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I&J Waterway Site

Exhibit B
Cleanup Action Plan

Issued by
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Toxics Cleanup Program
Northwest Regional Office
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ABBREVIATIONS

µg/kg	microgram per kilogram
AET	Apparent Effects Threshold
BSL	bioaccumulation screening level
CAP	Cleanup Action Plan
City	City of Bellingham
cm	centimeter
CMCRP	Compliance Monitoring and Contingency Response Plan
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CQAP	Construction Quality Assurance Plan
CSL	Cleanup Screening Level
CSM	conceptual site model
cy	cubic yard
DCA	disproportionate cost analysis
DMMP	Dredged Material Management Program
Ecology	Washington State Department of Ecology
EDR	Engineering Design Report
ENR	enhanced natural recovery
GP	Georgia-Pacific
H:V	horizontal to vertical
HPA	Hydraulic Project Approval
IC	institutional control
mg/kg	milligram per kilogram
MLLW	mean lower low water
MNR	monitored natural recovery
MTCA	Model Toxics Control Act
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
Pilot	Bellingham Bay Demonstration Pilot
PLP	potentially liable party
Port	Port of Bellingham
RCW	Revised Code of Washington
RI/FS	Remedial Investigation and Feasibility Study
SCO	Sediment Cleanup Objective
SEPA	State Environmental Policy Act

Site	I&J Waterway Site
SMP	Shoreline Master Plan
SMS	Sediment Management Standards
TEQ	toxic equivalents quotient
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WQMP	Water Quality Monitoring Plan

1 Introduction

This Cleanup Action Plan (CAP) describes the cleanup action proposed by the Washington State Department of Ecology (Ecology) for the cleanup of contamination at the I&J Waterway Site (Site) in Bellingham, Washington. The plan was developed using information presented in the final *Remedial Investigation and Feasibility Study Report, I&J Waterway Site, Bellingham, Washington* (RI/FS; Anchor QEA 2015). This document has been prepared to satisfy the requirements of the Model Toxics Control Cleanup Act (MTCA), Chapter 70.105D Revised Code of Washington (RCW), administered by Ecology under the MTCA Cleanup Regulation, Chapter 173-340 Washington Administrative Code (WAC).

1.1 Site Description

The Site is located within Bellingham Bay between Hilton Avenue and Bellwether Way on the Bellingham waterfront and was formerly called the Olivine-Hilton sediment site (Figure 1-1). The Site includes areas of contaminated marine sediment in the federally authorized I&J Waterway navigation channel and adjacent berthing areas, primarily located on state-owned aquatic land (Figure 1-2). The federally authorized navigation channel has a current authorized channel depth of 18 feet below mean lower low water (MLLW). The Port of Bellingham (Port) owns the berthing areas on the south side of the Site and the surrounding uplands to the south, east, and west. The upland areas near the Site include the former Olivine Corporation lease area and a property to its southwest that is currently leased to Bornstein Seafoods. The United States of America owns the property north of the Site and the U.S. Coast Guard (USCG) berths vessels within the Waterway and northern berth areas.

1.2 Purpose and Scope

The main state law that governs the cleanup of contaminated sites is MTCA. When contaminated sediment is involved, the cleanup levels and other procedures are also regulated by the Sediment Management Standards (SMS; Chapter 173-204 WAC). MTCA regulations specify criteria for the evaluation and conduct of a state cleanup action. SMS regulations dictate the standards for cleanup of sediment. Under both laws, a cleanup must protect human health and the environment, meet environmental standards in other laws that apply, and provide for monitoring to confirm compliance with site cleanup standards.

This CAP was developed using information presented in the RI/FS. Ecology issued the draft RI/FS for public comment in November of 2014. The RI/FS was then revised and approved by Ecology in February of 2015. The RI/FS summarizes approximately 10 years of environmental investigations performed under Ecology direction to characterize the nature and extent of contamination at the site. The RI/FS also screens cleanup technologies and evaluates different potential cleanup alternatives consistent with MTCA regulatory criteria.

The purpose of this CAP is to describe Ecology's proposed cleanup action for the site, consistent with MTCA and SMS requirements. Consistent with the requirements of WAC 173-340-380, this document provides the following information:

- Summary of project background and current environmental conditions (Section 2);
- Cleanup requirements applicable to the site, including cleanup standards and other federal, state, and local laws applicable to the cleanup action (Section 3);
- Summary description of the cleanup action alternatives evaluated in the RI/FS (Section 4);
- Rationale for selection of the proposed cleanup action (Section 5);
- A description of the cleanup action proposed by Ecology, consistent with MTCA requirements (Section 6), including a description of the types, levels, and amounts of hazardous substances and/or other deleterious substances that will remain on site as part of the cleanup, the measures that will be used to prevent migration and contact with those substances, compliance monitoring, potential contingency actions, and institutional controls (ICs); and
- Description of the schedule for implementation of the cleanup action (Section 7).

2 Site Background

This section describes background information relevant to the cleanup of the Site. Information presented in this section includes the following:

- Site History and Background: Section 2.1 describes the history of the site and vicinity, including a summary of previous site activities, current land use, previous investigations, and other nearby cleanup sites.
- Current Site Conditions: Section 2.2 provides a brief summary of the environmental information presented in the RI/FS.
- Sediment Site Units: Section 2.3 presents the Sediment Site Units developed in the RI/FS.

2.1 Site History and Background

The Site consists of lands located within and adjacent to the I&J Waterway in Bellingham, Washington (Figure 1-1). Metals and other contaminants have been detected within the Site at concentrations that exceed cleanup standards defined under MTCA and SMS regulations.

The ownership and history for the Site and adjacent upland properties were described in the Phase 2 Sediment Sampling Report (ThermoRetec 2001). The Whatcom Falls Mill Company owned and operated a lumber mill in the vicinity of the Site between the early 1900s and 1940. In 1944, these properties were acquired by the Port and leased to tenants, including Bayshore Lumber, which operated a lumber mill (1947 to 1962) and H&H Products, which managed the same lumber mill (1963 to 1972) at the head of the Waterway. The Olivine Corporation operated a rock crushing plant for the mineral olivine on upland property adjacent to the Site between 1963 and 1992. Fugitive dusts and wastewaters from that plant were released to the I&J Waterway at times during plant operation. North Pacific Frozen Products managed a food processing plant between 1946 and 1959 on upland property adjacent to the Site. Bornstein Seafoods has operated a seafood processing plant from 1959 to the present in this same location. Bornstein Seafoods provided diesel fuel to boats at its dock between 1960 and the early 1980s. A fire destroyed the main Bornstein Seafoods building in July 1985. Fire suppression efforts lasted for two days, during which time fire control water was discharged directly to the Site.

The adjacent northern upland area was constructed in the early 1980s as part of the Inner Squalicum Harbor Marina development. The Bellwether peninsula was created from dredge material and subsequent structural base to support construction of the Bellwether Hotel and other commercial buildings. The USCG Bellingham facility was constructed along the northern shoreline of the I&J Waterway during the 1990s.

The I&J Waterway includes a federally authorized navigation channel with a current authorized channel depth of -18 feet MLLW. The federal dredging of the I&J Waterway was completed in 1966, with subsequent maintenance dredging of selected areas completed by the U.S. Army Corps of Engineers (USACE) in 1992.

2.1.1 Current Land Use

Current land use and zoning is presented in Figure 1-2. The Port owns a majority of upland and aquatic land in the vicinity of the I&J Waterway. Other land is owned by the state of Washington, the United States of America (which owns the United States Coast Guard [USCG] facility), and City of Bellingham (City; right-of-way along Hilton Avenue). Land use in the vicinity is generally through leases by the Port to tenants. Leases are in place for seafood processing at the Bornstein Seafoods facility, boat storage and maintenance at Hilton Harbor, and commercial buildings at the northern upland areas. The former Olivine lease area and head of the Waterway is currently vacant with no aboveground structures; however, the City constructed a multi-use trail around the perimeter of the Waterway in this area in 2015. The Bellwether Peninsula is zoned commercial, and the Hilton Avenue shoreline and the upland area at the head of the Waterway are zoned urban village.

2.1.2 Summary of Investigations

The I&J Waterway Site is one of 12 cleanup sites in the Bellingham Bay Demonstration Pilot Project (Pilot), a coordinated bay-wide effort by federal, tribal, state, and local governments to clean up contamination, control pollution sources, and restore habitat, with consideration for land and water uses. Earlier investigations were conducted for the Whatcom Waterway site, which includes more than 200 acres within the inner portion of Bellingham Bay from the I&J Waterway down to Boulevard Park. The I&J Waterway Site overlaps the Whatcom Waterway site. The Whatcom Waterway and I&J Waterway sites share a number of relevant characteristics, and some of the analysis conducted for the Whatcom Waterway site informs the I&J Waterway Site.

Contamination at the I&J Waterway Site was originally identified in 1995 as part of the Whatcom Waterway investigation, which prompted additional sampling in 1996 (Hart Crowser 1997), 1998 (Anchor Environmental and Hart Crowser 2000), and 2000 (ThermoRetec 2001). Ecology identified the Port and Bornstein Seafoods as potentially liable parties (PLPs) for the I&J Waterway site in 2004. In January 2005, Agreed Order DE1090 was signed by Ecology and the Port and required an RI/FS be completed for the Site. Agreed Order Amendment No. 1 was signed in October 2005 and incorporated the Sediments RI/FS Work Plan (RETEC 2005) into the Agreed Order. The Port and Ecology executed a Second Amendment to the Agreed Order in April 2012, which incorporated the Work Plan Addendum (Anchor QEA 2012). Ecology identified the Olivine Corporation as a PLP for the I&J Waterway site in 2016.

Sediment chemical and biological testing occurred in 2005, and additional bioassay testing was repeated on samples collected in early 2006 based on quality control criteria. Subsurface sediment cores were collected and tested in 2006 for suitability of open-water disposal under the Dredged Material Management Program (DMMP; RETEC 2006).

Additional work was conducted under the Second Amendment to the Agreed Order and associated Work Plan Addendum (Anchor QEA 2012). These additional activities included supplemental surface sediment chemical and biological testing, subsurface sediment chemical testing, storm drain solid chemical testing, a multi-beam bathymetric survey, and structural conditions surveys in April and May 2012.

Separate from the cleanup studies, sediment cores were collected from the I&J Waterway by USACE in 2011 to evaluate the suitability of open-water disposal at the Bellingham Bay open-water disposal site of sediment dredged from federal navigation channels. Additional testing of archived samples collected by USACE was conducted as part of the I&J Waterway site supplemental investigation activities, which were provided to Ecology in the *Supplemental Investigation Memorandum* in 2013 (Anchor QEA 2013a).

During development of the RI/FS, the Port identified data gaps that were key to developing the remedial alternatives. These data gaps included the need for additional information on sediment quality and strength beneath the Bornstein Seafoods dock, as described in the *Sampling and Analysis Plan Memorandum* (Anchor QEA 2013b). Additional surface and subsurface sampling and strength testing were conducted in the area beneath the Bornstein Seafoods dock in August 2013.

2.1.3 Other Cleanup Sites

As described above, the Site is located in the vicinity of other MTCA cleanup sites. This section describes the relationship of the I&J Waterway site to the other MTCA sites and applicable site documents.

The Whatcom Waterway sediment cleanup site overlaps the I&J Waterway site (Figure 1-1). The primary contaminant at the Whatcom Waterway site is mercury, and the required cleanup described in the Consent Decree (Whatcom County Superior Court No. 07-2-02257-7 [2007 and 2011 first amendment]) in the area of the I&J Waterway site is monitored natural recovery (MNR).

The upland Central Waterfront site is located adjacent to the I&J Waterway site, as shown in Figure 1-2. An RI/FS is concurrently being prepared for the Central Waterfront site under a separate Agreed Order (No. DE3441) and includes evaluation of potential sources to the I&J Waterway site. Any ongoing sources identified will be controlled as part of the remediation of the Central Waterfront site. Upland cleanup levels for the Central Waterfront site will be protective of the I&J Waterway site sediment.

2.2 Current Site Conditions

This section provides a brief overview of the current site conditions developed as part of the RI/FS and as summarized in the Conceptual Site Model (CSM). The key elements of the CSM include the following:

- Contaminants and sources
- Nature and extent of impacts
- Contaminant fate and transport processes
- Exposure pathways and receptors

Graphical illustrations of the CSM are included in Figures 2-1 and 2-2. Table 2-1 and Figure 2-3 summarize chemical data at the Site.

2.2.1 Contaminants and Sources

Based on exceedances of SMS criteria, contaminants in the Site surface sediments include nickel and polycyclic aromatic hydrocarbons (PAHs), and localized areas near the Bornstein Seafoods dock with bis(2-ethylhexyl)phthalate, dimethyl phthalate, N-nitrosophenylamine, dibenzofuran, benzoic acid, and benzyl alcohol. Mercury and total polychlorinated biphenyls (PCBs) in surface sediment were detected at levels exceeding natural background in several samples near the Bornstein Seafoods dock. Contaminants above SMS criteria in subsurface sediments include mercury, bis(2-ethylhexyl) phthalate, and 2,4-methylphenol, and localized areas along the southern edge and the head of the I&J Waterway with benzoic acid, dibenzofuran, dimethyl phthalate, phenol, and PAHs. Total PCBs were present in several subsurface sediment samples above natural background. Dioxin/furans are also present above background levels in surface and subsurface sediment at the Site and throughout much of Bellingham Bay. Contaminants and sources are further described below:

- **Nickel contamination is from historical sources:** The primary source of nickel within the I&J Waterway site surface sediments is historical activities at the Olivine Corporation facility, which operated a rock crushing plant for the mineral olivine. Nickel is a constituent within olivine ore and was periodically released to the Waterway through dust and wastewater. Potential surface soil erosion to the Waterway will be addressed as part of the cleanup of the Central Waterfront site.

- **Bis(2-ethylhexyl)phthalate is from historical sources:** Potential sources of phthalate contamination previously investigated include stormwater outfalls, leachate from the Roeder Avenue landfill, and compressor oil that may have leaked from a compressor on the Bornstein Seafoods dock, but the latter two were previously determined not to be major contributors of bis(2-ethylhexyl)phthalate to the Waterway. Sediment concentrations of bis(2-ethylhexyl) phthalate continue to decrease in most areas of the Waterway, indicating that there are no ongoing significant sources of bis(2-ethylhexyl)phthalate.

- **PAHs are predominantly from historical sources:** Elevated PAHs are localized adjacent to the Bornstein Seafoods dock and along bulkhead/shoreline areas. Historical sources of PAHs are likely related to the fire that destroyed the main Bornstein Seafoods building in 1985, the diesel fueling facility for boats at the Bornstein Seafoods dock between 1960 and the early 1980s, stormwater discharges, and controlled and uncontrolled combustion sources (such as hog fuel burners and/or other fires). Existing creosoted piles and bulkhead structures are also a potential source.

- **Mercury and phenol contamination is predominantly from historical sources:** The primary source of mercury within the I&J Waterway site sediment is the discharge of mercury-containing wastewaters from the former Georgia-Pacific (GP) Chlor-Alkali Plant (located adjacent to the Whatcom Waterway) between 1965 and the 1970s. This historical source of mercury contamination has been controlled. Following initial pollution control upgrades by GP in the early 1970s, direct discharge of Chlor-Alkali Plant wastewaters to Whatcom Waterway was terminated. Then in 1999 the Chlor-Alkali Plant was closed by GP, eliminating the generation of mercury-containing wastewater. The cleanup of the Log Pond area of the Whatcom Waterway site in 2000 and 2001 controlled the secondary source of mercury by capping sediment with the highest levels of mercury contamination. Some regional and natural sources of mercury continue to exist, but these sources are not expected to result in exceedances of benthic criteria. Mercury concentrations in the I&J Waterway are lower in surface sediments than in subsurface sediments and are expected to continue approaching natural background concentrations over time. Surface sediment concentrations were not present above benthic criteria values in 2005/2006, 2012, or 2013. In addition, mercury did not exceed the Whatcom Waterway site sediment bioaccumulation screening level (BSL) of 1.2 milligrams per kilogram (mg/kg) (Ecology 2007) that includes the I&J Waterway site and is protective of both recreational and tribal fishing and seafood consumption practices.

