available in MTCA Table 749-3.

EPC = exposure point concentration

COPEC = Contaminant of Potential Ecological Concern

mg/kg = micrograms per kilogram

N/A = not applicable

ng/kg = nanograms per kilogram

TEC = toxic equivalency concentration

TEE = terrestrial ecological evaluation

µg/kg = microliters per kilogram

UCL = upper confidence limit

Table 9

City Purchase Area (0-15 feet) - COPEC Screen

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	Concentrations			Indicator Soil Concentration[1]	Background	
	Maximum	95%UCL	EPC	Wildlife	Value	Reference
Polychlorinated Biphenyls (µg/kg)						
Total PCBs	190	61.3	61.3	650	--	--
Dioxin & Furans (ng/kg)						
TEC Bird	28.3	N/A	28.3	2	5.2	Ecology 2010
TEC Mammal	19.2	N/A	19.2	2	5.2	Ecology 2010
Total Petroleum Hydrocarbons (mg/kg)						
Gasoline Range	N/A	N/A	N/A	5000	--	--
Diesel Range	230	70.5	70.5	6000	--	--
Heavy Oil Range	2700	798.7	798.7	6000	--	--
Fuel Oil Range	N/A	N/A	N/A	6000	--	--
Metals (mg/kg)						
Antimony	N/A	N/A	N/A	0.27	3.12	From MP 2007 TEE
Arsenic	6.1	4.085	4.085	102	20	MTCA Method A
Barium	319	138.9	138.9	2000	703.8	From MP 2007 TEE
Cadmium	0.86	0.318	0.318	14	1	Ecology 1994
Chromium	64	44.22	44.22	67	48	Ecology 1994
Cobalt	21.6	14.95	14.95	120	32.13	From MP 2007 TEE
Copper	187	105	105	217	36	Ecology 1994
Lead	186	75.89	75.89	118	24	Ecology 1994
Manganese	5790	2900	2900	1500	1200	Ecology 1994
Mercury	0.23	0.0982	0.0982	0.4	0.07	Ecology 1994
Nickel	150	70.75	70.75	980	48	Ecology 1994
Selenium	N/A	N/A	N/A	0.3	2	From MP 2007 TEE
Silver	14.9	5.671	5.671	4.2	0.24	From MP 2007 TEE
Thallium	1.2	1.2	1.2	--	4.53	From MP 2007 TEE
Vanadium	180	97.39	97.39	7.8	296.6	From MP 2007 TEE
Zinc	249	145.1	145.1	360	85	Ecology 1994

Notes:

[1] Indicator soil concentrations are generally from MTCA Table 749-3. Additional soil screening values were obtained from EPA ecological soil screening level documents or were derived for the 2007 TEE (see text for details).

Yellow shading indicates EPC is greater than background value (if available) and Indicator Soil Concentration from MTCA Table 749-3.

Green shading indicates EPC is greater than background value (if available) and no Indicator Soil Concentration is available in MTCA Table 749-3.

EPC = exposure point concentration

COPEC = Contaminant of Potential Ecological Concern

mg/kg = micrograms per kilogram

N/A = not applicable

ng/kg = nanograms per kilogram

TEC = toxic equivalency concentration

TEE = terrestrial ecological evaluation

µg/kg = microliters per kilogram

UCL = upper confidence limit

Table 10

City Purchase Area (0-6 feet) - COPEC Screen

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	Concentrations			Indicator Soil Concentration[1]	Background	
	Maximum	95%UCL	EPC	Wildlife	Value	Reference
Polychlorinated Biphenyls (µg/kg)						
Total PCBs	190	72.4	72.4	650	--	--
Dioxin & Furans (ng/kg)						
TEC Bird	28.3	N/A	28.3	2	5.2	Ecology 2010
TEC Mammal	19.2	N/A	19.2	2	5.2	Ecology 2010
Total Petroleum Hydrocarbons (mg/kg)						
Gasoline Range	N/A	N/A	N/A	5,000	--	--
Diesel Range	230	70.39	70.39	6,000	--	--
Heavy Oil Range	2,700	952.2	952.2	6,000	--	--
Fuel Oil Range	N/A	N/A	N/A	6,000	--	--
Metals (mg/kg)						
Antimony	N/A	N/A	N/A	0.27	3.12	From MP 2007 TEE
Arsenic	6.1	4.128	4.128	102	20	MTCA Method A
Barium	319	153.1	153.1	2,000	703.8	From MP 2007 TEE
Cadmium	0.86	0.347	0.347	14	1	Ecology 1994
Chromium	64	43.57	43.57	67	48	Ecology 1994
Cobalt	18	14.25	14.25	120	32.13	From MP 2007 TEE
Copper	187	118.7	118.7	217	36	Ecology 1994
Lead	186	95.25	95.25	118	24	Ecology 1994
Manganese	5,790	3,050	3,050	1,500	1,200	Ecology 1994
Mercury	0.23	0.112	0.112	0.4	0.07	Ecology 1994
Nickel	150	78.43	78.43	980	48	Ecology 1994
Selenium	N/A	N/A	N/A	0.3	2	From MP 2007 TEE
Silver	14.9	7.006	7.006	4.2	0.24	From MP 2007 TEE
Thallium	1.2	N/A	1.2	--	4.53	From MP 2007 TEE
Vanadium	180	100.9	100.9	7.8	296.6	From MP 2007 TEE
Zinc	249	156.8	156.8	360	85	Ecology 1994

Notes:

[1] Indicator soil concentrations are generally from MTCA Table 749-3. Additional soil screening values were obtained from EPA ecological soil screening level documents or were derived for the 2007 TEE (see text for details).

Yellow shading indicates EPC is greater than background value (if available) and Indicator Soil Concentration from MTCA Table 749-3.

EPC = exposure point concentration

COPEC = Contaminant of Potential Ecological Concern

mg/kg = micrograms per kilogram

N/A = not applicable

ng/kg = nanograms per kilogram

TEC = toxic equivalency concentration

TEE = terrestrial ecological evaluation

µg/kg = microliters per kilogram

UCL = upper confidence limit

Table 11

Chemicals of Potential Ecological Concern in Soil

Port Angeles Mill Study Area

Port Angeles, Washington

Exposure Area	Receptor Group	PCBs	Dioxins/ Furans	TPH	Antimony	Chromium	Copper	Lead	Manganese	Mercury	Nickel	Silver	Zinc
West Mill (0-15 feet)	Wildlife		X		X		X	X		X			
West Mill (0-6 feet)	Wildlife		X		X		X	X		X			X
East Mill (0-15 feet)	Plants		X[1]	X[1]								X	
	Soil Biota						X					X[1]	
	Wildlife		X									X	
East Mill (0-6 feet)	Plants		X[1]	X[1]				X				X	X
	Soil Biota						X					X[1]	
	Wildlife		X									X	
Marine Bluffs (0-6 feet)	Plants		X[1]										
	Soil Biota	X[1]											
	Wildlife		X										
Ennis Creek/Estuary (0-15 feet)	Plants		X[1]	X[1]		X	X	X			X		X
	Soil Biota	X[1]		X		X	X			X		X[1]	
	Wildlife		X			X		X					
Ennis Creek/Estuary (0-6 feet)	Plants		X[1]	X[1]		X	X	X		X	X		X
	Soil Biota	X[1]		X		X	X			X		X[1]	
	Wildlife		X			X		X					
City Purchase (0-15 feet)	Wildlife		X						X			X	
City Purchase (0-6 feet)	Wildlife		X						X			X	

Notes:

[1]Indicates chemical was identified as a COPEC because chemical was detected at at concentration greater than background (if available), but MTCA Table 749-3 does not provide an ISC for this receptor group.

Table 12

Calculation of Site-Specific Plant Uptake Coefficient (K_{plant}) Values

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	K_{plant} Calculations by Sample															
	EC034 (West Mill)				EC035 (West Mill)				EC033 (East Mill)				EC021 (East Mill)			
	Soil	Plant (ww)	Plant (dw)	K_{plant} (dw)	Soil	Plant (ww)	Plant (dw)	K_{plant} (dw)	Soil	Plant (ww)	Plant (dw)	K_{plant} (dw)	Soil	Plant (ww)	Plant (dw)	K_{plant} (dw)
Polychlorinated Biphenyls (µg/kg)																
Total PCBs	38.4	1.1375	4.532	0.118	20.4	1.1375	7.065	0.346	215.1	1.1375	5.688	0.026	--	1.1375	--	--
Dioxins and Furans (ng/kg)																
1,2,3,4,6,7,8-HpCDD	1220.96	0.129	0.514	0.000	735.308	0.073	0.453	0.001	1318.158	0.595	2.975	0.002	24.072	0.1425	0.682	0.028
1,2,3,4,6,7,8-HpCDF	147.87	0.209	0.833	0.006	573.539	0.056	0.348	0.001	186.961	0.085	0.425	0.002	4.454	0.082	0.392	0.088
1,2,3,4,7,8,9-HpCDF	7.069	0.137	0.546	0.077	15.449	0.094	0.584	0.038	9.991	0.164	0.820	0.082	0.177	0.123	0.589	3.325
1,2,3,4,7,8-HxCDD	5.423	0.051	0.203	0.037	11.795	0.0635	0.394	0.033	34.238	0.078	0.390	0.011	0.801	0.0835	0.400	0.499
1,2,3,4,7,8-HxCDF	9.081	0.0325	0.129	0.014	14.03	0.0265	0.165	0.012	31.489	0.049	0.245	0.008	0.624	0.049	0.234	0.376
1,2,3,6,7,8-HxCDD	47.245	0.0605	0.241	0.005	62.581	0.0645	0.401	0.006	132.246	0.0805	0.403	0.003	2.263	0.1115	0.533	0.236
1,2,3,6,7,8-HxCDF	3.835	0.0315	0.125	0.033	8.462	0.023	0.143	0.017	15.854	0.04	0.200	0.013	0.371	0.088	0.421	1.135
1,2,3,7,8,9-HxCDD	17.963	0.0525	0.209	0.012	30.867	0.0605	0.376	0.012	83.939	0.075	0.375	0.004	20.25	0.0915	0.438	0.022
1,2,3,7,8,9-HxCDF	0.2475	0.0415	0.165	0.668	0.2345	0.041	0.255	1.086	1.953	0.074	0.370	0.189	0.0655	0.065	0.311	4.748
1,2,3,7,8-PeCDD	3.593	0.051	0.203	0.057	10.386	0.0325	0.202	0.019	41.079	0.0505	0.253	0.006	1.025	0.0665	0.318	0.310
1,2,3,7,8-PeCDF	3.272	0.0395	0.157	0.048	5.317	0.028	0.174	0.033	28.149	0.04	0.200	0.007	0.581	0.046	0.220	0.379
2,3,4,6,7,8-HxCDF	6.767	0.0355	0.141	0.021	16.411	0.03	0.186	0.011	17.464	0.0525	0.263	0.015	0.381	0.0885	0.423	1.111
2,3,4,7,8-PeCDF	4.059	0.042	0.167	0.041	6.202	0.0305	0.189	0.031	30.116	0.0425	0.213	0.007	0.667	0.049	0.234	0.351
2,3,7,8-TCDD	0.646	0.0365	0.145	0.225	4.86	0.026	0.161	0.033	11.182	0.0385	0.193	0.017	0.792	0.055	0.263	0.332
2,3,7,8-TCDF	2.263	0.0485	0.193	0.085	10.043	0.0265	0.165	0.016	76.367	0.0275	0.138	0.002	0.901	0.0595	0.285	0.316
OCDD	11270.94	1.998	7.960	0.001	3938.625	0.767	4.764	0.001	6991.464	6.095	30.475	0.004	149.62	1.968	9.416	0.063
OCDF	596.315	0.0415	0.165	0.000	995.919	0.181	1.124	0.001	513.979	0.5875	2.938	0.006	6.646	0.323	1.545	0.233
Metals (mg/kg)																
Antimony	8.02	0.022	0.088	0.011	0.13	0.012	0.075	0.573	0.16	0.022	0.110	0.688	0.12	0.012	0.057	0.478
Arsenic	4.1	0.03	0.120	0.029	3.2	0.01	0.062	0.019	7.3	0.01	0.050	0.007	1.9	0.01	0.048	0.025
Barium	71.8	1.47	5.857	0.082	43.6	0.961	5.969	0.137	107	2.46	12.300	0.115	51.5	3.26	15.598	0.303
Cadmium	0.36	0.004	0.016	0.044	0.14	0.006	0.037	0.266	0.52	0.016	0.080	0.154	0.18	0.013	0.062	0.346
Chromium	37.2	0.14	0.558	0.015	25.2	0.03	0.186	0.007	104	0.035	0.175	0.002	27.7	0.1	0.478	0.017
Cobalt	12.2	0.041	0.163	0.013	7.2	0.0005	0.003	0.000	17.3	0.005	0.025	0.001	7	0.021	0.100	0.014
Copper	77.8	1.05	4.183	0.054	22.9	1.03	6.398	0.279	80.9	0.93	4.650	0.057	20.9	1.26	6.029	0.288
Lead	102	0.063	0.251	0.002	17.3	0.014	0.087	0.005	80.8	0.031	0.155	0.002	15.4	0.061	0.292	0.019
Manganese	360	24.8	98.805	0.274	402	5.05	31.366	0.078	610	9.09	45.450	0.075	272	36.9	176.555	0.649
Mercury	0.08	0.008	0.032	0.398	0.1	0.007	0.043	0.435	0.19	0.007	0.035	0.184	0.05	0.004	0.019	0.383
Nickel	47.8	0.51	2.032	0.043	31.7	0.26	1.615	0.051	53.5	0.39	1.950	0.036	31.5	0.72	3.445	0.109
Selenium	0.1	0.15	0.598	5.976	0.15	0.1	0.621	4.141	0.8	0.1	0.500	0.625	0.1	0.1	0.478	4.785
Silver	0.12	0.0025	0.010	0.083	0.05	0.002	0.012	0.248	0.14	0.0025	0.013	0.089	0.05	0.002	0.010	0.191
Thallium	0.048	0.001	0.004	0.083	0.033	0.0005	0.003	0.094	0.075	0.0005	0.003	0.033	0.086	0.0005	0.002	0.028
Vanadium	49.2	0.02	0.080	0.002	53.1	0.005	0.031	0.001	94.4	0.02	0.100	0.001	49.2	0.02	0.096	0.002
Zinc	329	3.85	15.339	0.047	65	4.03	25.031	0.385	173	4.28	21.400	0.124	54.8	7.05	33.732	0.616
Additional Plant Data																
Moisture Content (%)	--	74.9	--	--	--	83.9	--	--	--	80	--	--	--	79.1	--	--

Analyte	K_{plant} Calculations by Sample																K_{plant} Values	
	EC031 (Marine Bluff)				EC023 (Ennis Creek)				EC026 (Ennis Creek)				EC028 (Ennis Creek)				Updated	2007
	Soil	Plant (ww)	Plant (dw)	K_{plant} (dw)	Soil	Plant (ww)	Plant (dw)	K_{plant} (dw)	Soil	Plant (ww)	Plant (dw)	K_{plant} (dw)	Soil	Plant (ww)	Plant (dw)	K_{plant} (dw)	TEE	TEE
Polychlorinated Biphenyls (µg/kg)																		
Total PCBs	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.164	0.223
Dioxins and Furans (ng/kg)																		
1,2,3,4,6,7,8-HpCDD	12.292	0.72	4.932	0.401	23.796	0.1295	0.996	0.042	53.778	0.124	0.660	0.012	65.931	0.1545	0.813	0.012	0.062	0.062
1,2,3,4,6,7,8-HpCDF	1.824	0.0815	0.558	0.306	3.43	0.079	0.608	0.177	10.1	0.0855	0.455	0.045	11.498	0.1115	0.587	0.051	0.084	0.084
1,2,3,4,7,8,9-HpCDF	0.142	0.1655	1.134	7.983	0.3065	0.149	1.146	3.739	0.565	0.131	0.697	1.233	0.3115	0.174	0.916	2.940	2.427	2.427
1,2,3,4,7,8-HxCDD	1.384	0.0485	0.332	0.240	1.702	0.063	0.485	0.285	1.316	0.077	0.410	0.311	3.363	0.0615	0.324	0.096	0.189	0.189
1,2,3,4,7,8-HxCDF	0.625	0.0365	0.250	0.400	0.971	0.0305	0.235	0.242	2.045	0.045	0.239	0.117	3.115	0.047	0.247	0.079	0.156	0.156
1,2,3,6,7,8-HxCDD	2.605	0.0525	0.360	0.138	4.125	0.0635	0.488	0.118	4.092	0.0905	0.481	0.118	9.046	0.0715	0.376	0.042	0.083	0.083
1,2,3,6,7,8-HxCDF	0.336	0.0285	0.195	0.581	0.562	0.023	0.177	0.315	0.876	0.044	0.234	0.267	1.826	0.0475	0.250	0.137	0.312	0.312
1,2,3,7,8,9-HxCDD	2.534	0.0475	0.325	0.128	4.007	0.0595	0.458	0.114	3.811	0.079	0.420	0.110	9.498	0.063	0.332	0.035	0.055	0.079
1,2,3,7,8,9-HxCDF	0.1085	0.06	0.411	3.788	0.0975	0.046	0.354	3.629	0.191	0.062	0.330	1.727	0.05	0.0635	0.334	6.684	2.815	2.815
1,2,3,7,8-PeCDD	1.446	0.0485	0.332	0.230	1.925	0.0565	0.435	0.226	1.233	0.0615	0.327	0.265	4.223	0.0705	0.371	0.088	0.150	0.15
1,2,3,7,8-PeCDF	0.589	0.036	0.247	0.419	0.928	0.0335	0.258	0.278	1.059	0.0475	0.253	0.239	3.215	0.0425	0.224	0.070	0.184	0.184
2,3,4,6,7,8-HxCDF	0.384	0.0415	0.284	0.740	0.566	0.031	0.238	0.421	1.031	0.0495	0.263	0.255	1.989	0.055	0.289	0.146	0.340	0.34
2,3,4,7,8-PeCDF	0.754	0.0365	0.250	0.332	1.084	0.0365	0.281	0.259	1.358	0.0495	0.263	0.194	3.879	0.0475	0.250	0.064	0.160	0.16
2,3,7,8-TCDD	0.481	0.0295	0.202	0.420	0.486	0.03	0.231	0.475	0.42	0.042	0.223	0.532	1.577	0.041	0.216	0.137	0.271	0.271
2,3,7,8-TCDF	1.272	0.0395	0.271	0.213	2.288	0.033	0.254	0.111	1.312	0.0425	0.226	0.172	5.364	0.063	0.332	0.062	0.122	0.122
OCDD	43.439	17.72	121.370	2.794	96.46	2.167	16.669	0.173	382.569	1.225	6.516	0.017	325.935	1.066	5.611	0.017	0.384	0.375
OCDF	2.562	0.4015	2.750	1.073	5.821	0.3565	2.742	0.471	28.129	0.296	1.574	0.056	22.734	0.3585	1.887	0.083	0.240	0.241
Metals (mg/kg)																		
Antimony	0.06	0.01	0.068	1.142	0.06	0.011	0.085	1.410	0.32	0.015	0.080	0.249	0.1	0.013	0.068	0.684	0.654	0.654
Arsenic	2.1	0.01	0.068	0.033	4.4	0.01	0.077	0.017	3.5	0.01	0.053	0.015	4.2	0.01	0.053	0.013	0.020	--
Barium	41.3	0.936	6.411	0.155	75.9	0.636	4.892	0.064	78.2	1.95	10.372	0.133	105	0.75	3.947	0.038	0.128	--
Cadmium	0.06	0.006	0.041	0.685	0.15	0.008	0.062	0.410	0.22	0.003	0.016	0.073	0.3	0.003	0.016	0.053	0.254	--
Chromium	23.2	0.09	0.616	0.027	45.3	0.15	1.154	0.025	55.6	0.13	0.691	0.012	56.3	0.1	0.526	0.009	0.014	0.014
Cobalt	6.9	0.025	0.171	0.025	16.3	0.009	0.069	0.004	16.1	0.009	0.048	0.003	19.9	0.004	0.021	0.001	0.008	--
Copper	15.6	1.18	8.082	0.518	38.1	1.01	7.769	0.204	53.1	0.94	5.000	0.094	49.7	1.23	6.474	0.130	0.203	0.203
Lead	3.48	0.016	0.110	0.031	23.6	0.058	0.446	0.019	17.9	0.042	0.223	0.012	18.8	0.02	0.105	0.006	0.012	0.012
Manganese	317	28.2	193.151	0.609	551	9.81	75.462	0.137	549	25.7	136.702	0.249	649	11.9	62.632	0.097	0.271	--
Mercury	0.03	0.004	0.027	0.913	0.05	0.005	0.038	0.769	0.06	0.007	0.037	0.621	0.08	0.006	0.032	0.395	0.512	0.512
Nickel	30.3	0.98	6.712	0.222	47.1	0.25	1.923	0.041	57.9	0.6	3.191	0.055	65.9	0.33	1.737	0.026	0.073	0.073
Selenium	0.1	0.1	0.685	6.849	0.15	0.1	0.769	5.128	0.1	0.1	0.532	5.319	0.7	0.1	0.526	0.752	4.197	--
Silver	0.03	0.0015	0.010	0.342	0.07	0.0015	0.012	0.165	0.06	0.002	0.011	0.177	0.1	0.002	0.011	0.105	0.175	0.175
Thallium	0.027	0.0005	0.003	0.127	0.047	0.0005	0.004	0.082	0.055	0.002	0.011	0.193	0.072	0.0005	0.003	0.037	0.085	--
Vanadium	38	0.01	0.068	0.002	83.3	0.02	0.154	0.002	116	0.02	0.106	0.001	107	0.01	0.053	0.0005	0.001	--
Zinc	33.9	4.38	30.000	0.885	64.3	3.37	25.923	0.403	76.9	3.85	20.479	0.266	200	4.38	23.053	0.115	0.355	0.355
Additional Plant Data																		
Moisture Content (%)	--	85.4	--	--	--	87	--	--	--	81.2	--	--	--	81	--	--	--	--

Notes:

-- = value is not available or not applicable

Yellow shading indicates analyte was not detected and value is 1/2 of the method reporting limit

dw = dry weight

mg/kg = milligrams per kilogram

ng/kg = nanograms per kilogram

µg/kg = micrograms per kilogram

ww = wet weight

Table 13

Calculation of Site-Specific Bioaccumulation Factor (BAF) Values

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	Bioaccumulation Factor Calculations by Sample															
	EC034 (West Mill)				EC035 (West Mill)				EC033 (East Mill)				EC021 (East Mill)			
	Soil	Worm (ww)	Worm (dw)	BAF (dw)	Soil	Worm (ww)	Worm (dw)	BAF (dw)	Soil	Worm (ww)	Worm (dw)	BAF (dw)	Soil	Worm (ww)	Worm (dw)	BAF (dw)
Polychlorinated Biphenyls (µg/kg)																
Total PCBs	38.4	78.04	448.506	11.680	20.4	1.1375	6.537	0.320	215.1	1.1375	7.245	0.034	--	--	--	--
Dioxins and Furans (ng/kg)																
1,2,3,4,6,7,8-HpCDD	1220.96	22.345	128.420	0.105	735.308	53.554	307.782	0.419	1318.158	7.833	49.892	0.038	24.072	2.984	14.075	0.585
1,2,3,4,6,7,8-HpCDF	147.87	5.426	31.184	0.211	573.539	45.913	263.868	0.460	186.961	0.964	6.140	0.033	4.454	0.865	4.080	0.916
1,2,3,4,7,8,9-HpCDF	7.069	0.268	1.540	0.218	15.449	1.496	8.598	0.557	9.991	0.1385	0.882	0.088	0.177	0.1345	0.634	3.584
1,2,3,4,7,8-HxCDD	5.423	0.418	2.402	0.443	11.795	0.763	4.385	0.372	34.238	0.08	0.510	0.015	0.801	0.082	0.387	0.483
1,2,3,4,7,8-HxCDF	9.081	0.717	4.121	0.454	14.03	1.051	6.040	0.431	31.489	0.047	0.299	0.010	0.624	0.0645	0.304	0.488
1,2,3,6,7,8-HxCDD	47.245	3.773	21.684	0.459	62.581	6.015	34.569	0.552	132.246	0.564	3.592	0.027	2.263	0.097	0.458	0.202
1,2,3,6,7,8-HxCDF	3.835	0.528	3.034	0.791	8.462	0.694	3.989	0.471	15.854	0.0455	0.290	0.018	0.371	0.0625	0.295	0.795
1,2,3,7,8,9-HxCDD	17.963	0.745	4.282	0.238	30.867	0.809	4.649	0.151	83.939	0.0875	0.557	0.007	20.25	0.0875	0.413	0.020
1,2,3,7,8,9-HxCDF	0.2475	0.109	0.626	2.531	0.2345	0.2515	1.445	6.164	1.953	0.0615	0.392	0.201	0.0655	0.0855	0.403	6.157
1,2,3,7,8-PeCDD	3.593	0.795	4.569	1.272	10.386	0.826	4.747	0.457	41.079	0.062	0.395	0.010	1.025	0.067	0.316	0.308
1,2,3,7,8-PeCDF	3.272	0.641	3.684	1.126	5.317	0.193	1.109	0.209	28.149	0.048	0.306	0.011	0.581	0.048	0.226	0.390
2,3,4,6,7,8-HxCDF	6.767	0.36	2.069	0.306	16.411	1.153	6.626	0.404	17.464	0.0525	0.334	0.019	0.381	0.069	0.325	0.854
2,3,4,7,8-PeCDF	4.059	0.541	3.109	0.766	6.202	0.303	1.741	0.281	30.116	0.0515	0.328	0.011	0.667	0.048	0.226	0.339
2,3,7,8-TCDD	0.646	0.0655	0.376	0.583	4.86	0.255	1.466	0.302	11.182	0.0555	0.354	0.032	0.792	0.0575	0.271	0.342
2,3,7,8-TCDF	2.263	0.806	4.632	2.047	10.043	0.458	2.632	0.262	76.367	0.354	2.255	0.030	0.901	0.248	1.170	1.298
OCDD	11270.94	134.952	775.586	0.069	3938.625	293.542	1687.023	0.428	6991.464	55.994	356.650	0.051	149.62	21.127	99.656	0.666
OCDF	596.315	10.868	62.460	0.105	995.919	84.66	486.552	0.489	513.979	1.887	12.019	0.023	6.646	0.4135	1.950	0.293
Metals (mg/kg)																
Antimony	8.02	0.257	1.477	0.184	0.13	0.004	0.023	0.177	0.16	0.003	0.019	0.119	0.12	0.004	0.019	0.157
Arsenic	4.1	13.3	76.437	18.643	3.2	0.4	2.299	0.718	7.3	0.32	2.038	0.279	1.9	0.71	3.349	1.763
Barium	71.8	0.411	2.362	0.033	43.6	2.89	16.609	0.381	107	2.98	18.981	0.177	51.5	3.93	18.538	0.360
Cadmium	0.36	0.777	4.466	12.404	0.14	0.478	2.747	19.622	0.52	0.668	4.255	8.182	0.18	0.463	2.184	12.133
Chromium	37.2	0.17	0.977	0.026	25.2	1.14	6.552	0.260	104	1.31	8.344	0.080	27.7	1.19	5.613	0.203
Cobalt	12.2	1.05	6.034	0.495	7.2	0.44	2.529	0.351	17.3	0.484	3.083	0.178	7	0.6	2.830	0.404
Copper	77.8	4.45	25.575	0.329	22.9	2.42	13.908	0.607	80.9	2.87	18.280	0.226	20.9	2.54	11.981	0.573
Lead	102	3.03	17.414	0.171	17.3	0.821	4.718	0.273	80.8	0.554	3.529	0.044	15.4	0.78	3.679	0.239
Manganese	360	3.22	18.506	0.051	402	13.3	76.437	0.190	610	10.8	68.790	0.113	272	12.1	57.075	0.210
Mercury	0.08	0.022	0.126	1.580	0.1	0.189	1.086	10.862	0.19	0.023	0.146	0.771	0.05	0.086	0.406	8.113
Nickel	47.8	1.22	7.011	0.147	31.7	1.24	7.126	0.225	53.5	0.9	5.732	0.107	31.5	1.08	5.094	0.162
Selenium	0.1	0.1	0.575	5.747	0.15	0.6	3.448	22.989	0.8	0.6	3.822	4.777	0.1	1.1	5.189	51.887
Silver	0.12	0.005	0.029	0.239	0.05	0.01	0.057	1.149	0.14	0.009	0.057	0.409	0.05	0.014	0.066	1.321
Thallium	0.048	0.0076	0.044	0.910	0.033	0.0039	0.022	0.679	0.075	0.0045	0.029	0.382	0.086	0.005	0.024	0.274
Vanadium	49.2	0.2	1.149	0.023	53.1	2.13	12.241	0.231	94.4	1.67	10.637	0.113	49.2	1.95	9.198	0.187
Zinc	329	25	143.678	0.437	65	66.4	381.609	5.871	173	55	350.318	2.025	54.8	80.1	377.830	6.895
Additional Earthworm Data																
Moisture Content (%)	--	82.6	--	--	--	82.6	--	--	--	84.3	--	--	--	78.8	--	--

Analyte	Bioaccumulation Factor Calculations by Sample																BAF Values	
	EC031 (Marine Bluff)				EC023 (Ennis Creek)				EC026 (Ennis Creek)				EC028 (Ennis Creek)				Updated	2007
	Soil	Worm (ww)	Worm (dw)	BAF (dw)	Soil	Worm (ww)	Worm (dw)	BAF (dw)	Soil	Worm (ww)	Worm (dw)	BAF (dw)	Soil	Worm (ww)	Worm (dw)	BAF (dw)	TEE	TEE
Polychlorinated Biphenyls (µg/kg)																		
Total PCBs	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4.011	3.57
Dioxins and Furans (ng/kg)																		
1,2,3,4,6,7,8-HpCDD	12.292	2.733	15.354	1.249	23.796	0.5685	3.158	0.133	53.778	4.484	23.233	0.432	65.931	1.187	6.631	0.101	0.383	0.29
1,2,3,4,6,7,8-HpCDF	1.824	0.649	3.646	1.999	3.43	0.1665	0.925	0.270	10.1	0.932	4.829	0.478	11.498	0.1225	0.684	0.060	0.553	0.478
1,2,3,4,7,8,9-HpCDF	0.142	0.1545	0.868	6.113	0.3065	0.2695	1.497	4.885	0.565	0.153	0.793	1.403	0.3115	0.2365	1.321	4.242	2.636	3.12
1,2,3,4,7,8-HxCDD	1.384	0.078	0.438	0.317	1.702	0.0805	0.447	0.263	1.316	0.0805	0.417	0.317	3.363	0.1065	0.595	0.177	0.298	0.156
1,2,3,4,7,8-HxCDF	0.625	0.0575	0.323	0.517	0.971	0.0825	0.458	0.472	2.045	0.0595	0.308	0.151	3.115	0.1005	0.561	0.180	0.338	0.224
1,2,3,6,7,8-HxCDD	2.605	0.086	0.483	0.185	4.125	0.0905	0.503	0.122	4.092	0.44	2.280	0.557	9.046	0.122	0.682	0.075	0.273	0.169
1,2,3,6,7,8-HxCDF	0.336	0.0585	0.329	0.978	0.562	0.079	0.439	0.781	0.876	0.058	0.301	0.343	1.826	0.0965	0.539	0.295	0.559	0.467
1,2,3,7,8,9-HxCDD	2.534	0.08	0.449	0.177	4.007	0.0835	0.464	0.116	3.811	0.0855	0.443	0.116	9.498	0.112	0.626	0.066	0.111	0.038
1,2,3,7,8,9-HxCDF	0.1085	0.0715	0.402	3.702	0.0975	0.097	0.539	5.527	0.191	0.0815	0.422	2.211	0.05	0.1735	0.969	19.385	5.735	6.901
1,2,3,7,8-PeCDD	1.446	0.091	0.511	0.354	1.925	0.088	0.489	0.254	1.233	0.0685	0.355	0.288	4.223	0.0745	0.416	0.099	0.380	0.25
1,2,3,7,8-PeCDF	0.589	0.0675	0.379	0.644	0.928	0.062	0.344	0.371	1.059	0.0445	0.231	0.218	3.215	0.057	0.318	0.099	0.383	0.258
2,3,4,6,7,8-HxCDF	0.384	0.0625	0.351	0.914	0.566	0.0865	0.481	0.849	1.031	0.064	0.332	0.322	1.989	0.113	0.631	0.317	0.498	0.409
2,3,4,7,8-PeCDF	0.754	0.063	0.354	0.469	1.084	0.0645	0.358	0.331	1.358	0.045	0.233	0.172	3.879	0.0585	0.327	0.084	0.307	0.183
2,3,7,8-TCDD	0.481	0.077	0.433	0.899	0.486	0.0665	0.369	0.760	0.42	0.05	0.259	0.617	1.577	0.0535	0.299	0.190	0.466	0.361
2,3,7,8-TCDF	1.272	0.2225	1.250	0.983	2.288	0.0745	0.414	0.181	1.312	0.196	1.016	0.774	5.364	0.253	1.413	0.263	0.730	0.662
OCDD	43.439	14.36	80.674	1.857	96.46	8.21	45.611	0.473	382.569	34.199	177.197	0.463	325.935	7.146	39.922	0.122	0.516	0.422
OCDF	2.562	0.845	4.747	1.853	5.821	0.1625	0.903	0.155	28.129	2.365	12.254	0.436	22.734	0.676	3.777	0.166	0.440	0.339
Metals (mg/kg)																		
Antimony	0.06	0.005	0.028	0.468	0.06	0.0005	0.003	0.046	0.32	0.003	0.016	0.049	0.1	0.0005	0.003	0.028	0.154	0.076
Arsenic	2.1	0.17	0.955	0.455	4.4	0.33	1.833	0.417	3.5	0.52	2.694	0.770	4.2	0.34	1.899	0.452	2.937	--
Barium	41.3	1.58	8.876	0.215	75.9	5.15	28.611	0.377	78.2	9.62	49.845	0.637	105	4.31	24.078	0.229	0.301	--
Cadmium	0.06	0.263	1.478	24.625	0.15	0.254	1.411	9.407	0.22	0.328	1.699	7.725	0.3	0.231	1.291	4.302	12.300	--
Chromium	23.2	0.6	3.371	0.145	45.3	2.94	16.333	0.361	55.6	4.28	22.176	0.399	56.3	2.15	12.011	0.213	0.211	0.052
Cobalt	6.9	0.348	1.955	0.283	16.3	0.763	4.239	0.260	16.1	1.11	5.751	0.357	19.9	0.592	3.307	0.166	0.312	--
Copper	15.6	1.1	6.180	0.396	38.1	2.32	12.889	0.338	53.1	5.48	28.394	0.535	49.7	2.69	15.028	0.302	0.413	0.291
Lead	3.48	0.207	1.163	0.334	23.6	0.938	5.211	0.221	17.9	2.07	10.725	0.599	18.8	0.539	3.011	0.160	0.255	0.122
Manganese	317	12.4	69.663	0.220	551	20	111.111	0.202	549	39.3	203.627	0.371	649	14.9	83.240	0.128	0.186	--
Mercury	0.03	0.017	0.096	3.184	0.05	0.035	0.194	3.889	0.06	0.034	0.176	2.936	0.08	0.032	0.179	2.235	4.196	5.057
Nickel	30.3	0.862	4.843	0.160	47.1	1.72	9.556	0.203	57.9	3.88	20.104	0.347	65.9	1.64	9.162	0.139	0.186	0.039
Selenium	0.1	0.1	0.562	5.618	0.15	0.6	3.333	22.222	0.1	0.4	2.073	20.725	0.7	1	5.587	7.981	17.743	--
Silver	0.03	0.007	0.039	1.311	0.07	0.012	0.067	0.952	0.06	0.016	0.083	1.382	0.1	0.013	0.073	0.726	0.936	0.96
Thallium	0.027	0.024	0.135	4.994	0.047	0.0073	0.041	0.863	0.055	0.0101	0.052	0.951	0.072	0.0055	0.031	0.427	1.185	--
Vanadium	38	0.92	5.169	0.136	83.3	3.61	20.056	0.241	116	8.18	42.383	0.365	107	3.15	17.598	0.164	0.183	--
Zinc	33.9	40	224.719	6.629	64.3	37	205.556	3.197	76.9	51.9	268.912	3.497	200	74.4	415.642	2.078	3.829	4.416
Additional Earthworm Data																		
Moisture Content (%)	--	82.2	--	--	--	82	--	--	--	80.7	--	--	--	82.1	--	--	--	--

Notes:

-- = value is not available or not applicable

Yellow shading indicates analyte was not detected and value is 1/2 of the method reporting limit

dw = dry weight

mg/kg = milligrams per kilogram

ng/kg = nanograms per kilogram

µg/kg = micrograms per kilogram

ww = wet weight

Table 14

West Mill Area (0-15 feet) - Wildlife Risk Evaluation

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	Maximum	95%UCL	EPC	Site-Specific Wildlife ISCs				Hazard Quotient			
				Shrew	Vole	Robin	Goose	Shrew	Vole	Robin	Goose
Polychlorinated Biphenyls (µg/kg)											
Total PCBs	--	--	--	--	--	--	--	--	--	--	--
Dioxin & Furans (ng/kg)											
1,2,3,4,6,7,8-HpCDD	120,000	14,956	14,956	24,262	61,976	2,231,925	3,760,408	6.E-01	2.E-01	7.E-03	4.E-03
1,2,3,4,6,7,8-HpCDF	13,000	1,728	1,728	17,064	49,476	172,786	342,633	1.E-01	3.E-02	1.E-02	5.E-03
1,2,3,4,7,8,9-HpCDF	1,500	180.2	180.2	3,681	2,201	45,866	32,752	5.E-02	8.E-02	4.E-03	6.E-03
1,2,3,4,7,8-HxCDD	1,400	150	150	3,075	2,519	52,262	48,122	5.E-02	6.E-02	3.E-03	3.E-03
1,2,3,4,7,8-HxCDF	570	60.19	60.19	2,731	2,980	24,187	26,545	2.E-02	2.E-02	2.E-03	2.E-03
1,2,3,6,7,8-HxCDD	3,640	600	600	3,337	4,993	275,126	344,023	2.E-01	1.E-01	2.E-03	2.E-03
1,2,3,6,7,8-HxCDF	330	49.61	49.61	1,689	1,600	17,142	17,839	3.E-02	3.E-02	3.E-03	3.E-03
1,2,3,7,8,9-HxCDD	2,800	316.2	316.2	7,464	5,184	41,856	34,969	4.E-02	6.E-02	8.E-03	9.E-03
1,2,3,7,8,9-HxCDF	19.67	1.818	1.818	170	190	2,192	2,849	1.E-02	1.E-02	8.E-04	6.E-04
1,2,3,7,8-PeCDD	580	68.47	68.47	244	308	2,243	2,705	3.E-01	2.E-01	3.E-02	3.E-02
1,2,3,7,8-PeCDF	106.2	17.22	17.22	8,087	8,604	22,319	24,407	2.E-03	2.E-03	8.E-04	7.E-04
2,3,4,6,7,8-HxCDF	380.7	51.94	51.94	1,888	1,478	18,641	16,847	3.E-02	4.E-02	3.E-03	3.E-03
2,3,4,7,8-PeCDF	190	34.62	34.62	997	972	2,567	2,622	3.E-02	4.E-02	1.E-02	1.E-02
2,3,7,8-TCDD	74	6.903	6.903	201	182	1,954	1,952	3.E-02	4.E-02	4.E-03	4.E-03
2,3,7,8-TCDF	140	23.22	23.22	1,304	3,669	1,399	2,971	2.E-02	6.E-03	2.E-02	8.E-03
OCDD	530,000	72,096	72,096	608,071	449,646	18,171,850	15,752,461	1.E-01	2.E-01	4.E-03	5.E-03
OCDF	68,000	7,572	7,572	708,535	676,092	20,330,634	20,969,071	1.E-02	1.E-02	4.E-04	4.E-04
2,3,7,8-TCDD TEQ (sum of congener HQs)	--	--	--	--	--	--	--	2	1	0.1	0.1
Total Petroleum Hydrocarbons (mg/kg)											
Gasoline Range	--	--	--	5000	5000	5,000	5000	--	--	--	--
Diesel Range	--	--	--	6000	6000	6,000	6000	--	--	--	--
Heavy Oil Range	--	--	--	6000	6000	6,000	6000	--	--	--	--
Fuel Oil Range	--	--	--	6000	6000	6,000	6000	--	--	--	--
Metals (mg/kg)											
Antimony	--	--	5.6	38	5	--	--	0.1	1	--	--
Chromium	--	--	--	677	2405	113	171	--	--	--	--
Copper	--	--	219.6	589	467	1120	1020	0.4	0.5	0.2	0.2
Lead	--	--	153.5	323	1712	231	390	0.5	0.1	0.7	0.4
Mercury (inorganic)	--	--	0.418	3.01	12.89	1.90	8.07	0.1	0.03	0.2	0.1
Nickel	--	--	--	4201	5845	5344	8883	--	--	--	--
Silver	--	--	--	21	54	2200	422	--	--	--	--
Zinc	--	--	--	812	4489	302	1531	--	--	--	--

Notes:

EPC = exposure point concentration

ISC = indicator soil concentrations

mg/kg = micrograms per kilogram

ng/kg = nanograms per kilogram

µg/kg = microliters per kilogram

Yellow shading indicates Hazard Quotient is greater than 1.