  The primary sources of methyl-phenolic compounds within the I&J Waterway site sediment include historical log rafting, wood products handling as part of lumber company/mill activities that historically operated at the Site, and potential lesser contributions from historical stormwater and wastewater discharges.

- **Other contaminants from unknown historical sources:** Other contaminants, including benzyl alcohol, benzoic acid, dimethylphthalate, N-nitrosodiphenylamine, and dibenzofuran are present in one or two samples above SMS criteria beneath the Bornstein Seafoods dock; see Figure 2-3. Total PCBs were detected above natural background in surface and subsurface sediment samples in the vicinity of the dock. Some contaminants exceed SMS criteria in subsurface sediment at IJ13-VC-102, but none are found in other areas of the Site, suggesting that there is no ongoing source of these contaminants to the Site. Sediment resuspension associated with propeller wash mixing near the Bornstein Seafoods dock could be contributing to slower sediment quality recovery than in other parts of the Site.

- **Dioxin/furans are a bay-wide issue:** Dioxin/furans are present at levels above background in surface and subsurface sediments as a result of historical and potential on-going sources throughout Bellingham Bay. Potential sources of dioxin/furans include activities associated with the historical GP mill, historical operations of The Oeser Company, and stormwater discharges. Other sources to Bellingham Bay may also include historical controlled and uncontrolled combustion sources (such as hog fuel burners and/or other fires).

Because primary sources of contamination have been controlled, the main focus of the Site cleanup actions will be to address residual contamination in sediment at the Site. Other contaminated sites located in the vicinity of the I&J Waterway site are being addressed by Ecology, including the Whatcom Waterway and Central Waterfront sites. Additionally, stormwater management practices have improved over the past several decades, reducing the contaminant load to the Site. The Port, City, and Bornstein Seafoods will continue to administer stormwater upgrades, maintenance, and best management practices under current National Pollutant Discharge Elimination System (NPDES) permits to identify and reduce contaminants into the Site. Post-construction sediment evaluations will provide information on these source control efforts.

2.2.2 Nature and Extent of Contamination

The nature and extent of sediment contamination has been delineated through investigations in 2005/2006, 2012, and 2013 and is depicted in Figures 2-3, 2-4, and 2-5. The findings are presented graphically as a CSM in Figures 2-1 and 2-2 and summarized in the following bulleted list:

- **Head of Waterway Sediments:** The head of the Waterway is a gradual sloping beach to an elevation of approximately -5 feet MLLW where the slope steepens down to the toe of the federal navigation channel. Two surface sediment samples in this area contain concentrations above the benthic chemical criteria for nickel.[1] cPAHs are present in surface sediment in this area at concentrations above preliminary human and ecological health criteria[2]. Dioxin/furans are also present at concentrations above natural background. Most of the surface sediment in this area also exceeds benthic biological criteria.

  Subsurface sediment in this area contains nickel concentrations elevated above benthic chemical criteria, and mercury and dioxin/furans above natural background.

[1] The SCO for nickel has been established at 211 mg/kg based on a site-specific AET (see Section 3.1.2 and Appendix A).
2 The preliminary SCO for cPAHs has been recalculated since the RI/FS based on new information related to methods and parameters for calculating risk-based concentrations. The revised calculations are presented in Appendix B.

- **Navigation Channel Sediments:** Navigation channel sediment includes the federal navigation channel and areas immediately adjacent to the channel, including the area by the USCG facility. Sediment generally consists of a layer of soft, silty contaminated sediment. Most of the surface sediment in the navigation channel in this area exceeds benthic biological criteria. Surface sediment contains elevated concentrations of cPAHs above natural background, with only one sample above preliminary human and ecological health criteria. Mercury is above natural background but not above benthic criteria or the Whatcom Waterway BSL. Dioxin/furans are also elevated above background.

  Subsurface sediment contains elevated nickel, and mercury above benthic criteria, total PCBs above natural background, and dioxin/furan above regional background. The depth and thickness of the contaminated sediment layer varies with location but is generally between 3 and 7 feet in thickness. The vertical extent of contamination was delineated based on the presence of the native uncontaminated glacial marine drift (clay) layer in the navigation channel, which was exposed as a result of historical dredging activities.

- **Nearshore Bulkhead and Dock Sediments:** The southern shoreline of the Site consists of marine trade infrastructure, including the east and west bulkheads and the Bornstein Seafoods dock. Figure 2-2 presents a longitudinal view of the nearshore bulkhead and dock areas. The slope from the bulkheads to the toe of the navigation channel is generally at or steeper than a 2H:1V slope. Chemical, biological, and preliminary human and ecological health criteria exceedances (Figures 2-3, 2-4, and 2-5) have been identified in the nearshore area, consistent with historical sources to the Waterway. Surface sediment in this area contains elevated nickel, PAHs (including cPAHs), and dioxin/furans, with elevated bis(2-ethylhexyl)phthalate, dibenzofuran, phenols, benzoic acid, benzyl alcohol, dimethylphthalate, and N-nitrosodiphenylamine present near the dock. Total PCBs were detected above natural background in surface sediment near the dock.

  Subsurface sediment contains elevated nickel, mercury, bis(2-ethylhexyl)phthalate, phenols, and dioxin/furans. Total PCBs were detected above natural background in some subsurface sediment samples. Localized areas near the dock contain elevated benzoic acid, dibenzofuran, dimethylphthalate, 2-methylnaphthalene, and naphthalene.

2.2.3 Contaminant Fate and Transport Processes

Sediment within the Site is acted upon by natural and anthropogenic forces that affect the fate and transport of contaminants. Significant fate and transport processes include the following:

- **Sediment Natural Recovery:** Processes of natural recovery have been observed within the Site and have also been extensively documented in Bellingham Bay as part of the Whatcom Waterway cleanup investigations. Most areas of the Site are stable and depositional, and cleaner sediment continually deposits on top of the sediment surface. RI investigations for Whatcom Waterway and bathymetry comparisons for the I&J Waterway have documented depositional rates and have verified that patterns of deposition and natural recovery are consistent throughout most Site areas. One potential exception to this general observation is in nearshore, underpier, and berth areas near the Bornstein Seafoods dock, where recovery rates may be reduced by the resuspension of fine-grained sediments from propeller wash or wave activity. In all other areas of the Site, cleaner sediments are consistently observed on top of impacted sediments throughout most areas, and generally improved at co-located stations between 2005/2006 and 2012.

- **Wind and Wave Processes:** The effects of wind/wave erosional forces represent the principal natural process affecting sediment stability. High-energy, nearshore areas such as at the head of the Waterway may have slower natural deposition of fine-grained sediments than other areas. In these areas, fine-grained sediments can be resuspended, mixed, or transported by wave energy. The erosional forces vary with location, water depth, sediment particle size, and shoreline geometry. These forces are minimal in deep-water areas that represent the majority of the Site. The proposed cleanup action considers erosional forces.

- **Navigation Dredging and Shoreline Infrastructure:** Navigation dredging and the construction of associated shoreline marine trade infrastructure has been a prominent feature of the Site and has shaped the current Site lithology. The proposed cleanup action considers current and future community land-use, navigation, maintenance dredging, infrastructure, and habitat enhancement.

- **Other Erosional or Sediment Disturbing Processes:** Bioturbation and propeller wash can result in periodic disturbances of the sediment column and can enhance mixing of surface sediment with underlying sediment. These processes are ongoing and are incorporated in the empirically measured rates and performance of natural recovery. Propeller wash in particular affects sediment stability in nearshore navigation areas. These factors were considered in development of the proposed cleanup action.

2.2.4 Exposure Pathways and Receptors

Exposure pathways and receptors are summarized in the following bulleted list and illustrated in Figure 2-2:

- **Protection of Benthic Organisms:** The primary environmental receptors applicable to the Site consist of sediment-dwelling organisms. These benthic and epibenthic invertebrates are located near the base of the food chain and are important indicators of overall environmental health. Both chemical and biological monitoring are used to test for toxic effects. Chemical and biological standards specified under SMS are used to screen for such effects. The whole-sediment bioassays provide an ability to test for potential synergistic and antagonistic effects between multiple chemicals, and to test for potential impacts associated with parameters not measured as part of chemical testing.

- **Protection of Human and Ecological Health:** cPAHs have been retained as bioaccumulative contaminants based on preliminary levels protective of human health for beach play, clamming, and seafood consumption. These levels are also protective of ecological health for aquatic dependent wildlife foraging at the Site. The highest concentrations of cPAHs are present along the bulkhead and shoreline areas (Figure 2-5) and are generally within the area above benthic biological criteria.

  Dioxin/furans, mercury, and PCBs are not associated with the contaminant releases that resulted in the I&J Waterway site, but are present at concentrations above natural background levels in Puget Sound. These contaminants are co-located with other Site contaminants and will be addressed as part of the Site remediation.

The exposure pathways are complete with surface sediment. In addition, exposure pathways could become complete with subsurface sediment if it is uncovered.

2.3 Site Units

Different areas of the Site have different uses, contributions to site risk, and chemical and physical conditions. The division of the Site into different areas or "site units" was performed in the RI/FS based on the following factors:

- **Physical Factors** including bathymetry, sediment particle size and texture, the characteristics of overwater structures, and adjacent shorelines
- **Land Use and Navigation** including upland zoning, shoreline infrastructure, navigation uses, natural resources, ongoing waterfront revitalization activities, and potential interrelationships between cleanup considerations and these factors
- **Natural Resources** including the types of existing aquatic habitats within the site unit
- **Contaminant Distribution**, including patterns of surface and subsurface contamination and relative contaminant concentrations.

Figure 2-6 shows the I&J Waterway site units. Figures 2-3, 2-4, and 2-5 show SMS criteria exceedances. Characteristics of the site units are listed in Table 2-2. The site units are briefly summarized in the following sections.

2.3.1 Navigation Channel Units

The navigation channel units consist of the Navigation Channel West and the Navigation Channel East site units. Navigation Channel unit water depths vary from approximately 0 foot MLLW near the east end of the unit to -16 feet MLLW near the western portion of the unit. These depths are the result of historical dredging activities in the federal navigation channel and subsequent sedimentation. The authorized channel elevation is -18 feet MLLW. Selected areas of these units were most recently dredged by USACE to the authorized elevation in 1992.

The Navigation Channel West unit is used by USCG vessels and vessels visiting Bornstein Seafoods, and the Navigation Channel East unit is used only by the USCG. Surface sediment contaminant concentrations within the Navigation Channel West unit are above benthic biological criteria, with two Cleanup Screening Level (CSL) bioassay exceedances from 2005/2006 and an SCO bioassay exceedance from 2012. Surface sediment within the Navigation Channel East unit also exceeds benthic biological criteria, with two CSL bioassay exceedances from 2005/2006 and an SCO bioassay exceedance from 2012.

Subsurface sediment contaminant concentrations in the Navigation Channel units are based primarily on historical composite samples, indicating potential SCO benthic chemical criteria exceedances for mercury, 2,4-dimethylphenol, 2-methylphenol, phthalates, and n-nitrosodiphenylamine.

2.3.2 Coast Guard and Coast Guard Bank Units

The Coast Guard unit consists of the area near the USCG dock structure. The Coast Guard Bank unit is the portion of the Bellwether shoreline adjacent to the Coast Guard site unit.

The Coast Guard Bank and Coast Guard units grade from MLLW to approximately -13 feet MLLW at the Coast Guard unit. These depths are largely the result of historical dredging activities in the Waterway, most recently conducted to -18 feet MLLW in 1992, and subsequent sedimentation. The slope is approximately 2.4H:1V. Soft surface sediment extends up to approximately 0 foot MLLW with rubble and riprap present at higher elevations. The Coast Guard unit consists of a fixed boathouse on piles and a floating pile-supported dock, and there are no structures in the Coast Guard Bank unit.

Sediment in the Coast Guard unit is dominated by fine particle size distributions (silts and clays). Fish matter was observed in core IJ-31 in the Coast Guard unit. The Coast Guard Bank unit consists of sediment and rubble with riprap in the shallow portion.

The Coast Guard unit is used only by USCG shallow draft vessels for berthing. Propeller wash from vessels are expected to be significantly less than in the Navigation Channel West unit due to the shallow drafts. Part of the Coast Guard unit is in the federal navigation channel.

The areas of the Coast Guard unit are composed of navigation and subtidal aquatic areas. The Coast Guard Bank unit includes shallow-water depths considered nearshore aquatic habitat (shallow-water habitat with appropriate elevation, substrate, wave energy, and other characteristics to maximize the benefits of the habitat to juvenile salmonids). The Coast Guard Bank unit also has an intertidal area that is accessible to the public from the Head of Waterway site unit, but this area consists of riprap and is not considered to contribute to clamming or beach play exposure scenarios.

Surface sediment contaminant concentrations within the Coast Guard unit exceed benthic biological criteria, with one CSL bioassay exceedance from 2005/2006 and one SCO bioassay exceedance from 2012. No locations were sampled in the Coast Guard Bank unit. Surface sediment concentrations are assumed to be similar to the adjacent Coast Guard and Head of Waterway site units.

Subsurface sediment contaminant concentrations in the Coast Guard site units are based primarily on historical composite samples, indicating potential SCO benthic chemical exceedances for mercury, 2,4-dimethylphenol, 2-methylphenol, phthalates, and n-nitrosodiphenylamine.

2.3.3 Berthing Area Unit

The Berthing Area unit is located between the Navigation Channel West unit and the Dock units.

The Berthing Area unit water depths vary from approximately -16 feet MLLW adjacent to the navigation channel to -10 feet MLLW at the dock face. These depths are the result of historical dredging activities in the Waterway in 1966 (to -18 feet MLLW), again in 1992 along the western portion of the dock (to -18 feet MLLW), and subsequent sedimentation.

Sediment in the Berthing Area unit is dominated by fine particle size distributions (clays and silts) and tend to have higher organic carbon content in subsurface sediments, including fish matter present above the native clay (glacial marine drift layer) present at approximately -20 feet MLLW in this area. Fish matter was observed in cores IJ-23 and IJ-27 in the Berthing Area unit.

Remediation of this site unit must consider the structural integrity of the adjacent dock structure.

This site unit is primarily used by commercial seafood vessels visiting Bornstein Seafoods for navigation and berthing. The appropriate berthing elevations for commercial seafood vessels that frequent the Bornstein Seafoods dock would be consistent with the elevations in the navigation channel but no shallower than -15 feet MLLW. Propeller wash effects from vessel traffic are potentially significant from vessel berthing activities.

Surface sediment contaminant concentrations within the Berthing Area unit exceed benthic chemical criteria for total PAHs, bis(2-ethylhexyl)phthalate, dibenzofuran, and CSL benthic biological criteria, with a bioassay exceedance from 2005/2006. This unit also contains surface sediment concentrations of cPAHs above preliminary human and ecological health criteria.

No discrete core samples were analyzed in the berthing area, but subsurface sediment concentrations based on historical composite samples (Dredged Material Management Units 5 and 6 from 2005), indicate SCO benthic chemical criteria exceedances for mercury, bis(2-ethylhexyl) phthalate, and 2,4-dimethylphenol.

2.3.4 Dock Units

The Dock units consist of the Dock unit and the Floating Dock unit situated between the Berthing Area unit and the adjacent upland bulkhead.

The water depths vary from approximately -10 feet MLLW adjacent to the navigation channel to +1 foot MLLW at the upland bulkhead. Slopes are not armored and have a grade of approximately 2.5H:1V, although debris and rubble is present in the intertidal area. Fish matter was observed in cores IJ-26 and IJ13-VC-101 in the Dock unit.

The Bornstein Seafoods dock is located in the Dock unit and has rows of creosote-treated support piles with a 10-foot spacing, except under the eastern portion, where the spacing is 5 feet. The appropriate berthing elevations for commercial seafood vessels that frequent the Bornstein Seafoods dock would be consistent with the elevations in the navigation channel, but no shallower than -15 feet MLLW. An upland creosote-treated timber bulkhead is present, which supports the upland property that is at an approximate elevation of +17 feet MLLW.

The floating dock in the Floating Dock unit is moored by four dolphins that consist of three piles each. A gangway extends down to the floating dock from the upland area. An upland creosote-treated timber bulkhead is present, which supports the upland property that is at an approximate elevation of +17 feet MLLW. The floating dock is used by commercial seafood vessels associated with Bornstein Seafoods operations.

Propeller wash effects on the surface sediment in these units from vessel traffic (specifically, berthing activities) are likely and are summarized in the RI/FS.

The Dock units also include shallow-water habitat with appropriate elevation, substrate, wave energy, and other characteristics to maximize the benefits of the habitat to juvenile salmonids.

Surface sediment contaminant concentrations within the Dock unit exceed benthic chemical criteria for total PAHs, 2,4-dimethylphenol, benzyl alcohol, bis(2-ethylhexyl)phthalate, and dibenzofuran. Surface sediment contaminant concentrations in the Floating Dock unit exceed benthic chemical criteria, total PAHs, and benthic biological criteria, with a SCO bioassay exceedance from 2005/2006. This unit also contains surface sediment contaminant concentrations of cPAHs above preliminary human and ecological health criteria.

Subsurface sediment in the Dock unit has benthic chemical criteria exceedances for a number of chemicals, including mercury, phthalates, methylphenols, phenol, benzoic acid, dibenzofuran, and PAHs.

Subsurface sediment in the Floating Dock unit has benthic chemical criteria exceedances for mercury, bis(2-ethylhexyl)phthalate, and 2,4-dimethylphenol. Fish matter was observed in core IJ-28 in the Floating Dock unit.

2.3.5 South Bank Unit

The South Bank unit is adjacent to the Floating Dock unit, the Navigation Channel East unit, and the Head of Waterway unit.

The water depths vary from approximately -10 feet MLLW adjacent to the navigation channel to +1 foot MLLW at the upland creosote-treated timber bulkhead to the south. Slopes are not armored and have a grade of approximately 3H:1V.

This unit does not currently support navigation. A multi-use trail is present in the adjacent upland area.

The South Bank unit consists of shallow-water habitat with appropriate elevation, substrate, wave energy, and other characteristics to maximize the benefits of the habitat to juvenile salmonids.

Surface sediment contaminant concentrations within the South Bank unit exceed benthic chemical criteria for nickel, PAHs, and benthic biological criteria, with a CSL bioassay exceedance from 2005/2006. This unit also contains surface sediment concentrations of cPAHs above preliminary human and ecological health criteria.

Subsurface sediment has benthic chemical criteria exceedances for mercury, bis(2-ethylhexyl) phthalate, and 2,4-dimethylphenol.

2.3.6 Head of Waterway Unit

The Head of Waterway unit includes the eastern shore of the Waterway grading down to the navigation channel to the west. It is bordered by constructed banks to the north and an upland creosote-treated timber bulkhead to the south.

The water depths within the Head of Waterway unit range from MLLW up to intertidal areas to the north, east, and south. Riprap and rubble are present along the north intertidal area, and an upland creosote-treated timber bulkhead is present to the south. Large riprap boulders and logs/driftwood are present near the high water line at the eastern end of the unit. A City stormwater outfall is present near high water at the upper end of this unit.

Sediment texture in the Head of Waterway unit is generally dominated by coarser sediment associated with higher energy shallow subtidal and intertidal areas. The grain size distribution grades to finer sediment at deeper elevations. Wood fragments have generally been observed in surface and subsurface sediment in this unit.

This unit does not support navigational uses. In the adjacent upland area, a multi-use trail is present to the south and east, and the USCG facility is present to the north.

Planned uses for this unit are described in the 2013 Waterfront District *Sub-Area Plan* (Port of Bellingham and City of Bellingham 2013). This document calls for the restoration of beach habitat and the creation of a beach park at the head of the I&J Waterway, which may include a public kayak launch area. The intertidal portion of the Head of Waterway unit is the only area of the Site with potential future clamming and beach play exposure scenarios.

The Head of Waterway unit includes intertidal areas of emergent shallow-water habitat. These areas, along with portions of its sides, are valuable forage and refuge areas as part of migration corridors for juvenile salmonids. Eelgrass is not known to be present in this area, but the fine-grained substrate mud at higher elevations (+8 feet to +11 feet MLLW) could potentially provide spawning habitat for sand lance and surf smelt. The preservation and enhancement of these shallow subtidal and intertidal areas was identified as a priority action under the Waterfront District *Sub-Area Plan*.

Surface sediment contaminant concentrations within the Head of Waterway unit exceed benthic chemical criteria for nickel, total PAHs, and benthic biological criteria, with a bioassay SCO exceedance from 2012. This unit also contains surface sediment contaminant concentrations of cPAHs above preliminary human and ecological health criteria.

Subsurface sediment has benthic chemical exceedances for mercury, nickel, bis(2-ethylhexyl) phthalate, and methylphenols.

3 Cleanup Requirements

This section presents applicable regulatory requirements for the cleanup action, develops cleanup standards for the Site based on these regulatory requirements, identifies the Site boundary, and summarizes applicable local, state, and federal laws.

3.1 Cleanup Standards and Site Boundary

This section discusses the development of cleanup standards and identifies the Site boundary, consistent with SMS. The following subjects are discussed:

- Statement of cleanup action objectives: These are narrative statements that describe the goals of cleanup.
- Summary of the exposure pathways, screening levels, and contaminants.
- Selection of cleanup standards for contaminants: Under SMS, the cleanup standards consist of a cleanup level (i.e., a concentration that must be met by the cleanup) and a depth or area of compliance where that cleanup level must be met.
- Identification of Site boundary: The Site Boundary is the area of the Site that must be remediated in order to meet cleanup standards.

3.1.1 Cleanup Action Objectives

Based on the site conditions and current regulations, the following cleanup action objectives are applicable to the Site:

- **Surface Sediment:** Use appropriate technologies including active and/or passive measures to ensure compliance with Site cleanup levels in the bioactive zone of subtidal sediment, and in the clamming/beach play zone of intertidal sediment.
- **Subsurface Sediment:** Where subsurface sediment has the potential to become exposed, use appropriate technologies including active and/or passive measures to ensure long-term compliance with Site cleanup levels in the bioactive zone.
- **Applicable Laws:** Ensure that implementation of the cleanup action complies with other applicable laws.

3.1.2 Summary of Exposure Pathways, Screening Levels, and Contaminants

In the RI/FS, screening levels were developed for potential contaminants for multiple exposure pathways, consistent with WAC 173-204-560, as summarized in the following list:

- Protection of human health, consistent with WAC 173-204-561, for the following exposure scenarios:
  - Seafood consumption
  - Direct contact and incidental ingestion of sediment

  - Beach play
  - Clamming
- Protection of the benthic community, consistent with WAC 173-204-562
- Protection of ecological (higher trophic level species) health, consistent with WAC 173-204-564

The SMS provide a framework for establishing cleanup levels based on exposure pathways, that also considers background concentrations and Practical Quantitation Limits. A two-tier framework is used to define the lower SCO and the upper CSL, which bound the allowable cleanup level. The SCO is the long-term sediment quality goal and is the level at which no adverse effects occur. The CSL is the maximum allowed concentration permissible after completion of a cleanup action and is the level at which minor adverse effects can occur. Using this SMS framework, the RI/FS identified an SCO and CSL for each chemical.

Contaminants were determined by comparing existing sediment concentrations in the I&J Waterway to the SCO (Table 2-1). Chemicals with one or more SCO exceedances were retained as contaminants. Dioxins/furans were not retained as a contaminant because congener profiles suggest no Site-associated release/activity and Site sediments are similar to Bellingham Bay profiles. Total polychlorinated biphenyls (PCBs) and mercury are also not associated with Site releases and were not retained as contaminants. The Site remediation will reduce concentrations of these co-occurring contaminants (i.e., dioxins/furans, PCBs, and mercury) to meet regulatory goals.

The SMS do not have a numeric benthic chemical criterion for nickel, but it was retained as a contaminant in the RI/FS based on concentrations above the former Dredged Material Management Program screening level of 140 mg/kg. However, since completion of the RI/FS, Ecology determined that development of a site-specific Apparent Effects Threshold (AET) is most appropriate to establish a numeric benthic chemical criterion for nickel. Appendix A describes the derivation of the site-specific AET for nickel, which is the level above which adverse biological effects would be expected to occur. The site-specific AET for nickel was found to be 211 mg/kg and establishes the benthic chemical SCO for nickel at the Site.

For protection of human health, the RI/FS developed SCO and CSL values for cPAHs, but the following new information required recalculation of these values:

- Determination of a regional background cPAH concentration of 86 μg TEQ/kg in Bellingham Bay (Ecology 2015)
- Change in cancer potency factor for benzo(a)pyrene from 7.3 $(mg/kg\text{-}day)^{-1}$ to 1 $(mg/kg\text{-}day)^{-1}$ (EPA 2017)
- Consideration of early life stage (ELS) exposure to mutagenic chemicals in risk-calculations

Appendix B presents the revised human health SCO and CSL development work based on this new information. For the ELS exposure, the methodology to derive risk-based concentrations (RBCs) is preliminary because Ecology plans to perform a broader evaluation of the issue. Therefore, the RBCs are preliminary. The future implementation stage of the Site cleanup will define final RBCs.

Appendix B develops both preliminary ELS-based RBCs and standard RBCs for cPAHs. For seafood consumption, the ELS-based RBC is 229 μg TEQ/kg, and the standard RBC is 445 μg TEQ/kg. For the direct contact clamming scenario, the ELS-based RBC is 450 μg TEQ/kg, and the standard RBC is 800 μg TEQ/kg. For the beach play scenario, the ELS-based RBC is 1,160 μg TEQ/kg, and the standard RBC is 6,210 μg TEQ/kg.

3.1.3 Cleanup Standards for Contaminants

Under SMS, the cleanup standards consist of a cleanup level (i.e., a concentration that must be met by the cleanup) and the depth or area of compliance where that cleanup level must be met. The SMS state that cleanup levels are initially set at the SCO but may be adjusted upward as high as the CSL, based on site-specific evaluation of technical possibility and net adverse environmental impact. For the I&J Waterway site, it is technically possible to achieve the SCO for all retained contaminants in a reasonable restoration time frame (Table 3-1). The preliminary cleanup standard for cPAHs reflects the two methods for calculating RBCs presented in Appendix B.

Cleanup levels are applied at different vertical and horizontal spatial scales depending on the exposure pathway they were developed to protect. The site-wide cleanup level for total cPAHs was developed to protect human health from seafood consumption; therefore, the cleanup level must be met on an area-weighted average basis in the upper 12 cm of sediment (the biological active zone that could transfer contaminants up the food chain). The relevant exposure area depends on the species, which includes crab and fish (subtidal home range of approximately 10 square kilometers) and clam (potentially harvested from the intertidal portion of the Site). This site-wide cleanup level for protection of human health is also protective of ecological health. The intertidal cleanup level for cPAHs was developed to protect human health from direct contact; therefore, the cleanup level must be met on an area-weighted average basis in the upper 45 cm of sediment (the approximate depth of potential exposure) in intertidal areas that are accessible to the public. All other cleanup levels were developed to protect the health of the benthic community and therefore must be met for individual points in the upper 12 cm of the Site.

3.1.4 Site Boundary

The Site boundary has been established using the following point-based criteria:

- Based on protection of the benthic community, all contaminants (except cPAHs) with point concentrations above the SCO benthic chemical criteria were incorporated into the Site boundary.

- Based on protection of the benthic community, all SCO exceedances of benthic biological criteria were incorporated into the Site boundary.

The Site totals 3.1 acres, as shown in Figure 2-6. The Site boundary developed to protect the benthic community also results in meeting the preliminary cPAH cleanup standards for protection of human and ecological health and the Bellingham Bay dioxin/furan regional background concentration of 15 ng TEQ/kg.[3]

3.2 Applicable Local, State, and Federal Laws

Cleanup actions must comply with applicable local, state, and federal laws. In certain cases, a permit is required. In other cases, the cleanup action must comply with the substantive requirements of the law but is exempt from the procedural requirements of the law (RCW 70.105D.090; WAC 173-340-710).

Additionally, persons conducting remedial actions have a continuing obligation to determine whether additional permits or approvals are required or whether additional substantive requirements for permits or approvals must be met.

3.2.1 Required Permits and Approvals

Cleanup actions at the Site are anticipated to require a permit for discharge of dredged, excavated or fill material to waters of the United States pursuant to Section 404 of the Clean Water Act. It is anticipated that the cleanup of the Site will be performed using a Federal 404 Individual permit or a Nationwide Permit 38, issued by the USACE. Impacts of the cleanup action on the federal navigation channel will also be conducted pursuant to Section 408 of the Clean Water Act by the USACE. The federal permitting process includes review of issues relating to wetlands, tribal treaty rights, threatened and endangered species, habitat impacts, and other factors, including impacts to the federal navigation channel.

The time required to complete permitting and associated regulatory reviews can vary from one to several years. The following describes several of the permitting issues:

- **Endangered Species Act Review:** The Site area is potential habitat for threatened and/or endangered species; therefore, cleanup actions will be subject to Endangered Species Act review. The National Marine Fisheries Service and the U.S. Fish and Wildlife Service will perform the review as part of the permit process.

[3] Regional background is expected to be achieved for dioxin/furan following active remediation based on the predicted weighted average concentration following remediation of 12 ng TEQ/kg. This assumes a replacement value of 5 ng TEQ/kg in the dredging, ENR, and capping areas (2.3 acres) and an interpolated concentration of 17.6 ng TEQ/kg in the MNR and no action areas (3.1 acres).

- **Historical/Archaeological Review:** As part of the permit process, the USACE will review the cleanup actions to determine whether they will disturb historical or archaeological resources.

- **Dredged Material Management Program:** In Puget Sound, the open-water disposal and reuse of sediments are managed by the DMMP. This program is administered jointly by the USACE, U.S. Environmental Protection Agency, Washington Department of Natural Resources (WDNR), and Ecology. As part of the permit process, the USACE will ensure dredged material is managed in accordance with the requirements of the DMMP, and Ecology will review compliance with state anti-degradation requirements.

- **National Environmental Policy Act Review:** Construction projects are subject to environmental impact review under State Environmental Policy Act (SEPA) and/or National Environmental Policy Act (NEPA) regulations. The SEPA review for the cleanup of the Site is being completed by Ecology. NEPA review will be completed by the USACE through the 404 permit process.

- **Water Quality Certification from the State of Washington pursuant to Section 401 of the Clean Water Act:** As part of the 404 permitting process, a Section 401 water quality certification must be obtained from Ecology. Certification ensures that the 404 permitted actions will comply with state water quality standards and other aquatic resource protection requirements under Ecology's authority.

- **National Pollutant Discharge Elimination System (NPDES) Waste Discharge Permit for discharge of pollutants to waters of the United States pursuant to Section 402 of the Clean Water Act:** The cleanup of the Site will generate waste water that will be either discharged to the local sanitary sewer system or to surface water. Discharge of pollutants to surface water requires a permit under Section 402 of the Clean Water Act to ensure compliance with state water quality standards. NPDES permits are obtained from Ecology.

- **Washington State Scientific Collection Permit:** Post-cleanup compliance monitoring may require the collection of fish or shellfish tissue. The Washington Department of Fish and Wildlife (WDFW) issues this permit.

3.2.2 Substantive Requirements

The cleanup action must also meet the substantive requirements of permits or approvals that are procedurally exempt under RCW 70.105D.090. The substantive requirements of the following permits, known at this time to be applicable to the cleanup action, will be followed:

- **Hydraulic Project Approval:** Projects involving in-water construction activities typically require a Hydraulic Project Approval (HPA). HPAs are issued by WDFW and define state requirements for construction activities that could adversely affect fisheries and water resources.

- **Shoreline Management Substantial Development Permit:** Projects within the City Limits of Bellingham and within 200 feet of the ordinary high water mark of Bellingham Bay typically must obtain a Shoreline Management Substantial Development Permit (Shoreline Permit). Shoreline Permits are issued by the City and include requirements to protect the ecological function of shorelines.