Table 15

West Mill (0-6 feet) - Wildlife Risk Evaluation

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	Maximum	95%UCL	EPC	Site-Specific Wildlife ISCs				Hazard Quotient			
				Shrew	Vole	Robin	Goose	Shrew	Vole	Robin	Goose
Polychlorinated Biphenyls (µg/kg)											
Total PCBs	--	--	--	--	--	--	--	--	--	--	--
Dioxin & Furans (ng/kg)											
1,2,3,4,6,7,8-HpCDD	120,000	16,568	16,568	24,262	61,976	2,231,925	3,760,408	7.E-01	3.E-01	7.E-03	4.E-03
1,2,3,4,6,7,8-HpCDF	13,000	1,911	1,911	17,064	49,476	172,786	342,633	1.E-01	4.E-02	1.E-02	6.E-03
1,2,3,4,7,8,9-HpCDF	1,500	199.9	199.9	3,681	2,201	45,866	32,752	5.E-02	9.E-02	4.E-03	6.E-03
1,2,3,4,7,8-HxCDD	1,400	166.4	166.4	3,075	2,519	52,262	48,122	5.E-02	7.E-02	3.E-03	3.E-03
1,2,3,4,7,8-HxCDF	570	64.61	64.61	2,731	2,980	24,187	26,545	2.E-02	2.E-02	3.E-03	2.E-03
1,2,3,6,7,8-HxCDD	3,640	664.7	664.7	3,337	4,993	275,126	344,023	2.E-01	1.E-01	2.E-03	2.E-03
1,2,3,6,7,8-HxCDF	330	54.71	54.71	1,689	1,600	17,142	17,839	3.E-02	3.E-02	3.E-03	3.E-03
1,2,3,7,8,9-HxCDD	2,800	350.7	350.7	7,464	5,184	41,856	34,969	5.E-02	7.E-02	8.E-03	1.E-02
1,2,3,7,8,9-HxCDF	19.67	1.961	1.961	170	190	2,192	2,849	1.E-02	1.E-02	9.E-04	7.E-04
1,2,3,7,8-PeCDD	580	75.84	75.84	244	308	2,243	2,705	3.E-01	2.E-01	3.E-02	3.E-02
1,2,3,7,8-PeCDF	106.2	13.05	13.05	8,087	8,604	22,319	24,407	2.E-03	2.E-03	6.E-04	5.E-04
2,3,4,6,7,8-HxCDF	380.7	57.22	57.22	1,888	1,478	18,641	16,847	3.E-02	4.E-02	3.E-03	3.E-03
2,3,4,7,8-PeCDF	190	31.35	31.35	997	972	2,567	2,622	3.E-02	3.E-02	1.E-02	1.E-02
2,3,7,8-TCDD	74	7.638	7.638	201	182	1,954	1,952	4.E-02	4.E-02	4.E-03	4.E-03
2,3,7,8-TCDF	140	25.54	25.54	1,304	3,669	1,399	2,971	2.E-02	7.E-03	2.E-02	9.E-03
OCDD	530,000	79,271	79,271	608,071	449,646	18,171,850	15,752,461	1.E-01	2.E-01	4.E-03	5.E-03
OCDF	68,000	8,381	8,381	708,535	676,092	20,330,634	20,969,071	1.E-02	1.E-02	4.E-04	4.E-04
2,3,7,8-TCDD TEQ (sum of congener HQs)	--	--	--	--	--	--	--	2	1	0.1	0.1
Total Petroleum Hydrocarbons (mg/kg)											
Gasoline Range	--	--	--	5,000	5,000	5,000	5,000	--	--	--	--
Diesel Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Heavy Oil Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Fuel Oil Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Metals (mg/kg)											
Antimony	--	--	6.3	38	5	--	--	0.2	1	--	--
Chromium	--	--	--	677	2,405	113	171	--	--	--	--
Copper	--	--	243.4	589	467	1,120	1,020	0.4	0.5	0.2	0.2
Lead	--	--	167	323	1,712	231	390	0.5	0.1	0.7	0.4
Mercury (inorganic)	--	--	0.425	3.01	12.89	1.90	8.07	0.1	0.03	0.2	0.1
Nickel	--	--	--	4,201	5,845	5,344	8,883	--	--	--	--
Silver	--	--	--	21	54	2,200	422	--	--	--	--
Zinc	--	--	399.8	812	4,489	302	1,531	0.5	0.1	1	0.3

Notes:

EPC = exposure point concentration

ISC = indicator soil concentrations

mg/kg = micrograms per kilogram

ng/kg = nanograms per kilogram

µg/kg = microliters per kilogram

Yellow shading indicates Hazard Quotient is greater than 1.

Table 16

West Mill (0-6 inches) - Wildlife Risk Evaluation

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	Maximum	95%UCL	EPC	Site-Specific Wildlife ISCs				Hazard Quotient			
				Shrew	Vole	Robin	Goose	Shrew	Vole	Robin	Goose
Polychlorinated Biphenyls (µg/kg)											
Total PCBs	--	--	--	737	8563	3971	33296	--	--	--	--
Dioxin & Furans (ng/kg)											
1,2,3,4,6,7,8-HpCDD	120,000	18,043	18,043	24,262	61,976	2,231,925	3,760,408	7.E-01	3.E-01	8.E-03	5.E-03
1,2,3,4,6,7,8-HpCDF	13,000	3,081	3,081	17,064	49,476	172,786	342,633	2.E-01	6.E-02	2.E-02	9.E-03
1,2,3,4,7,8,9-HpCDF	1,500	588.3	588.3	3,681	2,201	45,866	32,752	2.E-01	3.E-01	1.E-02	2.E-02
1,2,3,4,7,8-HxCDD	1,400	490.3	490.3	3,075	2,519	52,262	48,122	2.E-01	2.E-01	9.E-03	1.E-02
1,2,3,4,7,8-HxCDF	570	183.6	183.6	2,731	2,980	24,187	26,545	7.E-02	6.E-02	8.E-03	7.E-03
1,2,3,6,7,8-HxCDD	3,640	1894	1894	3,337	4,993	275,126	344,023	6.E-01	4.E-01	7.E-03	6.E-03
1,2,3,6,7,8-HxCDF	330	88	88	1,689	1,600	17,142	17,839	5.E-02	6.E-02	5.E-03	5.E-03
1,2,3,7,8,9-HxCDD	2,800	1020	1020	7,464	5,184	41,856	34,969	1.E-01	2.E-01	2.E-02	3.E-02
1,2,3,7,8,9-HxCDF	19.67	3.897	3.897	170	190	2,192	2,849	2.E-02	2.E-02	2.E-03	1.E-03
1,2,3,7,8-PeCDD	580	217.2	217.2	244	308	2,243	2,705	9.E-01	7.E-01	1.E-01	8.E-02
1,2,3,7,8-PeCDF	106.2	37.01	37.01	8,087	8,604	22,319	24,407	5.E-03	4.E-03	2.E-03	2.E-03
2,3,4,6,7,8-HxCDF	380.7	91.15	91.15	1,888	1,478	18,641	16,847	5.E-02	6.E-02	5.E-03	5.E-03
2,3,4,7,8-PeCDF	190	60.23	60.23	997	972	2,567	2,622	6.E-02	6.E-02	2.E-02	2.E-02
2,3,7,8-TCDD	74	19.33	19.33	201	182	1,954	1,952	1.E-01	1.E-01	1.E-02	1.E-02
2,3,7,8-TCDF	140	48.19	48.19	1,304	3,669	1,399	2,971	4.E-02	1.E-02	3.E-02	2.E-02
OCDD	530,000	128,007	128,007	608,071	449,646	18,171,850	15,752,461	2.E-01	3.E-01	7.E-03	8.E-03
OCDF	68,000	24,794	24,794	708,535	676,092	20,330,634	20,969,071	3.E-02	4.E-02	1.E-03	1.E-03
2,3,7,8-TCDD TEQ (sum of congener HQs)	--	--	--	--	--	--	--	3	3	0.3	0.2
Total Petroleum Hydrocarbons (mg/kg)											
Gasoline Range	--	--	--	5,000	5,000	5,000	5,000	--	--	--	--
Diesel Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Heavy Oil Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Fuel Oil Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Metals (mg/kg)											
Antimony	--	--	11.12	38	5	--	--	0.3	2	--	--
Chromium	--	--	--	677	2,405	113	171	--	--	--	--
Copper	--	--	508.4	589	467	1,120	1,020	0.9	1	0.5	0.5
Lead	--	--	181.7	323	1,712	231	390	0.6	0.1	0.8	0.5
Mercury (inorganic)	--	--	0.739	3.01	12.89	1.90	8.07	0.2	0.1	0.4	0.1
Nickel	--	--	--	4,201	5,845	5,344	8,883	--	--	--	--
Silver	--	--	--	21	54	2,200	422	--	--	--	--
Zinc	--	--	728	812	4,489	302	1,531	0.9	0.2	2	0.5

Notes:

EPC = exposure point concentration

ISC = indicator soil concentrations

mg/kg = micrograms per kilogram

ng/kg = nanograms per kilogram

µg/kg = microliters per kilogram

Yellow shading indicates Hazard Quotient is greater than 1.

Table 17

East Mill (0-15 feet) - Wildlife Risk Evaluation

Port Angeles Mill Study Area
Port Angeles, Washington

Analyte	Maximum	95%UCL	EPC	Site-Specific Wildlife ISCs				Hazard Quotient			
				Shrew	Vole	Robin	Goose	Shrew	Vole	Robin	Goose
Polychlorinated Biphenyls (µg/kg)											
Total PCBs	--	--	--	--	--	--	--	--	--	--	--
Dioxin & Furans (ng/kg)											
1,2,3,4,6,7,8-HpCDD	1,541	1,081	1,081	24,262	61,976	2,231,925	3,760,408	4.E-02	2.E-02	5.E-04	3.E-04
1,2,3,4,6,7,8-HpCDF	194.6	132.3	132.3	17,064	49,476	172,786	342,633	8.E-03	3.E-03	8.E-04	4.E-04
1,2,3,4,7,8,9-HpCDF	18.42	18.42	18.42	3,681	2,201	45,866	32,752	5.E-03	8.E-03	4.E-04	6.E-04
1,2,3,4,7,8-HxCDD	26.45	26.45	26.45	3,075	2,519	52,262	48,122	9.E-03	1.E-02	5.E-04	5.E-04
1,2,3,4,7,8-HxCDF	15.3	15.3	15.3	2,731	2,980	24,187	26,545	6.E-03	5.E-03	6.E-04	6.E-04
1,2,3,6,7,8-HxCDD	72.37	72.37	72.37	3,337	4,993	275,126	344,023	2.E-02	1.E-02	3.E-04	2.E-04
1,2,3,6,7,8-HxCDF	14.98	12.15	12.15	1,689	1,600	17,142	17,839	7.E-03	8.E-03	7.E-04	7.E-04
1,2,3,7,8,9-HxCDD	62.74	62.74	62.74	7,464	5,184	41,856	34,969	8.E-03	1.E-02	1.E-03	2.E-03
1,2,3,7,8,9-HxCDF	0.3305	0.3305	0.3305	170	190	2,192	2,849	2.E-03	2.E-03	2.E-04	1.E-04
1,2,3,7,8-PeCDD	22.42	22.42	22.42	244	308	2,243	2,705	9.E-02	7.E-02	1.E-02	8.E-03
1,2,3,7,8-PeCDF	6.234	6.234	6.234	8,087	8,604	22,319	24,407	8.E-04	7.E-04	3.E-04	3.E-04
2,3,4,6,7,8-HxCDF	14.84	12.32	12.32	1,888	1,478	18,641	16,847	7.E-03	8.E-03	7.E-04	7.E-04
2,3,4,7,8-PeCDF	6.084	6.084	6.084	997	972	2,567	2,622	6.E-03	6.E-03	2.E-03	2.E-03
2,3,7,8-TCDD	6.256	6.256	6.256	201	182	1,954	1,952	3.E-02	3.E-02	3.E-03	3.E-03
2,3,7,8-TCDF	5.108	5.108	5.108	1,304	3,669	1,399	2,971	4.E-03	1.E-03	4.E-03	2.E-03
OCDD	12,701	87,893	12,701	608,071	449,646	18,171,850	15,752,461	2.E-02	3.E-02	7.E-04	8.E-04
OCDF	546.3	601.9	546.3	708,535	676,092	20,330,634	20,969,071	8.E-04	8.E-04	3.E-05	3.E-05
2,3,7,8-TCDD TEQ (sum of congener HQs)	--	--	--	--	--	--	--	0.3	0.2	0.03	0.02
Total Petroleum Hydrocarbons (mg/kg)											
Gasoline Range	--	--	--	5,000	5,000	5,000	5,000	--	--	--	--
Diesel Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Heavy Oil Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Fuel Oil Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Metals (mg/kg)											
Antimony	--	--	--	38	5	--	--	--	--	--	--
Chromium	--	--	--	677	2,405	113	171	--	--	--	--
Copper	--	--	--	589	467	1,120	1,020	--	--	--	--
Lead	--	--	--	323	1,712	231	390	--	--	--	--
Mercury (inorganic)	--	--	--	3.01	12.89	1.90	8.07	--	--	--	--
Nickel	--	--	--	4,201	5,845	5,344	8,883	--	--	--	--
Silver	--	--	18.26	21	54	2,200	422	0.9	0.3	0.01	0.04
Zinc	--	--	--	812	4,489	302	1,531	--	--	--	--

Notes:

EPC = exposure point concentration
ISC = indicator soil concentrations
mg/kg = micrograms per kilogram
ng/kg = nanograms per kilogram
µg/kg = microliters per kilogram

Table 18

East Mill (0-6 feet) - Wildlife Risk Evaluation

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	Maximum	95%UCL	EPC	Site-Specific Wildlife ISCs				Hazard Quotient			
				Shrew	Vole	Robin	Goose	Shrew	Vole	Robin	Goose
Polychlorinated Biphenyls (µg/kg)											
Total PCBs	--	--	--	--	--	--	--	--	--	--	--
Dioxin & Furans (ng/kg)											
1,2,3,4,6,7,8-HpCDD	1,541	1,081	1,081	24,262	61,976	2,231,925	3,760,408	4.E-02	2.E-02	5.E-04	3.E-04
1,2,3,4,6,7,8-HpCDF	194.6	132.3	132.3	17,064	49,476	172,786	342,633	8.E-03	3.E-03	8.E-04	4.E-04
1,2,3,4,7,8,9-HpCDF	18.42	18.42	18.42	3,681	2,201	45,866	32,752	5.E-03	8.E-03	4.E-04	6.E-04
1,2,3,4,7,8-HxCDD	26.45	26.45	26.45	3,075	2,519	52,262	48,122	9.E-03	1.E-02	5.E-04	5.E-04
1,2,3,4,7,8-HxCDF	15.3	15.3	15.3	2,731	2,980	24,187	26,545	6.E-03	5.E-03	6.E-04	6.E-04
1,2,3,6,7,8-HxCDD	72.37	57.34	57.34	3,337	4,993	275,126	344,023	2.E-02	1.E-02	2.E-04	2.E-04
1,2,3,6,7,8-HxCDF	14.98	12.15	12.15	1,689	1,600	17,142	17,839	7.E-03	8.E-03	7.E-04	7.E-04
1,2,3,7,8,9-HxCDD	62.74	62.74	62.74	7,464	5,184	41,856	34,969	8.E-03	1.E-02	1.E-03	2.E-03
1,2,3,7,8,9-HxCDF	0.3305	0.3305	0.3305	170	190	2,192	2,849	2.E-03	2.E-03	2.E-04	1.E-04
1,2,3,7,8-PeCDD	22.42	22.42	22.42	244	308	2,243	2,705	9.E-02	7.E-02	1.E-02	8.E-03
1,2,3,7,8-PeCDF	6.234	6.234	6.234	8,087	8,604	22,319	24,407	8.E-04	7.E-04	3.E-04	3.E-04
2,3,4,6,7,8-HxCDF	14.84	14.84	14.84	1,888	1,478	18,641	16,847	8.E-03	1.E-02	8.E-04	9.E-04
2,3,4,7,8-PeCDF	6.084	6.084	6.084	997	972	2,567	2,622	6.E-03	6.E-03	2.E-03	2.E-03
2,3,7,8-TCDD	6.256	6.256	6.256	201	182	1,954	1,952	3.E-02	3.E-02	3.E-03	3.E-03
2,3,7,8-TCDF	5.108	5.108	5.108	1,304	3,669	1,399	2,971	4.E-03	1.E-03	4.E-03	2.E-03
OCDD	12,701	87,893	12,701	608,071	449,646	18,171,850	15,752,461	2.E-02	3.E-02	7.E-04	8.E-04
OCDF	546.3	601.9	546.3	708,535	676,092	20,330,634	20,969,071	8.E-04	8.E-04	3.E-05	3.E-05
2,3,7,8-TCDD TEQ (sum of congener HQs)	--	--	--	--	--	--	--	0.3	0.2	0.03	0.02
Total Petroleum Hydrocarbons (mg/kg)											
Gasoline Range	--	--	--	5,000	5,000	5,000	5,000	--	--	--	--
Diesel Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Heavy Oil Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Fuel Oil Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Metals (mg/kg)											
Antimony	--	--	--	38	5	--	--	--	--	--	--
Chromium	--	--	--	677	2,405	113	171	--	--	--	--
Copper	--	--	--	589	467	1,120	1,020	--	--	--	--
Lead	--	--	--	323	1,712	231	390	--	--	--	--
Mercury (inorganic)	--	--	--	3.01	12.89	1.90	8.07	--	--	--	--
Nickel	--	--	--	4,201	5,845	5,344	8,883	--	--	--	--
Silver	--	--	23.46	21	54	2,200	422	1	0.4	0.01	0.06
Zinc	--	--	--	812	4,489	302	1,531	--	--	--	--

Notes:

EPC = exposure point concentration

ISC = indicator soil concentrations

mg/kg = micrograms per kilogram

ng/kg = nanograms per kilogram

µg/kg = microliters per kilogram

Table 19

Marine Bluffs (0-6 feet) - Wildlife Risk Evaluation

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	Maximum	95%UCL	EPC	Site-Specific Wildlife ISCs				Hazard Quotient			
				Shrew	Vole	Robin	Goose	Shrew	Vole	Robin	Goose
Polychlorinated Biphenyls (µg/kg)											
Total PCBs	--	--	--	--	--	--	--	--	--	--	--
Dioxin & Furans (ng/kg)											
1,2,3,4,6,7,8-HpCDD	735.3	517.2	517.2	24,262	61,976	2,231,925	3,760,408	2.E-02	8.E-03	2.E-04	1.E-04
1,2,3,4,6,7,8-HpCDF	573.5	892	573.5	17,064	49,476	172,786	342,633	3.E-02	1.E-02	3.E-03	2.E-03
1,2,3,4,7,8,9-HpCDF	15.45	16.88	15.45	3,681	2,201	45,866	32,752	4.E-03	7.E-03	3.E-04	5.E-04
1,2,3,4,7,8-HxCDD	11.8	7.297	7.297	3,075	2,519	52,262	48,122	2.E-03	3.E-03	1.E-04	2.E-04
1,2,3,4,7,8-HxCDF	14.03	10.28	10.28	2,731	2,980	24,187	26,545	4.E-03	3.E-03	4.E-04	4.E-04
1,2,3,6,7,8-HxCDD	62.58	46.29	46.29	3,337	4,993	275,126	344,023	1.E-02	9.E-03	2.E-04	1.E-04
1,2,3,6,7,8-HxCDF	8.462	6.23	6.23	1,689	1,600	17,142	17,839	4.E-03	4.E-03	4.E-04	3.E-04
1,2,3,7,8,9-HxCDD	30.87	17.97	17.97	7,464	5,184	41,856	34,969	2.E-03	3.E-03	4.E-04	5.E-04
1,2,3,7,8,9-HxCDF	0.193	0.193	0.193	170	190	2,192	2,849	1.E-03	1.E-03	9.E-05	7.E-05
1,2,3,7,8-PeCDD	10.39	7.194	7.194	244	308	2,243	2,705	3.E-02	2.E-02	3.E-03	3.E-03
1,2,3,7,8-PeCDF	5.317	4.22	4.22	8,087	8,604	22,319	24,407	5.E-04	5.E-04	2.E-04	2.E-04
2,3,4,6,7,8-HxCDF	16.41	11.62	11.62	1,888	1,478	18,641	16,847	6.E-03	8.E-03	6.E-04	7.E-04
2,3,4,7,8-PeCDF	6.235	5.195	5.195	997	972	2,567	2,622	5.E-03	5.E-03	2.E-03	2.E-03
2,3,7,8-TCDD	4.86	3.374	3.374	201	182	1,954	1,952	2.E-02	2.E-02	2.E-03	2.E-03
2,3,7,8-TCDF	10.23	7.678	7.678	1,304	3,669	1,399	2,971	6.E-03	2.E-03	5.E-03	3.E-03
OCDD	3,939	6,082	3,939	608,071	449,646	18,171,850	15,752,461	6.E-03	9.E-03	2.E-04	3.E-04
OCDF	995.9	1,550	995.9	708,535	676,092	20,330,634	20,969,071	1.E-03	1.E-03	5.E-05	5.E-05
2,3,7,8-TCDD TEQ (sum of congener HQs)	--	--	--	--	--	--	--	0.2	0.1	0.02	0.01
Total Petroleum Hydrocarbons (mg/kg)											
Gasoline Range	--	--	--	5,000	5,000	5,000	5,000	--	--	--	--
Diesel Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Heavy Oil Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Fuel Oil Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Metals (mg/kg)											
Antimony	--	--	--	38	5	--	--	--	--	--	--
Chromium	--	--	--	677	2,405	113	171	--	--	--	--
Copper	--	--	--	589	467	1,120	1,020	--	--	--	--
Lead	--	--	--	323	1,712	231	390	--	--	--	--
Manganese	--	--	--	13,463	5,114	--	--	--	--	--	--
Mercury (inorganic)	--	--	--	3.01	12.89	1.90	8.07	--	--	--	--
Nickel	--	--	--	4,201	5,845	5,344	8,883	--	--	--	--
Silver	--	--	--	21	54	2,200	422	--	--	--	--
Zinc	--	--	--	812	4,489	302	1,531	--	--	--	--

Notes:

EPC = exposure point concentration

ISC = indicator soil concentrations

mg/kg = micrograms per kilogram

ng/kg = nanograms per kilogram

µg/kg = microliters per kilogram

Table 20

Ennis Creek/Estuary (0-15 feet) - Wildlife Risk Evaluation

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	Maximum	95%UCL	EPC	Site-Specific Wildlife ISCs				Hazard Quotient			
				Shrew	Vole	Robin	Goose	Shrew	Vole	Robin	Goose
Polychlorinated Biphenyls (µg/kg)											
Total PCBs	--	--	--	--	--	--	--	--	--	--	--
Dioxin & Furans (ng/kg)											
1,2,3,4,6,7,8-HpCDD	1,318	1,329	1318	24,262	61,976	2,231,925	3,760,408	5.E-02	2.E-02	6.E-04	4.E-04
1,2,3,4,6,7,8-HpCDF	187	126.4	126.4	17,064	49,476	172,786	342,633	7.E-03	3.E-03	7.E-04	4.E-04
1,2,3,4,7,8,9-HpCDF	9.991	12.92	9.991	3,681	2,201	45,866	32,752	3.E-03	5.E-03	2.E-04	3.E-04
1,2,3,4,7,8-HxCDD	34.24	23.54	23.54	3,075	2,519	52,262	48,122	8.E-03	9.E-03	5.E-04	5.E-04
1,2,3,4,7,8-HxCDF	31.49	21.54	21.54	2,731	2,980	24,187	26,545	8.E-03	7.E-03	9.E-04	8.E-04
1,2,3,6,7,8-HxCDD	132.2	133.4	132.2	3,337	4,993	275,126	344,023	4.E-02	3.E-02	5.E-04	4.E-04
1,2,3,6,7,8-HxCDF	15.85	5.106	5.106	1,689	1,600	17,142	17,839	3.E-03	3.E-03	3.E-04	3.E-04
1,2,3,7,8,9-HxCDD	83.94	57.81	57.81	7,464	5,184	41,856	34,969	8.E-03	1.E-02	1.E-03	2.E-03
1,2,3,7,8,9-HxCDF	1.953	1.7	1.7	170	190	2,192	2,849	1.E-02	9.E-03	8.E-04	6.E-04
1,2,3,7,8-PeCDD	41.08	21.27	21.27	244	308	2,243	2,705	9.E-02	7.E-02	9.E-03	8.E-03
1,2,3,7,8-PeCDF	28.15	8.972	8.972	8,087	8,604	22,319	24,407	1.E-03	1.E-03	4.E-04	4.E-04
2,3,4,6,7,8-HxCDF	17.46	5.428	5.428	1,888	1,478	18,641	16,847	3.E-03	4.E-03	3.E-04	3.E-04
2,3,4,7,8-PeCDF	30.12	9.833	9.833	997	972	2,567	2,622	1.E-02	1.E-02	4.E-03	4.E-03
2,3,7,8-TCDD	11.18	3.59	3.59	201	182	1,954	1,952	2.E-02	2.E-02	2.E-03	2.E-03
2,3,7,8-TCDF	76.37	52.01	52.01	1,304	3,669	1,399	2,971	4.E-02	1.E-02	4.E-02	2.E-02
OCDD	6,991	7,042	6,991	608,071	449,646	18,171,850	15,752,461	1.E-02	2.E-02	4.E-04	4.E-04
OCDF	514	346	346	708,535	676,092	20,330,634	20,969,071	5.E-04	5.E-04	2.E-05	2.E-05
2,3,7,8-TCDD TEQ (sum of congener HQs)	--	--	--	--	--	--	--	0.3	0.2	0.1	0.04
Total Petroleum Hydrocarbons (mg/kg)											
Gasoline Range	--	--	--	5000	5000	5,000	5000	--	--	--	--
Diesel Range	--	--	--	6000	6000	6,000	6000	--	--	--	--
Heavy Oil Range	--	--	--	6000	6000	6,000	6000	--	--	--	--
Fuel Oil Range	--	--	--	6000	6000	6,000	6000	--	--	--	--
Metals (mg/kg)											
Antimony	--	--	--	38	5	--	--	--	--	--	--
Chromium[1]	--	--	58	677	2405	113	171	0.1	0.02	0.5	0.3
Copper	--	--	--	589	467	1120	1020	--	--	--	--
Lead	--	--	122.3	323	1712	231	390	0.4	0.1	0.5	0.3
Manganese	--	--	--	13463	5114	--	--	--	--	--	--
Mercury (inorganic)	--	--	--	3.01	12.89	1.90	8.07	--	--	--	--
Nickel	--	--	--	4201	5845	5344	8883	--	--	--	--
Silver	--	--	--	21	54	2200	422	--	--	--	--
Zinc	--	--	--	812	4489	302	1531	--	--	--	--

Notes:

[1] Chromium EPC calculated after removing outlier result of 307 mg/kg (RS20 with a midpoint depth of 1.5-inches; see text for discussion). EPC with outlier result was 138.1 mg/kg.

EPC = exposure point concentration

ISC = indicator soil concentrations

mg/kg = micrograms per kilogram

ng/kg = nanograms per kilogram

µg/kg = microliters per kilogram

Table 21

Ennis Creek/Estuary (0-6 feet) - Wildlife Risk Evaluation

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	Maximum	95%UCL	EPC	Site-Specific Wildlife ISCs				Hazard Quotient			
				Shrew	Vole	Robin	Goose	Shrew	Vole	Robin	Goose
Polychlorinated Biphenyls (µg/kg)											
Total PCBs	--	--	--	--	--	--	--	--	--	--	--
Dioxin & Furans (ng/kg)											
1,2,3,4,6,7,8-HpCDD	1,318	1,452	1318	24,262	61,976	2,231,925	3,760,408	5.E-02	2.E-02	6.E-04	4.E-04
1,2,3,4,6,7,8-HpCDF	187	138	138	17,064	49,476	172,786	342,633	8.E-03	3.E-03	8.E-04	4.E-04
1,2,3,4,7,8,9-HpCDF	9.991	14.09	9.991	3,681	2,201	45,866	32,752	3.E-03	5.E-03	2.E-04	3.E-04
1,2,3,4,7,8-HxCDD	34.24	25.67	25.67	3,075	2,519	52,262	48,122	8.E-03	1.E-02	5.E-04	5.E-04
1,2,3,4,7,8-HxCDF	31.49	23.47	23.47	2,731	2,980	24,187	26,545	9.E-03	8.E-03	1.E-03	9.E-04
1,2,3,6,7,8-HxCDD	132.2	145.7	132.2	3,337	4,993	275,126	344,023	4.E-02	3.E-02	5.E-04	4.E-04
1,2,3,6,7,8-HxCDF	15.45	5.515	5.515	1,689	1,600	17,142	17,839	3.E-03	3.E-03	3.E-04	3.E-04
1,2,3,7,8,9-HxCDD	83.94	63.03	63.03	7,464	5,184	41,856	34,969	8.E-03	1.E-02	2.E-03	2.E-03
1,2,3,7,8,9-HxCDF	1.953	1.843	1.843	170	190	2,192	2,849	1.E-02	1.E-02	8.E-04	6.E-04
1,2,3,7,8-PeCDD	41.08	23.2	23.2	244	308	2,243	2,705	9.E-02	8.E-02	1.E-02	9.E-03
1,2,3,7,8-PeCDF	28.15	9.446	9.446	8,087	8,604	22,319	24,407	1.E-03	1.E-03	4.E-04	4.E-04
2,3,4,6,7,8-HxCDF	17.46	6.007	6.007	1,888	1,478	18,641	16,847	3.E-03	4.E-03	3.E-04	4.E-04
2,3,4,7,8-PeCDF	30.12	10.47	10.47	997	972	2,567	2,622	1.E-02	1.E-02	4.E-03	4.E-03
2,3,7,8-TCDD	11.18	3.873	3.873	201	182	1,954	1,952	2.E-02	2.E-02	2.E-03	2.E-03
2,3,7,8-TCDF	76.37	56.79	56.79	1,304	3,669	1,399	2,971	4.E-02	2.E-02	4.E-02	2.E-02
OCDD	6,991	7,696	6,991	608,071	449,646	18,171,850	15,752,461	1.E-02	2.E-02	4.E-04	4.E-04
OCDF	514	378	378.1	708,535	676,092	20,330,634	20,969,071	5.E-04	6.E-04	2.E-05	2.E-05
2,3,7,8-TCDD TEQ (sum of congener HQs)	--	--	--	--	--	--	--	0.3	0.2	0.1	0.04
Total Petroleum Hydrocarbons (mg/kg)											
Gasoline Range	--	--	--	5000	5000	5,000	5000	--	--	--	--
Diesel Range	--	--	--	6000	6000	6,000	6000	--	--	--	--
Heavy Oil Range	--	--	--	6000	6000	6,000	6000	--	--	--	--
Fuel Oil Range	--	--	--	6000	6000	6,000	6000	--	--	--	--
Metals (mg/kg)											
Antimony	--	--	--	38	5	--	--	--	--	--	--
Chromium[1]	--	--	59.24	677	2405	113	171	0.1	0.02	0.5	0.3
Copper	--	--	--	589	467	1120	1020	--	--	--	--
Lead	--	--	129.4	323	1712	231	390	0.4	0.1	0.6	0.3
Manganese	--	--	--	13463	5114	--	--	--	--	--	--
Mercury (inorganic)	--	--	--	3.01	12.89	1.90	8.07	--	--	--	--
Nickel	--	--	--	4201	5845	5344	8883	--	--	--	--
Silver	--	--	--	21	54	2200	422	--	--	--	--
Zinc	--	--	--	812	4489	302	1531	--	--	--	--

Notes:

[1] Chromium EPC calculated after removing outlier result of 307 mg/kg (RS20 with a midpoint depth of 1.5-inches; see text for discussion). EPC with outlier result was 144.3 mg/kg.

EPC = exposure point concentration

ISC = indicator soil concentrations

mg/kg = micrograms per kilogram

ng/kg = nanograms per kilogram

µg/kg = microliters per kilogram

Table 22

City Parcel (0-15 feet) - Wildlife Risk Evaluation

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	Maximum	95%UCL	EPC	Site-Specific Wildlife ISCs				Hazard Quotient			
				Shrew	Vole	Robin	Goose	Shrew	Vole	Robin	Goose
Polychlorinated Biphenyls (µg/kg)											
Total PCBs	--	--	--	--	--	--	--	--	--	--	--
Dioxin & Furans (ng/kg)											
1,2,3,4,6,7,8-HpCDD	211	211	211	24,262	61,976	2,231,925	3,760,408	9.E-03	3.E-03	9.E-05	6.E-05
1,2,3,4,6,7,8-HpCDF	35.7	35.7	35.7	17,064	49,476	172,786	342,633	2.E-03	7.E-04	2.E-04	1.E-04
1,2,3,4,7,8,9-HpCDF	2.7	2.7	2.7	3,681	2,201	45,866	32,752	7.E-04	1.E-03	6.E-05	8.E-05
1,2,3,4,7,8-HxCDD	2.7	2.7	2.7	3,075	2,519	52,262	48,122	9.E-04	1.E-03	5.E-05	6.E-05
1,2,3,4,7,8-HxCDF	7.04	7.04	7.04	2,731	2,980	24,187	26,545	3.E-03	2.E-03	3.E-04	3.E-04
1,2,3,6,7,8-HxCDD	26.5	26.5	26.5	3,337	4,993	275,126	344,023	8.E-03	5.E-03	1.E-04	8.E-05
1,2,3,6,7,8-HxCDF	7.17	7.17	7.17	1,689	1,600	17,142	17,839	4.E-03	4.E-03	4.E-04	4.E-04
1,2,3,7,8,9-HxCDD	9.64	9.64	9.64	7,464	5,184	41,856	34,969	1.E-03	2.E-03	2.E-04	3.E-04
1,2,3,7,8,9-HxCDF	1.53	1.53	1.53	170	190	2,192	2,849	9.E-03	8.E-03	7.E-04	5.E-04
1,2,3,7,8-PeCDD	4.9	4.9	4.9	244	308	2,243	2,705	2.E-02	2.E-02	2.E-03	2.E-03
1,2,3,7,8-PeCDF	6.04	6.04	6.04	8,087	8,604	22,319	24,407	7.E-04	7.E-04	3.E-04	2.E-04
2,3,4,6,7,8-HxCDF	7.54	7.54	7.54	1,888	1,478	18,641	16,847	4.E-03	5.E-03	4.E-04	4.E-04
2,3,4,7,8-PeCDF	8.22	8.22	8.22	997	972	2,567	2,622	8.E-03	8.E-03	3.E-03	3.E-03
2,3,7,8-TCDD	1.68	1.68	1.68	201	182	1,954	1,952	8.E-03	9.E-03	9.E-04	9.E-04
2,3,7,8-TCDF	6.65	6.65	6.65	1,304	3,669	1,399	2,971	5.E-03	2.E-03	5.E-03	2.E-03
OCDD	2,060	2,060	2060	608,071	449,646	18,171,850	15,752,461	3.E-03	5.E-03	1.E-04	1.E-04
OCDF	54.6	54.6	54.6	708,535	676,092	20,330,634	20,969,071	8.E-05	8.E-05	3.E-06	3.E-06
2,3,7,8-TCDD TEQ (sum of congener HQs)	--	--	--	--	--	--	--	0.1	0.1	0.01	0.01
Total Petroleum Hydrocarbons (mg/kg)											
Gasoline Range	--	--	--	5,000	5,000	5,000	5,000	--	--	--	--
Diesel Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Heavy Oil Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Fuel Oil Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Metals (mg/kg)											
Antimony	--	--	--	38	5	--	--	--	--	--	--
Chromium	--	--	--	677	2,405	113	171	--	--	--	--
Copper	--	--	--	589	467	1,120	1,020	--	--	--	--
Lead	--	--	--	323	1,712	231	390	--	--	--	--
Manganese	--	--	2,900	13,463	5,114	--	--	0.2	0.6	--	--
Mercury (inorganic)	--	--	--	3.01	12.89	1.90	8.07	--	--	--	--
Nickel	--	--	--	4,201	5,845	5,344	8,883	--	--	--	--
Silver	--	--	5.67	21	54	2,200	422	0.3	0.1	0.003	0.01
Zinc	--	--	--	812	4,489	302	1,531	--	--	--	--

Notes:

EPC = exposure point concentration

ISC = indicator soil concentrations

mg/kg = micrograms per kilogram

ng/kg = nanograms per kilogram

µg/kg = microliters per kilogram

Table 23

City Parcel (0-6 feet) - Wildlife Risk Evaluation

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	Maximum	95%UCL	EPC	Site-Specific Wildlife ISCs				Hazard Quotient			
				Shrew	Vole	Robin	Goose	Shrew	Vole	Robin	Goose
Polychlorinated Biphenyls (µg/kg)											
Total PCBs	--	--	--	--	--	--	--	--	--	--	--
Dioxin & Furans (ng/kg)											
1,2,3,4,6,7,8-HpCDD	211	211	211	24,262	61,976	2,231,925	3,760,408	9.E-03	3.E-03	9.E-05	6.E-05
1,2,3,4,6,7,8-HpCDF	35.7	35.7	35.7	17,064	49,476	172,786	342,633	2.E-03	7.E-04	2.E-04	1.E-04
1,2,3,4,7,8,9-HpCDF	2.7	2.7	2.7	3,681	2,201	45,866	32,752	7.E-04	1.E-03	6.E-05	8.E-05
1,2,3,4,7,8-HxCDD	2.7	2.7	2.7	3,075	2,519	52,262	48,122	9.E-04	1.E-03	5.E-05	6.E-05
1,2,3,4,7,8-HxCDF	7.04	7.04	7.04	2,731	2,980	24,187	26,545	3.E-03	2.E-03	3.E-04	3.E-04
1,2,3,6,7,8-HxCDD	26.5	26.5	26.5	3,337	4,993	275,126	344,023	8.E-03	5.E-03	1.E-04	8.E-05
1,2,3,6,7,8-HxCDF	7.17	7.17	7.17	1,689	1,600	17,142	17,839	4.E-03	4.E-03	4.E-04	4.E-04
1,2,3,7,8,9-HxCDD	9.64	9.64	9.64	7,464	5,184	41,856	34,969	1.E-03	2.E-03	2.E-04	3.E-04
1,2,3,7,8,9-HxCDF	1.53	1.53	1.53	170	190	2,192	2,849	9.E-03	8.E-03	7.E-04	5.E-04
1,2,3,7,8-PeCDD	4.9	4.9	4.9	244	308	2,243	2,705	2.E-02	2.E-02	2.E-03	2.E-03
1,2,3,7,8-PeCDF	6.04	6.04	6.04	8,087	8,604	22,319	24,407	7.E-04	7.E-04	3.E-04	2.E-04
2,3,4,6,7,8-HxCDF	7.54	7.54	7.54	1,888	1,478	18,641	16,847	4.E-03	5.E-03	4.E-04	4.E-04
2,3,4,7,8-PeCDF	8.22	8.22	8.22	997	972	2,567	2,622	8.E-03	8.E-03	3.E-03	3.E-03
2,3,7,8-TCDD	1.68	1.68	1.68	201	182	1,954	1,952	8.E-03	9.E-03	9.E-04	9.E-04
2,3,7,8-TCDF	6.65	6.65	6.65	1,304	3,669	1,399	2,971	5.E-03	2.E-03	5.E-03	2.E-03
OCDD	2,060	2,060	2060	608,071	449,646	18,171,850	15,752,461	3.E-03	5.E-03	1.E-04	1.E-04
OCDF	54.6	54.6	54.6	708,535	676,092	20,330,634	20,969,071	8.E-05	8.E-05	3.E-06	3.E-06
2,3,7,8-TCDD TEQ (sum of congener HQs)	--	--	--	--	--	--	--	0.1	0.1	0.01	0.01
Total Petroleum Hydrocarbons (mg/kg)											
Gasoline Range	--	--	--	5,000	5,000	5,000	5,000	--	--	--	--
Diesel Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Heavy Oil Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Fuel Oil Range	--	--	--	6,000	6,000	6,000	6,000	--	--	--	--
Metals (mg/kg)											
Antimony	--	--	--	38	5	--	--	--	--	--	--
Chromium	--	--	--	677	2,405	113	171	--	--	--	--
Copper	--	--	--	589	467	1,120	1,020	--	--	--	--
Lead	--	--	--	323	1,712	231	390	--	--	--	--
Manganese	--	--	3,050	13,463	5,114	--	--	0.2	0.6	--	--
Mercury (inorganic)	--	--	--	3.01	12.89	1.90	8.07	--	--	--	--
Nickel	--	--	--	4,201	5,845	5,344	8,883	--	--	--	--
Silver	--	--	7.01	21	54	2,200	422	0.3	0.1	0.003	0.02
Zinc	--	--	--	812	4,489	302	1,531	--	--	--	--

Notes:

EPC = exposure point concentration

ISC = indicator soil concentrations

mg/kg = micrograms per kilogram

ng/kg = nanograms per kilogram

µg/kg = microliters per kilogram

Table 24

Site-Specific Plant Evaluation

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	Soil EPC (mg/kg)				Site-Specific K_{plant}	Predicted Plant Tissue Concentration (mg/kg)				Plant Tissue Thresholds (mg/kg)		
	East Mill (0-15 feet)	East Mill (0-6 feet)	Ennis Creek (0-15 feet)	Ennis Creek (0-6 feet)		East Mill (0-15 feet)	East Mill (0-6 feet)	Ennis Creek (0-15 feet)	Ennis Creek (0-6 feet)	Deficient	Sufficient or Normal	Excessive or Toxic
Chromium	n/a	n/a	138	144	0.014	n/a	n/a	1.9	2.0	--	0.1 - 0.5	5 - 30
Copper	n/a	n/a	102	105	0.203	n/a	n/a	21	21	2 - 5	5 - 30	20 - 100
Lead	n/a	53.2	122	129	0.012	n/a	0.64	1.5	1.5	--	5 - 10	30 - 300
Mercury	n/a	n/a	n/a	0.31	0.512	n/a	n/a	n/a	0.16	--	--	1 - 3
Nickel	n/a	n/a	51.7	50.9	0.073	n/a	n/a	3.8	3.7	--	0.1 - 5	10 - 100
Silver	18.3	23.6	n/a	n/a	0.175	3.20	4.13	n/a	n/a	--	0.5	5 - 10
Zinc	n/a	92.6	112	116	0.355	n/a	32.87	40	41	10 - 20	27 - 150	100 - 400

Notes:

EPC = Exposure point concentration

mg/kg = milligram per kilogram

n/a = not applicable; analyte is not a plant COPEC for this exposure area

-- = not available; value was not provided in the reference source (Kabata-Pendias 2011)

Table 25

Site-Specific Earthworm Evaluation

Port Angeles Mill Study Area

Port Angeles, Washington

Analyte	Soil EPC (mg/kg)				Site-Specific Earthworm BAF	Predicted Earthworm Tissue Concentration (mg/kg)				Earthworm Tissue No Effects Level
	East Mill (0-15 feet)	East Mill (0-6 feet)	Ennis Creek (0-15 feet)	Ennis Creek (0-6 feet)		East Mill (0-15 feet)	East Mill (0-6 feet)	Ennis Creek (0-15 feet)	Ennis Creek (0-6 feet)	
Chromium[1]	n/a	n/a	138.1	144.3	0.211	n/a	n/a	29.1	30.4	16
Copper[2]	68.7	73.6	102	105	0.413	28.4	30.4	42.1	43.4	70
Mercury	n/a	n/a	0.291	0.31	4.196	n/a	n/a	1.2	1.3	7
Silver	18.3	23.6	0.333	0.364	0.936	17.1	22.1	0.3	0.3	--

Notes:

[1] Chromium EPCs for the Ennis Creek area were calculated after removing outlier result of 307 mg/kg (RS20 with a midpoint depth of 1.5-inches; see text for discussion). EPCs with outlier result included were 138.1 mg/kg (0-15') and 144.3 mg/kg (0-6').