As part of remedial design activities, a request will be made to the City and WDFW for a written description of their substantive permit requirements. This information will be included in the Engineering Design Report.

4 Cleanup Action Alternatives Considered in the RI/FS

This section summarizes the cleanup action alternatives developed and evaluated in the RI/FS. Six cleanup action alternatives were developed to capture the range of potential actions. All alternatives were designed to achieve significant risk reduction following construction, and achieve cleanup standards either following construction or within 10 years following construction. Stepping from Alternative 1 to Alternative 6, the cleanup action alternatives generally increase in reliance on removal and decrease in reliance on natural recovery (Tables 4-1 and 4-2).

4.1 Common Assumptions for the Cleanup Action Alternatives

All alternatives include sediment removal, placement of clean material, and extensive work in the vicinity of the Bornstein Seafoods dock. In addition to construction items, all alternatives include costs for permitting and design, mobilization and demobilization, staging, transloading, monitoring, ICs, and oversight. Many construction items are common to the remedial alternatives, and the costs and construction time frames were estimated using the same assumptions for all alternatives. The costs and engineering assumptions were based on experience with other remediation sites in the Puget Sound region.

All alternatives meet cleanup goals given the land use plans at the head of the Waterway, which include a park and public access area, and continued operation of the Coast Guard and Bornstein Seafoods facilities. Alternatives that incorporate MNR in the federal navigation channel will require ICs, including a possible memorandum of agreement between the Port and Ecology to ensure that cleanup goals are maintained over the long term in this area.

4.2 Alternative 1

Alternative 1 generally consists of capping and dredging areas with the highest contribution to site risk, and MNR in areas with lower contribution to site risk. As shown in Table 4-1 and Figure 4-1, Alternative 1 includes the following technologies:

- The Head of Waterway unit is capped to isolate contaminated sediment from clamming and beach play.
- The Dock and Floating Dock units are capped to immediately reduce surface sediment contaminant concentrations. A sheetpile toe wall will be installed at the dock face to support the cap.
- The Berthing Area unit is dredged to the native clay layer to immediately reduce surface and subsurface sediment contaminant concentrations and because other remedial technologies do not provide adequate berthing elevations.
- MNR is assigned to the rest of the site units, including the Navigation Channel, Coast Guard, Coast Guard Bank, and South Bank units. These are generally subtidal areas that have lower

surface sediment contaminant concentrations, higher sedimentation rates, and evidence of natural recovery.

4.3 Alternative 2

Similar to Alternative 1, Alternative 2 generally consists of capping and dredging site units with the highest contribution to site risk, and MNR in areas with lower contribution to site risk. Alternative 2 differs from Alternative 1 in that it includes additional enhanced natural recovery (ENR) in the South Bank unit to further reduce risks following construction (Table 4-1 and Figure 4-2).

4.4 Alternative 3

Alternative 3 is similar to Alternative 2, but with dredging to the native clay layer in the Navigation Channel West unit to immediately reduce surface and subsurface sediment contaminant concentrations (Table 4-1 and Figure 4-3).

4.5 Alternative 4

Alternative 4 is similar to Alternative 3, but with dredging to the native clay layer in the Dock unit and Floating Dock unit to immediately reduce surface and subsurface sediment contaminant concentrations, instead of capping (Table 4-1 and Figure 4-4). Removal of contaminated sediment would require that the Bornstein Seafoods dock in the Dock unit and the adjacent bulkhead be removed and replaced as part of cleanup because the existing dock and bulkhead would be destabilized as a result of dredging. The dock in the Floating Dock unit is assumed to be temporarily relocated and restored to its original position following remediation.

4.6 Alternative 5

Alternative 5 is similar to Alternative 3, but does not rely on ENR or MNR. Instead of ENR, this alternative relies on dredging to the native clay layer in the Navigation Channel East, Coast Guard, Coast Guard Bank, and South Bank site units. Like Alternatives 1 through 3, Alternative 5 caps contaminated sediment in the Dock unit and includes a subtidal sheetpile toe wall to provide cap stability and maintain berthing depths (Table 4-1 and Figure 4-5). Removal of contaminated sediment adjacent to the South Bank unit would require that the adjacent bulkhead be removed and replaced as part of cleanup because the bulkhead would be destabilized as a result of dredging.

4.7 Alternative 6

Alternative 6 is the full removal alternative and features dredging to the native clay layer in all locations. The alternative is shown in Table 4-1 and Figure 4-6.

5 Basis for the Selection of the Proposed Cleanup Action

The SMS criteria for selecting a cleanup action are specified in WAC 173-204-570. The RI/FS presented an evaluation of the six cleanup action alternatives described above against these criteria. This section summarizes the evaluation and provides the basis for selecting the proposed cleanup action.

5.1 Minimum Requirements

Cleanup actions performed under the SMS must comply with 11 minimum requirements under WAC 173-204-570(3). This section discusses the achievement of the SMS minimum requirements.

5.1.1 Compliance with Cleanup Standards

Under SMS, compliance with cleanup standards represents the measure of whether and when an alternative has reduced risk sufficiently to protect human health and the environment. The cleanup standards were developed to protect human health, the health of the benthic community, and ecological (higher trophic level species) health under WAC 173-204-560 through 564. Therefore, compliance with cleanup standards is used to evaluate the minimum requirements of "protection of human health and the environment" (WAC 173-204-570(3)(a)), "compliance with cleanup standards" (WAC 173-204-570(3)(c)), and to "provide for a reasonable restoration time frame" (WAC 173-204-570(3)(e)).

Table 5-1 presents the estimated performance of the cleanup action alternatives relative to cleanup standards. As discussed for each alternative, all alternatives are expected to meet cleanup standards either following construction, or within 10 years following construction.[4] Consistent with WAC 173-204-570(5)(a), all alternatives are considered to have a reasonable restoration time frame and meet these three minimum requirements.

5.1.2 Other Minimum Requirements

The achievement of other minimum requirements is discussed in the following list:

- All alternatives comply with all applicable laws as summarized in Section 3.2 (WAC 173-204-570(3)(b)).
- Source control measures are not necessary for any of the cleanup alternatives (WAC 173-204-570(3)(f)) because the historical sources of Site-related contamination no longer exist.
- A sediment recovery zone is not expected to be necessary for any of the cleanup action alternatives ((WAC 173-204-570(3)(g)) because cleanup standards are achieved within 10 years following construction.

[4] Concentrations of co-occurring contaminants, including dioxins/furans, mercury, and total PCBs, will achieve SMS requirements following construction.

- None of the cleanup action alternatives exclusively rely on MNR or ICs (WAC 173-204-570(3)(h)).
- The RI/FS has undergone, and the CAP will undergo, appropriate public review and comment by affected landowners and the general public (WAC 173-204-570(3)(i)).
- All alternatives include adequate monitoring to ensure effectiveness of the cleanup action (WAC 173-204-570(3)(j)).
- All alternatives that leave contamination in-place will be subject to periodic reviews under WAC 173-204-570(3)(k).

The disproportionate cost analysis (DCA) performed in the RI/FS is summarized in the next section and addresses the minimum requirement of "using permanent solutions to the maximum extent practicable" (WAC 173-204-570(3)(d)).

5.2 Disproportionate Cost Analysis

SMS specifies that preference shall be given to actions that are permanent solutions to the maximum extent practicable. Identifying an alternative that is permanent to the maximum extent practicable requires weighing the costs and benefits of each. SMS uses the MTCA DCA (WAC 173-340-360(3)(e)) as the tool for comparing each remedial alternative's incremental environmental benefits with its incremental costs; see WAC 173-204-570(4).

Seven criteria, which are defined under WAC 173-340-360(3)(f), were used in the RI/FS to evaluate and compare cleanup action alternatives. The first six criteria were weighted and assigned a score for total benefits; these total benefits were then compared with costs across all alternatives.

- Protectiveness (30% of total benefit score)
- Permanence (20% of total benefit score)
- Effectiveness over the long term (20% of total benefit score)
- Management of short-term risks (10% of total benefit score)
- Technical and administrative implementability (10% of total benefit score)
- Consideration of public concerns (10% of total benefit score)
- Cost (compared to total benefits)

Total benefit scores and costs are shown in Table 5-2 and plotted in Figures 5-1 and 5-2. The total weighted benefits range from 2.4 for Alternative 1 to 4.5 for Alternative 6, and costs range from $5.4 million to $20.6 million. For Alternatives 1 through 4, the alternatives increase in both costs and benefits. Alternative 5 has higher costs than Alternative 4 but does not have increased benefits. Alternative 6 has the highest benefits and the highest costs.

MTCA states that "Costs are disproportionate to benefits if the incremental costs of the alternative over that of a lower cost alternative exceed the incremental degree of benefits achieved by the alternative over that of the lower cost alternative" (WAC 173-340-360(3)(e)(i)). Evaluating the costs and the benefits of the alternatives, Alternatives 5 and 6 are disproportionately costly compared to the benefits; Alternative 4 has the highest benefits of the remaining alternatives, and therefore is the alternative that "uses permanent solutions to the maximum extent practicable" (WAC 173-204-570(3)(d)).

6 Proposed Cleanup Action

This section describes the proposed cleanup action for the Site. Information summarized in this section includes the following:

- Description of the proposed cleanup action, including which technologies are applied in the different site units (Section 6.1);
- Summary of the basis for selecting the proposed cleanup action (Section 6.2);
- Summary of the types and quantities of hazardous substances remaining at the Site after construction of the cleanup action (Section 6.3);
- Discussion of the compliance monitoring to be performed during and after construction of the cleanup action (Section 6.4); and
- Presentation of the ICs to be applied as part of the cleanup action (Section 6.5).

6.1 Description of the Proposed Cleanup Action

Alternative 4, described in Section 4.5, is the proposed cleanup action for the Site (Figure 6-1). Under this alternative, contaminated sediment is remediated using both active and passive cleanup technologies, including removal of sediment in the Dock, Floating Dock, Berthing Area, and Navigation Channel West site units, capping in the Head of Waterway Unit, ENR in the South Bank Unit, and MNR in the Coast Guard and Navigation Channel East units. Removal of contaminated sediment in the Dock and Floating Dock units will require the removal and rebuild of the Bornstein Seafoods dock and bulkhead, which will also remove treated wood from the aquatic environment. The Coast Guard facility will not be removed or rebuilt as part of dredging; appropriate offsets and slopes will be incorporated during design to maintain structural stability. Monitoring and ICs will be used to ensure the long-term effectiveness of the remedy. Dredged sediments will be disposed of in a permitted landfill.

6.2 Basis for Selecting the Proposed Cleanup Action

Alternative 4 is selected as the proposed cleanup action consistent with MTCA and SMS alternatives evaluation and remedy selection criteria. These criteria include the following:

- **Compliance with SMS Minimum Requirements:** Alternative 4 complies with minimum requirements discussed in Section 5.1, including protecting human health and the environment, and complying with the cleanup standards in a reasonable restoration time frame (meet all cleanup standards in less than 10 years).

- **Use of Permanent Solutions to the Maximum Extent Practicable:** As described in Section 5.2, Alternative 4 uses permanent solutions to the maximum extent practicable, based on the findings of the disproportionate cost analysis. Alternative 4 costs an estimated $12.6 million; however, these costs are proportionate to the environmental benefits. Other lower-cost alternatives provide a lower degree of environmental benefit than Alternative 4. Higher-cost alternatives were determined to be impracticable because their incremental increase in cost over Alternative 4 is disproportionate to the incremental increase in benefit over Alternative 4.

6.3 Types, Levels, and Amounts of Contamination Remaining

The proposed cleanup action removes high concentrations of contaminated sediment from the I&J Waterway site, restores the biologically active zone (top 12 cm) of subtidal sediment to below cleanup levels, and restores the top 45 cm of intertidal sediment to below cleanup levels.

In the capping, ENR, and MNR areas near the head of the Waterway, buried contaminated sediment will remain following construction of the cleanup action. Based on historical sediment cores and surface sediment samples, remaining contamination exceeding the SCO will include nickel (up to 1,120 mg/kg), mercury (up to 0.88 mg/kg), 2,4-dimethylphenol (up to 610 µg/kg), 2-methylphenol (up to 400 µg/kg), phthalates (up to 130 mg/kg OC for bis(2 ethylhexyl)phthalate), n-nitrosodiphenylamine (up to 36 µg/kg), and cPAHs (up to 1,154 µg/kg).[5] The total volume of contaminated sediment remaining at the head of the Waterway is estimated to be 21,000 cy.

6.4 Compliance Monitoring and Contingency Responses

Compliance monitoring and contingency responses (as needed) will be implemented in accordance with WAC 173-340-410, Compliance Monitoring Requirements. Detailed requirements will be described in the Site Construction Quality Assurance Plan (CQAP), Compliance Monitoring and Contingency Response Plan (CMCRP), and Water Quality Monitoring Plan (WQMP) to be prepared as a part of remedial design. The objective of the first two plans is to confirm that the goals of the cleanup action have been achieved, and to confirm the long-term effectiveness of cleanup actions. The objective of the WQMP is to provide quality assurance that the contractor's operations are in compliance with water quality criteria. The plans will outline the duration and frequency of monitoring, the trigger for contingency response actions, and the rationale for terminating monitoring. The plans will be part of an Engineering Design Report (EDR).

6.4.1 Compliance Monitoring Objectives

The objectives of compliance monitoring as stated in WAC 173-340-410 are the following:

1. **Protection Monitoring:** This type of monitoring is used to confirm that human health and the environment are adequately protected during the construction period of the cleanup action.
2. **Performance Monitoring:** This type of monitoring is used to confirm that the cleanup action has attained cleanup standards and other performance standards.

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[5] Maximum concentrations are based on the maximum of all historical surface sediment and subsurface sediment samples where contaminants will remain in place following remediation.

3. **Confirmation Monitoring:** This type of monitoring is used to confirm the long-term effectiveness of the cleanup action once performance standards have been attained.

Cleanup standards and associated points of compliance for the cleanup action are described in Section 3.

6.4.2 Compliance Monitoring Categories

Five types of compliance monitoring will be undertaken at the Site as follows:

- **Water Quality (Protection Monitoring):** During remedial action, various construction controls will be implemented as feasible to ensure water quality protection within the Site area. Protection will be verified through a combination of intensive monitoring (e.g., once per construction shift) and routine monitoring (e.g., once weekly). Protection monitoring will identify the need for further controls as appropriate.

- **Physical Integrity (Performance and Confirmation Monitoring):** Physical integrity monitoring may include bathymetric surveys and direct inspections of intertidal and shoreline areas. Monitoring will be conducted during the cleanup action to verify the performance objectives (e.g., minimum cap thickness or minimum dredge depths). Following completion of construction, long-term physical monitoring of cap surfaces and naturally recovered areas will be performed to verify that they are not substantially eroded over time by natural or anthropogenic forces. Evidence of erosion may result in additional monitoring evaluation and contingency actions to protect human health and the environment.

- **Sediment Quality in Removal, Capping, and ENR Areas (Performance Monitoring):** The effectiveness of sediment removal during and following construction will be verified in a two-step sequence. First, physical surveys (as outlined above) will be performed to verify that dredging has achieved required dredge depths as developed in remedial design. If placement of a clean sand residuals management cover layer is used as part of management of dredge residuals, then these areas will also be included within the scope of performance monitoring. In capping and ENR areas, physical surveys will be used to ensure that desired placement thicknesses are achieved. In the second step, post-construction (Year 0) surface sediment samples (0 to 12 cm) will be collected and analyzed for priority contaminants as part of performance monitoring.

- **Sediment Quality in Cap and Natural Recovery Areas (Confirmation Monitoring):** Sediment quality in all cap and natural recovery areas will be documented during long-term confirmation monitoring. Sediment quality monitoring events are anticipated to be conducted during years 1, 3, 5, 10, 20, and 30 after completion of the remedial action. Additional monitoring events may be required and/or the term extended in the event that sediment areas are shown during physical and chemical monitoring to be unstable, exhibit recontamination, or show insufficient recovery. Chemical and/or confirmatory biological monitoring of surface sediment will be performed to verify that these areas achieve and maintain compliance with Site cleanup standards as described in Section 3 of this CAP.

- **Tissue Testing:** Targeted tissue testing may also be performed as part of confirmation monitoring.

Additional details regarding the anticipated monitoring requirements are provided below. Final specific monitoring requirements (i.e., sample locations, monitoring parameters) will be defined as part of remedial design and permitting. The following parameters are provided to clarify Ecology expectations as part of the CAP.

6.4.3 Water Quality Monitoring

Water quality will be monitored during dredging of sediments, following procedures to be detailed in the WQMP. Water quality samples will be obtained and analyzed to monitor and control short-term water quality impacts from dredging activities, and to invoke corrective actions or modify dredging procedures, if necessary, to bring construction activities into compliance with water quality standards.

The purpose of the water quality monitoring is to provide ongoing assessment of the water quality impacts of dredging of Site sediment. General requirements of the monitoring program for open-water dredge and cap areas are as follows:

- Characterize baseline water quality conditions prior to construction.
- Assess dissolved oxygen compared to prescribed minimums.
- Assess turbidity compared to prescribed maximums (compliance with turbidity criteria also ensures protection from dredging-related contaminant releases).
- Allow for appropriate adjustment of construction activities in a manner to protect human health and the environment.
- Document the results of the water quality performance monitoring.

Water quality monitoring will include documentation of baseline water quality monitoring within or near dredging and capping operation areas to establish ambient water quality conditions. Determination of baseline water quality will be presented in a baseline water quality monitoring report.

Dissolved oxygen and turbidity can fluctuate greatly in Inner Bellingham Bay due to silt distribution from the Nooksack River and turnover effects that can bring water with lower dissolved oxygen to the surface. Therefore, in addition to pre-construction monitoring/sampling of the ambient water quality locations, some of the locations shall be monitored daily during those periods of construction activity which also require intensive water quality monitoring, to check for unusual departures of ambient conditions from normal levels. The selection of daily ambient monitoring locations shall be rotated to best complement current dredging operations. Ambient threshold criteria will be recalculated periodically to incorporate these additional background measurements.

During construction, water quality monitoring will be performed in the vicinity of dredging and capping operations when the activity is in progress. The compliance boundary for the zone of disturbance will be established at a maximum distance of 150 feet from the point of dredging or cap placement, and the boundary will move with equipment operation. Monitoring stations will be established downstream of the dredge or cap placement location along the predominant direction of tidal flow (flood or ebb). The exact monitoring locations may move laterally along the compliance boundary and the midpoint. Monitoring locations will be positioned to intercept any visible turbidity plumes released from construction activities. At each monitoring location, water quality will be monitored at shallow (within 3 feet of the water surface), deep (within 6 feet of the sediment surface), and mid-column depths.

Ongoing dredging and capping activities require rapid feedback from the monitoring program to support implementation of corrective actions in a timely manner. The WQMP will specify the appropriate balance between rapid turn-around results and maintenance of an appropriate level of quality control.

6.4.4 Sediment Monitoring

Performance monitoring will be conducted for surface sediment in dredge, cap, and ENR areas at Year 0. Confirmational monitoring of surface sediment is anticipated to be conducted in cap, ENR, MNR, and No Action areas during years 1, 3, 5, 10, 20, and 30 following completion of the cleanup action (with potential modifications in the schedule depending upon prior sampling results). This may include decrease or increase in frequency and/or intensity of sampling efforts.

Performance and confirmational surface grab samples (upper 12 cm of sediment) will be collected along a systematic grid. Sample collection procedures will be specified in the CQAP. Data quality objectives and procedures used in performance monitoring sample collection, analysis, and data validation shall correspond to those used in the RI/FS. The number of confirmational monitoring locations is expected to be up to six locations for the cap and natural recovery areas. Additional sampling locations will be established in removal and No Action areas for performance monitoring. Final monitoring locations and number will be determined during remedial design. Monitoring priorities will include the following:

- **Target Sampling Areas:** The sampling locations will be sufficient to monitor surface and subsurface sediment quality throughout the active and passive remedial action areas. This will include but not be limited to dredged, capped, natural recovery, and No Action areas. The sampling will generally follow a grid pattern, but the sample density may vary depending on the type of remedial action (e.g., cap versus MNR area) and the relative concentrations of underlying or adjacent subsurface sediments (i.e., sample density may be greater in areas with higher subsurface concentrations).

- **Different Elevations and Slopes:** Monitoring points will be placed to ensure representative monitoring of different slopes or elevations through the cap and natural recovery areas.

- **Stormwater Discharges:** Sampling locations may be targeted to ensure monitoring of areas of the Site subject to stormwater discharges or other discharges that could potentially affect surface sediment quality.

6.4.5 Contingency Response Actions

Detailed contingency response actions will be described in the Site CQAP, CMCRP, and WQMP to be prepared as a part of remedial design. The objective of these plans is to confirm that cleanup standards have been achieved, to confirm the long-term effectiveness of cleanup actions at the Site, and to provide quality assurance that the contractor's operations are in compliance with water quality criteria. Along with the information on monitoring, these plans will discuss the types of contingency actions that could potentially be required in response to monitoring observations, and will discuss triggers for different types of contingency response actions. The plans will be part of an EDR. Examples of types of potential contingency response actions are discussed below to clarify Ecology expectations for the types of information to be developed as part of the CQAP, CMCRP, and WQMP.

6.4.5.1 Construction Contingencies

The EDR will define specific performance standards for the cleanup action. During construction of the cleanup action, contingency response actions could be triggered by a number of types of events. The following types of contingencies shall be addressed in the CQAP and WQMP:

- **Achievement of Physical Performance Standards:** Construction contingencies shall address compliance with physical performance standards such as dredging depth or cap elevation. Contingencies could be triggered by the presence of unanticipated field conditions and generally can be addressed through modifications of equipment selection, dredging/capping methods, or production rate.

- **Dredging Residuals Management:** Ecology expects that the CQAP will consider potential management options and contingencies for dredge residuals, such as limited redredging and/or use of MNR or ENR (including placement of a clean sand residuals management cover layer).

- **Water Quality Impacts:** Construction contingencies shall be considered in the event that water quality performance standards are not met during dredging or capping. These contingencies may include actions such as temporary cessation of operations, assessment of the cause of the water quality problem, definition of appropriate measures to correct the problem, and appropriate notifications and reporting to Ecology relating to the water quality problem and the measures taken to correct the problem.

6.4.5.2 Post-Construction Contingencies

The EDR will also discuss contingencies applicable to the period following completion of construction. The following types of contingencies shall be addressed in the CMCRP:

- **Recontamination of Cap or Natural Recovery Areas:** The potential for sediment recontamination will be monitored as part of long-term sediment monitoring. The CMCRP will discuss triggers and potential contingency responses including response timelines if recontamination is observed. Generally these responses will include collection of appropriate data to define the source and extent of recontamination, assessment of control options for the source of the recontamination (e.g., implementation of enhanced stormwater source control and/or treatment), and implementation of appropriate corrective measures for the area of recontamination (e.g., monitoring, ENR, capping, or dredging as appropriate to the location, extent, and stability of the affected area).

- **Stability of Sediment Caps:** The sediment caps to be placed as part of the proposed cleanup are intended to be stable under Site conditions and anticipated land and navigation uses. The physical integrity of the caps will be monitored to ensure that this stability is achieved. If erosion is observed in cap areas, then contingency response measures will be implemented in a timely manner to correct the problem and restore stability. Generally these responses will include collection of appropriate data to define the source and extent of the cap erosion, assessment of potential control options, and implementation of appropriate corrective measures for the affected area. These corrective measures could include placement of additional cap material, construction of protective groins or armoring, or modifications to cap elevation through dredging and new material placement.

6.5 Institutional Controls

The cleanup action was developed to ensure protection under anticipated land and navigation uses. However, in conjunction with compliance monitoring, ICs will be undertaken to limit or prohibit activities that could interfere with the integrity of the cleanup action or result in exposure to hazardous substances. ICs will include multiple actions as described below.

6.5.1 *Anticipated Uses*

Anticipated land and navigation uses include the following:

- **Head of the Waterway:** In 2013, Ecology approved the City's revised state-mandated Shoreline Master Plan (SMP). The SMP regulates and manages uses and activities within 200 feet of the shorelines of the City. The pocket beach at the head of the I&J Waterway is categorized as an urban maritime recreational use subarea and is identified as an area where public access will be established or enhanced.

- **Navigation Channel:** The I&J Waterway includes a federal navigation channel, with a width of 100 feet and an authorized depth of -18 feet MLLW. Berth areas adjacent to the federal channel include a mixture of state-owned and privately owned lands with varying water depth needs.

  Current navigation uses in the Waterway include commercial fishing vessels berthing at the Bornstein Seafoods processing facility and USCG vessels that dock at the USCG station on the east side of the Waterway. The outer portion of the I&J Waterway federal navigation channel has elevations around -15 feet MLLW and provides sufficient navigation access for vessels entering Squalicum Inner Harbor or visiting the Hilton Harbor facilities.

  The western portion of the navigation channel adjacent to the Bornstein Seafoods dock will retain the authorized depth of -18 feet MLLW. The eastern portion of the navigation channel, where MNR is planned and USCG vessels operate, has shallower depth requirements. Ecology will review any future maintenance dredging in these areas to ensure that cleanup goals are maintained over the long term.

- **Dock and Floating Dock Units:** The Bornstein Seafoods dock areas are expected to continue with navigation uses associated with Bornstein Seafoods. Periodic maintenance dredging of this area may be performed to maintain water depths, but deepening of this area (beyond environmental dredging depths) is not anticipated.

6.5.2 *Institutional Control Mechanisms*

Upon completion of active cleanup measures, an IC Plan will be developed for the Site, in consultation with the appropriate federal, state, and local agencies. The IC Plan will address such matters as waterway signage on prohibited activities, vessel size, and speed; signage regarding protection of capped areas; lease prohibitions or usage restrictions and notifications; as well as a plan for enforcing the Waterway restrictions.

Environmental covenants will also be recorded with Whatcom County for all MNR, ENR, and capped areas that are not on state-owned property.

The environmental covenants will inform individuals that the property is the subject of a cleanup action under MTCA, describe the type and location of the cleanup action, and describe the principal contaminants present. They will prohibit any activity that may impact or interfere with the cleanup action, or may threaten continued protection of human health and the environment, without the prior written approval of Ecology. In addition, the environmental covenants will require owners of the property to notify all lessees or property purchasers of the restrictions on the use of the properties. Finally, the environmental covenants will require the owners of the properties to make provisions for continued monitoring and operation and maintenance of the remedial action prior to conveying title, easement, lease or other interest in the property. The environmental covenants will be subject to Ecology's approval before being recorded.

For MNR, ENR, and capped areas on state-owned property, the ICs may be undertaken using a variety of administrative mechanisms, including a remediation easement between WDNR and the Port, documentation in WDNR geospatial records, and an administrative agreement between WDNR and Ecology.

7 Implementation of the Cleanup Action

To expedite the removal of sediment with the highest levels of contamination, the cleanup action will be implemented in two separate and distinct areas, or Sediment Cleanup Units (SCU; Figure 6-1), in accordance with the SMS. The cleanup action for SCU-1 (the dredge/removal area) will be designed under the agreed order to which this CAP is an exhibit, followed by implementation under a future amendment to the agreed order, or a future consent decree between the PLPs and Ecology. Then the cleanup action for SCU-2 (the remainder of the Site) will be designed and implemented.

The anticipated schedule for design and implementation of the cleanup action for SCU-1 is described in the following subsections.

7.1 Design

The design process will include acquisition of required permits and approvals by the PLPs. Design and permitting activities are expected to require approximately 1 to 2 years to complete, though permitting time frames are uncertain. Pre-design data collection work will be necessary to document current conditions (e.g., current bathymetric data, supplemental surface sediment sampling and coring, and geotechnical data). Based on the pre-design data collection work, an EDR will be prepared that contains design details, as well as a CQAP, a CMCRP, a WQMP, proposed best management practices, permit exemptions and substantive requirements, and any other information necessary to secure required permits and approvals, and prepare construction plans and specifications. The EDR will be finalized following Ecology approval, and PLP acquisition of required permits or approvals. After this effort is complete, detailed construction plans and specifications will be prepared.

7.2 Implementation

(Under a future amendment to the agreed order, or a future consent decree)

- **Cleanup Construction:** Following design and permitting activities, the cleanup action will be constructed. Timing of most in-water work activities will be limited by permit-specified "fish windows" to appropriate time periods when those activities are least likely to affect migrating juvenile salmonids and other aquatic species. These time limitations will affect the amount of work that can be completed within a given construction season, and particularly affect the overall time required to complete dredging, capping, dock and bulkhead construction, and shoreline restoration activities. Other work does not require in-water activity (e.g., upland sediment staging/transport) but is subject to other logistical constraints. Cleanup construction is reasonably expected to be performed in a single construction season.

- **Institutional Controls:** Following construction, an Institutional Controls Plan will be prepared and implemented. ICs required by this plan will remain in place indefinitely unless removal is approved by Ecology.

- **Compliance Monitoring:** Compliance monitoring will occur during and following construction, in accordance with the CQAP, CMCRP, and WQMP that were prepared as part of design and permitting activities. Post-construction monitoring is expected to occur in years 1, 3, 5, 10, 20, and 30 following completion of construction.

After implementing the cleanup action for SCU-1, the cleanup action for SCU-2 will be designed and implemented.

8 References

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Tables

Table 2-1
Summary of Surface Sediment Concentrations of Contaminants

Analyte	Detection Frequency				Screening Level: Carbon Normalized Value		Screening Level: Dry-weight Value		Maximum Detected Value: Carbon Normalized Value (only samples with TOC >0.5% and <3.5%)		Maximum Detected Value: Dry-weight Value (only samples with TOC <0.5% or >3.5% for analytes with OC-normalized screening levels)		Screening Comparison: Detected Value Exceeding Appropriate Screening Criteria (LAET used for SCO and 2LAET used for CSL as appropriate)	
	N	Detect	Non-detect	% Detect	SCO	Unit	SCO (or LAET)	Unit	Max Detected	Unit	Max Detected	Unit	Exceeding SCO	% Exceeding SCO
Nickel	24	24	0	100%	n/a	n/a	211[a]	mg/kg	n/a	n/a	511	mg/kg	2	8%
Total cPAH TEQ	24	24	0	100%	n/a	n/a	229/445[b]	µg/kg	n/a	n/a	2,475	µg/kg	8/10	33%/42%
2-Methylnaphthalene	24	12	12	50%	38	mg/kg OC	670	µg/kg	6.5	mg/kg OC	870	µg/kg	1	4%
Acenaphthene	24	9	15	38%	16	mg/kg OC	500	µg/kg	29	mg/kg OC	2,000	µg/kg	2	8%
Anthracene	24	18	6	75%	220	mg/kg OC	960	µg/kg	61	mg/kg OC	1,200	µg/kg	1	4%
Benzo(a)anthracene	24	23	1	96%	110	mg/kg OC	1,300	µg/kg	107	mg/kg OC	2,300	µg/kg	1	4%
bis(2-Ethylhexyl)phthalate	24	18	6	75%	47	mg/kg OC	1,300	µg/kg	473	mg/kg OC	1,400	µg/kg	3	13%
Chrysene	24	24	0	100%	110	mg/kg OC	1,400	µg/kg	121	mg/kg OC	3,300	µg/kg	2	8%
Dibenzo(a,h)anthracene	24	12	12	50%	12	mg/kg OC	230	µg/kg	14	mg/kg OC	89	µg/kg	1	4%
Dibenzofuran	24	12	12	50%	15	mg/kg OC	540	µg/kg	23	mg/kg OC	2,000	µg/kg	2	8%
Dimethyl phthalate	24	12	12	50%	53	mg/kg OC	71	µg/kg	9.0	mg/kg OC	130	µg/kg	1	4%
Fluoranthene	24	24	0	100%	160	mg/kg OC	1,700	µg/kg	346	mg/kg OC	11,000	µg/kg	3	13%
Fluorene	24	12	12	50%	23	mg/kg OC	540	µg/kg	38	mg/kg OC	1,800	µg/kg	2	8%
n-Nitrosodiphenylamine	24	2	22	8%	11	mg/kg OC	28	µg/kg	1.3	mg/kg OC	180	µg/kg	1	4%
Phenanthrene	24	23	1	96%	100	mg/kg OC	1,500	µg/kg	206	mg/kg OC	7,100	µg/kg	2	8%
Pyrene	24	24	0	100%	1,000	mg/kg OC	2,600	µg/kg	196	mg/kg OC	9,200	µg/kg	1	4%
Total HPAH	24	24	0	100%	960	mg/kg OC	12,000	µg/kg	1,073	mg/kg OC	29,349	µg/kg	2	8%
Total LPAH	24	23	1	96%	370	mg/kg OC	5,200	µg/kg	340	mg/kg OC	14,090	µg/kg	1	4%
2,4-Dimethylphenol	24	7	17	29%	n/a	n/a	29	µg/kg	n/a	n/a	210	µg/kg	2	8%
2-Methylphenol (o-Cresol)	24	10	14	42%	n/a	n/a	63	µg/kg	n/a	n/a	120	µg/kg	1	4%
4-Methylphenol (p-Cresol)	24	12	12	50%	n/a	n/a	670	µg/kg	n/a	n/a	1,200	µg/kg	1	4%
Benzoic acid	24	5	19	21%	n/a	n/a	650	µg/kg	n/a	n/a	700	µg/kg	1	4%
Benzyl alcohol	24	11	13	46%	n/a	n/a	57	µg/kg	n/a	n/a	65	µg/kg	1	4%

Notes:

a. See Appendix A for the derivation of this value.

b. See Appendix B for the derivation of these values.