[2] The earthworm tissue no effects level for copper in the 2007 TEE was 130 mg/kg. However, based on a review of the source paper (Ma 1982) it appears that the value of 130 mg/kg is a soil concentration, not a earthworm tissue concentration. Following the same approach used in the 2007 TEE for chromium, the copper earthworm tissue no effects level for copper should be 70 mg/kg.

EPC = Exposure point concentration

mg/kg = milligram per kilogram

n/a = not applicable; analyte is not a plant COPEC for this exposure area

-- = not available; tissue-based data were not found (Malcolm Pirnie 2007)

Table 26

Red-Tailed Hawk Risk Calculations

Port Angeles Mill Study Area

Port Angeles, Washington

COPEC[a]	Site Use Factor[k]	Small Mammal Tissue BAF[b]	On-Site: 0 to 15 feet: Soils[c]	0 to 15 feet: Rabbit Tissue[d]	0 to 15 feet: Intake (mg/kg/day)	0 to 6 feet: Soils[c]	0 to 6 feet: Rabbit Tissue[d]	0 to 6 feet: Intake (mg/kg/day)	0 to 6 inches: Soils[c]	0 to 6 inches: Rabbit Tissue[d]	0 to 6 inches: Intake (mg/kg/day)	TRV[e,f] (mg/kg/day)	Hazard Quotient: Soils (0 to 15 feet)	Hazard Quotient: Soils (0 to 6 feet)	Hazard Quotient: Soils (0 to 6 inches)
West Mill Area															
2,3,7,8-TCDD (µg/kg)	1.9%	1.29E+00	2.7E-01	3.4E-01	2.0E-07	3.0E-01	3.8E-01	2.2E-07	3.4E-01	4.4E-01	2.6E-07	1.0E-05	1.9E-02	2.1E-02	2.5E-02
East Mill Area															
2,3,7,8-TCDD (µg/kg)	1.2%	1.29E+00	4.4E-02	5.7E-02	2.1E-08	4.4E-02	5.7E-02	2.1E-08	n/a	--	--	1.0E-05	2.0E-03	2.0E-03	--
City Purchase Area															
2,3,7,8-TCDD (µg/kg)	0.7%	1.29E+00	2.8E-02	3.6E-02	7.9E-09	2.8E-02	3.6E-02	7.9E-09	n/a	--	--	1.0E-05	7.5E-04	7.5E-04	--
Marine Bluffs Area															
2,3,7,8-TCDD (µg/kg)	0.8%	1.29E+00	n/a	--	--	3.2E-02	4.1E-02	1.0E-08	n/a	--	--	1.0E-05	--	9.6E-04	--
Ennis Creek/Estuary Area															
2,3,7,8-TCDD (µg/kg)	1.8%	1.29E+00	9.7E-02	1.3E-01	7.0E-08	1.1E-01	1.4E-01	7.6E-08	n/a	--	--	1.0E-05	6.7E-03	7.3E-03	--

Exposure Assumptions and Equation:

		Value	Units
NIRprey(wet wt.)[g]	=	0.097	g/g-bw-day (wet weight)
IRsoil (dry wt.)[h]	=	0.00	g/g-bw-day (dry weight)
Cprey	=	chem-specific	mg/kg or µg/kg
Csoil	=	chem-specific	mg/kg or µg/kg
Tissue Moisture	=	68%	percent
Dietary Composition Factor[i]	=	100%	percent
Site Use Factor[j]	=	see above	percent
Organics Conversion Factor (CF)	=	0.001	mg/µg
Body Weight	=	1,126.0	g

conversion to dry weight → **NIRprey (dry wt.)** = NIRprey (wet wt.)*(1-TM)

→ **IRsoil (dry wt.)** = Ingestion of soil is not expected to be a significant source of exposure to the Red-tailed hawk.

Intake Equation = [NIRprey(wet) x (1-TM) x Cprey x CF x DCF x SUF] + (IRsoil x Csoil x DCF x SUF)

Risk (hazard quotient) = Intake / TRV

→ (note, a conversion factor (CF) was not necessary for metals since they are reported in mg/kg)

Notes:

a 2,3,7,8-TCDD is the only significant bioaccumulative COPEC at the PA Mill site.

b Small mammal BAFs are in dry weight as derived by Sample et al., 1998.

c Soil EPCs are based on the 95% UCL or the maximum detected concentration expressed in dry weight.

d Tissue concentrations are expressed in dry weight.

e TRV for the red-tailed hawk was developed using body weight normalization adjustment factors for\ birds from Sample and Arenal (1999).

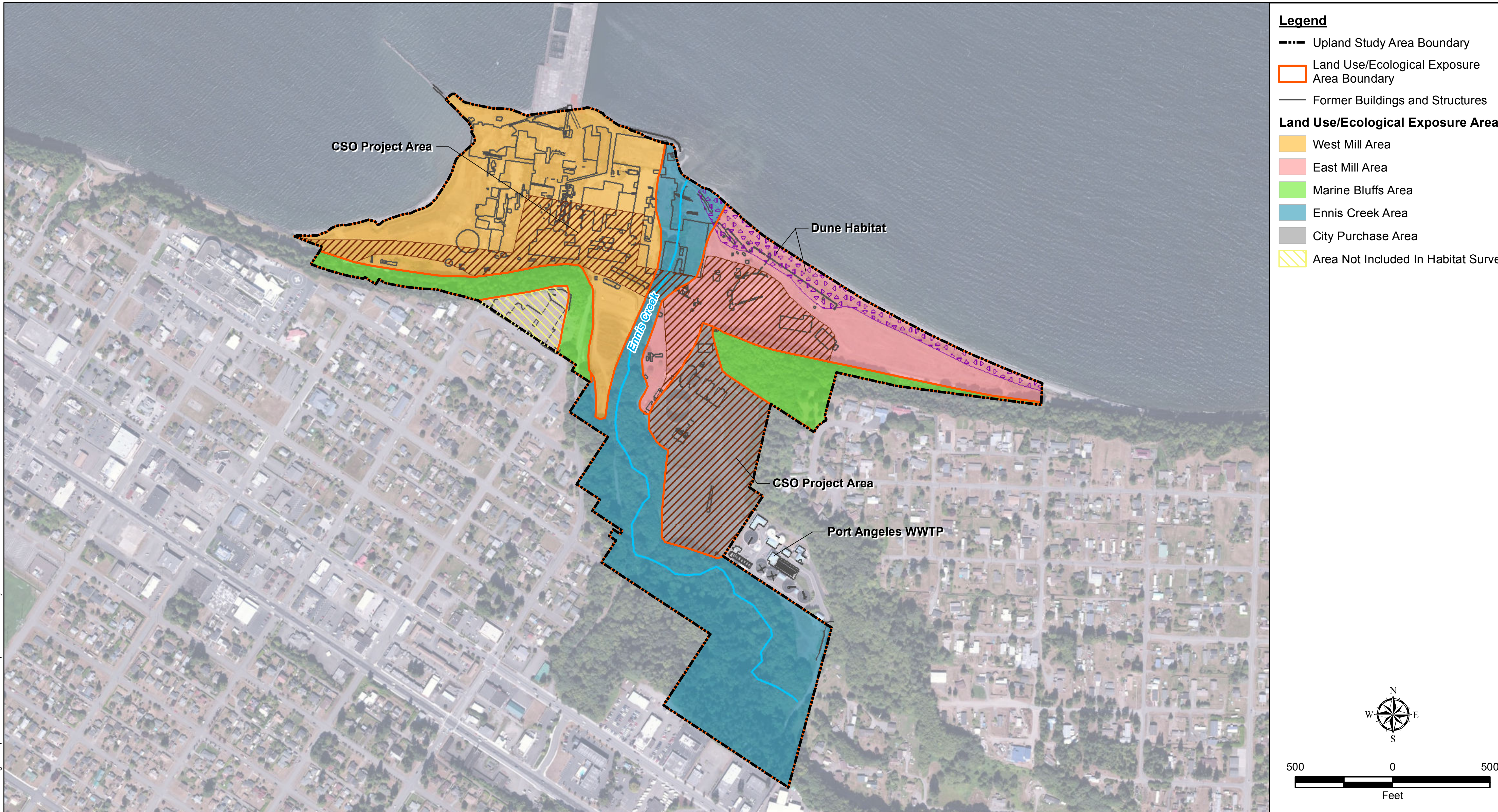
f TRV for the red-tailed hawk came from Cornell Lab of Ornithology, 2011.

g Based on the allometric equation for birds—IR (kg/day) = 0.0582 x Wt $^{0.651}$ (kg). See Eq. 3-3 in EPA, 1993. Ingestion rates are based on wet weight; conversion to dry weight based on percent moisture for small mammal tissues from EPA (1993).

h Ingestion rates are based on wet weight; conversion to dry weight based on percent moisture for small mammal tissues from EPA (1993).

i Red-tailed hawk was not expected to have significant ingestion of incidental soil. Therefore, dietary composition factor was based on a conservative assumption of 100% rabbit or small mammals.

j Site use factor was based on the seasonal foraging behavior of the red-tailed hawk relative to the size of individual ecological exposure areas as follows: spring/summer (400 acres), fall (4,400 acres), and winter (1,700 acres).



Path: P:\0\0137015\GIS\013701504_T200_HabitatEcologicalExposureAreas.mxd Map Revised: 09 July 2013 ccabrera

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. Based on site habitat survey conducted by GeoEngineers, Inc. on February 22, 2013.
4. Aerial image from Microsoft, 2010.

Land Use/Ecological Exposure Areas

Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

GEOENGINEERS

Figure 1

APPENDIX C

HYDRODYNAMICS AND SEDIMENT TRANSPORT INVESTIGATION

Hydrodynamics and Sediment Transport Investigation

Port Angeles Rayonier Mill Study Area
Port Angeles, Washington

Prepared for

Prepared by

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March 1, 2019
Revision 3

REVISION RECORD

Revision	Date	Submittal To	Portions Affected	Reason
0	February 20, 2015	Washington State Department of Ecology	All	Original submittal
1	March 30, 2018	Washington State Department of Ecology	All	Original submittal incorporated into Public Review Document Volume III as Appendix A
2	January 25, 2019	Washington State Department of Ecology	Sections 4, 5, 6	Additional modeling completed
3	March 1, 2019	Washington State Department of Ecology	Section 4	Additional figures and description of model scenarios added to address comments on Rev 2

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ACRONYMS AND ABBREVIATIONS

ADCP	acoustic Doppler current profiler
ASCII	American Standard Code for Information Interchange
BASE	Trimble R8 Base Station
CSM	conceptual site model
DEM	digital elevation model
Ecology	Washington State Department of Ecology
ENR	enhanced natural recovery
GPS	global positioning system
IMU	inertial motion unit
MBES	multi-beam echo-sounder
MWD	mean wave direction
NAVD88	North American Vertical Datum of 1988
NDBC	National Data Buoy Center
NGDC	National Geophysical Data Center
NGS	National Geodetic Survey
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NTU	nephelometric turbidity unit
OPUS	Online Positioning User Service
Rayonier AM	Rayonier Advanced Materials
ROVER	Trimble R8 GPS receiver
RTK	real-time kinematic
SEI	Sea Engineering Inc.
SWAN	Simulating WAves Nearshore
TIFF	tagged image file format
USACE	U.S. Army Corps of Engineers
WSDOT	Washington State Department of Transportation
YSI	Yellow Springs Inc.

1.0 INTRODUCTION

This document outlines surveying activities, hydrodynamics field studies, and modeling efforts completed to support remedial activities near the former Rayonier Mill in Port Angeles, Washington. This study was done to support the in-water remedial alternatives evaluation for the former Rayonier mill, which is presented in the Draft Interim Action Report, Volume III (Windward and GeoEngineers 2015) and in Public Review Draft Interim Action Report, Volume III (Tetra Tech and Windward 2019). In the Volume III report, combinations of removal, filling and capping, and enhanced natural recovery (ENR) are being considered. Sediment stability and hydrodynamic analyses are valuable in assessing the site-specific viability of capping and ENR under a number of environmental conditions, including a 100-year wind and wave event. As such, this analysis considered the extent of the remedial area for which ENR was considered in the alternatives. It is recognized that additional design analyses will be conducted to confirm the application of these technologies at proposed locations during remedial design.

The main objective of this study was to develop hydrodynamic conditions and ascertain sediment stability information to support the evaluation of in-water remedial alternatives and future design. The design of the studies was based on the near-field conceptual site models (CSMs) presented in Volume II of the Draft Interim Action Report (Windward 2014), herein referred to as Volume II, which presented the Integral Consulting Inc. (staff previously with Sea Engineering Inc.) and the Washington State Department of Ecology (Ecology) CSMs for sediment transport and stability, including specific questions from Ecology regarding grain size distribution near the former Rayonier mill, wave properties, nearshore transport, offshore transport, and log pond morphology.

The tasks undertaken to meet the study objective were:

1. Develop an accurate bathymetric data set offshore of the former Rayonier mill
2. Collect hydrodynamic data during typical and storm conditions offshore of the mill
3. Develop a coupled wave and hydrodynamic model to investigate the effects of typical and storm wave conditions on sediment stability at the site with and without the jetty and mill dock

The evaluation and presentation of the in-water remedial alternatives are presented in Volume III report (Tetra Tech and Windward 2019). This document presents the methods and results from the tasks outlined above.

2.0 HYDROGRAPHIC SURVEY

The primary goal of the hydrographic surveying task was to develop an accurate bathymetric data set in the vicinity of the former Rayonier mill for remedial analysis and design purposes. The resulting bathymetric data also provided important quantitative information for the hydrodynamic field data collection and modeling activities performed in this study.

In January 2014, Sea Engineering Inc. (SEI) completed a high-resolution multi-beam hydrographic survey in proximity to the former Rayonier mill in Port Angeles, Washington. A full seafloor coverage survey was completed around and offshore of the former Rayonier mill. Multi-beam sonar technology was paired with high accuracy real-time kinematic (RTK) global positioning system (GPS) to measure the surface elevations of the nearshore region to assist with identification of bottom types and debris.

The survey was completed between January 14 and 19, 2014. The survey team comprised three personnel holding the following comprehensive qualifications: a U.S. Coast Guard certified vessel captain license, two American Congress of Surveying and Mapping certified hydrographer certifications, and a Registered Professional Engineer license (Oregon and California).

2.1 METHODS

An R2 Sonic 2024 multi-beam echo-sounder (MBES) was utilized for the swath bathymetric survey (http://www.r2sonic.com). The R2 Sonic is a 200–400 kHz (user-selectable in real-time) system with up to a 160° swath width (also user-selectable in real-time). The wide swath and high frequency capabilities of the system make it ideal for extremely shallow water surveys (e.g., shallower than 3 to 4.5 m) but also efficient in deeper water. A frequency of 400 kHz on the MBES was used during this project, yielding a high-resolution beam angle of 0.5° x 1.0°.

The R2 Sonic was paired with an Applanix POS MV Wavemaster Inertial Motion Unit (IMU) capable of high-precision vessel motion measurements (pitch, roll, yaw, and heave) and inertial position tracking if GPS position signal is temporarily lost. The POS MV is capable of measuring vessel roll and pitch to an accuracy of 0.020° when using RTK GPS technology (http://www.applanix.com). Heave accuracies are measured to 5 cm (or 5 percent) and position accuracies are 0.02 to 0.10 m when using RTK GPS. Heading accuracies are 0.030°.

A vessel-mounted Trimble R8 GPS Receiver (ROVER) was used for high accuracy and precision vessel positioning (horizontal and vertical) (http://www.trimble.com). A land-side Trimble R8 Base Station (BASE) GPS receiver and repeater radio were setup to transmit RTK GPS corrections from the BASE to the ROVER such that vessel positioning was accurate to within several centimeters (horizontally and vertically).

An Odom Digibar Pro sound speed profiler provided the speed of sound in water for proper calibration of the MBES soundings. A standard bar-check plate was used for quality control verification of the sonar draft below water level and sound speed corrections.

2.2 CONTROL VERIFICATION

Project control was established using local Washington Department of Transportation (WSDOT) published benchmarks. The hydrographic survey team initially setup the base station GPS on WSDOT benchmark GP05101-23 (Monument ID 2023), located in Port Angeles, Washington. The benchmark has a published accuracy of 2 cm in the horizontal and 1 cm in the vertical. Subsequently, the SEI team checked-in on a nearby WSDOT point, GP05101-22 (Monument ID 2022), to verify survey control accuracy. This benchmark also had published accuracies of 2 cm in the horizontal and 1 cm in the vertical.

Once it was established that the base station GPS was setup and broadcasting in the proper coordinate system, the team traveled to the former Rayonier mill and established two local survey control points using the RTK GPS signal. One of the points would remain the control point for the remainder of the survey; the second would be a daily check-in point (Table 1). Each survey day, project personnel set up the base station GPS on the control point "Pier Base" and verified control on the point "Pier Check."

As additional verification of proper survey control, the raw GPS data (e.g., RINEX) from the "Pier Base" location were submitted to the National Oceanic and Atmospheric Administration (NOAA) National Geodetic Survey (NGS) Online Positioning User Service (OPUS) (http://www.ngs.noaa.gov/OPUS/). The results indicated that the coordinates used for "Pier Base" in Table 1 were accurate to less than 0.05 cm horizontally; and vertically by approximately 0.15 cm.

Table 1. Reported or Measured Coordinates of Survey Benchmarks during January 2014 Survey

Point ID	Owner	Easting (m)[a]	Northing (m)	Elevation (m)[b]
GP05101-23	WSDOT	306141.251	126325.262	69.09
GP05101-22	WSDOT	305411.329	126541.306	72.18
Pier Base	SEI	308467.034	127641.325	4.58
Pier Check	SEI	308458.952	127657.208	4.63

Notes:
[a] Horizontal coordinate system was Washington State Plane North NAD-83
[b] Vertical datum was NAVD88

2.3 MULTI-BEAM SURVEYING

The multi-beam survey commenced offshore of the former Rayonier dock and proceeded shoreward on shore-parallel transects to maximize coverage and to ensure coverage of the priority area first. When the nearshore region was complete, the survey then proceeded offshore to obtain full coverage in the survey area.

In general, the survey-able seafloor surface elevations within the defined project boundaries varied between –32.93 and 0.0 m, NAVD88 (North American Vertical Datum of 1988) datum, approximately. The high resolution multi-beam system was capable of sensing rocks, logs, and other debris on the seafloor, as well as the individual dock pilings, providing a detailed perspective of the condition of the seafloor. Shallow water prevented safe navigation in certain locations of the project site.

The MBES was side-mounted on a rigid aluminum pole on the starboard side of the vessel (Figure 1). The IMU was mounted immediately above the MBES transducer to capture the actual measurements of the MBES. The location of the IMU was used as the reference center of the vessel and all lever arm measurements were collected to the center of mass of the vessel to compensate for any induced motion measurements (i.e., heave).

The MBES was calibrated (i.e., "Patch Test") immediately offshore of the former Rayonier dock. Patch test procedures followed those described in the U.S. Army Corps of Engineers (USACE) Hydrographic Surveying Manual (EM 1110-2-1003). Raw POS MV (POSPac) data were also collected during surveying which allows for post-processing of the position data.

The HYPACK HYSWEEP (http://www.hypack.com) data acquisition and processing software was used for the data collection operations. HYPACK allows simultaneous data collection of GPS positioning, IMU positioning, MBES soundings, and proper time-synchronizing of each. Post-processing of the MBES data was later completed using CARIS HIPS Professional (http://www.caris.com) processing and visualization software.

The sound speed in the water column was profiled several times during the course of the survey to account for sound speed variations in the water column at different times of day due to variable seawater density. The sound speed varied very little throughout any of the survey days and with depth in the water column. Sound velocities fluctuated between 1478 m/s and 1479 m/s during all profile casts completed during the week.

Figure 1. Multi-beam Transducer Pole Mount and Sonar Installed

To account for variations in the water surface elevation, the elevation was measured with the RTK GPS at different times of the day to verify that the elevation agreed with the tidal states. These values compared very well (within ± 0.1 m) to the NAVD88 elevations measured at the NOAA Station 9444090 in Port Angeles (Table 2). To convert elevations from NAVD88 datum to the MLLW datum, an amount of 0.14 m was added to the NAVD88 elevations (e.g., NAVD88 = MLLW + 0.14 m). This offset value of 0.14 m was determined using the station datum information from NOAA Tides and Currents Station 9444090, Port Angeles, Washington (http://tidesandcurrents.noaa.gov/datums.html?id=9444090).

Table 2. Water Surface Elevation Spot Checks During Survey (NAVD88)

Date	Time (PDT)	RTK GPS-Measured Water Surface Elevation (m, NAVD88)	NOAA-Measured Water Surface Elevation (m, NAVD88)
1/15/2014	1210	1.84	1.83
1/16/2014	0830	1.31	1.40
1/16/2014	1645	1.02	1.04
1/17/2014	0850	1.31	1.40
1/18/2014	0850	1.43	1.46

2.4 SURVEY RESULTS

The surveyed project area and location of the GPS BASE control point used during the survey are shown in Figure 2.

The multi-beam survey was successful at ensonifying the seabed from an elevation of approximately –32.93 m NAVD88, up to an elevation of approximately 0.0 m NAVD88, in the nearshore survey areas. The multi-beam survey coverage map with 1.52-m and 0.3-m contour lines is presented in Figures 3 and 4. Figure 4 illustrates small elevation changes more prominently (e.g., outfall locations). An expanded view of the western nearshore region is shown in Figure 5, where submerged rocks, logs, and other debris are visible in the high-resolution data.

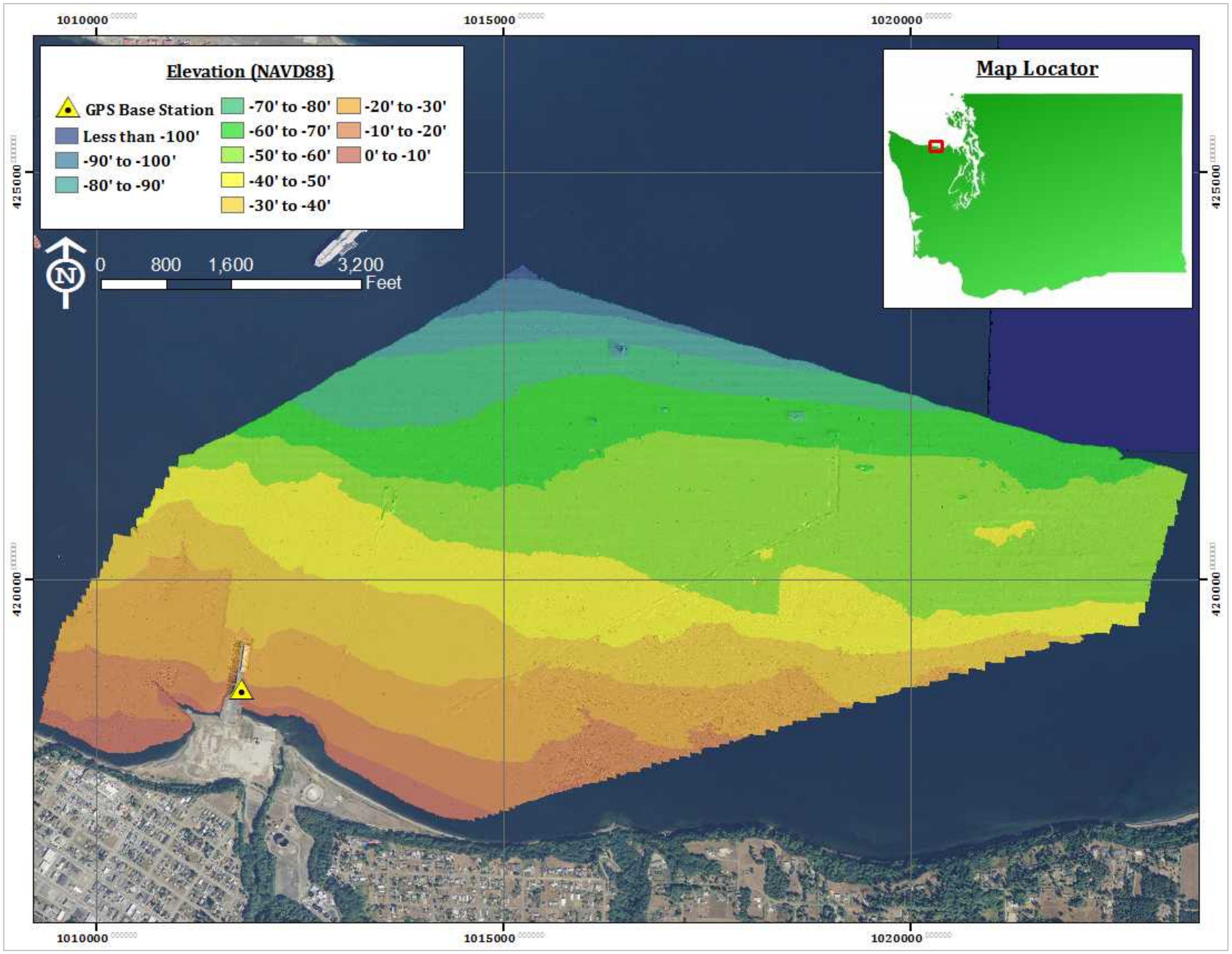

Figure 2. Surveyed Area and Location of RTK GPS Base Station

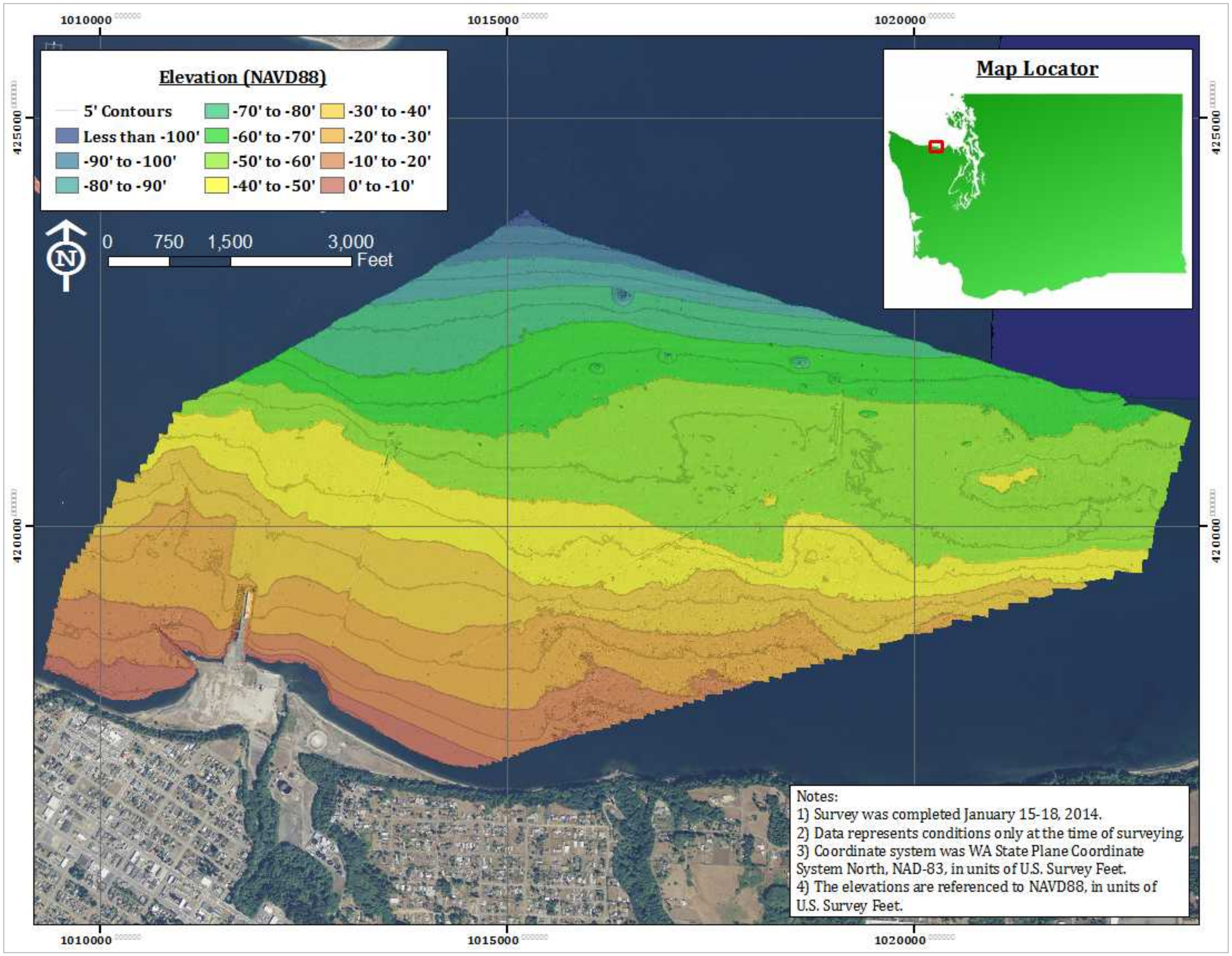

Figure 3. Hill-shaded Survey Results with 1.52 m Contour Lines

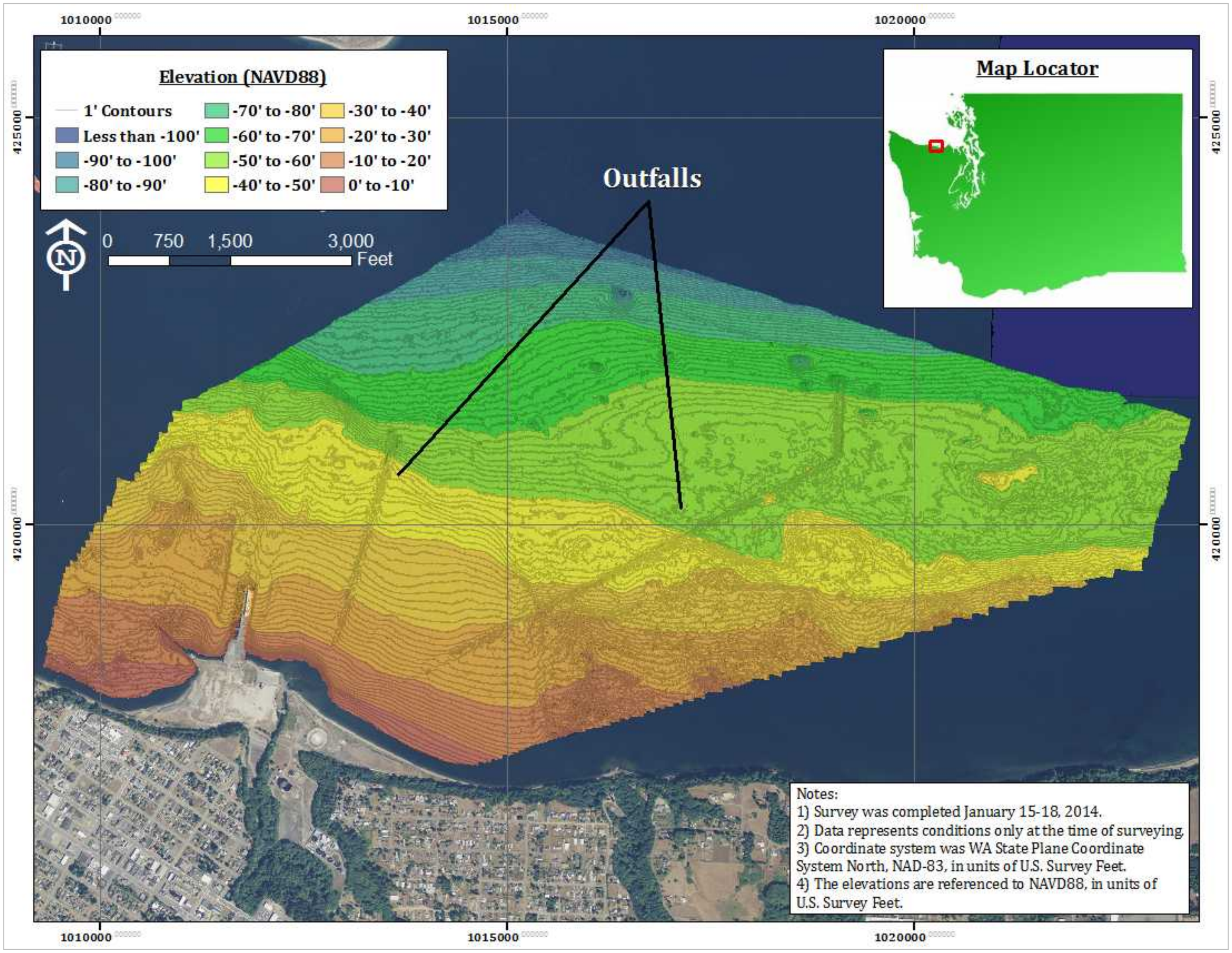

Figure 4. Hill-shaded Survey Results with 30 cm Contour Lines Indicating Features Such as Outfalls

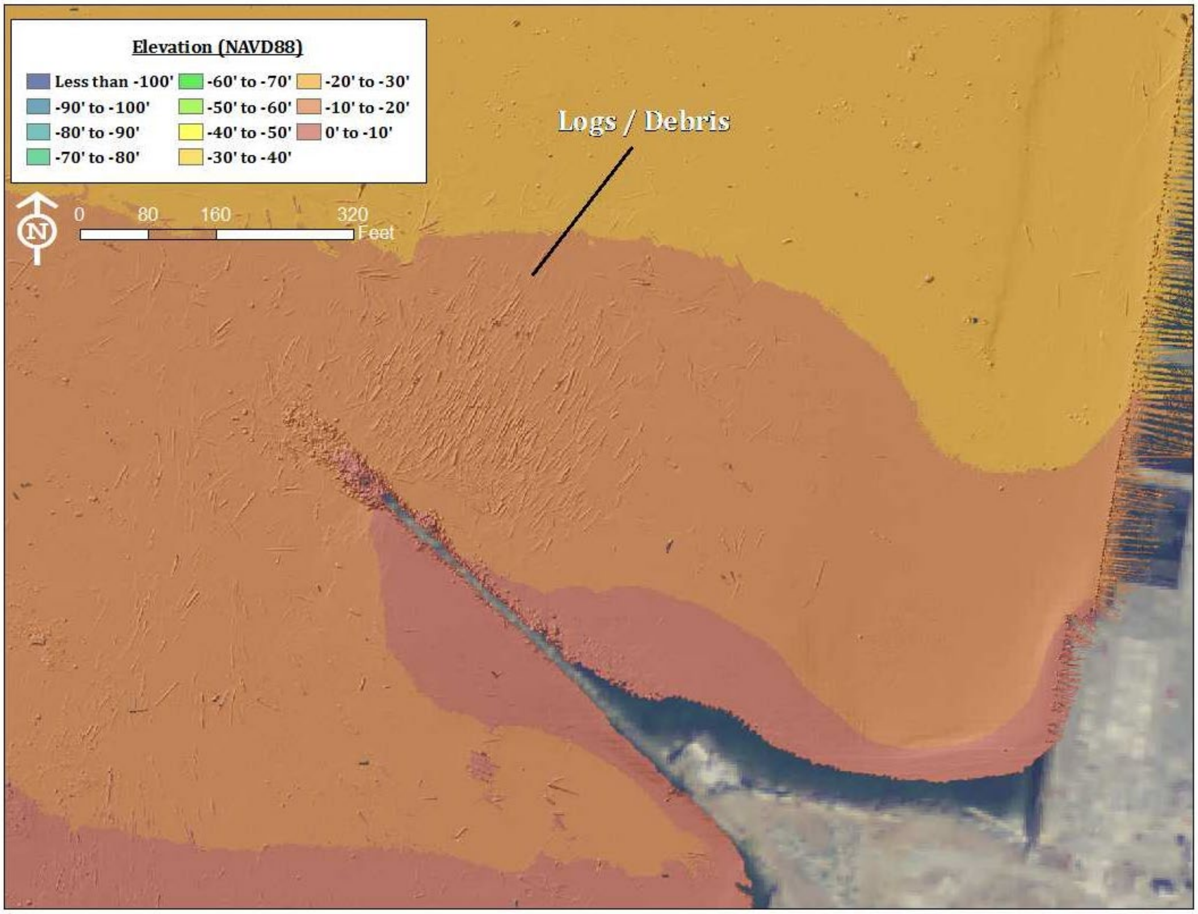

Figure 5. Enlarged Image Showing High-resolution Survey Data with Rocks, Logs, and Other Debris Visible

2.5 DATA PRODUCTS

The following multi-beam survey data products were generated from hydrographic survey activities.

- Google Earth image file containing multi-beam surface data at 1 m x 1 m resolution.
- Google Earth image file containing multi-beam surface data at 0.25 m x 0.25 m resolution.
- Georeferenced image in tagged image file format (TIFF) of the processed 1 m x 1 m multi-beam gridded elevation surface raster.
- World file associated with the geo-referenced 1 m x 1 m multi-beam elevation surface TIFF image.

- Georeferenced TIFF image of the processed 1 m x 1 m multi-beam gridded elevation surface raster.
- World file associated with the georeferenced 1 m x 1 m multi-beam elevation surface TIFF image.
- Processed 1 m x 1 m gridded XYZ American Standard Code for Information Interchange (ASCII) data file. The coordinates are Washington State Plane CS North, NAD-83, U.S. Survey Feet. The vertical datum is NAVD88 meters. These data encompass depths from 14 m to 50 m.
- Processed 0.5 m x 0.5 m gridded XYZ ASCII data file. The coordinates are Washington State Plane CS North, NAD-83 meters. The vertical datum is NAVD88, meters. These data encompass depths from 9 m to 15 m.
- Processed 0.25 m x 0.25 m gridded XYZ ASCII data file. The coordinates are Washington State Plane CS North, NAD-83, meters. The vertical datum is NAVD88, meters. These data encompass depths from 0 m to 10 m.
- One file containing the three processed gridded XYZ files described above. The coordinates are Washington State Plane CS North, NAD-83, meters. The vertical datum is NAVD88, meters.

3.0 HYDRODYNAMIC FIELD WORK

SEI performed a field study near the former Rayonier mill to collect data on hydrodynamics conditions offshore of the mill. The study locations and instrumentation deployed are based on the near-field CSMs presented in Volume II (Windward 2014).

3.1 METHODS

SEI deployed bottom-mounted hydrodynamics and water quality instrumentation platforms offshore of the former Rayonier mill dock from February 5 to March 6, 2014 (Figure 6). One platform was deployed in 5 m water depth and was located 260 m west of the end of the rock jetty. The other platform was deployed in 12 m water depth and was located 260 m northeast of the end of the dock. Each instrumentation platform consisted of a Teledyne RDI (Poway, CA) Workhorse Sentinel 1200 kHz acoustic Doppler current profiler (ADCP) with wave measurement capability and a Xylem/Yellow Springs Inc. (YSI) 6920-v2 water quality sonde (Figure 7). The YSI provided measurements of the following water quality parameters: temperature, conductivity (salinity), pressure, and turbidity. An ORE acoustic release was mounted on each platform and used to liberate a flotation sphere and line for recovery of the instrumented platforms.

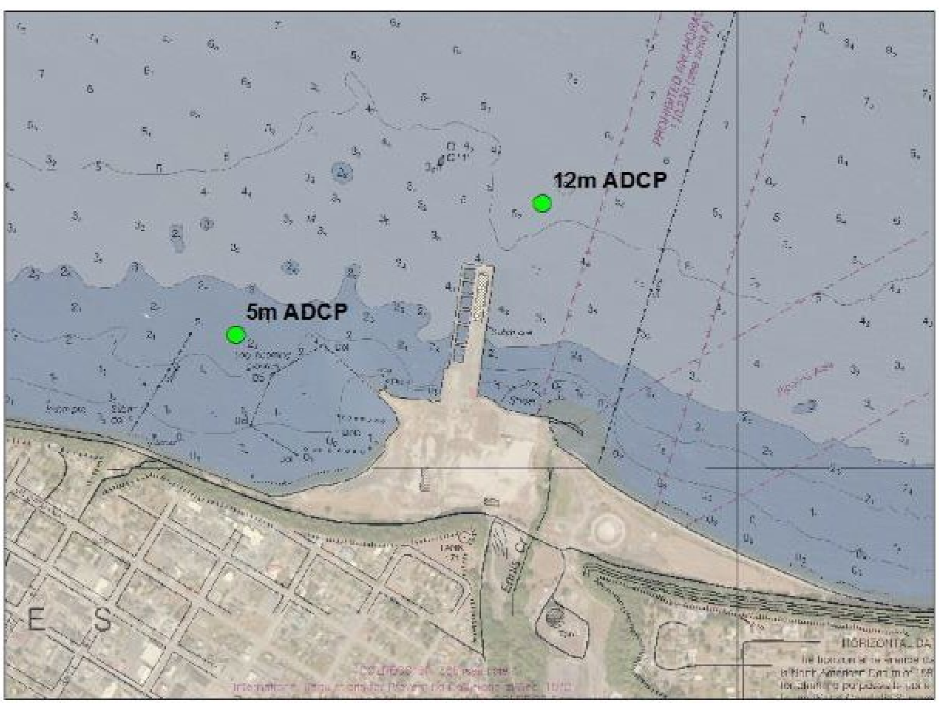

Figure 6. Map of the Former Rayonier Mill Site Showing the Deployment Locations of the Bottom-mount Instrumentation Platforms

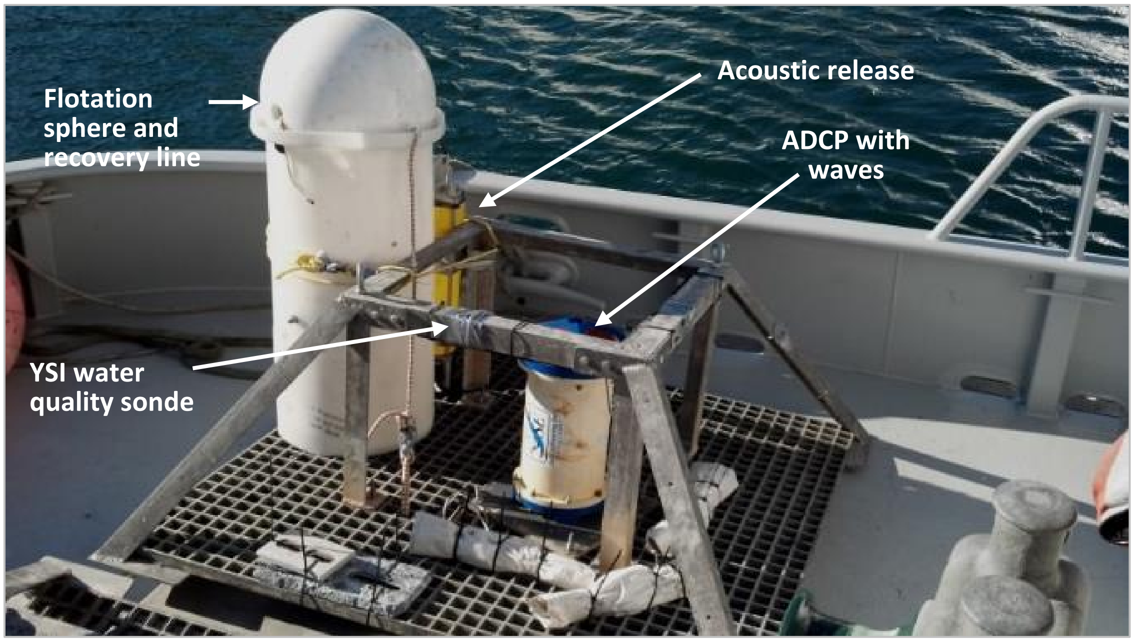

Figure 7. One of the Two Bottom-mount Instrumentation Platforms. The YSI water quality sonde is behind the cross bar.

Prior to the deployment, the factory recommended calibration and maintenance procedures were performed for the ADCPs and YSIs. Initial ADCP calibrations were accomplished through use of Teledyne RDI software and included: internal compass validation, electronic circuitry and internal memory confirmation, battery tests, and beam continuity verification to ensure properly functioning transducers. The YSI water quality sonde probes were calibrated with factory supplied National Institute of Standards and Technology (NIST) traceable calibration solution prior to deployment.

The ADCPs measured currents at 0.3 Hz over 200 samples every 10 minutes from near-bottom to near-surface, every 0.5 m in the vertical. The ADCP output was thus 10 minute averaged current velocity and direction between 1.1 m above the seabed to within 0.5 to 1 m of the sea surface. Hourly wave parameters (significant wave height, period, and direction) were derived from ADCP wave measurements that were collected over 17 minutes every hour. The YSI water quality sondes recorded temperature, salinity, water depth, and turbidity every 15 minutes. Water quality data were collected approximately 1 m above the seabed.

3.2 RESULTS

Current and wave data obtained by the ADCPs indicated that the region is relatively quiescent. Time-averaged, depth-averaged current velocities were 0.04 m/s and 0.09 m/s and average recorded significant wave heights were 0.15 m and 0.19 m at the 5 m and 12 m ADCP locations, respectively. Time-averaged, near-surface current velocities were higher than near-bed velocities at both locations (Table 3 and Table 4; Figure 8 and Figure 9). Significant wave heights did not exceed 0.75 m at either platform location (Figure 10 and Figure 11). Westerly waves were small (less than 0.1 m) and larger significant wave heights were generally associated with northwest swell.

Table 3. Statistics of Current, Wave, and Water Quality Measurements Collected by the ADCP and YSI Water Quality Sonde in 5 m Water Depth

Parameter	Mean	Minimum	Maximum	Standard Deviation
Depth-Averaged				
Velocity (m/s)	0.04	0.00	0.15	0.02
Surface				
Velocity (m/s)	0.06	0.00	0.30	0.04
Significant wave height (m)	0.15	0.00	0.66	0.12
Peak wave period (s)	5.81	1.60	25.30	4.37
Mean wave direction (°)	81	1	359	4
Near-Bed				
Velocity (m/s)	0.03	0.00	0.12	0.02
Temperature (°C)	7.09	5.84	7.59	0.30
Salinity (ppt)	30.87	29.60	32.12	0.70
Turbidity (NTU)	0.71	0.05	4.15	0.47

Table 4. Statistics of Current, Wave, and Water Quality Measurements Collected by the ADCP and YSI Water Quality Sonde in 12 m Water Depth

Parameter	Mean	Minimum	Maximum	Standard Deviation
Depth-Averaged				
Velocity (m/s)	0.09	0.00	0.40	0.06
Surface				
Velocity (m/s)	0.14	0.00	0.58	0.09
Significant wave height (m)	0.19	0.01	0.75	0.15
Peak wave period (s)	4.54	1.70	18.10	3.26
Mean wave direction (°)	55	1	359	3
Near-Bed				
Velocity (m/s)	0.08	0.00	0.29	0.04
Temperature (°C)	7.10	6.34	7.51	0.22

Table 4. Statistics of Current, Wave, and Water Quality Measurements Collected by the ADCP and YSI Water Quality Sonde in 12 m Water Depth

Parameter	Mean	Minimum	Maximum	Standard Deviation
Salinity (ppt)	29.65	28.24	33.43	0.81
Turbidity (NTU)	1.12	0.05	17.35	1.05

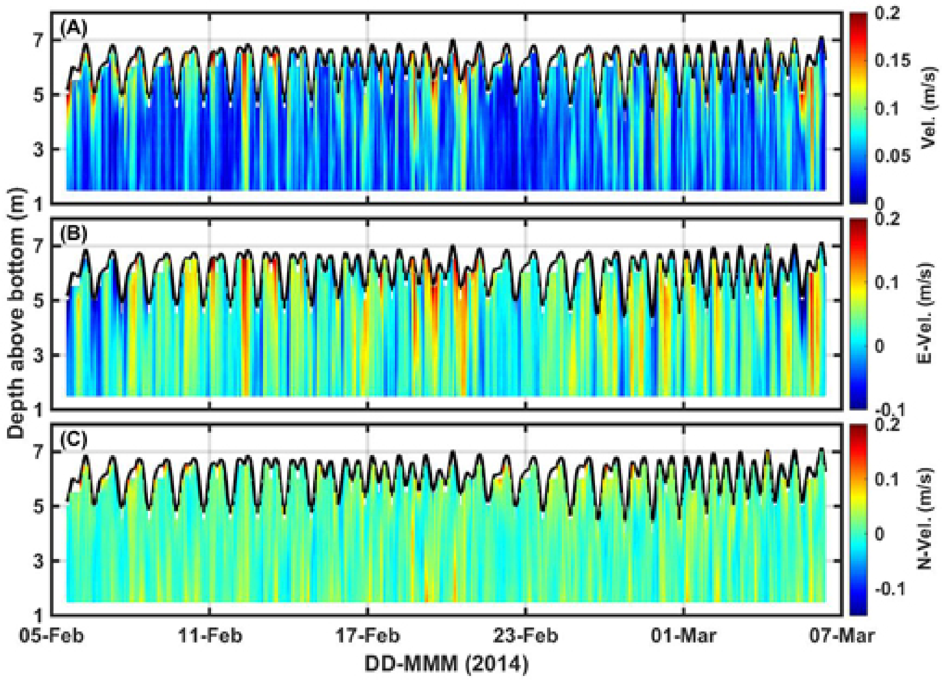

Figure 8. Depth-Resolved Time Series of (A) Current Velocity Magnitude, (B) East-velocity Currents, and (C) North-velocity Currents Measured by the ADCP at 5-m Depth

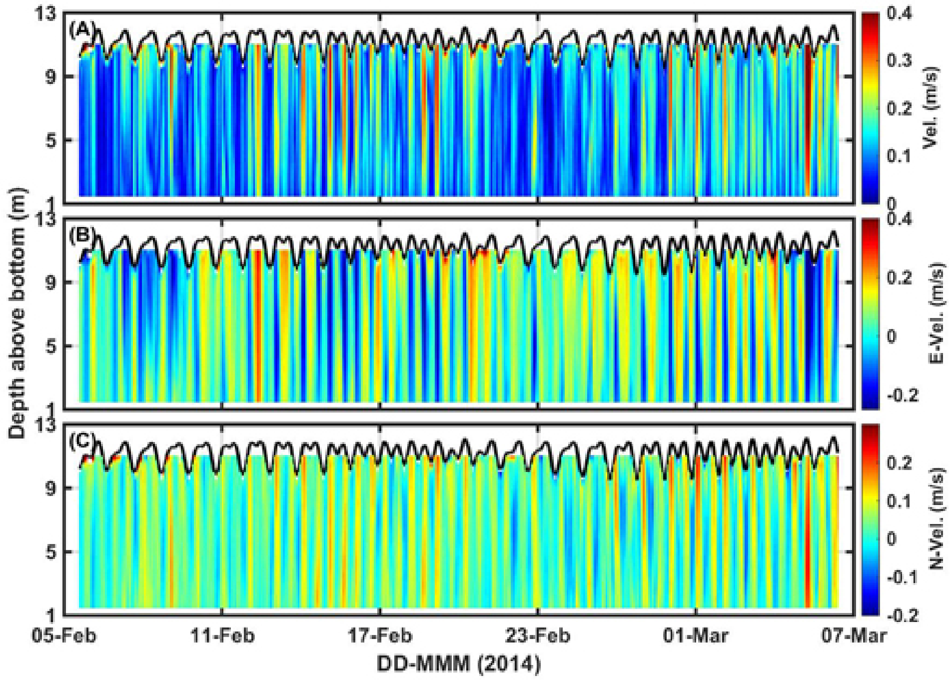

Figure 9. Depth-resolved Time Series of (A) Current velocity Magnitude, (B) East-velocity Currents, and (C) North-velocity Currents Measured by the ADCP at 12 m Depth

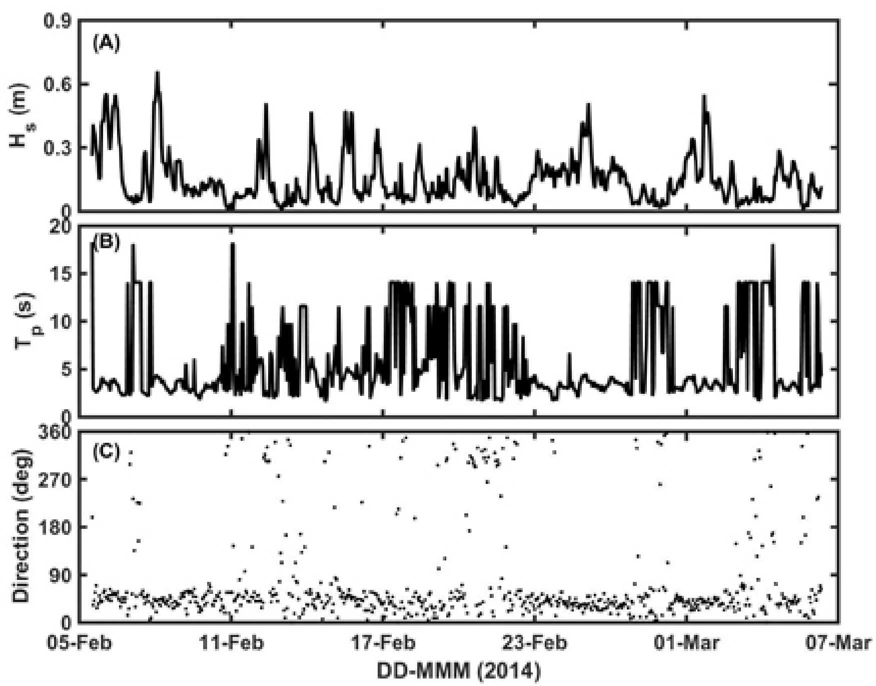

Figure 10. Time Series of (A) Significant Wave Height (Hs), (B) Peak Wave Period (Tp), and (C) Mean Wave Direction Recorded by the ADCP at 5-m Water Depth

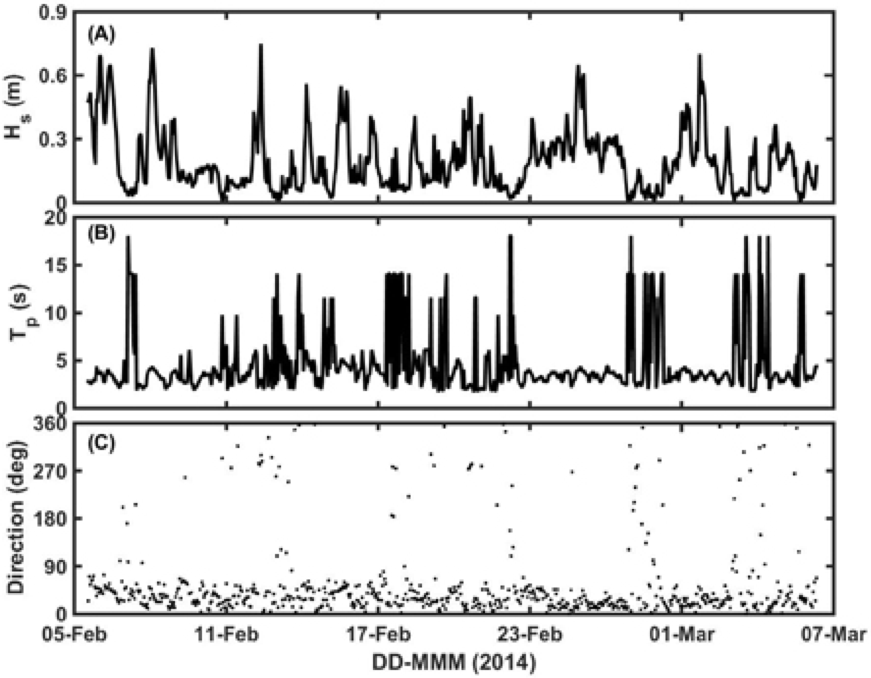

Figure 11. Time Series of (A) Significant Wave Height (Hs), (B) Peak Wave Period (Tp), and (C) Mean Wave Direction Recorded by the ADCP at 12-m Water Depth

Mean wave directions during the deployment were generally from the northeast whereas current directions were different between the 5- and 12-m instrument platform locations (Figure 12 and 13). Tidal current directions were east-to-west at the 5 m platform and southeast-to-northwest at the 12 m platform (Figure 12). Net current transport was toward the east at the shallower location and toward the east and northwest at the deeper sampling region. The general patterns of transport measured near the former Rayonier mill site during this field work study are in general agreement with net transport directions reported in Windward (2014).

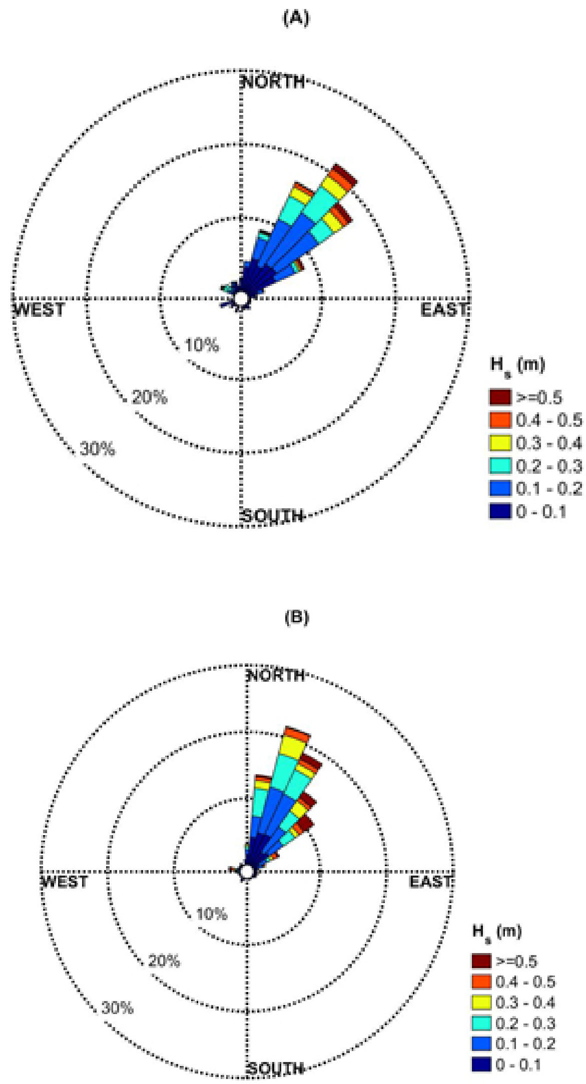

Figure 12. Rose Diagrams Showing Wave Direction *From* as Measured by the ADCPs at (A) 5-m and (B) 12-m Water Depths

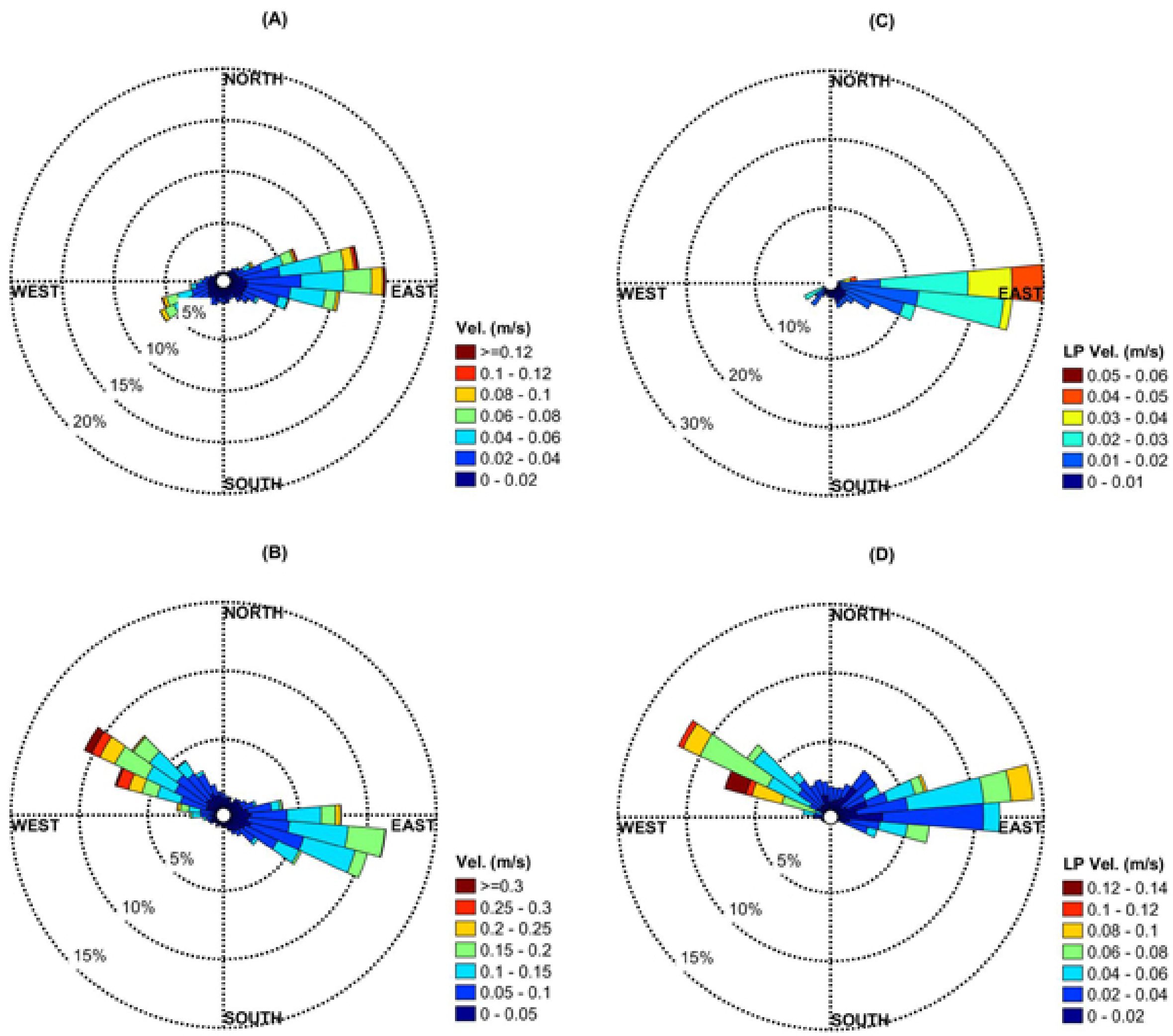

Figure 13. Rose Diagrams Showing Current Direction *Towards* as Measured by the (A and B) 5- and 12-m ADCPs, Respectively. (C and D) Low-pass Filtered (35-hr) Current Velocity as Measured by the 5- and 12-m ADCPs, Respectively

Turbidity recorded at the 5 m and 12 m bottom platforms was relatively low, exhibiting time-averaged values of 0.71 NTU and 1.12 NTU, respectively (Table 3 and Table 4). Increases in turbidity between 6 and 17 February 2014 were observed at both platform locations and these peaks in turbidity coincided with higher significant wave heights (Figure 14). These elevated wave heights were at times correlated with increased wind speeds (greater than 7 m/s) observed in Port Angeles at the NOAA National Data Buoy Center (NDBC) Station PTAW1. After February 17, only the 5-m peaks in turbidity were associated with increased wave heights and wind speeds whereas turbidity values at the 12 m platform location generally remained small (less than 5 NTU). Short-term elevated values in turbidity at the 12-m location on February 25 and March 3 were associated with increased wave height.

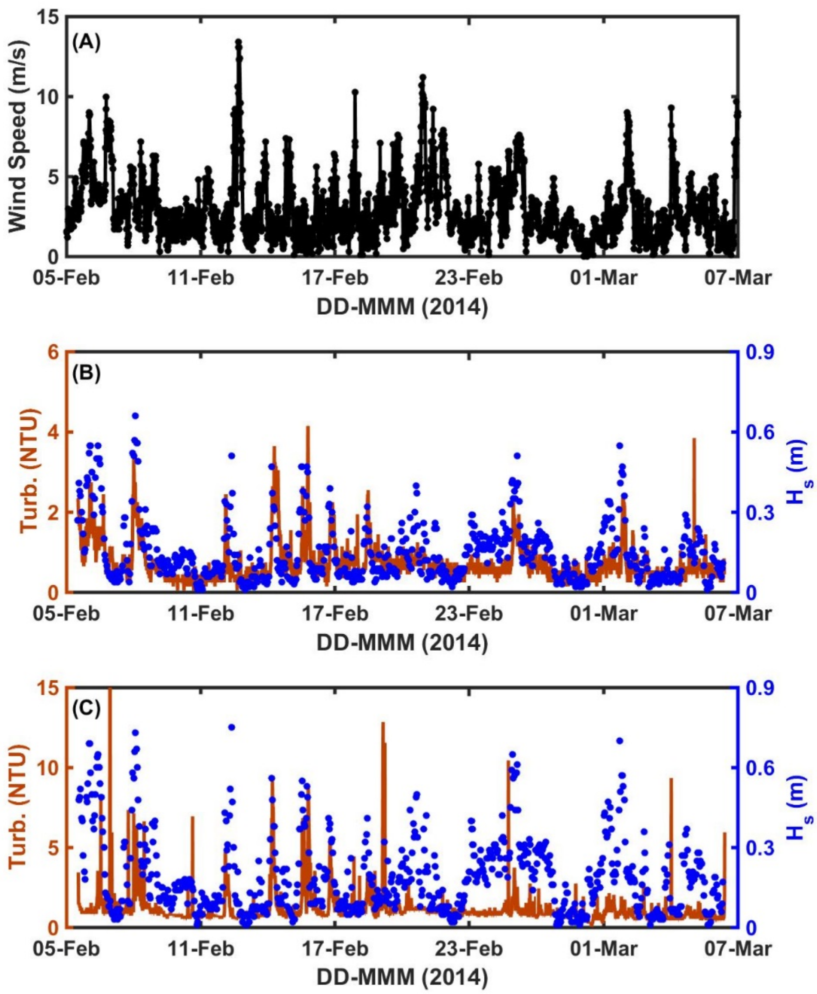

Figure 14. Time Series of (A) Wind Speed Recorded in Port Angeles (Black) and Turbidity (Brown) and Significant Wave Height (Blue) Recorded by the YSI Water Quality Sonde and ADCP at the (A) 5-m and (B) 12-m Platform Locations

4.0 WAVE & HYDRODYNAMICS MODELING

Waves have been identified as a primary factor affecting sediment transport in the nearshore regions of the former Rayonier mill (Windward 2014). As waves approach the coast, they are transformed by certain processes including refraction (as they pass over changing bottom contours), diffraction (as they propagate around objects such as headlands), shoaling (as the depth decreases), energy dissipation (due to bottom friction), and ultimately, by breaking. The shoaling and energy dissipation exert a force on the sediment bed in the form of shear stress, which is responsible for the potential movement of sediment. To account for waves and their effect on any material placed on the sediment bed in the remedial analysis and design, the propagation of waves into the Rayonier mill nearshore was modeled. The industry standard SWAN (Simulating WAves Nearshore; developed by Delft Hydraulics Laboratory; Booij et al. 1996) model was used, which has the capability of modeling all of the above-mentioned processes in shallow coastal waters.

The SWAN model is a non-stationary (non-steady state) third generation wave model based on the discrete spectral action balance equation (over the total range of wave frequencies). Wave propagation is based on linear wave theory. The processes of wind generation, dissipation, and nonlinear wave-wave interactions are represented explicitly with state-of-the-science third-generation formulations. SWAN provides many output quantities including 2-dimensional spectra, significant wave height, peak wave period, mean wave direction, and directional spreading. The SWAN modeling framework has been successfully validated and verified in laboratory and complex field cases.

The SWAN model can also couple with a hydrodynamic solver to represent the interaction of waves and currents. The wave model can incorporate water levels as well as current velocity and direction while providing wave field parameters to modify the nearshore currents. While previous studies have shown that waves are the primary driver for sediment suspension at the Site (Windward, 2014); the inclusion of currents allows for a more complete representation of the system and allows for the inclusion of not only resuspension potential but also transport dynamics. The hydrodynamic model was developed using Delft3D-Flow a model (Deltares Inc.) This (Delft3D-Flow). Their model allows for the two way coupling necessary to capture the non-linear interactions between waves and currents in an efficient manner.

4.1 WAVE MODEL VALIDATION

SWAN model validation for the Rayonier mill region was conducted for hourly wave data in February 2014. This validation period was chosen for the availability of wave data from the hydrodynamic field study and the time period's relatively strong variability in wave height over a short period of time. Modeled wave parameters were compared to measured wave data collected at two nearshore sites near the former Rayonier mill. Validation data—significant wave height (H_s) and peak wave period (T_P)—were measured by two RD Instruments 1200 kHz ADCPs with wave measurement capability (Workhorse Sentinel with waves) deployed in 5 m and 12 m water depth (see the Hydrodynamic Field Work section for more details).

The SWAN model was nested three times to propagate waves to the validation sites at the former Rayonier mill (Figure 15). A triple nested model was necessary to optimize computational capabilities without compromising small scale bathymetric details in the former Rayonier mill region. Initial wave conditions were obtained from the NOAA NDBC New Dungeness Station No. 46088, located 31.5 km northeast of Port Angeles at 48°20'8" N, 123°9'31" W in 120 m water depth. Initial wind conditions were derived from NDBC Station PTAW1. Station PTAW1 is located at 48°7'29" N 123°26'28" W, west of the former Rayonier mill and in the lee of Ediz Hook for northwest to northeast wind directions. Therefore, an average of wind speed and direction measured at NDBC Stations PTAW1 and No. 46088 was used for initial model wind conditions.

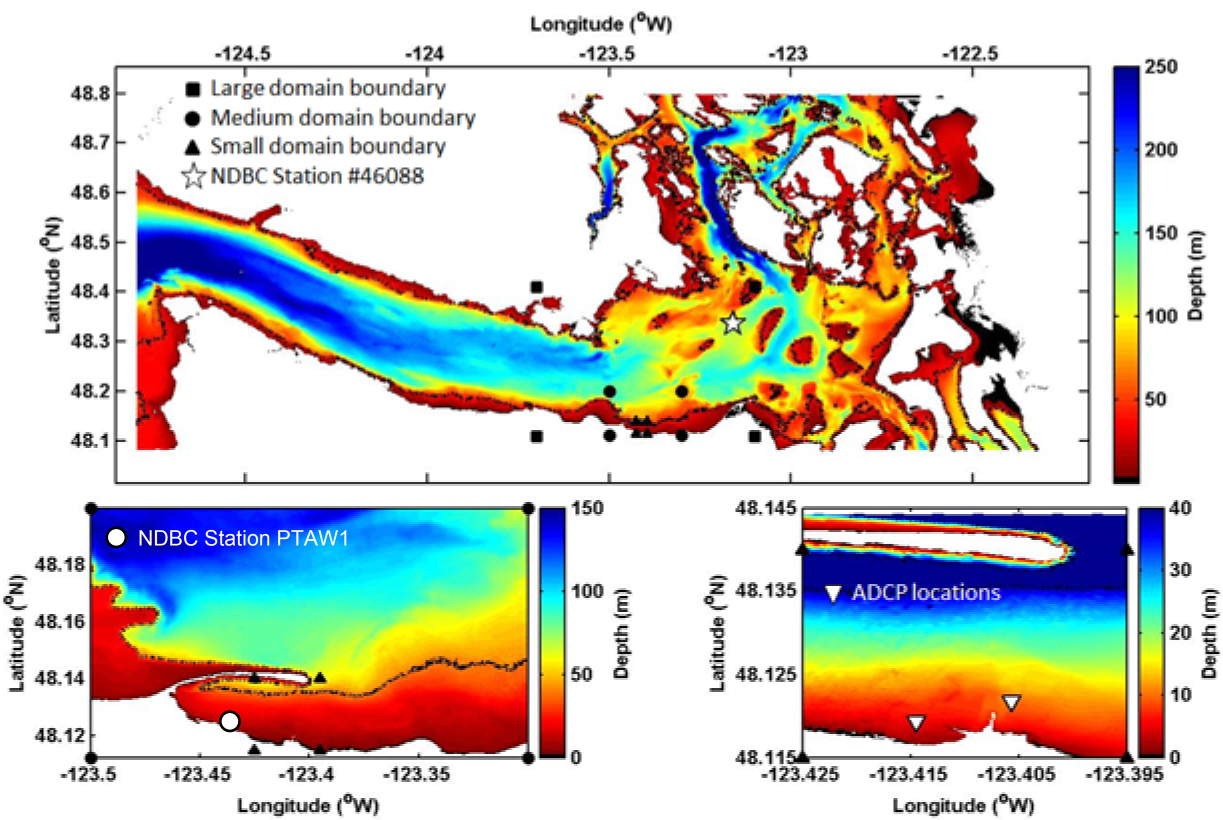

Figure 15. SWAN Nested Model Domains

The first nested domain (herein referred to as the large domain) propagated waves from Station No. 46088. Initial wind speed and direction were applied uniformly throughout the large model domain. The grid resolution of the large domain computational grid was approximately 0.003° in latitude and longitude (300 m x 300 m in x and y). Large scale bathymetry data were obtained from the NOAA National Geophysical Data Center (NGDC) Port Townsend, Washington, digital elevation model (DEM) (Lim et al. 2012). The wave spectrum boundary conditions were applied along the offshore (westerly, easterly, and northerly) boundaries of the large SWAN model domain.

Wave conditions were output for a second nested model domain (herein referred to as the medium domain). The grid resolution of the medium domain computational grid was approximately 0.0003° in latitude and longitude (30 m x 30 m in x and y). The medium scale bathymetric boundary conditions were obtained from the NOAA NGDC Port Townsend, Washington, DEM. The wave spectrum boundary conditions were applied along the offshore (western, eastern, and northern) boundaries of the medium SWAN model domain and initial wind speed and direction were applied uniformly throughout the medium model domain. The model was run as a stationary model.

Wave conditions were output for the third nested model domain (herein referred to as the small domain). The grid resolution of the small domain computational grid was approximately 0.00003° in latitude and longitude (3 m x 3 m in x and y). Bathymetry data were provided by the multi-beam surveys conducted by SEI in January 2014 (see 2.0 Hydrographic Survey). The wave spectrum boundary conditions were applied along the offshore (western, eastern, and northern) boundaries of the small SWAN model domain. Winds were assumed to have minimal effect on the nearshore wave conditions due to the relatively short distance from the model boundary to the coastline. The model was also run as a stationary model.

Wave heights (in meters) and peak wave periods (in seconds) were obtained from the nested SWAN model for validation with the ADCP measurements at 5 m and 12 m water depth near the former Rayonier mill. Data were outputted every hour at the discrete ADCP locations for direct comparison. Modeled versus measured data results during the period of study (Figure 16).

Validation results indicate that the model successfully captured the relatively strong variability in significant wave height observed on February 12, 2014. Due to the relatively large fetch distance, there is a change in relative wind magnitude and direction measured at the two NDBC stations (No. 46088 compared to PTAW1). The differences in initial winds between the two NDBC stations likely contributed to differences between modeled and measured peak wave period. South to westerly wind directions at PTAW1 compared to east to southerly wind directions at Station No. 46088 resulted in SWAN model underestimates of peak wave period; however, it is important to note that that ADCPs deployed perform relatively poorly for lower wave periods (< ~5 s) as it is generally unreasonable to have a 10 s period for waves under 0.2 m in height. Given the uncertainties associated with the wind fields and the wave measurements during low wave periods, the SWAN model developed for the former Rayonier mill nearshore showed good agreement with the validation data set and was suitable for modeling sediment stability as affected by larger (> 0.4-m wave height) wave conditions in the Port Angeles, Washington, region.