µg/kg: microgram per kilogram

COC: constituent of concern

cPAH: carcinogenic polycyclic aromatic hydrocarbon

HPAH: high-molecular-weight polycyclic aromatic hydrocarbon

LAET: lowest apparent effects threshold

LPAH: low-molecular-weight polycyclic aromatic hydrocarbon

mg/kg: milligram per kilogram

n/a: not applicable

OC: organic carbon

SCO: Sediment Cleanup Objective

TEQ: toxic equivalents quotient

TOC: total organic carbon

Table 2-2
Site Units

	Physical Factors					Contaminant Distribution	
Site Unit	Water Depths	Infrastructure	Sediment Type	Land Use and Navigation	Natural Resources	Surface Sediment	Subsurface Sediment
Navigation Channel West	-16 ft MLLW to -12 ft MLLW	None	Fine sediments	Used by Bornstein and USCG vessels. Authorized at -18 ft MLLW.	Subtidal area	Elevated cPAHs (interpolated from sample in berthing area). Bioassay exceedances	Elevated mercury, 2,4-dimethylphenol, 2-methylphenol phthalates, and n-nitrosodiphenylamine
Navigation Channel East	-14 ft MLLW to MLLW	None	Fine sediments	Used by Bornstein and USCG vessels. Authorized at -18 ft MLLW.	Subtidal area	Bioassay exceedances	
Coast Guard	-13 ft MLLW to MLLW	USCG dock	Fine sediments	Used by USCG vessels. Includes area designated as federal navigation channel.	Subtidal area	Bioassay exceedance	
Coast Guard Bank	-10 ft MLLW to approximately MLLW at upper limits	USCG dock	Fine sediments; Rubble and riprap shoreline along Bellwether shoreline	No existing uses	Shallow water habitat along shoreline used by juvenile salmonids	No data; nearby bioassay exceedances.	
Berthing Area	-16 ft MLLW to -10 ft MLLW at face of Bornstein dock	None	Fine sediments	Used for berthing by fishing vessels	Subtidal area	Elevated PAHs, bis(2-ethylhexyl)phthalate, dibenzofuran, and bioassay exceedance	Elevated mercury, bis(2-ethylhexyl)phthalate, and 2,4-dimethylphenol
Dock	-10 ft MLLW at face of Bornstein dock; Approximately +1 ft MLLW at shoreline bulkhead	Bornstein dock; Bornstein bulkhead	Fine sediments; Rubble shoreline along Bornstein bulkhead	Used for vessel berthing and seafood processing	Shallow water habitat along shoreline used by juvenile salmonids	Elevated PAHs, 2,4-dimethylphenol, benzyl alcohol, dibenzofuran, and bis(2-ethylhexyl)phthalate	Elevated mercury, phthalates, methylphenols, phenol, benzoic acid, dibenzofuran, and PAHs
Floating Dock	-10 ft MLLW at face of Bornstein dock; Approximately +1 ft MLLW at shoreline bulkhead	Bornstein float; Bornstein bulkhead	Fine sediments; Rubble shoreline along Bornstein bulkhead	Used for berthing by fishing vessels	Shallow water habitat along shoreline used by juvenile salmonids	Elevated PAHs, and bioassay exceedance	Elevated mercury, bis(2-ethylhexyl)phthalate, and 2,4-dimethylphenol
South Bank	-11 ft MLLW at navigation channel; Approximately +1 ft MLLW at shoreline bulkhead	"Northern bulkhead"	Fine sediments; Rubble shoreline along bulkhead	No existing uses	Shallow water habitat along shoreline used by juvenile salmonids	Elevated nickel, PAHs, and bioassay exceedance	Elevated mercury, bis(2-ethylhexyl)phthalate, and 2,4-dimethylphenol
Head of Waterway	MLLW to approximately +4 ft MLLW at upper limits	"Northern bulkhead"	Fine sediments; Rubble shoreline along bulkhead and eastern shoreline (head)	Future kayak launch and public access. Includes small area designated as federal navigation channel.	Shallow water and intertidal habitat used by juvenile salmonids	Elevated nickel, PAHs, and bioassay exceedance	Elevated nickel, mercury, 2,4-dimethyl phenol, 2-methylphenol, 4-methylphenol, and bis(2-ethylhexyl)phthalate.

Notes:
Contaminant distribution compared to SMS criteria.
Subsurface sediment based on historical cores and DMMP core composites
cPAH: carcinogenic polycyclic aromatic hydrocarbon
DMMP: Dredged Material Management Program
ft: feet
MLLW: mean lower low water
PAH: polycyclic aromatic hydrocarbon
SMS: Sediment Management Standards
USCG: U.S. Coast Guard

Table 3-1
Cleanup Standards

Analyte	Screening Level						Cleanup Level[a]	Horizontal Scale of Application	Vertical Point of Compliance
	Carbon Normalized Screening Level			Dry-weight Screening Level					
	SCO	CSL	Unit	SCO	CSL	Unit			
Nickel	n/a	n/a	n/a	211[b]	No value	mg/kg	SCO	Point-based	Upper 12 cm of sediment
Total cPAH TEQ	n/a	n/a	n/a	229/445[c]	2,290/4,450[c]	µg/kg	SCO	Area-weighted average	Upper 12 cm of sediment
Total cPAH TEQ	n/a	n/a	n/a	450/800[c]	4,500/8,000[c]	µg/kg	SCO	Area-weighted average in intertidal areas	Upper 45 cm of sediment
2-Methylnaphthalene	38	64	mg/kg OC	670	670	µg/kg	SCO	Point-based	Upper 12 cm of sediment
Acenaphthene	16	57	mg/kg OC	500	500	µg/kg	SCO	Point-based	Upper 12 cm of sediment
Anthracene	220	1,200	mg/kg OC	960	960	µg/kg	SCO	Point-based	Upper 12 cm of sediment
Benzo(a)anthracene	110	270	mg/kg OC	1,300	1,600	µg/kg	SCO	Point-based	Upper 12 cm of sediment
bis(2-Ethylhexyl)phthalate	47	78	mg/kg OC	1,300	3,100	µg/kg	SCO	Point-based	Upper 12 cm of sediment
Chrysene	110	460	mg/kg OC	1,400	2,800	µg/kg	SCO	Point-based	Upper 12 cm of sediment
Dibenzo(a,h)anthracene	12	33	mg/kg OC	230	230	µg/kg	SCO	Point-based	Upper 12 cm of sediment
Dibenzofuran	15	58	mg/kg OC	540	540	µg/kg	SCO	Point-based	Upper 12 cm of sediment
Dimethyl phthalate	53	53	mg/kg OC	71	160	µg/kg	SCO	Point-based	Upper 12 cm of sediment
Fluoranthene	160	1,200	mg/kg OC	1,700	2,500	µg/kg	SCO	Point-based	Upper 12 cm of sediment
Fluorene	23	79	mg/kg OC	540	540	µg/kg	SCO	Point-based	Upper 12 cm of sediment
n-Nitrosodiphenylamine	11	11	mg/kg OC	28	40	µg/kg	SCO	Point-based	Upper 12 cm of sediment
Phenanthrene	100	480	mg/kg OC	1,500	1,500	µg/kg	SCO	Point-based	Upper 12 cm of sediment
Pyrene	1,000	1,400	mg/kg OC	2,600	3,300	µg/kg	SCO	Point-based	Upper 12 cm of sediment
Total HPAH	960	5,300	mg/kg OC	12,000	17,000	µg/kg	SCO	Point-based	Upper 12 cm of sediment
Total LPAH	370	780	mg/kg OC	5,200	5,200	µg/kg	SCO	Point-based	Upper 12 cm of sediment
2,4-Dimethylphenol	n/a	n/a	n/a	29	29	µg/kg	SCO	Point-based	Upper 12 cm of sediment
2-Methylphenol (o-Cresol)	n/a	n/a	n/a	63	63	µg/kg	SCO	Point-based	Upper 12 cm of sediment
4-Methylphenol (p-Cresol)	n/a	n/a	n/a	670	670	µg/kg	SCO	Point-based	Upper 12 cm of sediment
Benzoic acid	n/a	n/a	n/a	650	650	µg/kg	SCO	Point-based	Upper 12 cm of sediment
Benzyl alcohol	n/a	n/a	n/a	57	73	µg/kg	SCO	Point-based	Upper 12 cm of sediment

Notes:

a. The SCO is the carbon normalized value when total organic carbon is within the range of 0.5% to 3.5%.

b. See Appendix A for the derivation of this value.

c. These are preliminary screening levels. See Appendix B for the derivation of these values.

µg/kg: microgram per kilogram

cm: centimeter

cPAH: carcinogenic polycyclic aromatic hydrocarbon

CSL: Cleanup Screening Level

HPAH: high-molecular-weight polycyclic aromatic hydrocarbon

LPAH: low-molecular-weight polycyclic aromatic hydrocarbon

mg/kg: milligram per kilogram

mg/kg-OC: milligram per kilogram organic carbon normalized

n/a: not applicable

SCO: Sediment Quality Objective

TEQ: toxic equivalent quotient

Table 4-1
Cleanup Action Alternative Technology Assignments

Site Unit	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Navigation Channel West	MNR	MNR	Removal	Removal	Removal	Removal
Navigation Channel East	MNR	MNR	MNR	MNR	Removal	Removal
Coast Guard	MNR	MNR	MNR	MNR	Removal	Removal
Coast Guard Bank	MNR	MNR	MNR	MNR	Removal	Removal
Berthing Area	Removal	Removal	Removal	Removal	Removal	Removal
Dock	Cap with sheetpile toe wall	Cap with sheetpile toe wall	Cap with sheetpile toe wall	Removal with dock and bulkhead replacement	Cap with sheetpile toe wall	Removal with dock and bulkhead modifications
Floating Dock	Cap with sheetpile toe wall	Cap with sheetpile toe wall	Cap with sheetpile toe wall	Removal with bulkhead replacement	Cap with sheetpile toe wall	Removal with bulkhead replacement
South Bank	MNR	ENR	ENR	ENR	Removal	Removal
Head of Waterway	Cap	Cap	Cap	Cap	Cap	Removal

Notes:

ENR: enhanced natural recovery

MNR: monitored natural recovery

Table 4-2
Cleanup Action Alternative Areas, Volumes, Costs, and Construction Time Frames

Parameter	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Areas (acres)						
Removal	0.2	0.2	1.0	1.3	2.1	3.1
Capping	1.0	1.0	1.0	0.7	1.0	0.0
Enhanced Natural Recovery	0.0	0.3	0.3	0.3	0.0	0.0
Monitored Natural Recovery	1.9	1.6	0.8	0.8	0.0	0.0
Volumes (cubic yards)						
Total Removal	5,563	5,563	14,964	18,144	30,093	39,101
Total Placement	5,835	6,374	7,535	7,034	8,882	5,994
Construction Timeframe (days)						
Construction Time	37	38	52	68	84	110
Cost ($ millions)						
Cost	$5.4	$5.5	$7.7	$12.6	$13.5	$20.6

Table 5-1
Performance of Cleanup Action Alternatives Compared to Cleanup Standards

Exposure Pathway	Parameter	Cleanup Standard	Area	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Protection of Human Health				*Estimated SWAC following construction (µg TEQ/kg dw)* [b]					
Protection of human health for seafood consumption[c]	cPAHs	SCO: 229/445 µg TEQ/kg[a]; SWAC of Site; upper 12 cm	I&J Site Area[d] Baseline = 399 µg TEQ/kg dw	167	114	65	65	21	21
		SCO: 229/445 µg TEQ/kg[a]; SWAC of home range; upper 12 cm	Crab and fish home range[e] Baseline = 44 µg TEQ/kg dw	44	44	44	44	44	44
Protection of human health for direct contact		SCO: 450/800 µg TEQ/kg[a]; SWAC of intertidal; upper 45 cm	Intertidal[f] Baseline = 445 µg TEQ/kg dw	21	21	21	21	21	21
Protection of the Benthic Community				*Point sample locations remediated* [g]					
Protection of the Benthic Community	SMS Chemicals[h]	SCO; point concentrations; upper 12 cm	I&J Site Area[d]	All points remediated post-construction					
	Nickel	SCO: 211 mg/kg; point concentrations; upper 12 cm		All points remediated post-construction					
	Biological Criteria	SCO; point evaluations; upper 12 cm		All points remediated within 10 years post-construction[i]				All points remediated post-construction	

Notes:

(blue) = anticipated to achieve cleanup standard within 10 years following construction

(green) = cleanup standard achieved immediately following construction

Concentrations of co-occurring contaminants, including dioxins/furans, mercury, and total PCBs, will achieve SMS requirements following construction.

a. These values are preliminary. See Appendix B.

b. Post-construction SWACs for cPAHs are calculated assuming that remediation areas have a post-construction concentration of 21 µg TEQ/kg dw (based on natural background).

c. cPAH cleanup standards developed to protect human health also protect ecological health.

d. The I&J Waterway site area is approximately 3.1 acres.

e. The crab and fish home range is assumed to include I&J Waterway and adjacent areas (approximately 2,500 acres).

f. The intertidal area is approximately 0.7 acre in the Head of Waterway unit.

g. The points achieving the benthic SCO following construction were estimated by assuming that all locations with dredging, capping, or enhanced natural recovery achieve cleanup standards, and locations in monitored natural recovery areas remain at baseline conditions. This is a conservative assumption because natural recovery is ongoing, and surface sediment conditions are expected to improve over baseline conditions prior to construction.

h. Includes all chemicals in SMS Table III (WAC 173-204-562).

i. As discussed in the Cleanup Action Plan, the adverse biological effects of I&J Waterway sediment on benthic organisms have reduced over time; 2005/2006 sampling resulted in multiple CSL exceedances, and 2012 sampling results indicated no CSL exceedances (SCO exceedances only). This trend forms that basis for the predictions for Alternatives 1 through 4, which use monitored natural recovery in marginally impacted areas of the waterway.