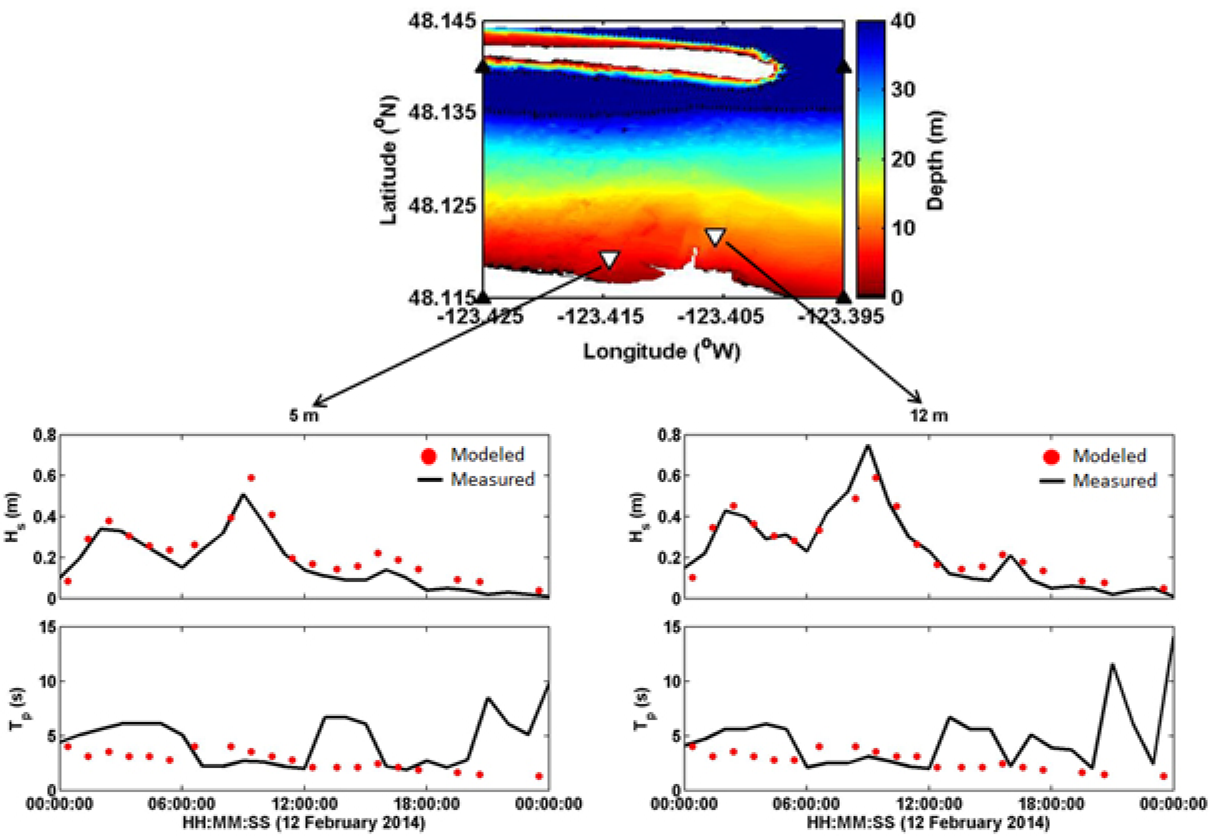

Figure 16. Top: Small Model Domain Indicating Validation Locations at 5 m and 12 m Water Depth. Bottom: Modeled versus Measured Significant Wave Height (H_s) and Peak Wave Period (T_p) at the Two Validation Locations as Indicated

4.2 MODEL PARAMETERS

The coupled wave and hydrodynamic models (SWAN-Delft3D-Flow) were used to investigate a range of conditions at the study site. Waves, currents, and subsequent resuspension forces resulting from a 100-year storm event, as well as typical winds experienced at the study site, were analyzed for two shoreline cases. A shoreline containing the pier and jetty, Case 0, representing existing conditions was analyzed to compare with observations and the conceptual site model. A shoreline with the removal of pier, jetty, and peninsula where the breakwater terminates, Case 5, was analyzed to determine the potential effects of removing the inhibition to flow and wave propagation these structures currently provide (Figure 17).

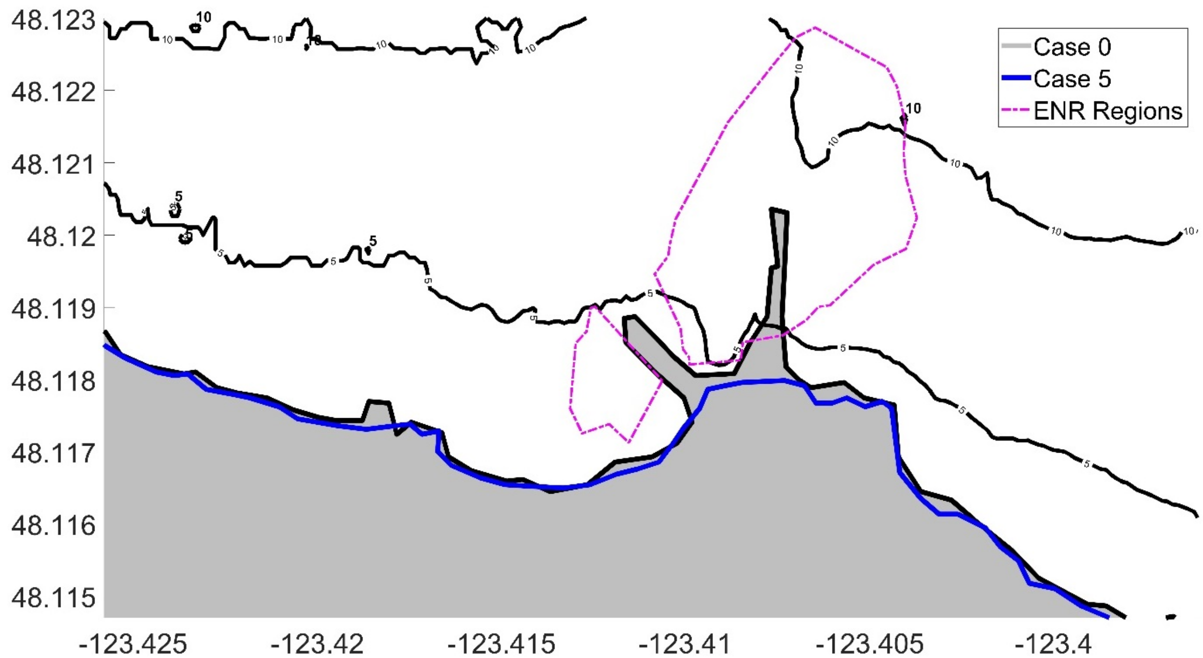

Figure 17. Shoreline cases considered and ENR regions. The regions designated for ENR are highlighted in magenta.

Coupled wave and hydrodynamic model runs were performed for the region around Ediz Hook, within the SWAN model medium domain (Figure 15). A combination of local water level and current velocity measurements provided the boundary conditions necessary to modulate water levels and drive tidal currents (NOAA tidal predictor station PUG1637 and NOAA tidal station 9444900). Water level and velocity boundary conditions were applied at the eastern and western edges of the domain, respectively. A two-day time period during the summer, a period of seasonally lower water levels, was chosen to use for boundary conditions. The two day period, during a spring tide event allows for forcing conditions to be considered over a range of water levels and prescribed wave events. Two days allowed the fully developed wave conditions to interact with a range of water levels and tidal currents. Water levels ranged from -0.3 to 2.56 m relative to MLLW and velocities at the model boundary ranged from -1.1 to 1.1 m/s (Figure 18). The velocities and water levels at the study site were allowed to develop based on the interaction of these conditions and the modeled waves that were generated by simulated wind conditions.

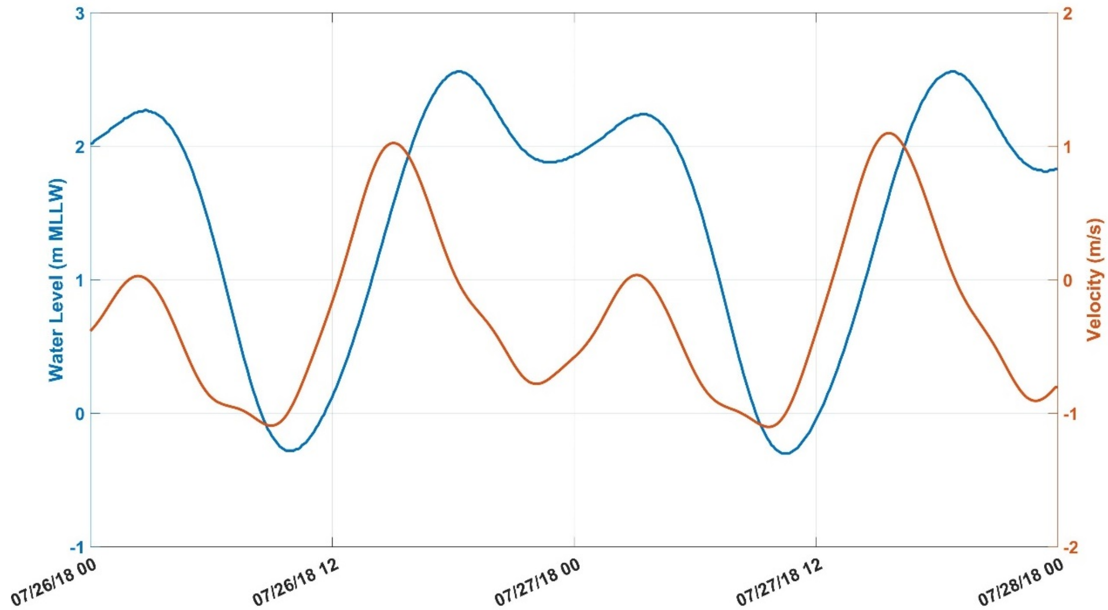

Figure 18. Hydrodynamic Boundary Conditions

Ediz Hook provides protection of the study site from ocean waves that could propagate through the Strait of Juan de Fuca from the west. Thus, the dominant wave conditions are locally generated waves due to storms. Wind conditions from the west and northeast were considered for this study. The northeast direction (67.5º) represents the longest fetch, or uninterrupted water surface, to allow for waves to generate, grow, and interact with the site.

Two wind conditions representing 100-year storm events from the west and from the northeast were applied to the two shoreline scenarios, Case 0 and Case 5 (Figure 17). Wind velocities for each storm condition were determined by analyzing data collected every half hour from a near-continuous 13-year record of local wind measurements collected at the NOAA National Data Buoy Center (NDBC) New Dungeness Station No. (46088) from 2004 to 2017. The data collected at the station was then analyzed by calculating a running 24-hr average (Figure 19). The 24-hr averaging period was chosen to represent the time over which sustained winds are able to produce fully-developed seas. The averaged data was then subdivided into two directional bins. The 24-hr averaging period was chosen to represent the time over which sustained winds are able to produce fully-developed seas. Westerly winds from 270-315º were considered and sustained winds from 47.5-87.5º were used for the northeasterly storm (Figure 20). Averaged sustained winds ranged from 0 to 15 m/s in both directions (Figure 22).

Data within each directional bin was then fit to an extreme value distribution to determine the one in 100 year conditions. The extreme value distribution considered yearly maximum winds fit to an extreme distribution function (Figure 21). Results from this analysis determined one in one hundred year conditions of 18 m/s for a westerly storm and northeasterly winds of 17 m/s for a northeasterly storm. The larger fetch to the northeast (49 km) results in the potential for larger waves than from the west (4.5 km). Each storm case was applied to the two shoreline cases as a constant value over the duration of the simulation because of the averaging used to determine the magnitudes.

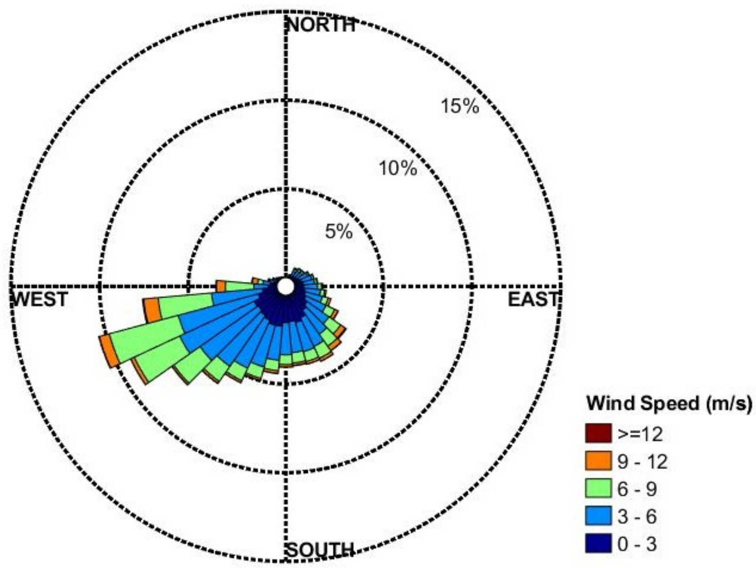

Figure 19. Wind rose showcasing magnitude, direction, and frequency of 13 year wind measurement record. Data has been processed with a 24-hr running average.

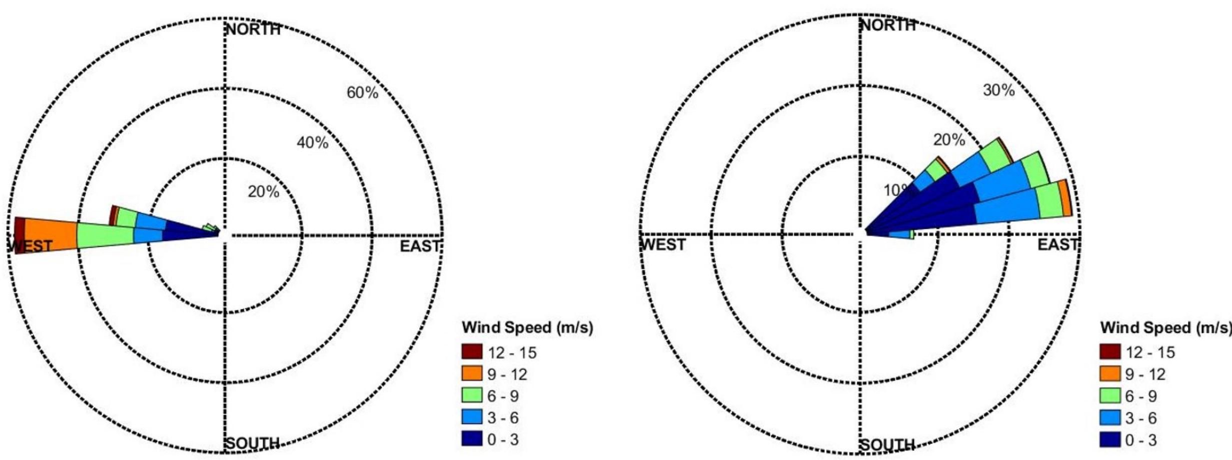

Figure 20. Wind rose of westerly storms (270-315°) on left and northeasterly storms (47.5-87.5°) on right.

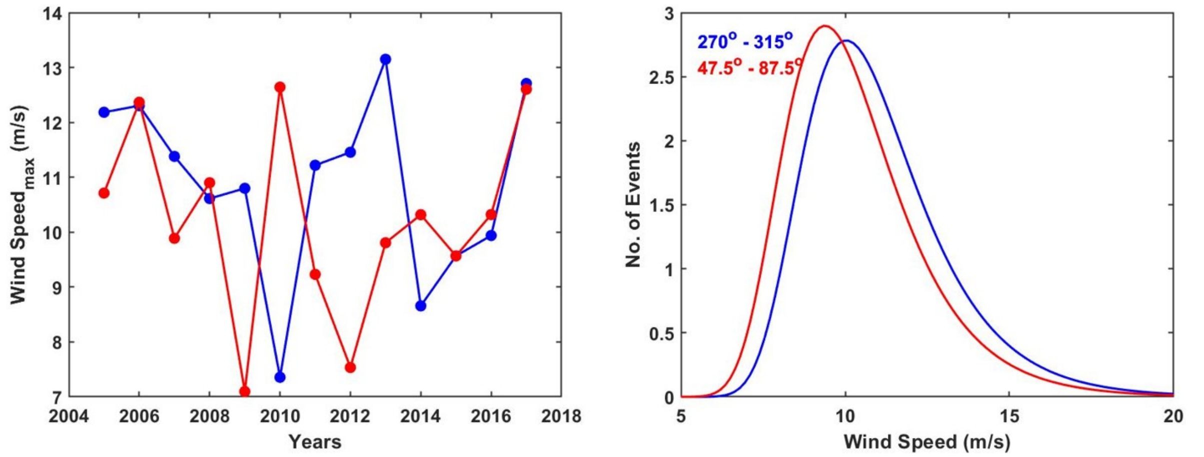

Figure 21. Left: Yearly maximum sustained (24-hr) wind speed for two directional bins (legend in right panel). Right: Extreme value probability distribution function for sustained wind speed at two directional bins. A 24 hour running mean was applied to data prior to binning.

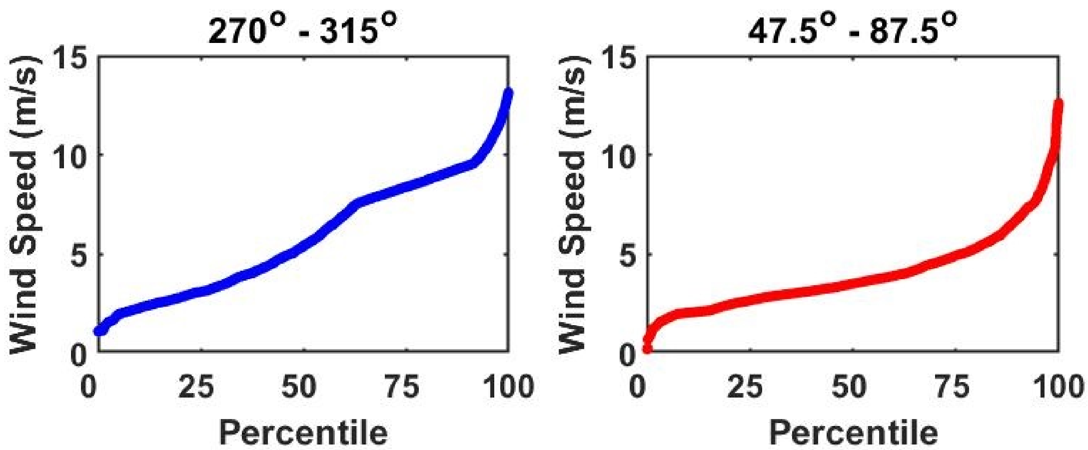

Figure 22. Cumulative distribution function for directionally binned sustained wind speed. A 24-hr running mean was first applied to the data before binning.

4.3 HYDRODYNAMIC MODEL RESULTS

The hydrodynamic model applied velocity and tidal elevation boundary conditions, obtained from local NOAA measurements, along the western and eastern model boundaries, respectively. Wind conditions from the typical, and one-in-100-year storm events were applied to the SWAN model to generate waves throughout the model domain. Through the two-way coupling of SWAN and Delft3D-Flow, the interaction of waves and hydrodynamic conditions were computed, resulting in a more accurate representation of forces in the system. Spatial results of wave conditions generated by the storm conditions and net hydrodynamic currents are presented below.

In general, waves generated due to westerly storms were an order of magnitude smaller than those generated due to a northeasterly storm due to the presence of Ediz Hook. The Hook limits the fetch and thus the ability for waves to grow. Wave shadowing occurs for the Case 0 shoreline configuration, representing the present conditions in the lee of the structures along the coast in both storm conditions (Figure 24, Figure 26). Removal of these structures, as represented by the Case 5 configuration, allows for waves to propagate in the regions previously shadowed (Figure 28, Figure 30). In both shoreline scenarios, waves from the northeast can reach up to 1.9 m in the offshore region and up to 1 m along the coast. The model calculated a relative peak wave period of 5.7 seconds. The wave parameters should be considered for design as they were produced by the most intense storms modeled in this study that considered the largest fetch and strongest sustained average winds expected at the study site.

Typical conditions compared generally well with measured values during the field effort. Wave heights were minimal due to the westerly direction of winds and protection provided by Ediz Hook. Modeled current velocities were in the range measured by the ADCP during the more energetic period of the field study (Figure 23, Table 3, Table 4).

The net direction of hydrodynamic currents correlates with the storm conditions. Westerly storms generate net currents from west to east (Figure 26). This is consistent with observations of the site in typical, non-storm conditions with winds from the west. Shoreline Case 0, which includes the structures, shows a reduction in current velocities around the jetty and pier. The removal of these (Case 5) structures allows for uninhibited flow along the coast (Figure 28). Maximum velocities throughout the system were lower during westerly storms (Figure 27, Figure 31) than northeasterly storms (Figure 25, Figure 29). The absence of shoreline features in Case 5 allows for unimpeded flow through the system, resulting in greater maximum velocities near the ENR areas but did not affect modeled values away from the altered shoreline (Figure 25, Figure 29).

During northeasterly storms, observations have indicated that easterly currents are still present along the coast in the lee of the structures along the coast, in the region known as the log pond, due to localized eddies (Figure 24). Removal of the coastal features removes this phenomenon and currents are observed to move, uninhibited, from east to west along the coast (Figure 30).

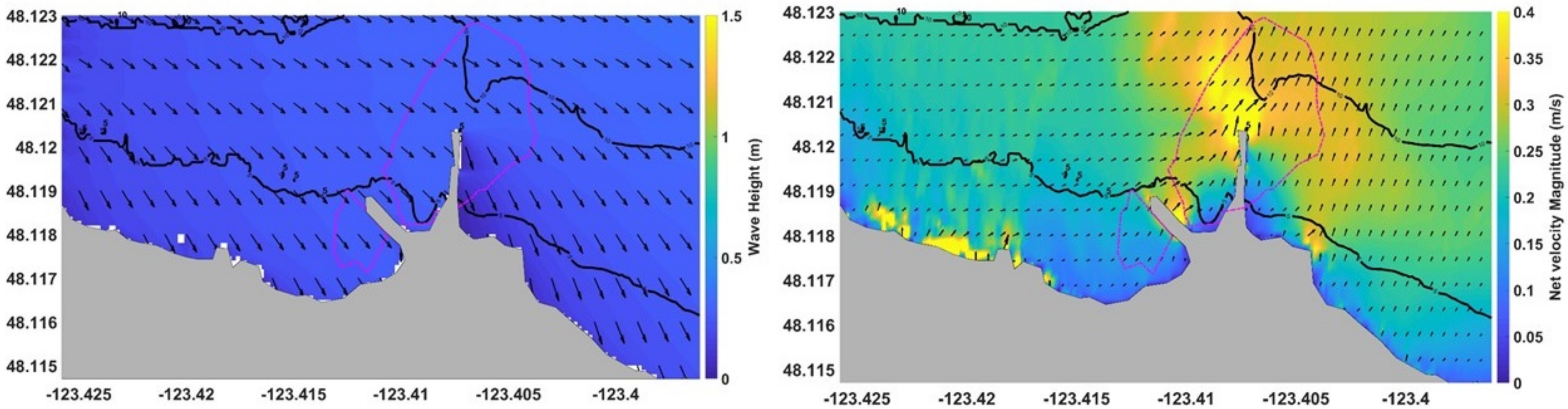

Figure 23 Wave height (left) and maximum velocity (right) due to typical conditions with Case 0 shoreline configuration. Wave and current directions are indicated with arrows in each panel and the regions designated for ENR are outlined in magenta.

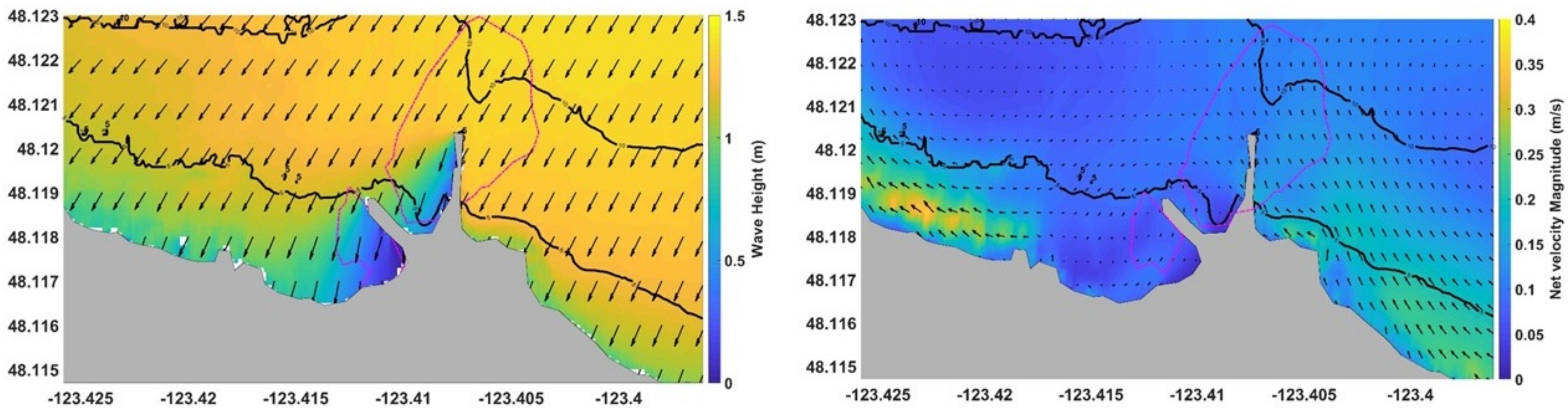

Figure 24 Wave height (left) and net circulation patterns (right) due to a northeast 100-year storm with Case 0 shoreline. Wave and current directions are indicated with arrows in each panel and the regions designated for ENR are outlined in magenta.

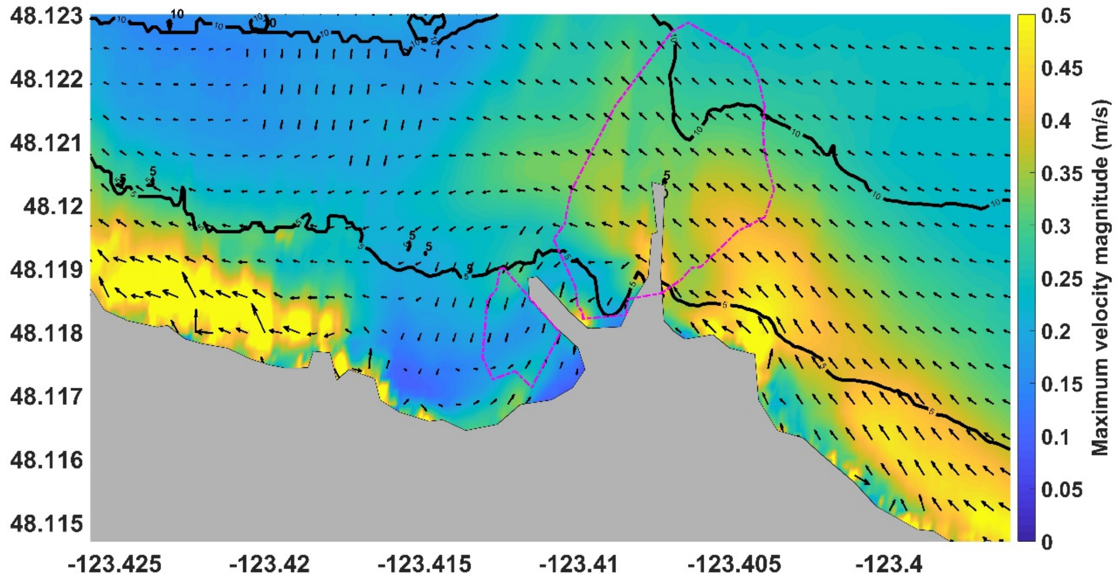

Figure 25. Maximum velocity magnitude and associated direction during a 100 year northeasterly storm with Case 0 shoreline.

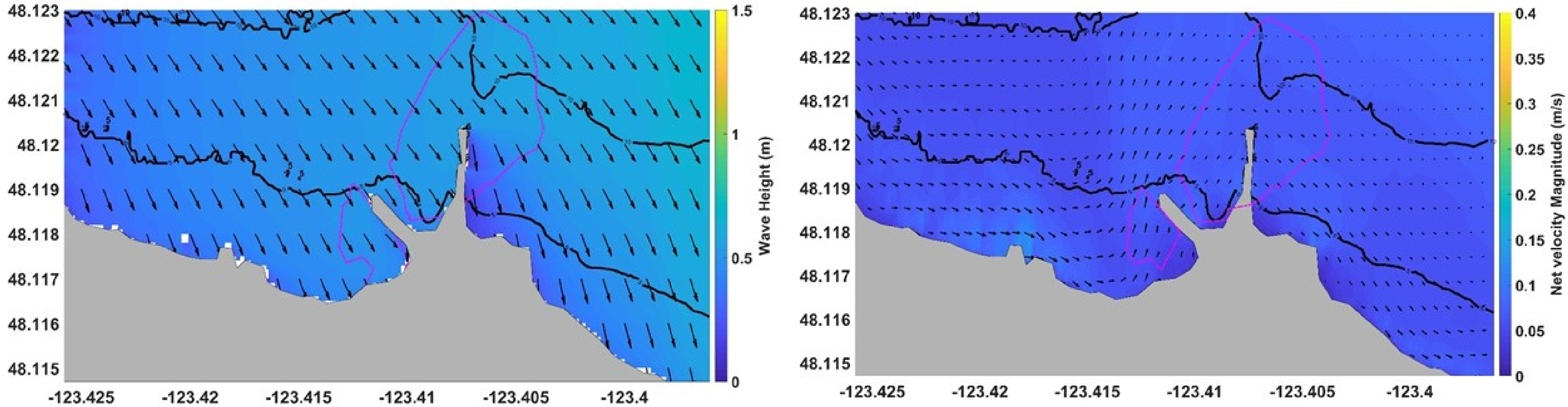

Figure 26. Wave height (left) and net circulation patterns (right) due to a westerly 100-year storm with Case 0 shoreline. Wave and current directions are indicated with arrows in each panel and the regions designated for ENR are outlined in magenta.

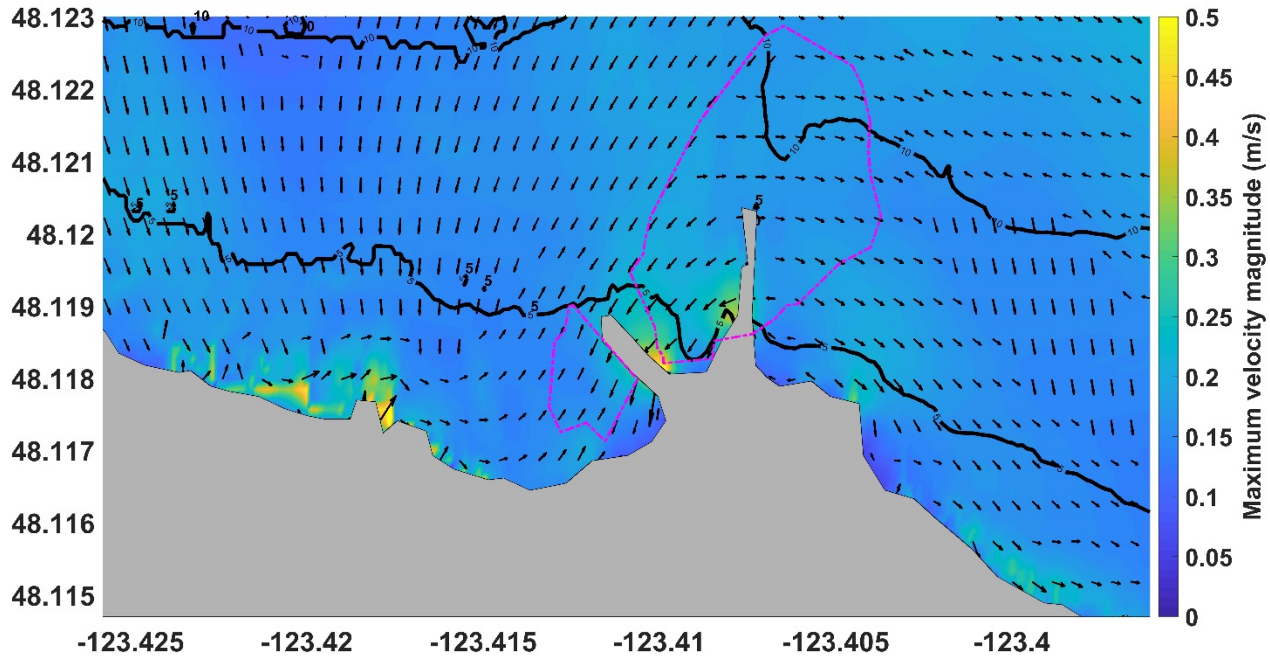

Figure 27. Maximum velocity magnitude and associated direction during a 100 year westerly storm with Case 0 shoreline.

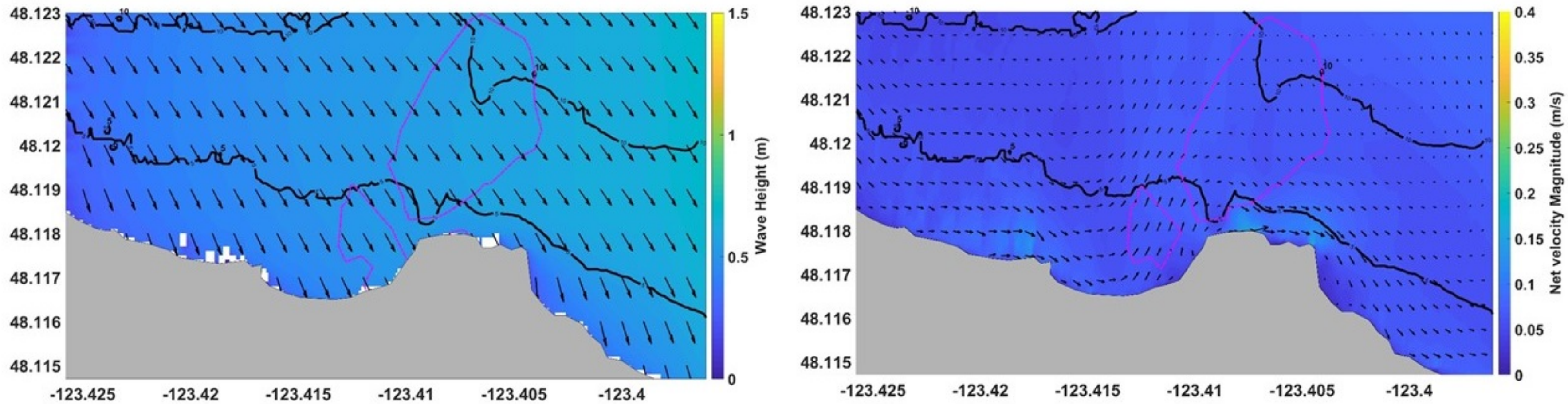

Figure 28. Wave height (left) and net circulation patterns (right) due to a westerly 100-year storm with Case 5 shoreline. Wave and current directions are indicated with arrows in each panel and the regions designated for ENR are outlined in magenta.

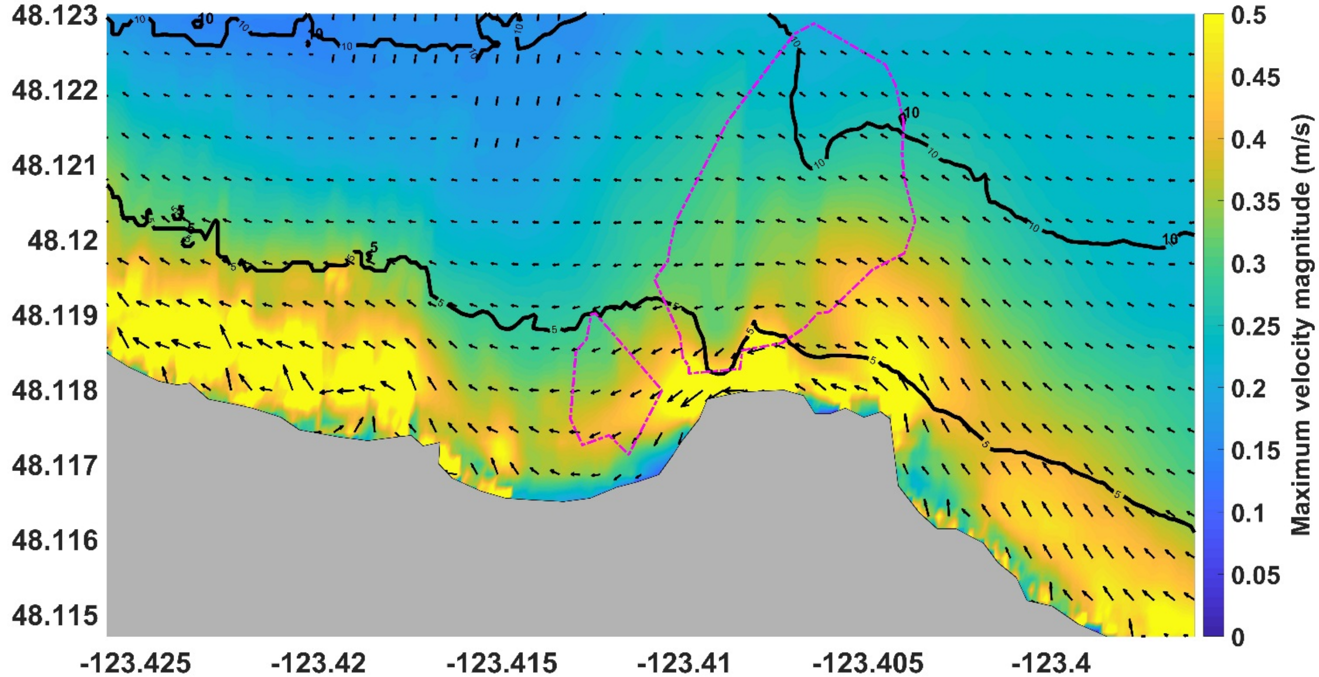

Figure 29. Maximum velocity magnitude and associated direction during a 100 year northeasterly storm with Case 0 shoreline.

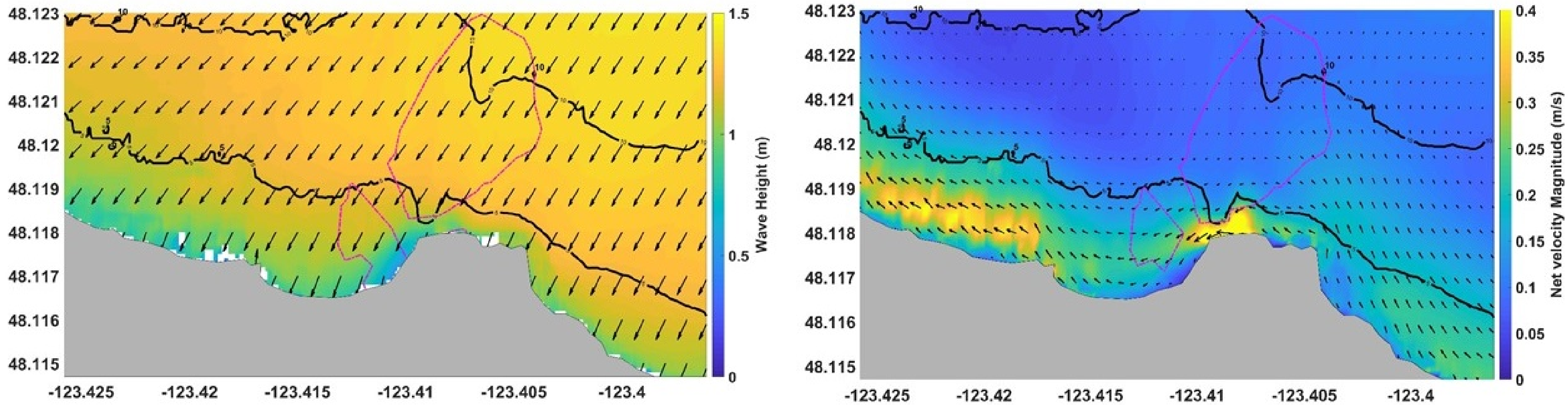

Figure 30. Wave height (left) and net circulation patterns (right) due to a northeast 100-year storm with Case 5 shoreline. Wave and current directions are indicated with arrows in each panel and the regions designated for ENR are outlined in magenta.

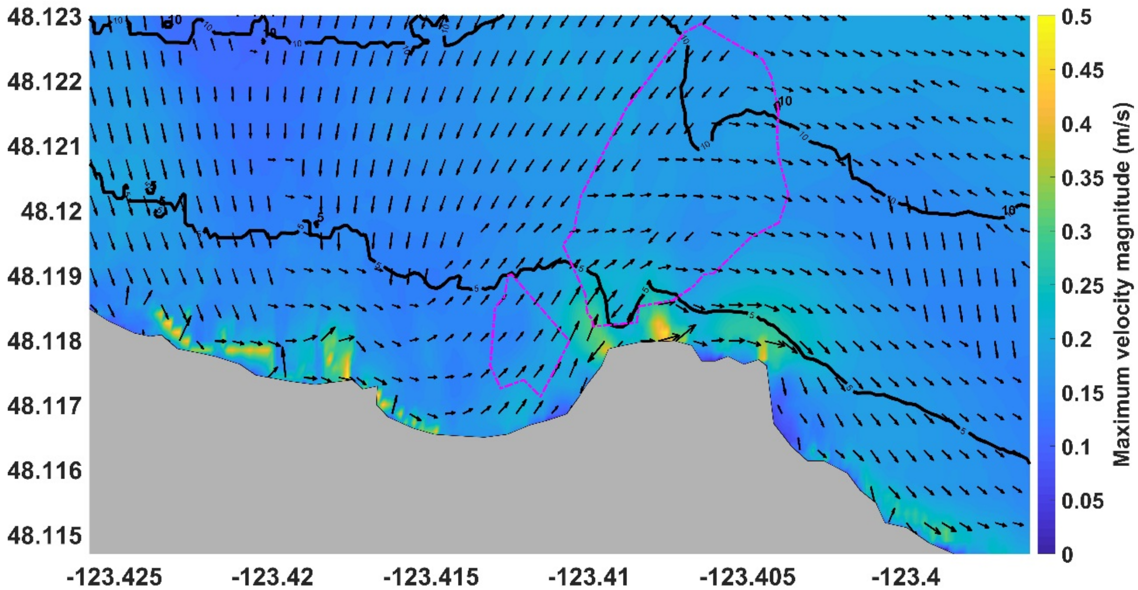

Figure 31. Maximum velocity magnitude and associated direction during a 100 year westerly storm with Case 5 shoreline.

Computed bottom shear stress at all model domain grid points was used to estimate the size of particles that could be subject to mobilization in the vicinity of the former Rayonier mill under varying environmental conditions and bathymetric cases. Sediment begins to move when the bed shear stress, τ_b, exceeds the critical shear stress, τ_c, for sediment motion, or:

$$\tau_b = \tau_c \qquad \text{Equation 1}$$

Typically, the process of initialization of sediment motion is parameterized by a dimensionless shear stress called the Shields parameter, τ^* or θ, and a dimensionless critical shear stress, called the critical Shields parameter, τ_{c^*}:

$$\tau_{b*} = \tau_{c^*} \qquad \text{Equation 2}$$

The Shields parameter is represented by:

$$\tau_{b^*} = \theta = \frac{\tau_b}{(\rho_S - \rho) g\, D} \qquad \text{Equation 3}$$

where ρ_s is the density of sediment, ρ is the density of fluid, g is the acceleration due to gravity, and D the characteristic particle diameter of the sediment. Equation 3 represents the comparison between the driving forces of particle motion (shear stress) and the particle resisting forces (particle density and size).

The relationship between τ_{c^*} and a non-dimensional particle grain size, D*, as presented by van Rijn (van Rijn 1993) is shown in Figure 32A, where:

$$D^* = D\, [(\rho_s - \rho)\, g / \nu^2]^{1/3} \qquad \text{Equation 4}$$

and ν is the viscosity of fluid (here, 0.0114 cm^2/s). By knowing the dimensionless critical shear stress as a function of grain size, Equation 3 can be solved for bed shear stress (Figure 32B), following:

$$\tau_b = \tau_{c^*}\, (\rho_s - \rho)\, g\, D \qquad \text{Equation 5}$$

where $\tau_{c*} = \tau_{b^*}$ (Equation 1).

Equation 5 was solved for grain sizes between 50 µm and 10 cm (Figure 32) assuming a material density of quartz sediment of 2.65 g/cm^3. Seawater density (1025 kg/m^3) was computed using the equation of state and measurements of temperature and salinity collected at the ADCP validation site at 12 m water depth and averaged over the month of February 2014. Shear stress, τ, was calculated over the model domain (i.e., using Equation 5) and related to τ_b as a function of D computed using Equation 5.

Grain sizes are represented on a Φ-scale (Krumbein and Sloss 1963), where:

$$D_{\Phi} = -\log_2 (D) \qquad \text{Equation 6}$$

and D (units of millimeters) (Table 5).

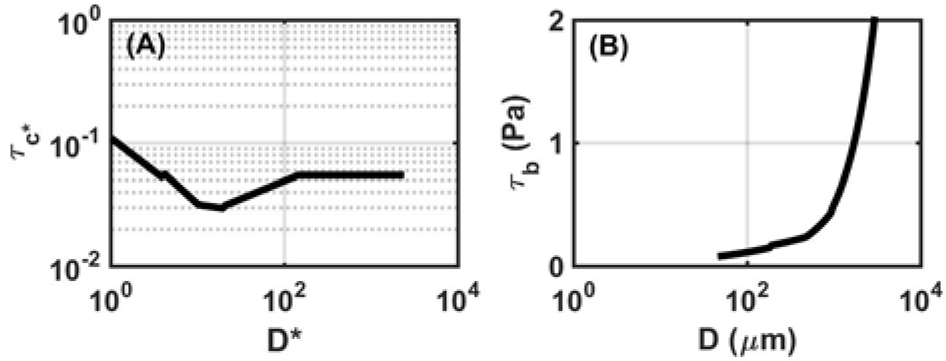

Figure 32. (A) Critical Shields Parameter as Related to Dimensionless Grain Size (from van Rijn 1993) and (B) Shear Stress as a Function of Grain Size

During the extreme conditions and resultant maximum bed shear stresses generated by a 100-year northeasterly storm, sediment up to a maximum phi size of -2.5 ϕ may be mobilized in ENR areas of the Case 0 or Case 5 shoreline scenarios (Figure 33, Figure 34). Areas associated with maximum velocities away from the ENR areas (Figure 25, Figure 29) and phi values increased up to -3 ϕ. It is worth noting that here, the term mobility does not imply suspension or erosion, but simply the ability to move. While the mobile grainsize study results suggest mobility of pebbles and granule sized sediment, results from a more detailed sediment transport model (Section 5.0) show that the proposed remedy of 1 mm (0ϕ) sediment would be effective for resisting 100-year storm forces. Therefore, these mobile grain size estimates should be considered as conservative for the type of material that would react to conditions at the study site.

Table 5. The Φ-scale for Grain Size

Description	D_{Φ}	D (mm)	D (μm)
Boulder	-8	256+	
Cobble			
Large	-7	128 – 256	
Small	-6	64 – 128	
Gravel			
Very coarse	-5	32 – 64	
Coarse	-4	16 – 32	
Medium	-3	16 – 8	
Fine	-2	8 – 4	
Very fine	-1	4 – 3	
Sand			
Very coarse	0	2 – 1	1,000 – 2,000
Coarse	1	0.5 – 1	500 – 1,000
Medium	2	0.25 – 0.5	250 – 500
Fine	3	0.125 – 0.25	125 – 250
Very fine	4	0.062 – 0.125	62.5 – 125
Silt			
Coarse	5	0.031 – 0.062	31.3 – 62.5
Medium	6	0.016 – 0.032	15.6 – 31.3
Fine	7	0.008 – 0.016	7.8 – 15.6
Very fine	8	0.004 – 0.008	3.9 – 7.8
Clay			
Coarse	9	0.002 – 0.004	1.95 – 3.9
Medium	10	0.001 – 0.002	0.98 – 1.95
Fine	11	0.0005 – 0.001	0.49 – 0.98
Very fine	12	0.00025 – 0.0005	0.24 – 0.49

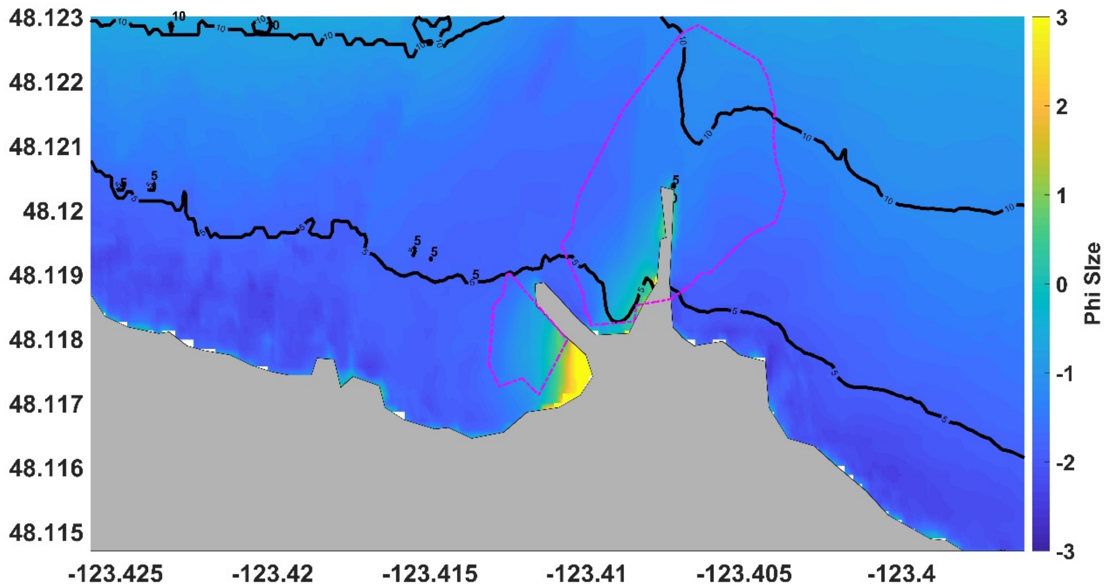

Figure 33. Range of Phi sizes that could be mobilized in ENR regions and the surrounding study area due to northeast 100 year storm conditions using Case 0 shoreline

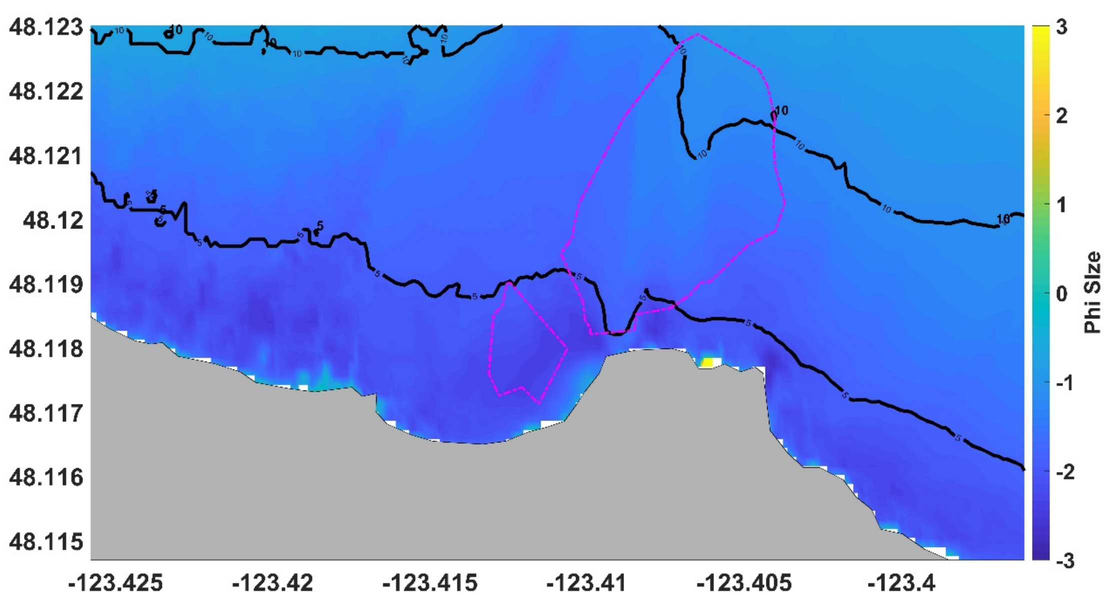

Figure 34. Range of Phi sizes that could be mobilized in ENR regions and the surrounding study area due to northeast 100 year storm conditions using Case 5 shoreline.

5.0 REMEDIAL DESIGN EVALUATION

As part of the remedial design evaluation, various combinations of sediment remediation technologies are being considered, including filling and capping and ENR (Tetra Tech and Windward 2019). The extents of the regions evaluated for the ENR are shown in Figure 17 with potential removal of the dock and jetty structures considered. While removal is also being evaluated for certain subareas, the hydrodynamic study focused on evaluating sediment stability in subareas being considered for ENR. It is anticipated that any cap or ENR material would be clean sand and would not significantly protrude above the surrounding bathymetry. The quantitative hydrodynamic and sediment stability evaluation provides quantitative parameters that can be used in final remedial design to ensure that any material placed will remain in place.

Sediment transport parameters, detailing the proposed sediment bed material in the ENR areas, were incorporated into the coupled hydrodynamic and wave model to assess the response to design storm conditions. Additionally, the threat of sea level rise (SLR) over the design life of the remedy required additional simulations to evaluate how the ENR areas would respond to any changes in hydrodynamic conditions. SLR analysis was completed utilizing Ecology's guidance document "Adaptation Strategies for Resilient Cleanup Remedies, A Guide for Cleanup Project Managers to Increase the Resilience of Toxic Cleanup Sites to the Impacts from Climate Change (Ecology 2017) and The Washington State Coastal Resiliency Project (Miller et al., 2018). A sediment bed consisting of a 15 cm layer of 1 mm sediment (0 ϕ) was applied to only the ENR areas to assess solely its response to hydrodynamic and wave forces.

Results showcasing the sediment bed response to design storm conditions highlight the limited response of minimal bed erosion or redistribution. Using present day water levels, bed elevation changes may reach up to 3 cm after two days of simulation time but show negligible (less than 1 cm) erosion averaged throughout the ENR areas. Changes to the sediment bed in ENR areas were analyzed with both shoreline scenarios, Case 0 and Case 5. Simulations using the Case 0 shoreline showed minimal erosion, limited to the areas around the pier for both the westerly (Figure 35) and northeasterly (Figure 36) 100-year storm scenarios. The removal of shoreline structures in Case 5 allows for unobstructed flow and waves to propagate through the area. This yields more redistribution of sediment within the ENR areas but still does not exceed more than 3 cm of erosion. Westerly 100-year storms produced minimal erosion anywhere within the region of interest (Figure 37). The more extreme conditions produced by a northeasterly 100-year storm resulted in a larger area of potential redistribution but did not yield erosion greater than 1 cm throughout the ENR areas (Figure 38).

The threat of sea level rise was also included to ensure the success of the remedy over its design life. Two estimates of sea level rise for the years 2050 and 2100 were included to address potential changes in circulation patterns, wave heights, and stability of the ENR remedy.

Estimates of sea level rise for the State of Washington predict an increase in net water levels of 0.121 m by 2050 and 0.369 m by 2100 (Miller, 2018). These values of sea level rise were added to the overall water levels and tidal boundaries used for the combination of storm and shoreline cases discussed in Section 4.2. Results show that while patterns of potential sediment redistribution change, overall maximum erosion depths are not impacted relative to the present-day conditions (Figure 39 through Figure 42). Even in the most extreme storm conditions presented by a 100-year storm and no shadowing due to the pier or jetty, sediment in the ENR areas were relatively stable with an average erosion of less than 1 cm (Figure 42).

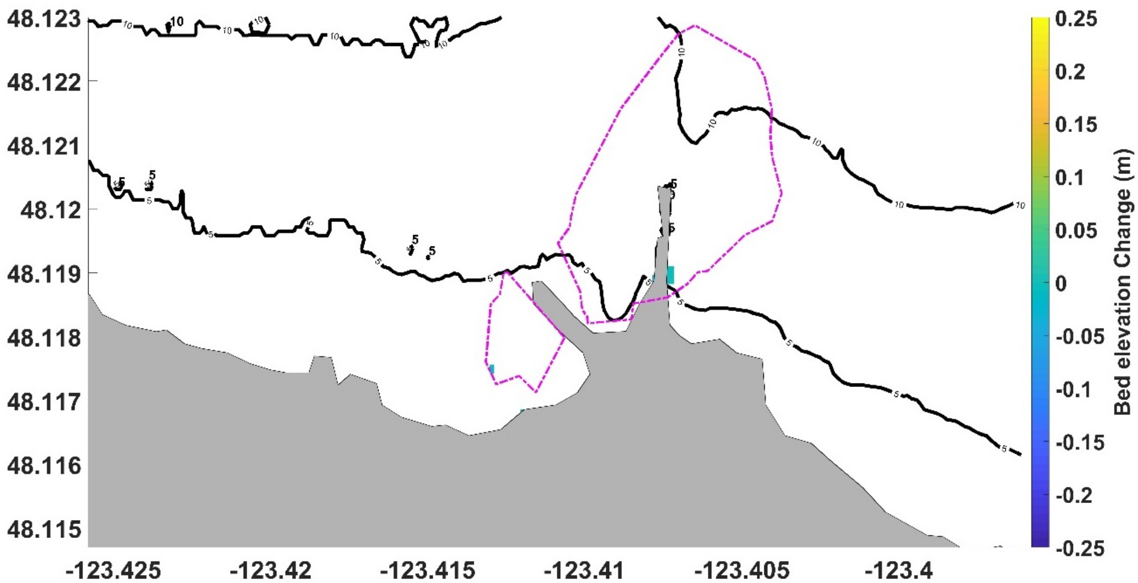

Figure 35. Potential Redistribution of ENR sediment in westerly 100-year storm conditions using Case 0 shoreline

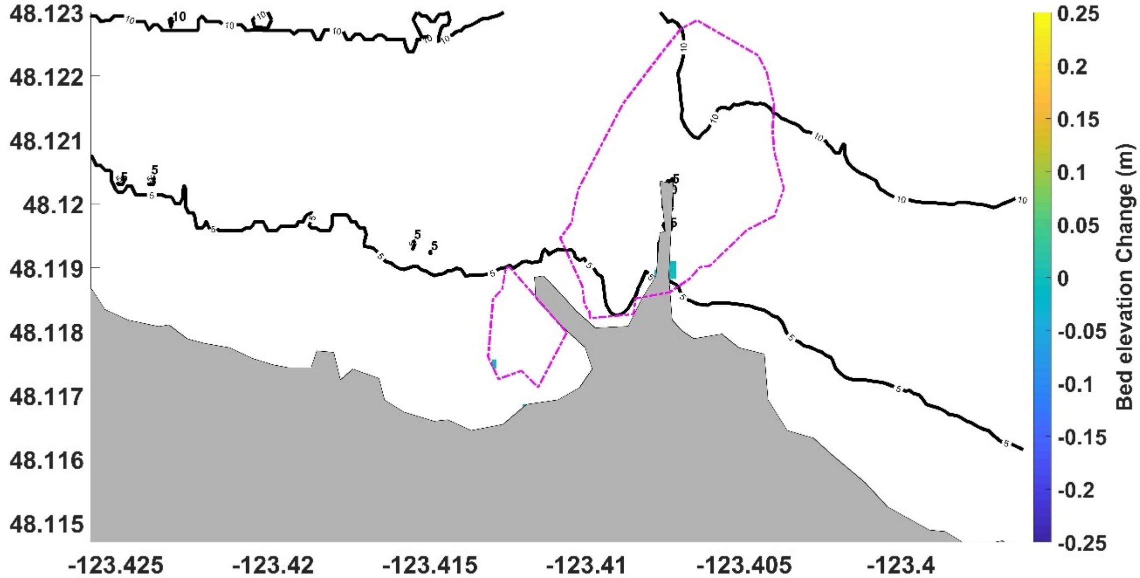

Figure 36.Potential Redistribution of ENR sediment in northeast 100-year storm conditions using Case 0 shoreline

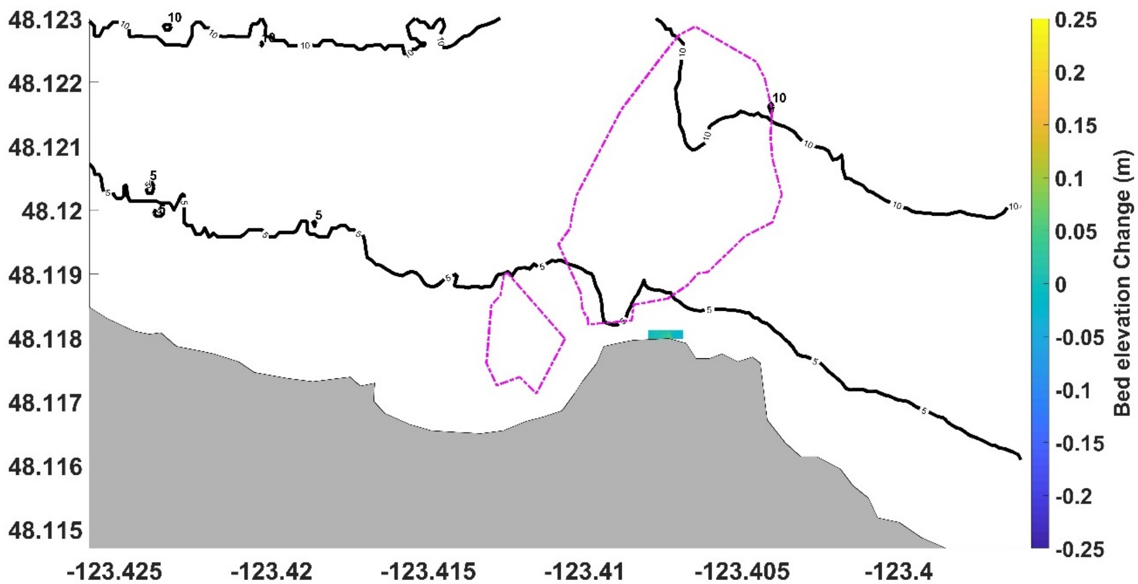

Figure 37. Potential Redistribution of ENR sediment in westerly 100-year storm conditions using Case 5 shoreline

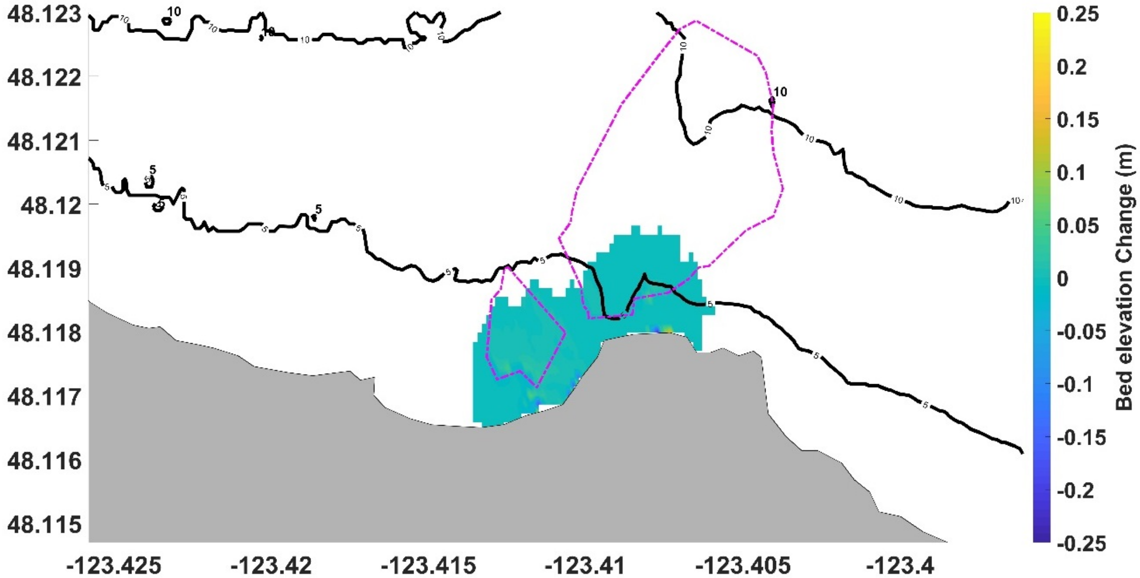

Figure 38. Potential Redistribution of ENR sediment in northeasterly 100-year storm conditions using Case 5 shoreline

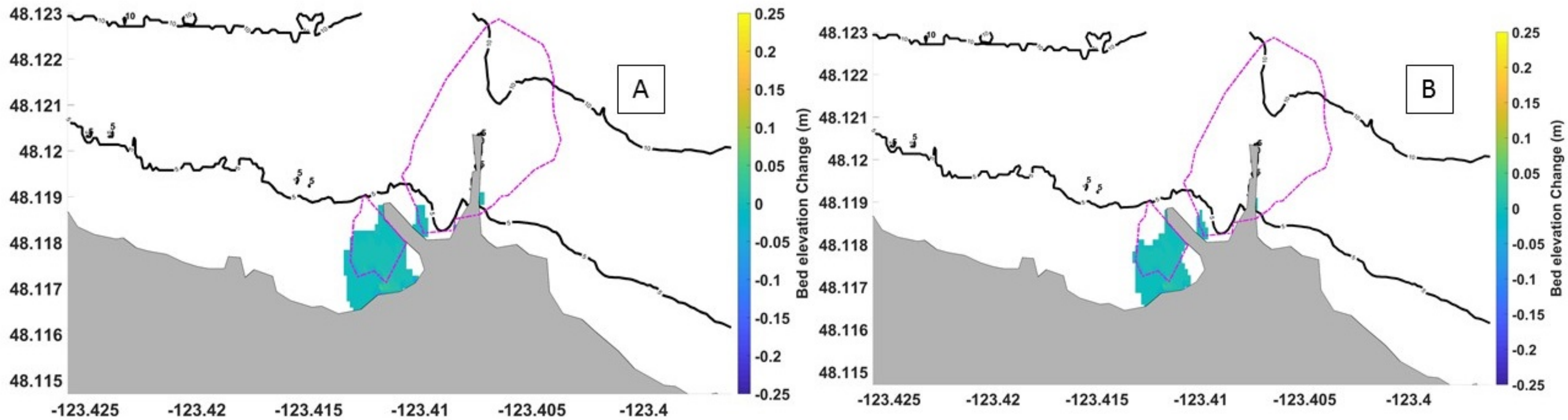

Figure 39. Bed elevation change due to sea level rise scenarios 2050 (A) and 2100 (B) with Case 0 shoreline due to a westerly 100-year storm.

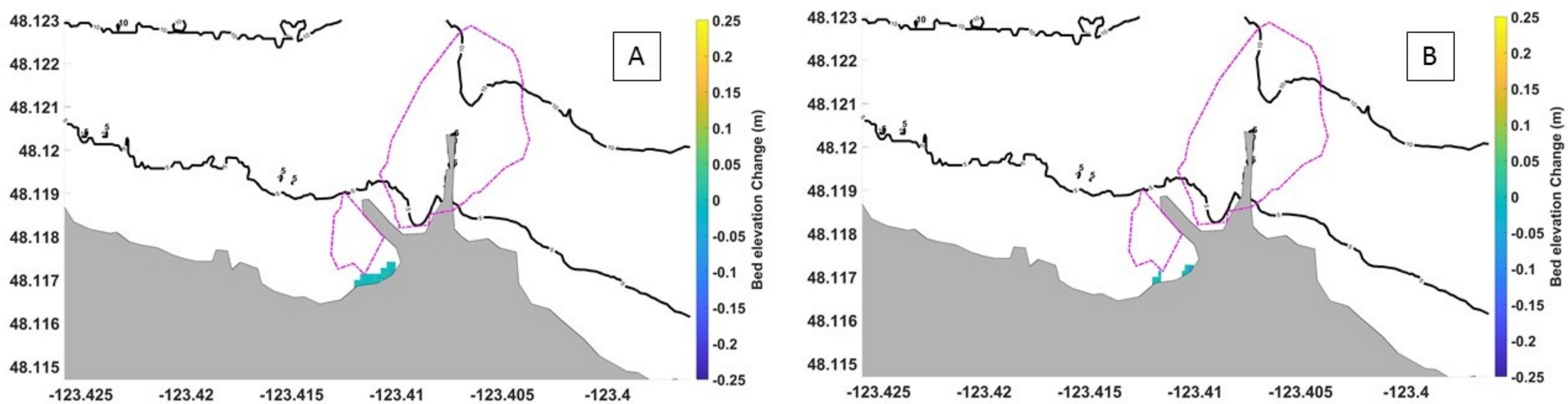

Figure 40. Bed elevation change due to sea level rise scenarios 2050 (A) and 2100 (B) with Case 0 shoreline due to a northeasterly 100-year storm.

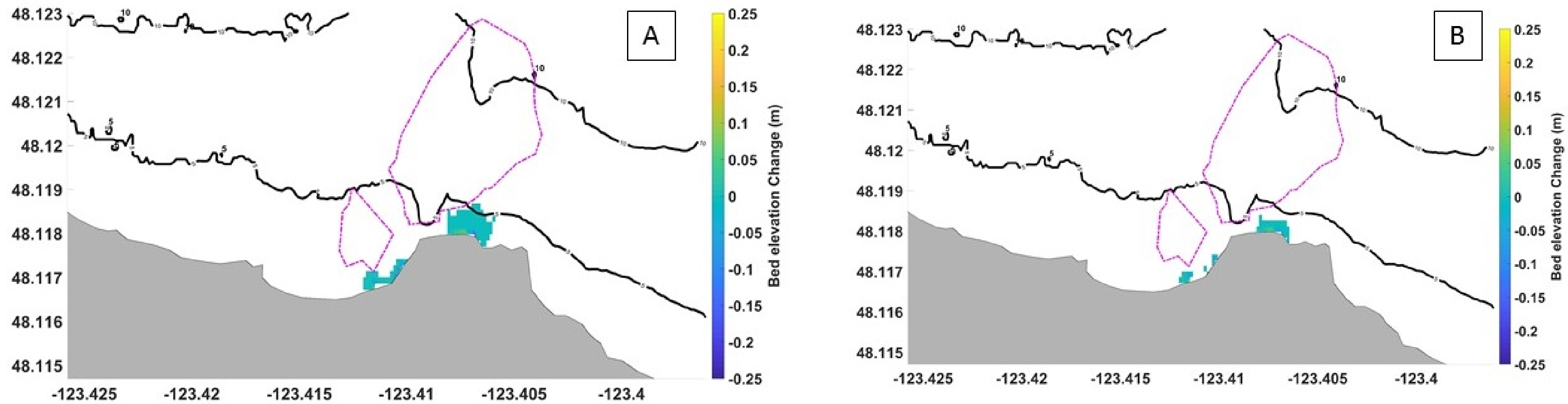

Figure 41. Bed elevation change due to sea level rise scenarios 2050 (A) and 2100 (B) with Case 5 shoreline due to a westerly 100-year storm.

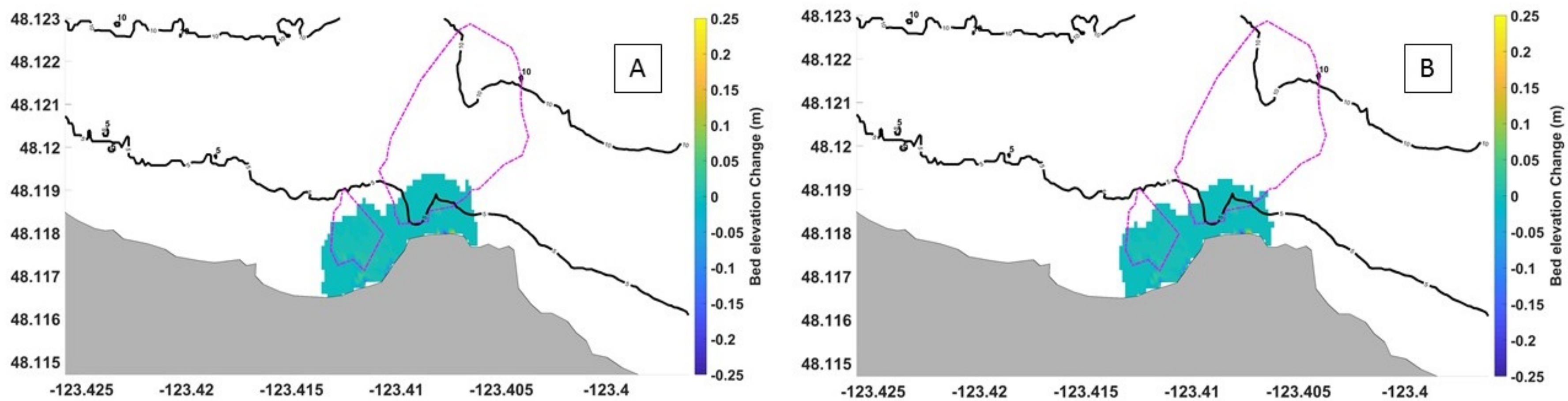

Figure 42. Bed elevation change due to sea level rise scenarios 2050 (A) and 2100 (B) with Case 5 shoreline due to a northeasterly 100-year storm.

6.0 SUMMARY

Hydrographic surveying activities, hydrodynamics field studies, and wave modeling activities were completed in support of the in-water remedial alternatives evaluation in the Port Angeles Harbor environment near the former Rayonier mill. The design of the studies was based on the near-field CSM presented by SEI (Windward 2014).

The site characterization for remedial analysis requires accurate knowledge of the offshore seafloor conditions. To obtain this information, a high-resolution multi-beam hydrographic survey was completed in January 2014 in proximity to the former Rayonier facility in Port Angeles, Washington. The survey was completed around and offshore of the former Rayonier peninsula perimeter to provide surface elevations and to assist with identification of bottom types and debris. The successful survey allowed for an accurate quantification of seafloor elevations and the identifications of features relevant to the remedial analysis.

To characterize the hydrodynamic characteristics in the vicinity of the former Rayonier mill, ADCPs and YSI water quality sondes were deployed on bottom-mounted instrumentation platforms offshore of the former Rayonier mill dock. One platform was deployed in 5 m water depth and the other platform was deployed in 12 m water depth.

Mean transport directions were generally from west to east at the 5 m location and toward the northwest and east at the 12 m platform location. The observed significant wave heights ranged between negligible and 0.75 m during the field study. The observed transport directions and storm wave magnitudes and directions agreed with those previously presented in Windward (2014).

To account for the hydrodynamic forces in the remedial analysis and future design, the propagation of waves and currents due to storms was modeled using a coupled Delft3D-Flow and SWAN model which has the capability of modeling processes important to sediment transport in shallow coastal waters. The models incorporated relevant shoreline cases representative of the present and potential remedial conditions and considered one-in-100-year storm cases from the west and northeast. Sediment parameters representative of the proposed ENR were included to assess the potential for erosion and redistribution of sediment. Results showed that minimal erosion (less than 1 cm) would occur throughout the area during current sea level conditions as well as when considering the effects of sea level rise on the wave and currents.

The results of the calibrated and validated wave and hydrodynamic model illustrate that the proposed ENR remedy is stable (less than 1 cm of erosion) during a 100-year storm event. Additionally, in conditions including sea level rise and increased frequency of 100-year storm events at the site, the ENR remedy would remain stable. Validations of the site wave and current conditions in previous desktop and field studies provide further confidence that the proposed ENR remedy will remain stable for the range of conditions expected at the site.

7.0 REFERENCES

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APPENDIX D

COST ESTIMATES FOR REMEDIAL ALTERNATIVES

Note: Cost estimates prepared in May 2019

COST ESTIMATES OF REMEDIAL ALTERNATIVES

Life-cycle cost estimates for the remedial alternatives for soil, groundwater and sediment for the Rayonier Port Angeles Mill are presented in the following tables. Each alternative is described in detail in the main report.

Cost Estimates Summary

- Table D-1 Soil and Groundwater Remediation Cost Estimates Summary
- Table D-2 Sediment Remediation Cost Estimate Summary

Upland Soil Remediation Alternatives

- Table D-3 Life-Cycle Cost Estimate for Soil Remediation Alternative SL-1
- Table D-4 Life-Cycle Cost Estimate for Soil Remediation Alternative SL-2
- Table D-5 Life-Cycle Cost Estimate for Soil Remediation Alternative SL-3
- Table D-6 Life-Cycle Cost Estimate for Soil Remediation Alternative SL-4
- Table D-7 Life-Cycle Cost Estimate for Soil Remediation Alternative SL-5

Groundwater Remediation Alternatives

- Table D-8 Life-Cycle Cost Estimate for Groundwater Remediation Alternative G-1
- Table D-9 Life-Cycle Cost Estimate for Groundwater Remediation Alternative G-2
- Table D-10 Life-Cycle Cost Estimate for Groundwater Remediation Alternative G-3

Sediment Remediation Alternatives

- Table D-11 Life-Cycle Cost Estimate for Sediment Remediation Alternative S-1
- Table D-12 Life-Cycle Cost Estimate for Sediment Remediation Alternative S-2
- Table D-13 Life-Cycle Cost Estimate for Sediment Remediation Alternative S-3
- Table D-14 Life-Cycle Cost Estimate for Sediment Remediation Alternative S-4
- Table B-15 Life-Cycle Cost Estimate for Sediment Remediation Alternative S-5

Table D-1. Soil and Groundwater Cleanup Cost Estimates Summary

Media	Alternative	Cleanup Alternative Description	Indirect Costs	Capital Costs	Total Initial Costs	O&M Costs[1]	Total Present-Value Life Cycle Cost
Soil	SL-1	Cover	$2,708,922	$7,663,576	$10,372,498	$350,800	$10,723,000
	SL-2	Consolidate and Cover with Remediation Levels	$2,218,712	$5,101,312	$7,320,025	$143,243	$7,463,000
	SL-3	Consolidate and Cover	$2,625,077	$7,373,343	$9,998,419	$143,243	$10,142,000
	SL-4	Excavation with Remediation Levels	$6,900,740	$21,308,332	$28,209,073	$0	$28,209,000
	SL-5	Excavation	$8,909,244	$28,260,843	$37,170,087	$0	$37,170,000
Groundwater	G-1	Sparging (Minimum)	$625,922	$920,498	$1,546,419	$591,782	$2,138,000
	G-1	Sparging (Full)	$1,298,514	$3,716,010	$5,014,524	$699,971	$5,714,000
	G-2	Funnel and Gate with Permeable Reactive Barrier	$5,531,717	$17,867,481	$23,399,198	$1,598,103	$24,997,000
	G-3	In-Situ Chemical Treatment	$7,977,455	$26,506,575	$34,484,030	$442,185	$34,926,000

Notes:

1. O&M costs are net present values calculated to be deferred for 30 years to start in 2018, using a discount rate of 2.3 percent.