µg: microgram
cm: centimeter
cPAH: carcinogenic polycyclic aromatic hydrocarbon
CSL: Cleanup Screening Level
dw: dry weight
kg: kilogram
PCB: polychlorinated biphenyl
PQL: practical quantitation limit
RI/FS: Remedial Investigation/Feasibility Study
SCO: Sediment Cleanup Objective
SMS: Sediment Management Standards
SWAC: spatially weighted area concentration
TEQ: toxic equivalents quotient
WAC: Washington Administrative Code

Table 5-2
Disproportionate Cost Analysis

<table>
<tr><th>Criterion</th><th>Weighting</th><th>Washington Administrative Code (WAC) Language</th><th colspan="2">Considerations for Site-specific Evaluation</th><th>Alternative 1</th><th>Alternative 2</th><th>Alternative 3</th><th>Alternative 4</th><th>Alternative 5</th><th>Alternative 6</th></tr>
<tr><td rowspan="7">Protectiveness</td><td rowspan="7">30%</td><td rowspan="7">Overall protectiveness of human health and the environment, including the degree to which existing risks are reduced, time required to reduce risk at the facility and attain cleanup standards, on-site and offsite risks resulting from implementing the alternative, and improvement of the overall environmental quality.</td><td rowspan="2">Protection of Human Health - Seafood Consumption</td><td>Performance</td><td colspan="6">Alternatives achieve cleanup standards following construction.</td></tr>
<tr><td>Score</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td></tr>
<tr><td rowspan="2">Protection of Human Health - Direct Contact</td><td>Performance</td><td colspan="6">Alternatives achieve cleanup standards prior to construction.</td></tr>
<tr><td>Score</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td></tr>
<tr><td rowspan="2">Protection of the Environment - Benthic Community</td><td>Performance</td><td colspan="4">MNR used in marginally impacted areas of the Site. Alternatives achieve cleanup standards within 10 years following construction.</td><td colspan="2">Alternatives achieve cleanup standards following construction.</td></tr>
<tr><td>Score</td><td>4</td><td>4</td><td>4</td><td>4</td><td>5</td><td>5</td></tr>
<tr><td>Total</td><td>Score</td><td>4.7</td><td>4.7</td><td>4.7</td><td>4.7</td><td>5.0</td><td>5.0</td></tr>
<tr><td rowspan="5">Permanence</td><td rowspan="5">20%</td><td rowspan="5">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 treatment residuals generated.</td><td rowspan="4">Certainty and Reliability the Alternative will not Result in Future Releases to the Biological Active Zone</td><td>Removal of impacted sediments from likely disturbance areas</td><td>Sediments remain in navigation areas and under-dock areas</td><td>Sediments remain in navigation areas and under-dock areas</td><td>Sediments removed from likely disturbance areas, but remain under dock</td><td>Sediments removed from likely disturbance areas</td><td>Sediments removed from all navigation areas, but remain under dock</td><td>Sediments removed from all navigation and under dock areas</td></tr>
<tr><td>Score</td><td>1</td><td>1</td><td>3</td><td>4</td><td>4</td><td>5</td></tr>
<tr><td>Removal of potential ongoing sources</td><td>Capping of Dock/Floating Dock units</td><td>Capping of Dock/Floating Dock units</td><td>Capping of Dock/Floating Dock units</td><td>Removal of dock and bulkhead in Dock/Floating Dock units</td><td>Capping of Dock/Floating Dock units and partial bulkhead removal in South Bank Unit</td><td>Removal of dock in Dock/Floating Dock units and all bulkheads</td></tr>
<tr><td>Score</td><td>1</td><td>1</td><td>1</td><td>3</td><td>2</td><td>4</td></tr>
<tr><td>Total</td><td>Score</td><td>1.0</td><td>1.0</td><td>2.0</td><td>3.5</td><td>3.0</td><td>4.5</td></tr>
</table>

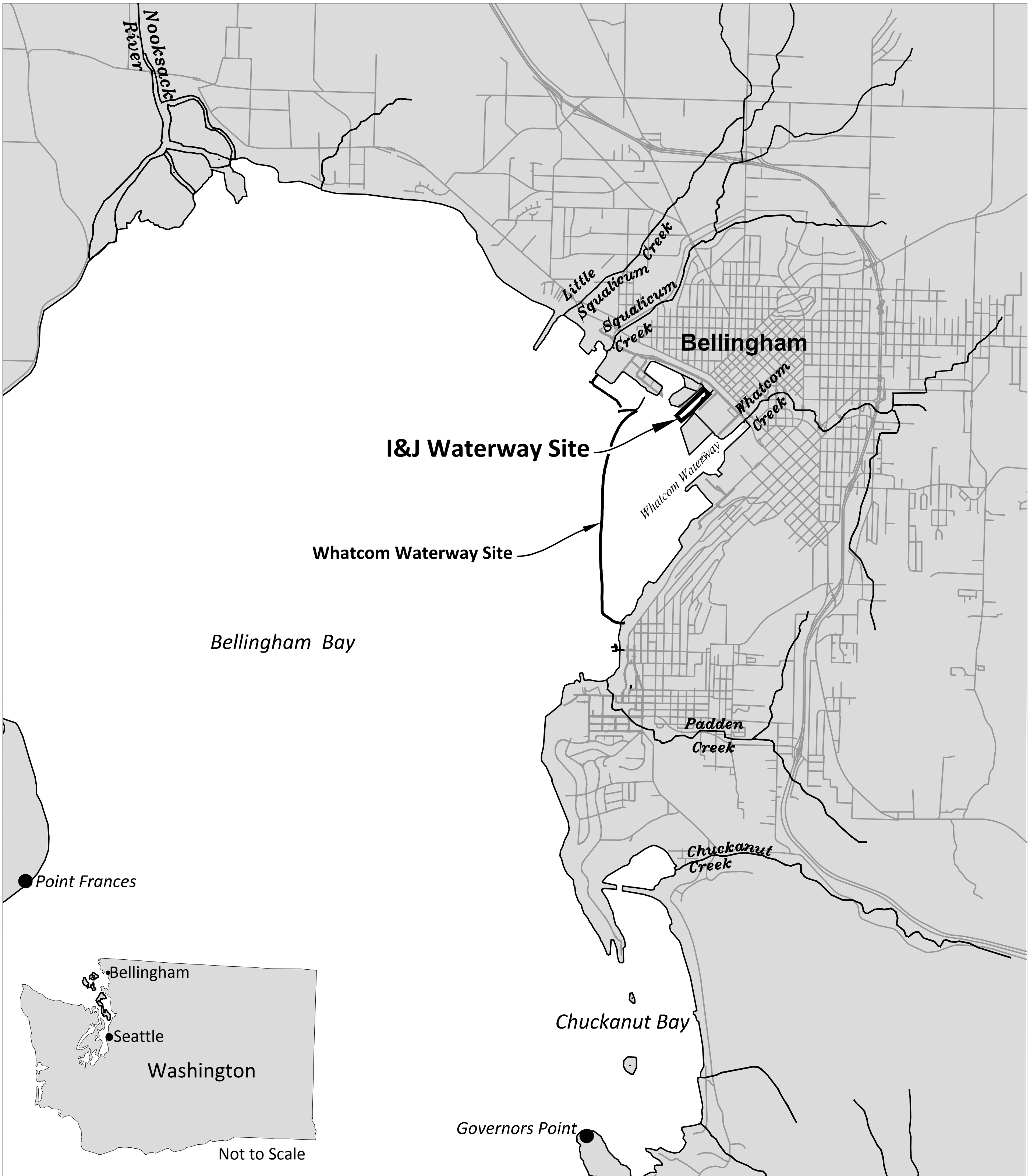
Table 5-2
Disproportionate Cost Analysis

Criterion	Weighting	Washington Administrative Code (WAC) Language	Considerations for Site-specific Evaluation		Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Effectiveness over the Long Term	20%	*When assessing the relative degree of long-term effectiveness of cleanup action components, the following types of components may be used as a guide, in descending order:* *(i) Source controls in combination with other cleanup technologies;* *(ii) Beneficial reuse of the sediments;* *(iii) Treatment to immobilize, destroy, or detoxify contaminants;* *(iv) Dredging and disposal in an upland engineered facility that minimizes subsequent releases and exposures to contaminants;* *(v) Dredging and disposal in a nearshore, in-water, confined aquatic disposal facility;* *(vi) Containment of contaminated sediments in-place with an engineered cap;* *(vii) Dredging and disposal at an open water disposal site approved by applicable state and federal agencies;* *(viii) Enhanced natural recovery;* *(ix) Monitored natural recovery; and* *(x) Institutional controls and monitoring.*	Remedial Technologies	Characteristics	Remedial Technology by Area					
			Berthing Area Unit	Likely Disturbance Area; Highest Concentration Areas	Dredging					
			Dock and Floating Dock Units		Capping			Dredging	Capping	Dredging
			Navigation Channel West Unit	Likely Disturbance Area; Lower Concentration Area	MNR		Dredging			
			Coast Guard and Navigation Channel East Units	Low Disturbance Area; Lower Concentration Areas	MNR				Dredging	
			South Bank Unit		MNR	Enhanced natural recovery (ENR)			Dredging	
			Head of Waterway Unit		Capping					Dredging
			Remedial Technologies	**Score**	**1**	**2**	**3**	**4**	**3**	**5**
			Source Control	Performance	Capping of Dock/Floating Dock units	Capping of Dock/Floating Dock units	Capping of Dock/Floating Dock units	Removal of dock and bulkhead in Dock/Floating Dock units	Capping of Dock/Floating Dock units and partial bulkhead removal in South Bank Unit	Removal of dock in Dock/Floating Dock units and all bulkheads
				Score	**1**	**1**	**1**	**3**	**2**	**4**
			Total	**Score**	**1.0**	**1.5**	**2.0**	**3.5**	**2.5**	**4.5**
Management of Short-term Risk	10%	*The risk to human health and the environment associated with the alternative during construction and implementation, and the effectiveness of measures that will be taken to manage such risks.*	Risk to Human Health and Safety and Risks to Environment During Construction (Proportional to Construction Time)	Construction Time (days)	37	38	52	68	84	110
				Score	**5**	**5**	**4**	**3**	**2**	**1**
			Site Risks and Risks of Recontamination During Restoration Time	Time to Achieve Cleanup Standards	MNR within 10 years; capping under dock has elevated recontamination risk			MNR within 10 years; Dock area recontamination risk reduced by removal	Short restoration time-frame, but capping under dock has elevated recontamination risk	Short restoration time-frame
				Score	**2.0**	**2.0**	**3.0**	**4.0**	**4.0**	**5.0**
			Total	**Score**	**3.5**	**3.5**	**3.5**	**3.5**	**3.0**	**3.0**

Table 5-2
Disproportionate Cost Analysis

Criterion	Weighting	Washington Administrative Code (WAC) Language	Considerations for Site-specific Evaluation		Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Technical and Administrative Implementability	10%	*Technical and administrative implementability. 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, size, complexity, monitoring requirements, access for construction operations and monitoring, and integration with existing facility operations and other current or potential remedial actions.*	Technical feasibility to implement	Performance	Concerns about structural integrity of dock and bulkhead during construction (dredging, wall placement, cap placement); risks of damage and/or contractor claims			Complex project but utilizes standard construction methods	Same as Alt 1-3	Complex project but utilizes standard construction methods
				Score	**2**	**2**	**2**	**4**	**2**	**4**
			Feasibility to maintain over long-term	Performance	Requires long-term performance of under-dock capping with sheet-pile toe-wall. Future toe-wall replacement not included in remedy.			Potential future Olivine bulkhead maintenance or replacement	Same as Alt 1-3	Least long-term maintenance of the alternatives
				Score	**2**	**2**	**2**	**4**	**2**	**5**
			Permitting and Regulatory Implementability	Performance	MNR in Navigation Channel - West Unit could be impacted by future maintenance dredging. Requires maintenance and potential future replacement of toe-wall and underdock cap. Fender system may be moved waterward to accommodate sheetpile.		Same as Alt 1-2, but without MNR in the Navigation Channel - West Unit	Retains some MNR (in navigation channel), but no toe-wall and no under-dock cap issues	Same as Alt 3	Fewer long term permitting and regulatory concerns
				Score	**1**	**1**	**2**	**3**	**2**	**5**
			Total	**Score**	**1.7**	**1.7**	**2.0**	**3.7**	**2.0**	**4.7**
Consideration of Public Concerns	10%	*Whether the community has concerns regarding the alternative and, if so, the extent to which the alternative addresses those concerns. This process includes concerns from individuals, community groups, local governments, tribes, federal and state agencies, or any other organization that may have an interest in or knowledge of the site.*	Consistency with land use, protection of users, habitat restoration, and permanently improve the environment	Performance	Consistent with land use, protects users, restores habitat. Minimal removal of contaminated sediment or potential ongoing sources.		Consistent with land use, protects users, restores habitat. Moderate removal of contaminated sediment; minimal removal of potential ongoing sources.	Consistent with land use, protects users, restores habitat. Moderate removal of contaminated sediment; removes potential ongoing sources.	Consistent with land use, protects users, restores habitat. Moderate removal of contaminated sediment; minimal removal of potential ongoing sources.	Consistent with land use, protects users, restores habitat. Maximum removal of contaminated sediment and potential ongoing sources.
			Total	**Score**	**1**	**1**	**2**	**3.5**	**3**	**4.5**
Total Weighted Benefits					**2.4**	**2.5**	**3.0**	**3.9**	**3.4**	**4.5**
Cost					**$5.4**	**$5.5**	**$7.7**	**$12.6**	**$13.5**	**$20.6**

Figures



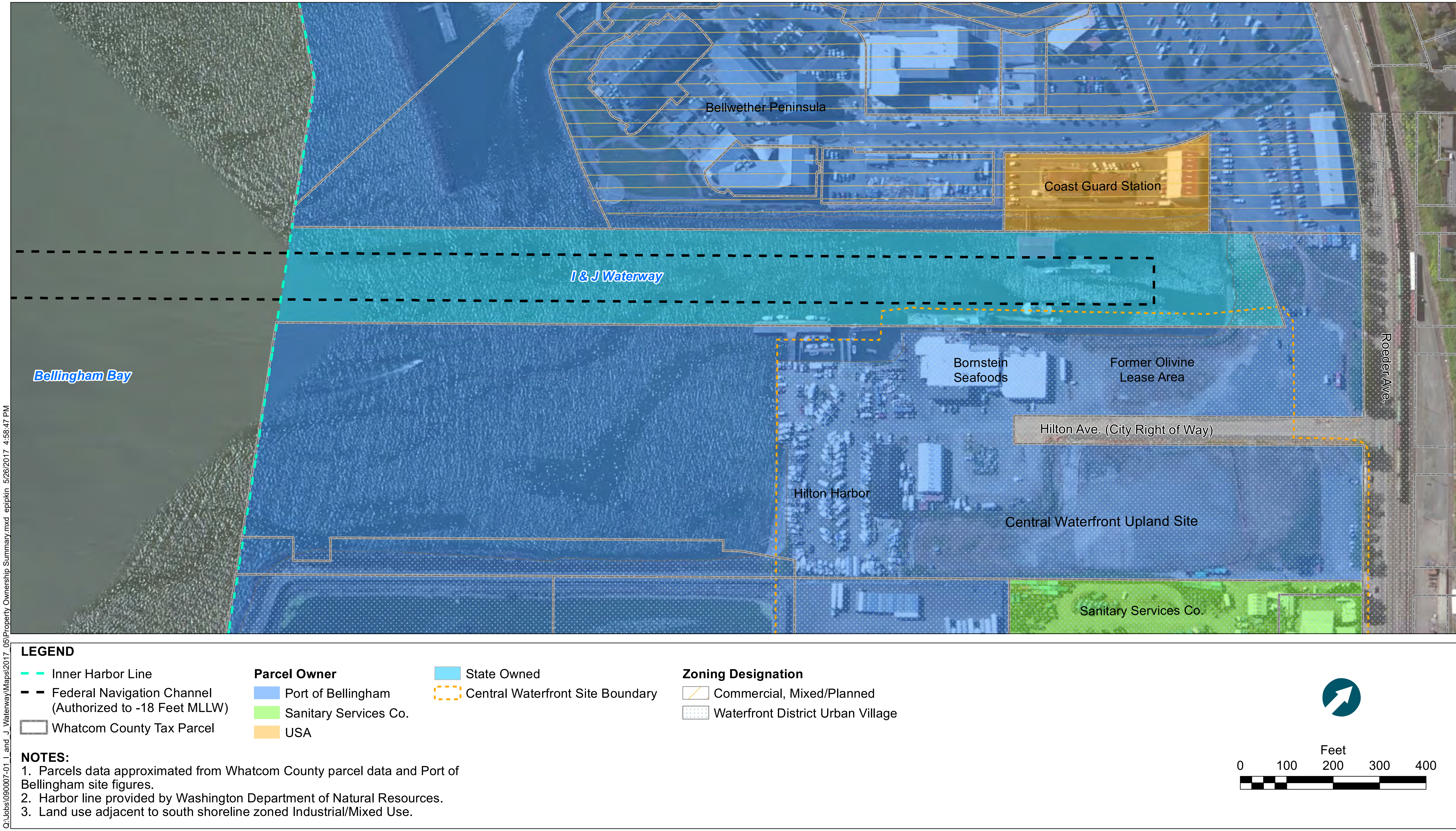
G:\Jobs\090007-01_I&J_Waterway\Maps\2013_04\Vicinity Map CAD.dwg 2-1

May 02, 2017 10:35am chewett

SOURCE: Prepared from GIS data
HORIZONTAL DATUM: Washington State Plane North, NAD27.