Table D-2. Sediment Remediation Cost Estimate Summary

Media	Alternative	Cleanup Alternative Description	Indirect Costs	Capital Costs	Total Initial Costs	O&M Costs[1]	Total Present-Value Life Cycle Cost (Rounded)
Sediment	Alternative S-1	Excavate/dredge log pond intertidal and dock landing and backfill ENR in remainder	$3,047,621	$5,317,921	$8,365,542	$1,587,347	**$9,953,000**
	Alternative S-2	Excavate/dredge Log Pond Intertidal and Dock Landing and Backfill Fill and ENR in Berth, ENR in remainder (Log Pond Subtital, Under Mill Dock, and Mill Dock Subtidal)	$3,060,946	$6,223,574	$9,284,520	$1,587,347	**$10,872,000**
	Alternative S-3	Excavate/dredge Log Pond Intertidal and Dock Landing and Backfill Cap in Log Pond Subtidal Fill and ENR in Berth Dredge under Mill Dock + RML ENR in Mill Dock Subtidal	$3,277,190	$10,605,769	$13,882,959	$1,329,600	**$15,213,000**
	Alternative S-4	Excavate/dredge Entire Log Pond and Dock Landing and Backfill Fill and ENR in Berth, ENR in remainder (Under Mill Dock and Mill Dock Subtidal)	$4,222,278	$12,584,707	$16,806,985	$1,215,523	**$18,023,000**
	Alternative S-5	Excavate/dredge Log Pond Intertidal and Dock Landing and Backfill Dredge rest of the Site + RML	$7,598,993	$46,721,087	$54,320,081	$1,022,534	**$55,343,000**

Notes:

1. Operation and maintenance (O&M) costs are net present values calculated to be deferred for 30 years to start in 2014, using a discount rate of 2.3 percent.
2. Standard Feasibility Study cost estimate assumptions apply. Cost range is -30% to +50% of estimate (based on "*A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* , USEPA 540-R-00-002, July 2000")

Table D-3. Life-Cycle Cost Estimate for Soil Remediation Alternative SL-1

DESCRIPTION	ESTIMATED QUANTITY		COST		SOURCE/ASSUMPTIONS
	Quantity	Units	Unit Cost	Extended Cost	
INDIRECT COSTS					
Pre-Construction Soil Investigation	1	Lump Sum	$250,000	$250,000	Professional Judgment. Refine area requiring cap and soil characterization for disposal if needed.
Remedial Design	$5,676,723	Percent	12%	$681,207	Professional Judgment based on EPA Cost Estimating Guidance, EPA 540-R-00-002
Permitting Coordination/Fees	$5,676,723	Percent	5%	$283,836	Professional Judgment
Contractor Submittals	$5,676,723	Percent	2%	$113,534	Professional Judgment
Construction Management	$5,676,723	Percent	8%	$454,138	Professional Judgment based on EPA Cost Estimating Guidance, EPA 540-R-00-002
Construction Completion Report	1	Lump Sum	$120,000	$120,000	Professional Judgment
Restrictive Covenants Preparation	1	Lump Sum	$75,000	$75,000	Professional Judgment
Project Management	$5,676,723	Percent	10%	$567,672	Professional Judgment based on EPA Cost Estimating Guidance, EPA 540-R-00-002
Ecology Oversight	$5,676,723	Percent	2%	$113,534	Professional Judgment
Contractor Bid Package/Selection	1	Lump Sum	$50,000	$50,000	Professional Judgment
INDIRECT COSTS TOTAL				**$2,708,922**	
CAPITAL COSTS					
Upland Soil--Construction Costs					
Pre-Construction					
Mobilization/Demobilization	1	Lump Sum	$150,000.00	$150,000	Previous Project Experience
Temporary Erosion and Sedimentation Control Measures	33.0	Acre	$5,000.00	$165,000	2013 RS Means Heavy Construction Cost Data
Air and Dust Monitoring	75	Day	$200.00	$15,000	Previous Project Experience
Utility Locate	6	Day	$1,000.00	$6,000	10 hour man-days at $100/hr
Site Survey	33.0	Acre	$2,000.00	$66,000	Previous Project Experience
Abandon Monitoring Wells	20	Each	$500.00	$10,000	Previous Project Experience
Temporary Construction Fence (rented, 6 feet high)	8,000	Linear Foot	$7.65	$61,200	2013 RS Means Heavy Construction Cost Data
Demolish Concrete Pads	10,000	Square Foot	$8.20	$82,000	2013 RS Means Heavy Construction Cost Data
Dispose of Demolition Debris	741	Cubic Yard	$18.80	$13,926	2013 RS Means Heavy Construction Cost Data
Excavation					
Shallow Soil Excavation (1' depth)	12,423	Cubic Yard	$12.00	$149,072	Previous experience; 1' depth + 10%
Deep Soil Excavation (>1' depth)	8,873	Cubic Yard	$12.00	$106,480	Previous experience; 10' avg depth + 10%
Archeological Monitoring	40	Day	$1,000.00	$40,000	Previous Project Experience: 1 archeological monitor on site full time during excavation
Purchase, Place, and Compact Backfill (granular aggregate)	21,296	Cubic Yard	$25.00	$532,400	Assume full volume of excavation; to be updated in restoration plan
Placement in Consolidation Area					
Transportation to Consolidation Area	31,944	Ton		$0	Included in Excavation cost
Place excavated material	21,296	Cubic Yard	$18.00	$383,328	Project experience

Table D-3. Life-Cycle Cost Estimate for Soil Remediation Alternative SL-1

DESCRIPTION	ESTIMATED QUANTITY		COST		SOURCE/ASSUMPTIONS
	Quantity	Units	Unit Cost	Extended Cost	
Cover					
Rough Grading for Cap	116,160	Square Yard	$1.20	$139,392	Previous Project Experience
Procure and Install Geotextile	1,045,440	Square Foot	$0.35	$365,904	Project experience
Purchase, Place, and Compact Backfill (granular aggregate)	38,720	Cubic Yard	$30.00	$1,161,600	Previous Project Experience. Assume graded and compacted.
Procure and Place Topsoil	38,720	Cubic Yard	$35.00	$1,355,200	Previous Project Experience, Assume an average 1 foot thickness over the footprint graded
Hydroseeding	116,160	Square Yard	$2.13	$247,421	Previous Project Experience
Stormwater Management					
Stormwater Improvements	1	Lump Sum	$50,000.00	$50,000	Previous Project Experience. Assume a network of drainage piping and catch basins for collection and routing of stormwater.
Stormwater Collection, Treatment and Disposal	1	Lump Sum	$100,000.00	$100,000	Previous Project Experience. For collection and management of stormwater from disturbed area during construction.
Other					
Permanent Fence (for restricting access)	6,000	Linear Foot	$43.50	$261,000	2013 RS Means Heavy Construction Cost Data, West Mill and City Purchase Area
Permanent Gates (8 feet high, 12 feet wide)	8	Each	$1,850.00	$14,800	2013 RS Means Heavy Construction Cost Data, West Mill and City Purchase Area
Site Survey (post-remediation)	50.0	Acre	$2,500.00	$125,000	Previous Project Experience
Establishment Period	24.0	Acre	$3,000.00	$72,000	Previous Project Experience
Signs	4	Lump Sum	$1,000.00	$4,000	Previous Project Experience
CONSTRUCTION DIRECT COSTS TOTAL				**$5,676,723**	
Bid Contingency	15%			$851,508	
Scope Contingency	20%			$1,135,345	
CAPITAL COSTS SUBTOTAL				**$7,663,576**	
TOTAL CAPITAL COSTS (Direct and Indirect)				**$10,372,498**	
OPERATION AND MAINTENANCE COSTS					
Soil - Capped Area					
- Cap Monitoring					
Annual Cap Monitoring, Maintenance, and Reporting	24.0	Acre	$ 1,500	$36,000	Previous project experience
UNDISCOUNTED SUBTOTAL				$396,000	
TOTAL NET PRESENT VALUE OF O&M COSTS (30 YEARS)				$313,214	
Indirect O&M Costs (PM, Ecology Oversight)			12%	*$37,586*	
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				**$10,723,000**	

Notes:

(1) Present worth calculated using equal series present worth analysis where i = 2.3%

(2) Based on annual operation and maintenance costs listed above. Cap monitoring, maintenance, and reporting: years 1, 2, 3, 4, 6, 8, 10, 15, 20, 25, and 30.

Table D-4. Life-Cycle Cost Estimate for Soil Remediation Alternative SL-2

DESCRIPTION	ESTIMATED QUANTITY		COST		SOURCE/ASSUMPTIONS
	Quantity	Units	Unit Cost	Extended Cost	
INDIRECT COSTS					
Pre-Construction Soil Investigation	1	Lump Sum	$500,000	$500,000	Professional Judgment. Refine area requiring cap and soil characterization for disposal if needed.
Remedial Design	$3,778,750	Percent	12%	$453,450	Professional Judgment based on EPA Cost Estimating Guidance, EPA 540-R-00-002
Permitting Coordination/Fees	$3,778,750	Percent	5%	$188,937	Professional Judgment
Contractor Submittals	$3,778,750	Percent	2%	$75,575	Professional Judgment
Construction Management	$3,778,750	Percent	8%	$302,300	Professional Judgment based on EPA Cost Estimating Guidance, EPA 540-R-00-002
Construction Completion Report	1	Lump Sum	$120,000	$120,000	Professional Judgment
Restrictive Covenants Preparation	1	Lump Sum	$75,000	$75,000	Professional Judgment
Project Management	$3,778,750	Percent	10%	$377,875	Professional Judgment based on EPA Cost Estimating Guidance, EPA 540-R-00-002
Ecology Oversight	$3,778,750	Percent	2%	$75,575	Professional Judgment
Contractor Bid Package/Selection	1	Lump Sum	$50,000	$50,000	Professional Judgment
INDIRECT COSTS TOTAL				**$2,218,712**	
CAPITAL COSTS					
Upland Soil--Construction Costs					
West Mill, Ennis Creek, East Mill, and City Purchase Areas					
Pre-Construction					
Mobilization/Demobilization	1	Lump Sum	$150,000.00	$150,000	Previous Project Experience
Temporary Erosion and Sedimentation Control Measures	20.5	Acre	$5,000.00	$102,500	2013 RS Means Heavy Construction Cost Data
Air and Dust Monitoring	50	Day	$200.00	$10,000	Previous Project Experience
Utility Locate	6	Day	$1,000.00	$6,000	10 hour man-days at $100/hr
Site Survey	20.5	Acre	$2,000.00	$41,000	Previous Project Experience
Abandon Monitoring Wells	20	Each	$500.00	$10,000	Previous Project Experience
Temporary Construction Fence (rented, 6 feet high)	6,000	Linear Foot	$7.65	$45,900	2013 RS Means Heavy Construction Cost Data
Demolish Concrete Pads	10,000	Square Foot	$8.20	$82,000	2013 RS Means Heavy Construction Cost Data
Dispose of Demolition Debris	741	Cubic Yard	$18.80	$13,926	2013 RS Means Heavy Construction Cost Data
Excavation					
Shallow Soil Excavation (1' depth)	18,102	Cubic Yard	$12.00	$217,219	Previous experience; 1' depth + 10%
Deep Soil Excavation (>1' depth)	8,873	Cubic Yard	$12.00	$106,480	Previous experience; 10' avg depth + 10%
Archeological Monitoring	50	Day	$1,000.00	$50,000	Previous Project Experience: 1 archeological monitor on site full time during excavation
Purchase, Place, and Compact Backfill (granular aggregate)	26,975	Cubic Yard	$25.00	$674,373	Assume full volume of excavation; to be updated in restoration plan
Placement in Consolidation Area					
Transportation to Consolidation Area	40,462	Ton		$0	Included in Excavation cost
Place excavated material	26,975	Cubic Yard	$18.00	$485,549	Project experience

Table D-4. Life-Cycle Cost Estimate for Soil Remediation Alternative SL-2

DESCRIPTION	ESTIMATED QUANTITY		COST		SOURCE/ASSUMPTIONS
	Quantity	Units	Unit Cost	Extended Cost	
Cover					
Rough Grading for Cap	47,432	Square Yard	$1.20	$56,918	Previous Project Experience
Procure and Install Geotextile	426,888	Square Foot	$0.35	$149,411	Project experience
Purchase, Place, and Compact Backfill (granular aggregate)	15,811	Cubic Yard	$30.00	$474,320	Previous Project Experience. Assume graded and compacted.
Procure and Place Topsoil	15,811	Cubic Yard	$35.00	$553,373	Previous Project Experience, Assume an average 1 foot thickness over the footprint graded
Hydroseeding	47,432	Square Yard	$2.13	$101,030	Previous Project Experience
Stormwater Management					
Stormwater Improvements	1	Lump Sum	$50,000.00	$50,000	Previous Project Experience. Assume a network of drainage piping and catch basins for collection and routing of stormwater.
Stormwater Collection, Treatment and Disposal	1	Lump Sum	$100,000.00	$100,000	Previous Project Experience. For collection and management of stormwater from disturbed area during construction.
Other					
Permanent Fence (for restricting access)	3,000	Linear Foot	$43.50	$130,500	2013 RS Means Heavy Construction Cost Data, West Mill and City Purchase Area
Permanent Gates (8 feet high, 12 feet wide)	5	Each	$1,850.00	$9,250	2013 RS Means Heavy Construction Cost Data, West Mill and City Purchase Area
Site Survey (post-remediation)	50.0	Acre	$2,500.00	$125,000	Previous Project Experience
Establishment Period	10.0	Acre	$3,000.00	$30,000	Previous Project Experience
Signs	4	Lump Sum	$1,000.00	$4,000	Previous Project Experience
CONSTRUCTION DIRECT COSTS TOTAL				**$3,778,750**	
Bid Contingency	15%			$566,812	
Scope Contingency	20%			$755,750	
CAPITAL COSTS SUBTOTAL				**$5,101,312**	
TOTAL CAPITAL COSTS (Direct and Indirect)				**$7,320,025**	
OPERATION AND MAINTENANCE COSTS					
Soil - Capped Area					
- Cap Monitoring					
Annual Cap Monitoring, Maintenance, and Reporting	9.8	Acre	$ 1,500	$14,700	Previous project experience
UNDISCOUNTED SUBTOTAL				$161,700	
TOTAL NET PRESENT VALUE OF O&M COSTS (30 YEARS)				$127,896	
Indirect O&M Costs (PM, Ecology Oversight)			12%	*$15,347*	
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				**$7,463,000**	

Notes:

(1) Present worth calculated using equal series present worth analysis where i = 2.3%

(2) Based on annual operation and maintenance costs listed above. Cap monitoring, maintenance, and reporting: years 1, 2, 3, 4, 6, 8, 10, 15, 20, 25, and 30.

Table D-5. Life-Cycle Cost Estimate for Soil Remediation Alternative SL-3

DESCRIPTION	ESTIMATED QUANTITY		COST		SOURCE/ASSUMPTIONS
	Quantity	Units	Unit Cost	Extended Cost	
INDIRECT COSTS					
Pre-Construction Soil Investigation	1	Lump Sum	$250,000	$250,000	Professional Judgment. Refine area requiring cap and soil characterization for disposal if needed.
Remedial Design	$5,461,735	Percent	12%	$655,408	Professional Judgment based on EPA Cost Estimating Guidance, EPA 540-R-00-002
Permitting Coordination/Fees	$5,461,735	Percent	5%	$273,087	Professional Judgment
Contractor Submittals	$5,461,735	Percent	2%	$109,235	Professional Judgment
Construction Management	$5,461,735	Percent	8%	$436,939	Professional Judgment based on EPA Cost Estimating Guidance, EPA 540-R-00-002
Construction Completion Report	1	Lump Sum	$120,000	$120,000	Professional Judgment
Restrictive Covenants Preparation	1	Lump Sum	$75,000	$75,000	Professional Judgment
Project Management	$5,461,735	Percent	10%	$546,174	Professional Judgment based on EPA Cost Estimating Guidance, EPA 540-R-00-002
Ecology Oversight	$5,461,735	Percent	2%	$109,235	Professional Judgment
Contractor Bid Package/Selection	1	Lump Sum	$50,000	$50,000	Professional Judgment
INDIRECT COSTS TOTAL				**$2,625,077**	
CAPITAL COSTS					
Upland Soil--Construction Costs					
West Mill, Ennis Creek, East Mill, and City Purchase Areas					
Pre-Construction					
Mobilization/Demobilization	1	Lump Sum	$150,000.00	$150,000	Previous Project Experience
Temporary Erosion and Sedimentation Control Measures	33.0	Acre	$5,000.00	$165,000	2013 RS Means Heavy Construction Cost Data
Air and Dust Monitoring	80	Day	$200.00	$16,000	Previous Project Experience
Utility Locate	8	Day	$1,000.00	$8,000	10 hour man-days at $100/hr
Site Survey	33.0	Acre	$2,000.00	$66,000	Previous Project Experience
Abandon Monitoring Wells	20	Each	$500.00	$10,000	Previous Project Experience
Temporary Construction Fence (rented, 6 feet high)	8,000	Linear Foot	$7.65	$61,200	2013 RS Means Heavy Construction Cost Data
Demolish Concrete Pads	10,000	Square Foot	$8.20	$82,000	2013 RS Means Heavy Construction Cost Data
Dispose of Demolition Debris	741	Cubic Yard	$18.80	$13,926	2013 RS Means Heavy Construction Cost Data
Excavation					
Shallow Soil Excavation (1' depth)	37,268	Cubic Yard	$12.00	$447,216	Previous experience; 1' depth + 10%
Deep Soil Excavation (>1' depth)	17,747	Cubic Yard	$12.00	$212,960	Previous experience; 10' avg depth + 10%
Archeological Monitoring	80	Day	$1,000.00	$80,000	Previous Project Experience: 1 archeological monitor on site full time during excavation
Purchase, Place, and Compact Backfill (granular aggregate)	55,015	Cubic Yard	$25.00	$1,375,367	Assume full volume of excavation; to be updated in restoration plan
Placement in Consolidation Area					
Transportation to Consolidation Area	82,522	Ton		$0	Included in Excavation cost
Place excavated material	55,015	Cubic Yard	$18.00	$990,264	Project experience

Table D-5. Life-Cycle Cost Estimate for Soil Remediation Alternative SL-3

DESCRIPTION	ESTIMATED QUANTITY		COST		SOURCE/ASSUMPTIONS
	Quantity	Units	Unit Cost	Extended Cost	
Cover					
Rough Grading for Cap	47,432	Square Yard	$1.20	$56,918	Previous Project Experience
Procure and Install Geotextile	426,888	Square Foot	$0.35	$149,411	Project experience
Purchase, Place, and Compact Backfill (granular aggregate)	15,811	Cubic Yard	$30.00	$474,320	Previous Project Experience. Assume graded and compacted.
Procure and Place Topsoil	15,811	Cubic Yard	$35.00	$553,373	Previous Project Experience, Assume an average 1 foot thickness over the footprint graded
Hydroseeding	47,432	Square Yard	$2.13	$101,030	Previous Project Experience
Stormwater Management					
Stormwater Improvements	1	Lump Sum	$50,000.00	$50,000	Previous Project Experience. Assume a network of drainage piping and catch basins for collection and routing of stormwater.
Stormwater Collection, Treatment and Disposal	1	Lump Sum	$100,000.00	$100,000	Previous Project Experience. For collection and management of stormwater from disturbed area during construction.
Other					
Permanent Fence (for restricting access)	3,000	Linear Foot	$43.50	$130,500	2013 RS Means Heavy Construction Cost Data, West Mill and City Purchase Area
Permanent Gates (8 feet high, 12 feet wide)	5	Each	$1,850.00	$9,250	2013 RS Means Heavy Construction Cost Data, West Mill and City Purchase Area
Site Survey (post-remediation)	50.0	Acre	$2,500.00	$125,000	Previous Project Experience
Establishment Period	10.0	Acre	$3,000.00	$30,000	Previous Project Experience
Signs	4	Lump Sum	$1,000.00	$4,000	Previous Project Experience
CONSTRUCTION DIRECT COSTS TOTAL				**$5,461,735**	
Bid Contingency	15%			$819,260	
Scope Contingency	20%			$1,092,347	
CAPITAL COSTS SUBTOTAL				**$7,373,343**	
TOTAL CAPITAL COSTS (Direct and Indirect)				**$9,998,419**	
OPERATION AND MAINTENANCE COSTS					
Soil - Capped Area					
- Cap Monitoring					
Annual Cap Monitoring, Maintenance, and Reporting	9.8	Acre	$ 1,500	$14,700	Previous project experience
UNDISCOUNTED SUBTOTAL				$161,700	
TOTAL NET PRESENT VALUE OF O&M COSTS (30 YEARS)				$127,896	
Indirect O&M Costs (PM, Ecology Oversight)			12%	*$15,347*	
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				**$10,142,000**	

Notes:

(1) Present worth calculated using equal series present worth analysis where i = 2.3%

(2) Based on annual operation and maintenance costs listed above. Cap monitoring, maintenance, and reporting: years 1, 2, 3, 4, 6, 8, 10, 15, 20, 25, and 30.

Table D-6. Life-Cycle Cost Estimate for Soil Remediation Alternative SL-4

DESCRIPTION	ESTIMATED QUANTITY		COST		SOURCE/ASSUMPTIONS
	Quantity	Units	Unit Cost	Extended Cost	
INDIRECT COSTS					
Pre-Construction Soil Investigation	1	Lump Sum	$500,000	$500,000	Professional Judgment. Refine area requiring cap and soil characterization for disposal if needed.
Remedial Design	$15,783,950	Percent	12%	$1,894,074	Professional Judgment based on EPA Cost Estimating Guidance, EPA 540-R-00-002
Permitting Coordination/Fees	$15,783,950	Percent	5%	$789,197	Professional Judgment
Contractor Submittals	$15,783,950	Percent	2%	$315,679	Professional Judgment
Construction Management	$15,783,950	Percent	8%	$1,262,716	Professional Judgment based on EPA Cost Estimating Guidance, EPA 540-R-00-002
Construction Completion Report	1	Lump Sum	$120,000	$120,000	Professional Judgment
Restrictive Covenants Preparation	1	Lump Sum	$75,000	$75,000	Professional Judgment
Project Management	$15,783,950	Percent	10%	$1,578,395	Professional Judgment based on EPA Cost Estimating Guidance, EPA 540-R-00-002
Ecology Oversight	$15,783,950	Percent	2%	$315,679	Professional Judgment
Contractor Bid Package/Selection	1	Lump Sum	$50,000	$50,000	Professional Judgment
INDIRECT COSTS TOTAL				**$6,900,740**	
CAPITAL COSTS					
Upland Soil--Construction Costs					
West Mill, Ennis Creek, East Mill, and City Purchase Areas					
Pre-Construction					
Mobilization/Demobilization	1	Lump Sum	$150,000.00	$150,000	Previous Project Experience
Temporary Erosion and Sedimentation Control Measures	20.5	Acre	$5,000.00	$102,500	2013 RS Means Heavy Construction Cost Data
Air and Dust Monitoring	40	Day	$200.00	$8,000	Previous Project Experience
Utility Locate	6	Day	$1,000.00	$6,000	10 hour man-days at $100/hr
Site Survey	20.5	Acre	$2,000.00	$41,000	Previous Project Experience
Abandon Monitoring Wells	20	Each	$500.00	$10,000	Previous Project Experience
Temporary Construction Fence (rented, 6 feet high)	6,000	Linear Foot	$7.65	$45,900	2013 RS Means Heavy Construction Cost Data
Demolish Concrete Pads	10,000	Square Foot	$8.20	$82,000	2013 RS Means Heavy Construction Cost Data
Dispose of Demolition Debris	741	Cubic Yard	$18.80	$13,926	2013 RS Means Heavy Construction Cost Data
Excavation					
Shallow Soil Excavation (1' depth)	24,845	Cubic Yard	$12.00	$298,144	Previous experience; 1' depth + 10%
Deep Soil Excavation (>1' depth)	70,987	Cubic Yard	$12.00	$851,840	Previous experience; 10' avg depth + 10%
Archeological Monitoring	40	Day	$1,000.00	$40,000	Previous Project Experience: 1 archeological monitor on site full time during excavation
Purchase, Place, and Compact Backfill (granular aggregate)	95,832	Cubic Yard	$25.00	$2,395,800	Assume full volume of excavation; to be updated in restoration plan
Disposal					
Transportation to Disposal Facility (Truck)	143,748	Ton	$40.00	$5,749,920	Previous Project Experience, assume unit weight factor of 1.5 tons/cy
Soil Disposal (Subtitle D Landfill)	143,748	Ton	$40.00	$5,749,920	Previous Project Experience, assume soil is contaminated but non-hazardous; assume unit weight factor of 1.5 tons/cy

Table D-6. Life-Cycle Cost Estimate for Soil Remediation Alternative SL-4

DESCRIPTION	ESTIMATED QUANTITY		COST		SOURCE/ASSUMPTIONS
	Quantity	Units	Unit Cost	Extended Cost	
Stormwater Management					
Stormwater Improvements	1	Lump Sum	$10,000.00	$10,000	#NAME?
Stormwater Collection, Treatment and Disposal	1	Lump Sum	$100,000.00	$100,000	Previous Project Experience. For collection and management of stormwater from disturbed area during construction.
Other					
Permanent Fence (for restricting access)		Linear Foot	$43.50	$0	2013 RS Means Heavy Construction Cost Data, West Mill and City Purchase Area
Permanent Gates (8 feet high, 12 feet wide)		Each	$1,850.00	$0	2013 RS Means Heavy Construction Cost Data, West Mill and City Purchase Area
Site Survey (post-remediation)	50.0	Acre	$2,500.00	$125,000	Previous Project Experience
Establishment Period		Acre	$3,000.00	$0	Previous Project Experience
Signs	4	Lump Sum	$1,000.00	$4,000	Previous Project Experience
CONSTRUCTION DIRECT COSTS TOTAL				**$15,783,950**	
Bid Contingency	15%			$2,367,592	
Scope Contingency	20%			$3,156,790	
CAPITAL COSTS SUBTOTAL				**$21,308,332**	
TOTAL CAPITAL COSTS (Direct and Indirect)				**$28,209,073**	
OPERATION AND MAINTENANCE COSTS					
Soil - Capped Area					
- Cap Monitoring					
Annual Cap Monitoring, Maintenance, and Reporting		Acre	$ 1,500	$0	Previous project experience
UNDISCOUNTED SUBTOTAL				$0	
TOTAL NET PRESENT VALUE OF O&M COSTS (30 YEARS)				$0	
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				**$28,209,000**	

Notes:
(1) Present worth calculated using equal series present worth analysis where i = 2.3%
(2) Based on annual operation and maintenance costs listed above. Cap monitoring, maintenance, and reporting: years 1, 2, 3, 4, 6, 8, 10, 15, 20, 25, and 30.

Table D-7. Life-Cycle Cost Estimate for Soil Remediation Alternative SL-5

DESCRIPTION	ESTIMATED QUANTITY		COST		SOURCE/ASSUMPTIONS
	Quantity	Units	Unit Cost	Extended Cost	
INDIRECT COSTS					
Pre-Construction Soil Investigation	1	Lump Sum	$500,000	$500,000	Professional Judgment. Refine area requiring cap and soil characterization for disposal if needed.
Remedial Design	$20,933,958	Percent	12%	$2,512,075	Professional Judgment based on EPA Cost Estimating Guidance, EPA 540-R-00-002
Permitting Coordination/Fees	$20,933,958	Percent	5%	$1,046,698	Professional Judgment
Contractor Submittals	$20,933,958	Percent	2%	$418,679	Professional Judgment
Construction Management	$20,933,958	Percent	8%	$1,674,717	Professional Judgment based on EPA Cost Estimating Guidance, EPA 540-R-00-002
Construction Completion Report	1	Lump Sum	$120,000	$120,000	Professional Judgment
Restrictive Covenants Preparation	1	Lump Sum	$75,000	$75,000	Professional Judgment
Project Management	$20,933,958	Percent	10%	$2,093,396	Professional Judgment based on EPA Cost Estimating Guidance, EPA 540-R-00-002
Ecology Oversight	$20,933,958	Percent	2%	$418,679	Professional Judgment
Contractor Bid Package/Selection	1	Lump Sum	$50,000	$50,000	Professional Judgment
INDIRECT COSTS TOTAL				**$8,909,244**	
CAPITAL COSTS					
Upland Soil--Construction Costs					
West Mill, Ennis Creek, East Mill, and City Purchase Areas					
Pre-Construction					
Mobilization/Demobilization	1	Lump Sum	$150,000.00	$150,000	Previous Project Experience
Temporary Erosion and Sedimentation Control Measures	33.0	Acre	$5,000.00	$165,000	2013 RS Means Heavy Construction Cost Data
Air and Dust Monitoring	70	Day	$200.00	$14,000	Previous Project Experience
Utility Locate	6	Day	$1,000.00	$6,000	10 hour man-days at $100/hr
Site Survey	33.0	Acre	$2,000.00	$66,000	Previous Project Experience
Abandon Monitoring Wells	20	Each	$500.00	$10,000	Previous Project Experience
Temporary Construction Fence (rented, 6 feet high)	8,000	Linear Foot	$7.65	$61,200	2013 RS Means Heavy Construction Cost Data
Demolish Concrete Pads	10,000	Square Foot	$8.20	$82,000	2013 RS Means Heavy Construction Cost Data
Dispose of Demolition Debris	741	Cubic Yard	$18.80	$13,926	2013 RS Means Heavy Construction Cost Data
Excavation					
Shallow Soil Excavation (1' depth)	47,916	Cubic Yard	$12.00	$574,992	Previous experience; 1' depth + 10%
Deep Soil Excavation (>1' depth)	79,860	Cubic Yard	$12.00	$958,320	Previous experience; 10' avg depth + 10%
Archeological Monitoring	70	Day	$1,000.00	$70,000	Previous Project Experience: 1 archeological monitor on site full time during excavation
Purchase, Place, and Compact Backfill (granular aggregate)	127,776	Cubic Yard	$25.00	$3,194,400	Assume full volume of excavation; to be updated in restoration plan
Disposal					
Transportation to Disposal Facility (Truck)	191,664	Ton	$40.00	$7,666,560	Previous Project Experience, assume unit weight factor of 1.5 tons/cy
Soil Disposal (Subtitle D Landfill)	191,664	Ton	$40.00	$7,666,560	Previous Project Experience, assume soil is contaminated but non-hazardous; assume unit weight factor of 1.5 tons/cy

Table D-7. Life-Cycle Cost Estimate for Soil Remediation Alternative SL-5

DESCRIPTION	ESTIMATED QUANTITY		COST		SOURCE/ASSUMPTIONS
	Quantity	Units	Unit Cost	Extended Cost	
Stormwater Management					
Stormwater Improvements	1	Lump Sum	$10,000.00	$10,000	#NAME?
Stormwater Collection, Treatment and Disposal	1	Lump Sum	$100,000.00	$100,000	Previous Project Experience. For collection and management of stormwater from disturbed area during construction.
Other					
Permanent Fence (for restricting access)		Linear Foot	$43.50	$0	2013 RS Means Heavy Construction Cost Data, West Mill and City Purchase Area
Permanent Gates (8 feet high, 12 feet wide)		Each	$1,850.00	$0	2013 RS Means Heavy Construction Cost Data, West Mill and City Purchase Area
Site Survey (post-remediation)	50.0	Acre	$2,500.00	$125,000	Previous Project Experience
Establishment Period		Acre	$3,000.00	$0	Previous Project Experience
Signs		Lump Sum	$1,000.00	$0	Previous Project Experience
CONSTRUCTION DIRECT COSTS TOTAL				**$20,933,958**	
Bid Contingency	15%			$3,140,094	
Scope Contingency	20%			$4,186,792	
CAPITAL COSTS SUBTOTAL				**$28,260,843**	
TOTAL CAPITAL COSTS (Direct and Indirect)				**$37,170,087**	
OPERATION AND MAINTENANCE COSTS					
Soil - Capped Area					
- Cap Monitoring					
Annual Cap Monitoring, Maintenance, and Reporting		Acre	$ 1,500	$0	Previous project experience
UNDISCOUNTED SUBTOTAL				$0	
TOTAL NET PRESENT VALUE OF O&M COSTS (30 YEARS)				$0	
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				**$37,170,000**	

Notes:

(1) Present worth calculated using equal series present worth analysis where i = 2.3%

(2) Based on annual operation and maintenance costs listed above. Cap monitoring, maintenance, and reporting: years 1, 2, 3, 4, 6, 8, 10, 15, 20, 25, and 30.

Table D-8a. Life-Cycle Cost Estimate for Groundwater Remediation Alternative G-1 (Sparging) -- MINIMUM

DESCRIPTION	QUANTITY		COST		NOTES
	Number	Unit	Unit Cost	Total Cost	
INDIRECT COSTS					
Pre-Design GW Investgation	1	Lump Sum	$300,000	$300,000	
Remedial Design	$681,850	Percent	12%	$81,822	EPA Cost Estimating Guidance, 2000
Permitting Coordination/Fees	$681,850	Percent	5%	$34,093	included as a 5 percent allowance on the construction subtotal
Contractor Submittals	$681,850	Percent	2%	$13,637	included as a 10 percent (aggregate) allowance on the construction subtotal
Construction Management	$681,850	Percent	8%	$54,548	
Construction Completion Report	1	Lump Sum	$60,000	$60,000	
Project Management	$681,850	Percent	10%	$68,185	EPA Cost Estimating Guidance, 2000
Ecology Oversight	$681,850	Percent	2%	$13,637	included as a 2 percent allowance on the construction subtotal
INDIRECT COSTS TOTAL				**$625,922**	
CAPITAL COSTS					
Upland Groundwater--Construction Costs					
Pre-Construction					
Utility Locate	1	Day	$1,000.00	$1,000	One 10 hour man-day at $100/hr; Previous Project Experience
Detailed Utility Locate	1	Day	$2,000.00	$1,000	
Site Survey	1.00	Acre	$2,000.00	$2,000	
Install Monitoring Wells	5	Each	$5,000.00	$25,000	Previous Project Experience
Abandon Monitoring Wells	5	Each	$500.00	$2,500	Estimate
Air and Dust Monitoring	5	Day	$200.00	$1,000	
Air Sparging					
Pilot Test	1	Lump Sum	$45,000.00	$45,000	For radius of influence; potential use of CO2
Install Wells	8	Each	$5,000.00	$40,000	Includes well vaults & development
Install System	1	Each	$100,000.00	$80,000	Average 15 shallow wells each; Includes piping, fittings, electricity, blowers. Assume reuse of equipment where cost-effective.
Assumed length of operation	36	Months			
Operation - Power	36	Months	$4,000.00	$144,000	Assume continuous operation
Operation - Labor	2,880	hr	$110.00	$316,800	Half FTE senior technician/operator, includes operator PM
Maintenance equipment & misc.	157	Wk	$150.00	$23,550	Maintenance supplies; rebound testing
CONSTRUCTION DIRECT COSTS TOTAL				**$681,850**	
Bid Contingency	$681,850		15%	$102,278	
Scope Contingency	$681,850		20%	$136,370	
CAPITAL COSTS SUBTOTAL				**$920,498**	
TOTAL CAPITAL COSTS (Direct and Indirect)				**$1,546,419**	

Table D-8a. Life-Cycle Cost Estimate for Groundwater Remediation Alternative G-1 (Sparging) -- MINIMUM

DESCRIPTION	QUANTITY		COST		NOTES
	Number	Unit	Unit Cost	Total Cost	
Operation & Maintenance Costs					
Upland Long Term Groundwater Monitoring					
Sampling Team Mob/Demob	1	Lump Sum	$ 3,000	$3,000	Quantity per sampling event
Groundwater Sampling Labor and Equipment	12	Well	$ 300	$3,600	Quantity per sampling event
Laboratory Analysis	12	Well	$ 600	$7,200	Quantity per sampling event
Annual Reporting	1	Lump Sum	$ 25,000	$25,000	Quantity per year
UNDISCOUNTED SUBTOTAL				$639,800	
TOTAL NET PRESENT VALUE OF O&M COSTS (30 YEARS)				$528,377	
Indirect O&M Costs (PM, Ecology Oversight)			12%	*$63,405*	
PRESENT VALUE SUBTOTAL (including indirect costs)				**$591,782**	
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				**$2,138,000**	

Notes:
(1) Present worth calculated using equal series present worth analysis where i = 2.3%

Table D-8b. Life-Cycle Cost Estimate for Groundwater Remediation Alternative G-1 (Sparging) -- FULL

DESCRIPTION	QUANTITY		COST		NOTES
	Number	Unit	Unit Cost	Total Cost	
INDIRECT COSTS					
Pre-Design GW Investgation	1	Lump Sum	$150,000	$150,000	(Less expensive for larger system)
Remedial Design	$2,752,600	Percent	12%	$330,312	EPA Cost Estimating Guidance, 2000
Permitting Coordination/Fees	$2,752,600	Percent	5%	$137,630	included as a 5 percent allowance on the construction subtotal
Contractor Submittals	$2,752,600	Percent	2%	$55,052	included as a 10 percent (aggregate) allowance on the construction subtotal
Construction Management	$2,752,600	Percent	8%	$220,208	
Construction Completion Report	1	Lump Sum	$60,000	$75,000	
Project Management	$2,752,600	Percent	10%	$275,260	EPA Cost Estimating Guidance, 2000
Ecology Oversight	$2,752,600	Percent	2%	$55,052	included as a 2 percent allowance on the construction subtotal
INDIRECT COSTS TOTAL				**$1,298,514**	
CAPITAL COSTS					
Upland Groundwater--Construction Costs					
Pre-Construction					
Utility Locate	2	Day	$1,000.00	$2,000	Two 10 hour man-day at $100/hr; Previous Project Experience
Detailed Utility Locate	2	Day	$2,000.00	$4,000	Additional detailed locating including potholing ($2,000/day)
Site Survey	2.00	Acre	$2,000.00	$4,000	
Install Monitoring Wells	15	Each	$5,000.00	$75,000	Previous Project Experience
Abandon Monitoring Wells	15	Each	$500.00	$7,500	Estimate
Air and Dust Monitoring	20	Day	$200.00	$4,000	
Air Sparging					
Pilot Test	1	Lump Sum	$45,000.00	$45,000	For radius of influence; potential use of CO2
Install Wells	87	Each	$5,000.00	$435,000	Includes well vaults & development
Install System	6	Each	$100,000.00	$600,000	Average 15 shallow wells each; Includes piping, fittings, electricity, blowers. Assume reuse of equipment where cost-effective.
Assumed length of operation	36	Months			
Operation - Power	216	Months	$4,000.00	$864,000	Assume continuous operation
Operation - Labor	5,760	hr	$110.00	$633,600	One FTE senior technician/operator, includes operator PM
Maintenance equipment & misc.	157	Wk	$500.00	$78,500	Maintenance supplies; rebound testing
CONSTRUCTION DIRECT COSTS TOTAL				**$2,752,600**	
Bid Contingency	$2,752,600		15%	$412,890	
Scope Contingency	$2,752,600		20%	$550,520	
CAPITAL COSTS SUBTOTAL				**$3,716,010**	
TOTAL CAPITAL COSTS (Direct and Indirect)				**$5,014,524**	

Table D-8b. Life-Cycle Cost Estimate for Groundwater Remediation Alternative G-1 (Sparging) -- FULL

DESCRIPTION	QUANTITY		COST		NOTES
	Number	Unit	Unit Cost	Total Cost	
Operation & Maintenance Costs					
Upland Long Term Groundwater Monitoring					
Sampling Team Mob/Demob	1	Lump Sum	$ 3,000	$3,000	Quantity per sampling event
Groundwater Sampling Labor and Equipment	18	Well	$ 300	$5,400	Quantity per sampling event
Laboratory Analysis	18	Well	$ 600	$10,800	Quantity per sampling event
Annual Reporting	1	Lump Sum	$ 25,000	$25,000	Quantity per year
UNDISCOUNTED SUBTOTAL				$753,200	
TOTAL NET PRESENT VALUE OF O&M COSTS (30 YEARS)				$624,974	
Indirect O&M Costs (PM, Ecology Oversight)			12%	*$74,997*	
PRESENT VALUE SUBTOTAL (including indirect costs)				**$699,971**	
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				**$5,714,000**	

Notes:
(1) Present worth calculated using equal series present worth analysis where i = 2.3%

Table D-9. Life-Cycle Cost Estimate for Groundwater Remediation Alternative G-2 (Funnel and Gate)

DESCRIPTION	ESTIMATED QUANTITY		COST		NOTES
	Quantity	Units	Unit Cost	Extended Cost	
INDIRECT COSTS					
Pre-Construction Design/Modeling	1	Lump Sum	$200,000.00	$200,000	Professional Judgment. Alternative specific pre-design bench-scale testing and/or modeling if needed.
Remedial Design	13,235,171	Percent	12%	$1,588,221	Professional Judgment based on EPA Cost Estimating Guidance, EPA 540-R-00-002
Permitting Coordination/Fees	13,235,171	Percent	5%	$661,759	Professional Judgment
Contractor Submittals	13,235,171	Percent	2%	$264,703	Professional Judgment
Construction Management	13,235,171	Percent	8%	$1,058,814	Professional Judgment based on EPA Cost Estimating Guidance, EPA 540-R-00-002
Construction Completion Report	1	Lump Sum	$120,000	$120,000	Professional Judgment
Project Management	13,235,171	Percent	10%	$1,323,517	Professional Judgment based on EPA Cost Estimating Guidance, EPA 540-R-00-002
Ecology Oversight	13,235,171	Percent	2%	$264,703	Professional Judgment
Contractor Bid Package/Selection	1	Lump Sum	$50,000	$50,000	Professional Judgment
INDIRECT COSTS TOTAL				**$5,531,717**	
CAPITAL COSTS					
Upland Groundwater--Construction Costs					
Pre-Construction					
Contractor Mob/Demob	1	Lump Sum	$50,000.00	$50,000	Professional Judgment
Temporary Construction Fence (rented, 6 feet high)	4,000	Linear Foot	7.65	$30,600	2013 RS Means Heavy Construction Cost Data
Temporary Erosion and Sedimentation Control Measures	5.00	Acre	5000.00	$25,000	2013 RS Means Heavy Construction Cost Data
Signs	4	Lump Sum	$1,000.00	$4,000	Previous Project Experience
Utility Locate	2.0	Day	$1,000.00	$2,000	10 hour man-days at $100/hr
Site Survey	5.00	Acre	$2,000.00	$10,000	Previous Project Experience
Abandon Monitoring Wells	10	Each	$500.00	$5,000	Previous Project Experience
Air and Dust Monitoring	30	Day	$200.00	$6,000	Previous Project Experience
Clear, Grub, and Rough Grade	24,200	Square Yard	$1.00	$24,200	Previous Project Experience
Demolish Concrete Pads	5,000	Square Foot	$8.20	$41,000	2013 RS Means Heavy Construction Cost Data
Dispose of Demolition Debris	370	Cubic Yard	$18.80	$6,963	2013 RS Means Heavy Construction Cost Data
PRB Installation					
Excavation of Soil for Gates	926	Cubic Yard	$9.00	$8,333	2014 RS Means Heavy Construction Cost Data. Slight cost increase to account for deep excavation. Includes excavation for 2 gates.
Excavation - Pre-trenching sheetpile wall alignment	2,963	Cubic Yard	$9.00	$26,667	2014 RS Means Heavy Construction Cost Data. Pre-trench sheetpile wall alignment (2 ft wide, 10 ft deep)
Transportation to Disposal Facility (Truck)	5,833	Ton	$40.00	$233,333	Previous Project Experience, assume unit weight factor of 1.5 tons/cy
Soil Disposal (Subtitle D Landfill)	5,833	Ton	$40.00	$233,333	Previous Project Experience, assume soil is contaminated but non-hazardous; assume unit weight factor of 1.5 tons/cy
PRB Pre-Installation Study	1	Lump Sum	$50,000.00	$50,000	2011 ITRC PRB Technology Update (PRB-5)
Concrete Vault (for the Gate of the PRB)	5	Each	$15,000.00	$75,000	2014 RS Means Heavy Construction Cost Data. Professional Judgment. Assume two vaults with dimensions 30' Lx10' Wx30' H.
Sheet Pile Installation (for Funnel of the PRB)	160,000	Square Feet	$32.50	$5,200,000	2014 RS Means Heavy Construction Cost Data. Assumes 40' deep installation
Reactive Media for the PRB	2,777,778	Pound	$2.50	$6,944,444	Assumes zero valent iron or emulsified vegetable oil or organophilic clay
Concrete Manhole (for accessing the PRB)	5	Each	$2,325.00	$11,625	2014 RS Means Heavy Construction Cost Data. Assumes 4' internal dia pre-cast concrete manholes 8' deep
Finish Grading	24,200	Square Yard	$0.91	$22,022	2014 RS Means Heavy Construction Cost Data
Installation of Groundwater Compliance Monitoring Wells	1	Lump Sum	$50,000.00	$50,000	Professional Judgment
Construction Dewatering					
Dewatering System	25	Day	$226.00	$5,650	2014 RS Means Heavy Construction Cost Data. Assume 25 days for dewatering.
Collection, Storage and Treatment of Water	1	Lump Sum	$130,000.00	$130,000	Previous Project Experience. Assume water is impacted.
Disposal/Discharge of Treated Water	200,000	Gallon	$0.20	$40,000	Previous project experience. Assume disposal at POTW.
				$13,235,171	
Bid Contingency				$1,985,276	

Table D-9. Life-Cycle Cost Estimate for Groundwater Remediation Alternative G-2 (Funnel and Gate)

DESCRIPTION	ESTIMATED QUANTITY		COST		NOTES
	Quantity	Units	Unit Cost	Extended Cost	
Scope Contingency				$2,647,034	
CAPITAL COSTS SUBTOTAL				**$17,867,481**	
TOTAL CAPITAL COSTS (Direct and Indirect)				**$23,399,198**	
OPERATION AND MAINTENANCE COSTS					
Upland Long Term Groundwater Monitoring					
Sampling Team Mob/Demob	1	Lump Sum	$ 3,000	$3,000	Previous Project Experience, Assume two field staff for completing work
Groundwater Sampling Labor and Equipment	15	Well	$ 300	$4,500	Previous Project Experience, Assume two field staff, 2 hours total per well
Laboratory Analysis	15	Well	$ 600	$9,000	Vendor Quote, Assume analysis for five metals, ammonia, SVOCs, cPAHs
Annual Reporting	1	Lump Sum	$ 25,000	$25,000	Previous project experience
Groundwater - PRB System					
- PRB Monitoring					
Annual PRB Monitoring, Maintenance, and Reporting Costs	1.0	Lump Sum	$ 80,000	$80,000	Professional Judgment. Assume rejuvenation or replenishment of reactive media once every two years.
UNDISCOUNTED SUBTOTAL				$1,896,500	
TOTAL NET PRESENT VALUE OF O&M COSTS (30 YEARS)				**$1,426,878**	
Indirect O&M Costs (PM, Ecology Oversight)			12%	*$171,225*	
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				**$24,997,000**	

Notes:

(1) Present worth calculated using equal series present worth analysis where i = 2.3%

(2) Based on annual operation and maintenance costs listed above. PRB monitoring, maintenance, and reporting; and groundwater monitoring and reporting: years 1, 2, 3, 4, 6, 8, 10, 15, 20, 25, and 30.

Table D-10. Life-Cycle Cost Estimate for Groundwater Remediation Alternative G-3 (Chemical Treatment)

DESCRIPTION	QUANTITY		COST		NOTES
	Number	Unit	Unit Cost	Total Cost	
INDIRECT COSTS					
Pre-Construction Design/Modeling	1	Lump Sum	$200,000.00	$200,000	
Remedial Design	$19,634,500	Percent	12%	$2,356,140	EPA Cost Estimating Guidance, 2000
Permitting Coordination/Fees	$19,634,500	Percent	5%	$981,725	included as a 5 percent allowance on the construction subtotal
Contractor Submittals	$19,634,500	Percent	2%	$392,690	included as a 10 percent (aggregate) allowance on the construction subtotal
Construction Management	$19,634,500	Percent	8%	$1,570,760	
Construction Completion Report	1	Lump Sum	$120,000	$120,000	
Project Management	$19,634,500	Percent	10%	$1,963,450	EPA Cost Estimating Guidance, 2000
Ecology Oversight	$19,634,500	Percent	2%	$392,690	included as a 2 percent allowance on the construction subtotal
INDIRECT COSTS TOTAL				**$7,977,455**	
CAPITAL COSTS					
Upland Groundwater--Construction Costs					
Pre-Construction					
Utility Locate	5	Day	$1,000.00	$5,000	10 hour man-days at $100/hr
Detailed Utility Locate	9	Day	$2,000.00	$18,000	Additional detailed locating including potholing ($2,000/day)
Site Survey	8.00	Acre	$2,000.00	$16,000	
Install Monitoring Wells	25	Each	$5,000.00	$125,000	Previous Project Experience
Abandon Monitoring Wells	25	Each	$500.00	$12,500	Estimate
Air and Dust Monitoring	30	Day	$200.00	$6,000	Assumes 30 days field operations
ISCO-ISCF Treatment (performed in year 1)					
ISCO-ISCF Contractor Mob/Demob	6	Event	$12,000.00	$72,000	Vendor Quote--Isotec
Bench Scale/Pilot Scale Testing for ISCO-ISCF	8	Reagent	$25,000.00	$200,000	Including Bench and/or Pilot Scale Evaluations (ISCO for PAHs, ISCF for arsenic, and 1 additional ISCF for other metals, others as needed)
Initial Chemical Application	35	Acre	$360,000.00	$12,600,000	Unit costs based on Vendor Quotes & Experience. Full plume
Confirmation Study	1	Lump Sum	$100,000.00	$100,000	
Second Chemical Application	14	Acre	$360,000.00	$5,040,000	Assume 40% of area requires second chemical or second applicaton
Confirmation Study	1	Lump Sum	$80,000.00	$80,000	
Third Chemical Application	3.5	Acre	$360,000.00	$1,260,000	Assume 10% requires polishing treatment
Process Monitoring	1	Lump Sum	$100,000.00	$100,000	Professional Judgment
CONSTRUCTION DIRECT COSTS TOTAL				**$19,634,500**	
Bid Contingency				$2,945,175	
Scope Contingency				$3,926,900	
CAPITAL COSTS SUBTOTAL				**$26,506,575**	
TOTAL CAPITAL COSTS (Direct and Indirect)				**$34,484,030**	
Operation & Maintenance Costs					
Upland Long Term Groundwater Monitoring					
Sampling Team Mob/Demob	1	Lump Sum	$ 3,000	$3,000	Quantity per sampling event
Groundwater Sampling Labor and Equipment	24	Well	$ 300	$7,200	Quantity per sampling event
Laboratory Analysis	24	Well	$ 600	$14,400	Quantity per sampling event
Annual Reporting	1	Lump Sum	$ 25,000	$25,000	Quantity per year
UNDISCOUNTED SUBTOTAL				$420,200	
TOTAL NET PRESENT VALUE OF O&M COSTS (5 YEARS)				**$394,808**	
Indirect O&M Costs (PM, Ecology Oversight)			12%	*$47,377*	
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				**$34,926,000**	

Notes:

Table D-10. Life-Cycle Cost Estimate for Groundwater Remediation Alternative G-3 (Chemical Treatment)

DESCRIPTION	QUANTITY		COST		NOTES
	Number	Unit	Unit Cost	Total Cost	

(1) Present worth calculated using equal series present worth analysis where i = 2.3%

(2) Based on annual operation and maintenance costs listed above. Groundwater monitoring and reporting: years 1, 2, 3, 4, and 5.

Table D-11. Life Cycle Cost Estimate for Sediment Remediation Alternative S-1

Description	QUANTITY		COST		Notes
	Number	Unit	Unit Cost	Total Cost	
INDIRECT COSTS					
Pre-Construction Design/Modeling	1	Lump Sum	$25,000	$25,000	Alternative specific pre-design and/or modeling if needed
Pre-construction sediment investigation	1	Lump Sum	$150,000	$150,000	Project knowledge
Engineering and Design	$3,939,201	Percent	14%	$551,488	Included as a percentage of the construction subtotal
Work Plans	1	Lump Sum	$500,000	$500,000	Included as a percentage of the construction subtotal
Permitting Coordination/Fees	$3,939,201	Percent	7%	$275,744	Included as a percentage of the construction subtotal
Contractor Submittals	$5,317,921	Percent	4%	$212,717	Included as a percentage of the construction subtotal
Construction Oversight	$3,939,201	Percent	9%	$354,528	Included as a percentage of the construction subtotal
Construction Completion Report	1	Lump Sum	$110,000	$110,000	Professional Judgment
Restrictive covenants preparation	1	Lump Sum	$50,000	$50,000	Professional Judgment
Project Management and Communications	$5,317,921	Percent	10%	$531,792	Included as a percentage of the construction subtotal
Ecology Oversight	$3,939,201	Percent	6%	$236,352	Included as a percentage of the construction subtotal
Contractor Bid Package/Selection	1	Lump Sum	$50,000	$50,000	Professional Judgment
INDIRECT COSTS TOTAL				**$3,047,621**	
CAPITAL COSTS					
Mobilization					
Site Preparation for upland materials staging	1	Lump Sum	$25,000	$25,000	Port Gamble FS - updated to 2014.
Select Removal and Disposal of Refuse Along Shoreline as needed	1	Lump Sum	$10,000	$10,000	Excluding large rip-rap and wood waste
Develop upland access to intertidal sediment excavation locations	1	Lump Sum	$10,000	$10,000	
ENR/Fill					
ENR cap material (sand only - not carbon amended) - purchase and transpor	42,415	Cubic Yard	$29	$1,230,021	Note: Add $132 to unit cost if carbon amendment is required
Benthic fill material - purchase and transport to site	20,231	Cubic Yard	$12	$235,744	$8.00/ton converted to CY based on 1.4 tons/CY
Place ENR layer	42,415	Cubic Yard	$7	$308,778	$5.00/ton converted to CY based on 1.4 tons/CY
Place benthic fill material	20,231	Cubic Yard	$7	$147,340	$5.00/ton converted to CY based on 1.4 tons/CY
Excavation/Dredging					
Mechanical (clamshell) dredge mob/demob	1	Lump Sum	$100,000	$100,000	Port Gamble FS x 2 to adjust for remote location
Upland shoreline excavation equipment mob/demob	1	Lump Sum	$35,000	$35,000	Professional Judgment
Excavation/dredging monitoring	20,231	Cubic Yard	$10	$202,312	Professional Judgment
Near-shore land-based soil/sediment excavation at or below OHW with silt curtain/water quality control	20,231	Cubic Yard	$34	$694,602	Includes excavate and stockpile on site.
Mechanical dredging (barge-mounted)	-	Cubic Yard	$26	$0	Based on $20,200/day at a production rate of 800 cy/day.
Barge protection	1	Lump Sum	$10,000	$10,000	Barge protection is required to prevent damage to barges during dredging

Table D-11. Life Cycle Cost Estimate for Sediment Remediation Alternative S-1

Description	QUANTITY		COST		Notes
	Number	Unit	Unit Cost	Total Cost	
Sediment Processing/Handling					
Sediment screening	20,231	Cubic Yard	$25	$505,780	Professional Judgment
Sediment-derived materials on-site staging/storage (piles)	20,231	Cubic Yard	$10	$202,312	Professional Judgment
Demob/restore upland sediment handling/drying areas	1	Lump Sum	$20,000	$20,000	Professional Judgment
Final Disposition (Reuse/Disposal)					
Sediment placement in upland (beneficial use)	20,231	Cubic Yard	$10	$202,312	Professional Judgment
In-water transportation (barge), remote transload (e.g., Seattle), transport, upland disposal at Sub D landfill	-	Cubic Yard	$119	$0	$85/ton converted to CY based on 1.4 tons/CY. Cost from transload facility
CONSTRUCTION DIRECT COSTS TOTAL				**$3,939,201**	
Bid Contingency			15%	$590,880.08	
Scope Contingency			20%	$787,840.11	
CAPITAL COSTS SUBTOTAL				**$5,317,921**	
TOTAL CAPITAL COSTS (Direct and Indirect)				**$8,365,542**	
Operation & Maintenance					
Annual monitoring of ENR performance - sampling and chemistry/bioassay testing and reporting	48	Acre	$3,000	$143,400	
Periodic measurement of final benthic bathymetry (per event)	52	Acre	$2,000	$103,200	
Periodic replenishment of ENR (per event)	$1,538,799	%	10%	$153,880	Percent of total ENR Capital Cost
UNDISCOUNTED SUBTOTAL				$1,928,920	
Indirect O&M Costs (PM, Ecology Oversight)				$308,627	
PRESENT VALUE SUBTOTAL (including indirect costs)				**$2,237,547**	
TOTAL UNDISCOUNTED O&M COSTS (30 YEARS)[3]				$1,928,920	
TOTAL NET PRESENT VALUE OF O&M COSTS (30 YEARS)[3]				$1,587,347	
TOTAL COST OF ALTERNATIVE, ROUNDED (PRESENT WORTH)				**$9,953,000**	

Notes:

(1) Present worth calculated using equal series present worth analysis where i = 2.3 %

(2) Indirect costs do not include Ecology/agency oversight

(3) Based on annual operation and maintenance costs listed above. ENR monitoring: years 1, 2, 5, 10, 15, 20 and 25. Bathymetric monitoring: years 1, 2 and 5, ENR replenishment: years 1, 6 , 11 and 20.

(4) Standard Feasibility Study cost estimate assumptions apply. Cost range is -30% to +50%.

Table D-12. Life-Cycle Cost Estimate for Sediment Remediation Alternative S-2

Description	QUANTITY		COST		Notes
	Number	Unit	Unit Cost	Total Cost	
INDIRECT COSTS					
Pre-Construction Design/Modeling	1	Lump Sum	$25,000	$25,000	Alternative specific pre-design and/or modeling if needed
Pre-construction sediment investigation	1	Lump Sum	$150,000	$150,000	Project knowledge
Engineering and Design	$4,610,055	Percent	12%	$553,207	Included as a percentage of the construction subtotal
Work Plans	1	Lump Sum	$500,000	$500,000	Included as a percentage of the construction subtotal
Permitting Coordination/Fees	$4,610,055	Percent	6%	$276,603	Included as a percentage of the construction subtotal
Contractor Submittals	$6,223,574	Percent	3%	$186,707	Included as a percentage of the construction subtotal
Construction Oversight	$4,610,055	Percent	8%	$368,804	Included as a percentage of the construction subtotal
Construction Completion Report	1	Lump Sum	$110,000	$110,000	Professional Judgment
Restrictive covenants preparation	1	Lump Sum	$50,000	$50,000	Professional Judgment
Project Management and Communications	$6,223,574	Percent	9%	$560,122	Included as a percentage of the construction subtotal
Ecology Oversight	$4,610,055	Percent	5%	$230,503	Included as a percentage of the construction subtotal
Contractor Bid Package/Selection	1	Lump Sum	$50,000	$50,000	Professional Judgment
INDIRECT COSTS TOTAL				**$3,060,946**	
CAPITAL COSTS					
Mobilization					
Site Preparation for upland materials staging	1	Lump Sum	$25,000	$25,000	Port Gamble FS - updated to 2014.
Select Removal and Disposal of Refuse Along Shoreline as needed	1	Lump Sum	$10,000	$10,000	Excluding large rip-rap and wood waste
Develop upland access to intertidal sediment excavation locations	1	Lump Sum	$10,000	$10,000	
ENR/Fill					
ENR cap material (sand only - not carbon amended) - purchase and transport to site	42,415	Cubic Yard	$29	$1,230,021	Note: Add $132 to unit cost if carbon amendment is required
Benthic fill material - purchase and transport to site	55,660	Cubic Yard	$12	$648,577	$8.00/ton converted to CY based on 1.4 tons/CY
Place ENR layer	42,415	Cubic Yard	$7	$308,778	$5.00/ton converted to CY based on 1.4 tons/CY
Place benthic fill material	55,660	Cubic Yard	$7	$405,361	$5.00/ton converted to CY based on 1.4 tons/CY
Excavation/Dredging					
Mechanical (clamshell) dredge mob/demob	1	Lump Sum	$100,000	$100,000	Port Gamble FS x 2 to adjust for remote location
Upland shoreline excavation equipment mob/demob	1	Lump Sum	$35,000	$35,000	Professional Judgment
Excavation/dredging monitoring	20,231	Cubic Yard	$10	$202,312	Professional Judgment
Near-shore land-based soil/sediment excavation at or below OHW with silt curtain/water quality control	20,231	Cubic Yard	$34	$694,602	Includes excavate and stockpile on site.
Mechanical dredging (barge-mounted)	-	Cubic Yard	$26	$0	Based on $20,200/day at a production rate of 800 cy/day.
Barge protection	1	Lump Sum	$10,000	$10,000	Barge protection is required to prevent damage to barges during dredging
Sediment Processing/Handling					
Sediment screening	20,231	Cubic Yard	$25	$505,780	Professional Judgment
Sediment-derived materials on-site staging/storage (piles)	20,231	Cubic Yard	$10	$202,312	Professional Judgment
Demob/restore upland sediment handling/drying areas	1	Lump Sum	$20,000	$20,000	Professional Judgment
Final Disposition (Reuse/Disposal)					
Sediment placement in upland (beneficial use)	20,231	Cubic Yard	$10	$202,312	Professional Judgment
In-water transportation (barge), remote transload (e.g., Seattle), transport, upland disposal at Sub D landfill	-	Cubic Yard	$119	$0	$85/ton converted to CY based on 1.4 tons/CY. Cost from transload facility
CONSTRUCTION DIRECT COSTS TOTAL				**$4,610,055**	
Bid Contingency			15%	$691,508.22	
Scope Contingency			20%	$922,010.96	
CAPITAL COSTS SUBTOTAL				**$6,223,574**	
TOTAL CAPITAL COSTS (Direct and Indirect)				**$9,284,520**	

Table D-12. Life-Cycle Cost Estimate for Sediment Remediation Alternative S-2

Description	QUANTITY		COST		Notes
	Number	Unit	Unit Cost	Total Cost	
Operation & Maintenance					
Annual monitoring of ENR performance - sampling and chemistry/bioassay testing and reporting	48	Acre	$3,000	$143,400	
Periodic measurement of final benthic bathymetry (per event)	52	Acre	$2,000	$103,200	
Periodic replenishment of ENR (per event)	$1,538,799	%	10%	$153,880	Percent of total ENR Capital Cost
UNDISCOUNTED SUBTOTAL				$615,520	
Indirect O&M Costs (PM, Ecology Oversight)				$86,173	
PRESENT VALUE SUBTOTAL (including indirect costs)					
TOTAL UNDISCOUNTED O&M COSTS (30 YEARS)[3]				$1,928,920	
TOTAL NET PRESENT VALUE OF O&M COSTS (30 YEARS)[3]				$1,587,347	
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				**$10,872,000**	

Notes:

(1) Present worth calculated using equal series present worth analysis where i = 2.3%

(2) Indirect costs do not include Ecology/agency oversight

(3) Based on annual operation and maintenance costs listed above. ENR monitoring: years 1, 2, 5, 10, 15, 20 and 25. Bathymetric monitoring: years 1, 2 and 5, ENR replenishment: years 1, 6 , 11 and 20.

(4) Standard Feasibility Study cost estimate assumptions apply. Cost range is -30% to +50%.

Figure D-13. Life-Cycle Cost Estimate for Sediment Remediation S-3

Description	QUANTITY		COST		Notes
	Number	Unit	Unit Cost	Total Cost	
INDIRECT COSTS					
Pre-Construction Design/Modeling	1	Lump Sum	$25,000	$25,000	Alternative specific pre-design and/or modeling if needed
Pre-construction sediment investigation	1	Lump Sum	$150,000	$150,000	Project knowledge
Engineering and Design	$7,856,125	Percent	8%	$628,490	Included as a percentage of the construction subtotal
Work Plans	1	Lump Sum	$500,000	$500,000	Included as a percentage of the construction subtotal
Permitting Coordination/Fees	$7,856,125	Percent	4%	$314,245	Included as a percentage of the construction subtotal
Contractor Submittals	$10,605,769	Percent	2%	$212,115	Included as a percentage of the construction subtotal
Construction Oversight	$7,856,125	Percent	6%	$471,367	Included as a percentage of the construction subtotal
Construction Completion Report	1	Lump Sum	$110,000	$110,000	Professional Judgment
Restrictive covenants preparation	1	Lump Sum	$50,000	$50,000	Professional Judgment
Project Management and Communications	$10,605,769	Percent	5%	$530,288	Included as a percentage of the construction subtotal
Ecology Oversight	$7,856,125	Percent	3%	$235,684	Included as a percentage of the construction subtotal
Contractor Bid Package/Selection	1	Lump Sum	$50,000	$50,000	Professional Judgment
INDIRECT COSTS TOTAL				**$3,277,190**	
CAPITAL COSTS					
Mobilization					
Site Preparation for upland materials staging	1	Lump Sum	$25,000	$25,000	Port Gamble FS - updated to 2014.
Select Removal and Disposal of Refuse Along Shoreline as needed	1	Lump Sum	$10,000	$10,000	Excluding large rip-rap and wood waste
Develop upland access to intertidal sediment excavation locations	1	Lump Sum	$10,000	$10,000	
ENR/Fill					
ENR cap material (sand only - not carbon amended) - purchase and transport to site	33,896	Cubic Yard	$29	$982,988	Note: Add $132 to unit cost if carbon amendment is required
Benthic fill material - purchase and transport to site	43,850	Cubic Yard	$12	$510,966	$8.00/ton converted to CY based on 1.4 tons/CY
In-water cap material - purchase and transport to site	33,106	Cubic Yard	$12	$385,762	$8.00/ton converted to CY based on 1.4 tons/CY
Gravel cap armoring - purchase and transport to site	11,035	Cubic Yard	$35	$385,349	Means 2014: 31-05-16.10-0300
Rip-rap cap protection for in-water placement (toe of caps) - purchase and transport to site	7,394	Ton	$25	$184,840	Means 2014: 31-37-13-0300
Place ENR layer	33,896	Cubic Yard	$7	$246,764	$5.00/ton converted to CY based on 1.4 tons/CY
Place benthic fill material	43,850	Cubic Yard	$7	$319,354	$5.00/ton converted to CY based on 1.4 tons/CY
Place Cap Material	33,106	Cubic Yard	$15	$482,203	$10.00/ton converted to CY based on 1.4 tons/CY
Place gravel armoring on cap	11,035	Cubic Yard	$7	$80,367	$5.00/ton converted to CY based on 1.4 tons/CY
Place armor rip-rap - in-water	7,394	Ton	$15	$110,904	expressed on per-ton basis.
Excavation/Dredging					
Mechanical (clamshell) dredge mob/demob	1	Lump Sum	$100,000	$100,000	Port Gamble FS x 2 to adjust for remote location
Hydraulic dredge mob/demob	0	Lump Sum	$100,000	$0	Port Gamble FS x 2 to adjust for remote location
Upland shoreline excavation equipment mob/demob	1	Lump Sum	$35,000	$35,000	Professional Judgment
Excavation/dredging monitoring	34,074	Cubic Yard	$10	$340,736	Professional Judgment
Near-shore land-based soil/sediment excavation at or below OHW with silt curtain/water quality control	20,231	Cubic Yard	$34	$694,602	Includes excavate and stockpile on site.
Mechanical dredging (barge-mounted)	13,842	Cubic Yard	$26	$363,641	Based on $20,200/day at a production rate of 800 cy/day.
Hydraulic dredging including piped transfer to upland	-	Cubic Yard	$16	$0	Gammett Fleming: $7/CY updated and adjusted per expected project scale
Barge protection	1	Lump Sum	$10,000	$10,000	Barge protection is required to prevent damage to barges during dredging
Sediment Processing/Handling					
Gravity dewatering on barge	-	Cubic Yard	$10	$0	LDW FS Appendix I
Transload mechanically dredged material to site upland (incl cost of transload facility construction)	-	Cubic Yard	$250	$0	Professional Judgment
Hydrocyclone processing	-	Cubic Yard	$60	$0	LDW FS cites $120/CY including disposal
Sediment screening	20,231	Cubic Yard	$25	$505,780	Professional Judgment
Sediment dewatering in upland drying bed (incl cost of dewatering bed facility construction)	-	Cubic Yard	$15	$0	Professional Judgment
Water management	0	day	$10,000	$0	LDW FS Appendix I

Figure D-13. Life-Cycle Cost Estimate for Sediment Remediation S-3

Description	QUANTITY		COST		Notes
	Number	Unit	Unit Cost	Total Cost	
Sediment-derived materials on-site staging/storage (piles)	20,231	Cubic Yard	$10	$202,312	Professional Judgment
Demob/restore upland sediment handling/drying areas	1	Lump Sum	$20,000	$20,000	Professional Judgment
Final Disposition (Reuse/Disposal)					
Sediment placement in upland (beneficial use)	20,231	Cubic Yard	$10	$202,312	Professional Judgment
In-water sediment transportation (barge) and Disposal (Open Water)	-	Cubic Yard	$21	$0	$15/ton converted to CY based on 1.4 tons/CY. Cost from transload facility.
In-water sediment transportation (barge) and disposal in confined aquatic disposal site (CAD)	-	Cubic Yard	$45	$0	Professional Judgment
Transport from upland (truck) and Disposal (nearby upland landfill site - as cover)	0	Ton	$87	$0	$60/ton converted to CY based on 1.4 tons/CY
Transport from upland (Truck) and Dispose Soil (Wenatchee WM) - Sub D	0	Ton	$176	$0	Previous Project Experience
In-water transportation (barge), remote transload (e.g., Seattle), transport, upland disposal at Sub D landfill	13,842	Cubic Yard	$119	$1,647,246	$85/ton converted to CY based on 1.4 tons/CY. Cost from transload facility
CONSTRUCTION DIRECT COSTS TOTAL				**$7,856,125**	
Bid Contingency			15%	$1,178,418.74	
Scope Contingency			20%	$1,571,224.99	
CAPITAL COSTS SUBTOTAL				**$10,605,769**	
TOTAL CAPITAL COSTS (Direct and Indirect)				**$13,882,959**	
Operation & Maintenance					
Annual monitoring of ENR performance - sampling and chemistry/bioassay testing and reporting	38	Acre	$3,000	$114,600	
Annual monitoring of cap performance - sampling and chemistry/bioassay testing and reporting	6	Acre	$15,000	$85,500	
Periodic measurement of final benthic bathymetry (per event)	52	Acre	$2,000	$103,200	
Periodic replenishment of ENR (per event)	$1,229,752	%	10%	$122,975	Percent of total ENR Capital Cost
Periodic repair of capped areas (per event)	$ 867,965	%	20%	$173,593	Percent of total Cap Capital Cost
UNDISCOUNTED SUBTOTAL				$368,926	
Indirect O&M Costs (PM, Ecology Oversight)				$29,514	
PRESENT VALUE SUBTOTAL (including indirect costs)					
TOTAL UNDISCOUNTED O&M COSTS (30 YEARS)[3]				$1,643,626	
TOTAL NET PRESENT VALUE OF O&M COSTS (30 YEARS)[3]				$1,329,600	
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				**$15,213,000**	

Notes:

(1) Present worth calculated using equal series present worth analysis where i = 2.3%

(2) Indirect costs do not include Ecology/agency oversight

(3) Based on annual operation and maintenance costs listed above. ENR monitoring: years 1, 2, 5 and 10. Bathymetric monitoring: year 2, ENR replenishment: years 1, 6 and 11.

(4) Standard Feasibility Study cost estimate assumptions apply. Cost range is -30% to +50%.

Table D-14. Life-Cycle Cost Estimate for Sediment Remediation Alternative S-4

Description	QUANTITY		COST		Notes
	Number	Unit	Unit Cost	Total Cost	
INDIRECT COSTS					
Pre-Construction Design/Modeling	1	Lump Sum	$25,000	$25,000	Alternative specific pre-design and/or modeling if needed
Pre-construction sediment investigation	1	Lump Sum	$150,000	$150,000	Project knowledge
Engineering and Design	$9,322,005	Percent	10%	$932,201	Included as a percentage of the construction subtotal
Work Plans	1	Lump Sum	$500,000	$500,000	Included as a percentage of the construction subtotal
Permitting Coordination/Fees	$9,322,005	Percent	4%	$372,880	Included as a percentage of the construction subtotal
Contractor Submittals	$12,584,707	Percent	2%	$251,694	Included as a percentage of the construction subtotal
Construction Oversight	$9,322,005	Percent	7%	$652,540	Included as a percentage of the construction subtotal
Construction Completion Report	1	Lump Sum	$110,000	$110,000	Professional Judgment
Restrictive covenants preparation	1	Lump Sum	$50,000	$50,000	Professional Judgment
Project Management and Communications	$12,584,707	Percent	6%	$755,082	Included as a percentage of the construction subtotal
Ecology Oversight (include?)	$9,322,005	Percent	4%	$372,880	Included as a percentage of the construction subtotal
Contractor Bid Package/Selection	1	Lump Sum	$50,000	$50,000	Professional Judgment
INDIRECT COSTS TOTAL				**$4,222,278**	
CAPITAL COSTS					
Mobilization					
Site Preparation for upland materials staging	1	Lump Sum	$25,000	$25,000	Port Gamble FS - updated to 2014.
Select Removal and Disposal of Refuse Along Shoreline as needed	1	Lump Sum	$10,000	$10,000	Excluding large rip-rap and wood waste
Develop upland access to intertidal sediment excavation locations	1	Lump Sum	$10,000	$10,000	
ENR/Fill					
ENR cap material (sand only - not carbon amended) - purchase and transport to site	42,415	Cubic Yard	$29	$1,230,021	Note: Add $132 to unit cost if carbon amendment is required
Benthic fill material - purchase and transport to site	55,660	Cubic Yard	$12	$648,577	$8.00/ton converted to CY based on 1.4 tons/CY
In-water cap material - purchase and transport to site	-	Cubic Yard	$12	$0	$8.00/ton converted to CY based on 1.4 tons/CY
Gravel cap armoring - purchase and transport to site	-	Cubic Yard	$35	$0	Means 2014: 31-05-16.10-0300
Rip-rap cap protection for in-water placement (toe of caps) - purchase and transport to site	-	Ton	$25	$0	Means 2014: 31-37-13-0300
Place ENR layer	42,415	Cubic Yard	$7	$308,778	$5.00/ton converted to CY based on 1.4 tons/CY
Place benthic fill material	55,660	Cubic Yard	$7	$405,361	$5.00/ton converted to CY based on 1.4 tons/CY
Excavation/Dredging					
Mechanical (clamshell) dredge mob/demob	1	Lump Sum	$100,000	$100,000	Port Gamble FS x 2 to adjust for remote location
Upland shoreline excavation equipment mob/demob	1	Lump Sum	$35,000	$35,000	Professional Judgment
Excavation/dredging monitoring	50,578	Cubic Yard	$10	$505,780	Professional Judgment
Near-shore land-based soil/sediment excavation at or below OHW with silt curtain/water quality control	20,231	Cubic Yard	$34	$694,602	Includes excavate and stockpile on site.
Mechanical dredging (barge-mounted)	30,347	Cubic Yard	$26	$797,213	Based on $20,200/day at a production rate of 800 cy/day.
Barge protection	1	Lump Sum	$10,000	$10,000	Barge protection is required to prevent damage to barges during dredging
Sediment Processing/Handling					
Sediment screening	20,231	Cubic Yard	$25	$505,780	Professional Judgment
Sediment-derived materials on-site staging/storage (piles)	20,231	Cubic Yard	$10	$202,312	Professional Judgment
Demob/restore upland sediment handling/drying areas	1	Lump Sum	$20,000	$20,000	Professional Judgment
Final Disposition (Reuse/Disposal)					
Sediment placement in upland (beneficial use)	20,231	Cubic Yard	$10	$202,312	Professional Judgment
In-water transportation (barge), remote transload (e.g., Seattle), transport, upland disposal at Sub D landfill	30,347	Cubic Yard	$119	$3,611,269	$85/ton converted to CY based on 1.4 tons/CY. Cost from transload facility

Table D-14. Life-Cycle Cost Estimate for Sediment Remediation Alternative S-4

Description	QUANTITY		COST		Notes
	Number	Unit	Unit Cost	Total Cost	
CONSTRUCTION DIRECT COSTS TOTAL				**$9,322,005**	
Bid Contingency			15%	$1,398,300.82	
Scope Contingency			20%	$1,864,401.09	
CAPITAL COSTS SUBTOTAL				**$12,584,707**	
TOTAL CAPITAL COSTS (Direct and Indirect)				**$16,806,985**	
Operation & Maintenance					
Annual monitoring of ENR performance - sampling and chemistry/bioassay testing and reporting	48	Acre	$3,000	$143,400	
Periodic measurement of final benthic bathymetry (per event)	52	Acre	$2,000	$103,200	
Periodic replenishment of ENR (per event)	$ 1,538,799	%	10%	$153,880	Percent of total ENR Capital Cost
UNDISCOUNTED SUBTOTAL				$461,640	
Indirect O&M Costs (PM, Ecology Oversight)				$46,164	
PRESENT VALUE SUBTOTAL (including indirect costs)					
TOTAL UNDISCOUNTED O&M COSTS (30 YEARS)[3]				$1,344,840	
TOTAL NET PRESENT VALUE OF O&M COSTS (30 YEARS)[3]				$1,215,523	
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				**$18,023,000**	

Notes:

(1) Present worth calculated using equal series present worth analysis where i = 2.3%

(2) Indirect costs do not include Ecology/agency oversight

(3) Based on annual operation and maintenance costs listed above. ENR monitoring: years 1, 2, 5 and 10. Bathymetric monitoring: years 1, 2 and 5, ENR replenishment: years 1, 6 and 11.

(4) Standard Feasibility Study cost estimate assumptions apply. Cost range is -30% to +50%.

Table D-15. Life-Cycle Cost Estimate for Sediment Remediation Alternative S-5

Description	QUANTITY		COST		Notes
	Number	Unit	Unit Cost	Total Cost	
INDIRECT COSTS					
Pre-Construction Design/Modeling	1	Lump Sum	$25,000	$25,000	Alternative specific pre-design and/or modeling if needed
Pre-construction sediment investigation	1	Lump Sum	$150,000	$150,000	Project knowledge
Engineering and Design	$ 34,608,213	Percent	4%	$1,384,329	Included as a percentage of the construction subtotal
Work Plans	1	Lump Sum	$500,000	$500,000	Included as a percentage of the construction subtotal
Permitting Coordination/Fees	$ 34,608,213	Percent	3%	$1,038,246	Included as a percentage of the construction subtotal
Contractor Submittals	$ 46,721,087	Percent	1%	$467,211	Included as a percentage of the construction subtotal
Construction Oversight	$ 34,608,213	Percent	5%	$1,730,411	Included as a percentage of the construction subtotal
Construction Completion Report	1	Lump Sum	$110,000	$110,000	Professional Judgment
Restrictive covenants preparation	1	Lump Sum	$50,000	$50,000	Professional Judgment
Project Management and Communications	$ 46,721,087	Percent	3%	$1,401,633	Included as a percentage of the construction subtotal
Ecology Oversight (include?)	$ 34,608,213	Percent	2%	$692,164	Included as a percentage of the construction subtotal
Contractor Bid Package/Selection	1	Lump Sum	$50,000	$50,000	Professional Judgment
INDIRECT COSTS TOTAL				**$7,598,993**	
CAPITAL COSTS					
Mobilization					
Site Preparation for upland materials staging	1	Lump Sum	$25,000	$25,000	Port Gamble FS - updated to 2014.
Select Removal and Disposal of Refuse Along Shoreline as needed	1	Lump Sum	$10,000	$10,000	Excluding large rip-rap and wood waste
Develop upland access to intertidal sediment excavation locations	1	Lump Sum	$10,000	$10,000	
ENR/Fill					
ENR cap material (sand only - not carbon amended) - purchase and transport to site	42,415	Cubic Yard	$29	$1,230,021	Note: Add $132 to unit cost if carbon amendment is required
Benthic fill material - purchase and transport to site	20,231	Cubic Yard	$12	$235,744	$8.00/ton converted to CY based on 1.4 tons/CY
Place ENR layer	42,415	Cubic Yard	$7	$308,778	$5.00/ton converted to CY based on 1.4 tons/CY
Place benthic fill material	20,231	Cubic Yard	$7	$147,340	$5.00/ton converted to CY based on 1.4 tons/CY
Excavation/Dredging					
Mechanical (clamshell) dredge mob/demob	1	Lump Sum	$100,000	$100,000	Port Gamble FS x 2 to adjust for remote location
Hydraulic dredge mob/demob	0	Lump Sum	$100,000	$0	Port Gamble FS x 2 to adjust for remote location
Upland shoreline excavation equipment mob/demob	1	Lump Sum	$35,000	$35,000	Professional Judgment
Excavation/dredging monitoring	217,752	Cubic Yard	$10	$2,177,516	Professional Judgment
Near-shore land-based soil/sediment excavation at or below OHW with silt curtain/water quality control	20,231	Cubic Yard	$34	$694,602	Includes excavate and stockpile on site.
Mechanical dredging (barge-mounted)	197,520	Cubic Yard	$26	$5,188,881	Based on $20,200/day at a production rate of 800 cy/day.
Barge protection	1	Lump Sum	$10,000	$10,000	Barge protection is required to prevent damage to barges during dredging
Sediment Processing/Handling					
Sediment screening	20,231	Cubic Yard	$25	$505,780	Professional Judgment
Sediment-derived materials on-site staging/storage (piles)	20,231	Cubic Yard	$10	$202,312	Professional Judgment
Demob/restore upland sediment handling/drying areas	1	Lump Sum	$20,000	$20,000	Professional Judgment
Final Disposition (Reuse/Disposal)					
Sediment placement in upland (beneficial use)	20,231	Cubic Yard	$10	$202,312	Professional Judgment
In-water transportation (barge), remote transload (e.g., Seattle), transport, upland disposal at Sub D landfill	197,520	Cubic Yard	$119	$23,504,928	$85/ton converted to CY based on 1.4 tons/CY. Cost from transload facility
CONSTRUCTION DIRECT COSTS TOTAL				**$34,608,213**	
Bid Contingency			15%	$5,191,231.92	
Scope Contingency			20%	$6,921,642.56	
CAPITAL COSTS SUBTOTAL				**$46,721,087**	
TOTAL CAPITAL COSTS (Direct and Indirect)				**$54,320,081**	

Table D-15. Life-Cycle Cost Estimate for Sediment Remediation Alternative S-5

Description	QUANTITY		COST		Notes
	Number	Unit	Unit Cost	Total Cost	
Operation & Maintenance					
Annual monitoring of ENR performance - sampling and chemistry/bioassay testing and reporting	48	Acre	$3,000	$143,400	
Periodic measurement of final benthic bathymetry (per event)	52	Acre	$2,000	$103,200	
Periodic replenishment of ENR (per event)	$1,538,799	%	10%	$153,880	Percent of total ENR Capital Cost
UNDISCOUNTED SUBTOTAL				$461,640	
Indirect O&M Costs (PM, Ecology Oversight)				$23,082	
PRESENT VALUE SUBTOTAL (including indirect costs)					
TOTAL UNDISCOUNTED O&M COSTS (30 YEARS)[3]				$1,138,440	
TOTAL NET PRESENT VALUE OF O&M COSTS (30 YEARS)[3]				$1,022,534	
TOTAL COST OF ALTERNATIVE (PRESENT WORTH)				**$55,343,000**	

Notes:

(1) Present worth calculated using equal series present worth analysis where i = 2.3%

(2) Indirect costs do not include Ecology/agency oversight

(3) Based on annual operation and maintenance costs listed above.

Bathymetric monitoring: year 2.

(4) Standard Feasibility Study cost estimate assumptions apply. Cost range is -30% to +50%.

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