DEPARTMENT OF ECOLOGY
State of Washington

Figure 1-1
Site Location
Cleanup Action Plan
I&J Waterway Site
Port of Bellingham



LEGEND

- Inner Harbor Line
- Federal Navigation Channel (Authorized to -18 Feet MLLW)
- Whatcom County Tax Parcel

Parcel Owner

- Port of Bellingham
- Sanitary Services Co.
- USA
- State Owned
- Central Waterfront Site Boundary

Zoning Designation

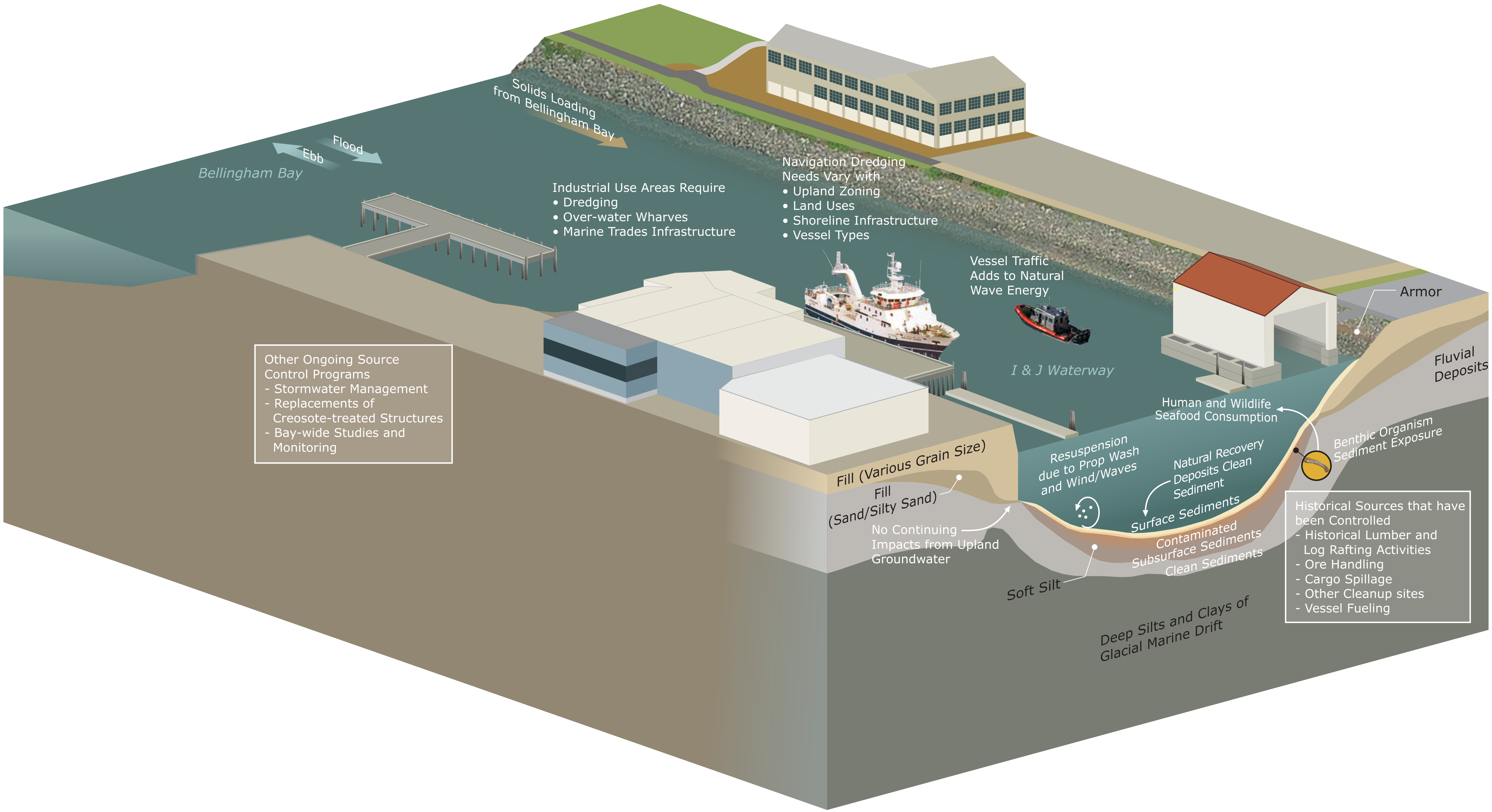
- Commercial, Mixed/Planned
- Waterfront District Urban Village

Feet
0 100 200 300 400

NOTES:
1. Parcels data approximated from Whatcom County parcel data and Port of Bellingham site figures.
2. Harbor line provided by Washington Department of Natural Resources.
3. Land use adjacent to south shoreline zoned Industrial/Mixed Use.

DEPARTMENT OF ECOLOGY State of Washington

Figure 1-2
Summary of Property Ownership and Land Use
Cleanup Action Plan
I&J Waterway Site
Port of Bellingham



5/2/2017 hhayward T:/CAD/Projects/0007-Port of Bellingham/I&J Waterway RI-FS/Corel/00007-RP-003.cdr

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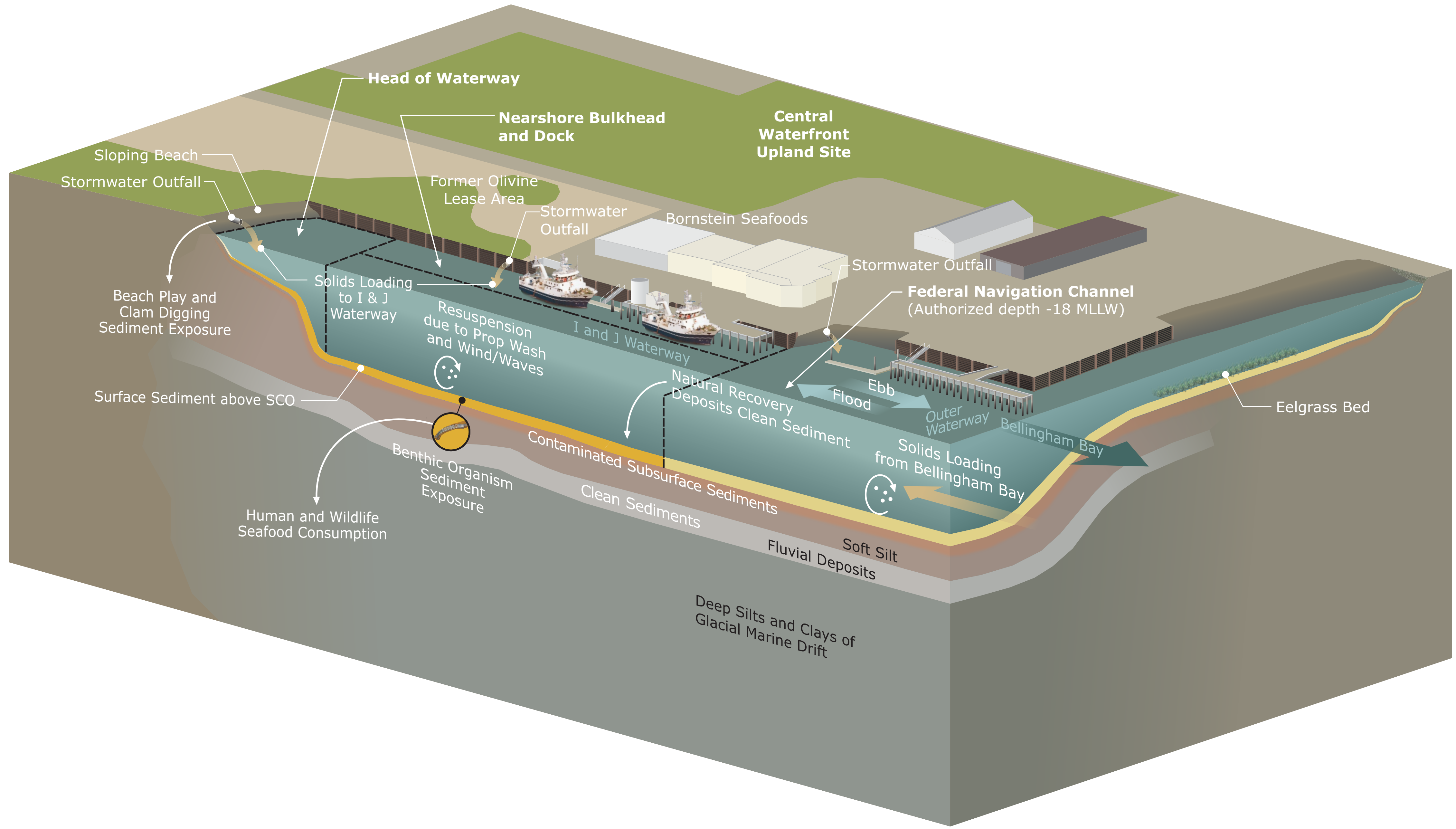
Figure 2-1
Conceptual Site Model - Part 1 of 2
Waterway Conceptual Cross Section and Northern Shoreline
Cleanup Action Plan
I & J Waterway Site
Port of Bellingham



2/19/2018 hmerrick K:/Projects/0007-Port of Bellingham/I&J Waterway RI-FS/Corel/00007-RP-005.cdr

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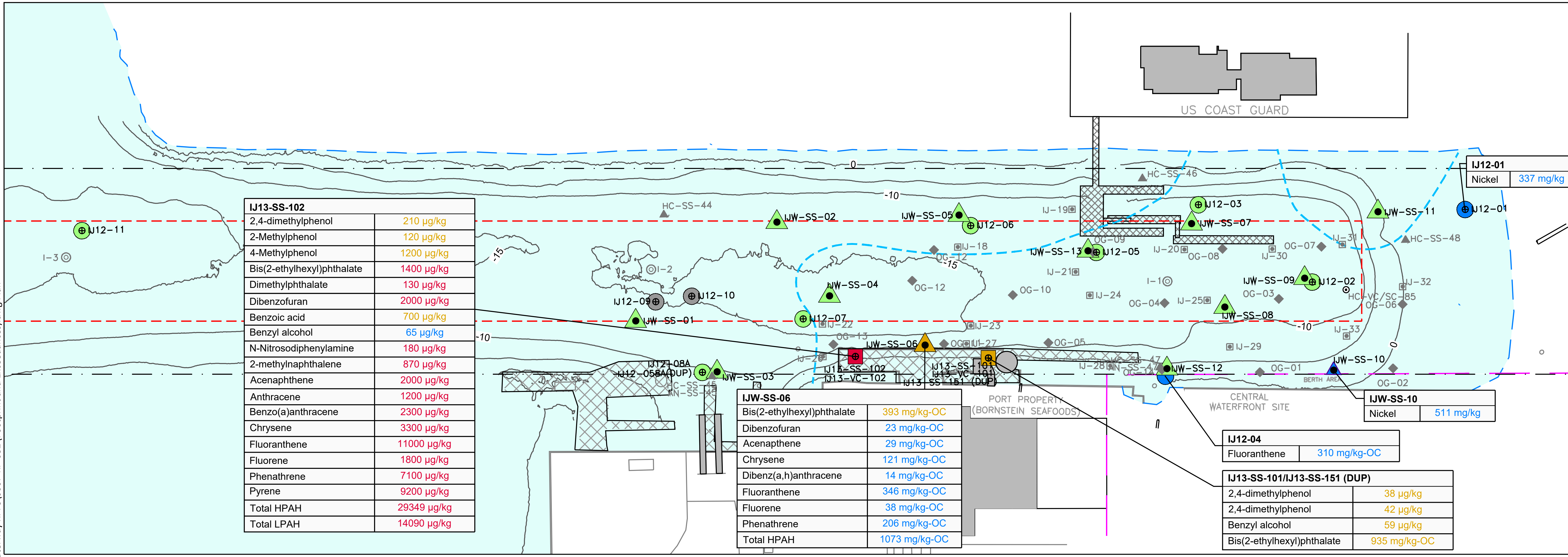
Figure 2-2
Conceptual Site Model - Part 2 of 2
Waterway Conceptual Cross Section and Southern Shoreline
Cleanup Action Plan
I & J Waterway Site
Port of Bellingham



IJ13-SS-102	
2,4-dimethylphenol	210 µg/kg
2-Methylphenol	120 µg/kg
4-Methylphenol	1200 µg/kg
Bis(2-ethylhexyl)phthalate	1400 µg/kg
Dimethylphthalate	130 µg/kg
Dibenzofuran	2000 µg/kg
Benzoic acid	700 µg/kg
Benzyl alcohol	65 µg/kg
N-Nitrosodiphenylamine	180 µg/kg
2-methylnaphthalene	870 µg/kg
Acenaphthene	2000 µg/kg
Anthracene	1200 µg/kg
Benzo(a)anthracene	2300 µg/kg
Chrysene	3300 µg/kg
Fluoranthene	11000 µg/kg
Fluorene	1800 µg/kg
Phenanthrene	7100 µg/kg
Pyrene	9200 µg/kg
Total HPAH	29349 µg/kg
Total LPAH	14090 µg/kg

IJW-SS-06	
Bis(2-ethylhexyl)phthalate	393 mg/kg-OC
Dibenzofuran	23 mg/kg-OC
Acenapthene	29 mg/kg-OC
Chrysene	121 mg/kg-OC
Dibenz(a,h)anthracene	14 mg/kg-OC
Fluoranthene	346 mg/kg-OC
Fluorene	38 mg/kg-OC
Phenanthrene	206 mg/kg-OC
Total HPAH	1073 mg/kg-OC

IJ12-01	
Nickel	337 mg/kg

IJW-SS-10	
Nickel	511 mg/kg

IJ12-04	
Fluoranthene	310 mg/kg-OC

IJ13-SS-101/IJ13-SS-151 (DUP)	
2,4-dimethylphenol	38 µg/kg
2,4-dimethylphenol	42 µg/kg
Benzyl alcohol	59 µg/kg
Bis(2-ethylhexyl)phthalate	935 mg/kg-OC

LEGEND:

- Docks or Piers (Over Water Structures)
- Existing Structures
- Existing Shoreline
- Bathymetric Contour (5-foot interval)
- Central Waterfront Site Boundary
- I & J Waterway Boundary
- Federal Channel Boundary
- Area Above Benthic Biological Criteria (See Figure 2-4)

2012/2013 RI/FS and Historic Sediment Sampling Station

- HC-SS-47 Whatcom Waterway Sediment Grab Sample Location (Hart Crowser 1997)
- HC-VC/SC-85 Whatcom Waterway Sediment Core Location (Hart Crowser 1997)
- AN-SS-47 Bioassay Sample Location (Anchor 2000)
- OG-10 Surface Sediment Grab Sample Location (ThermoRetec 2001)
- IJ-28 Subsurface DMMP Composite Sample Location (RETEC 2006)
- IJW-SS-02 Surface Sample Location (RETEC 2006)
- I-2 Subsurface Sample Location (USACE 2011)
- IJ12-10 Surface Sediment Sample Location (Anchor QEA 2013)

Benthic Chemical Criteria

2005/2006 | 2012 | 2013

- No Exceedances
- SCO Exceedances
- CSL Exceedances
- LAET Exceedances
- Archived

0 100
Scale in Feet

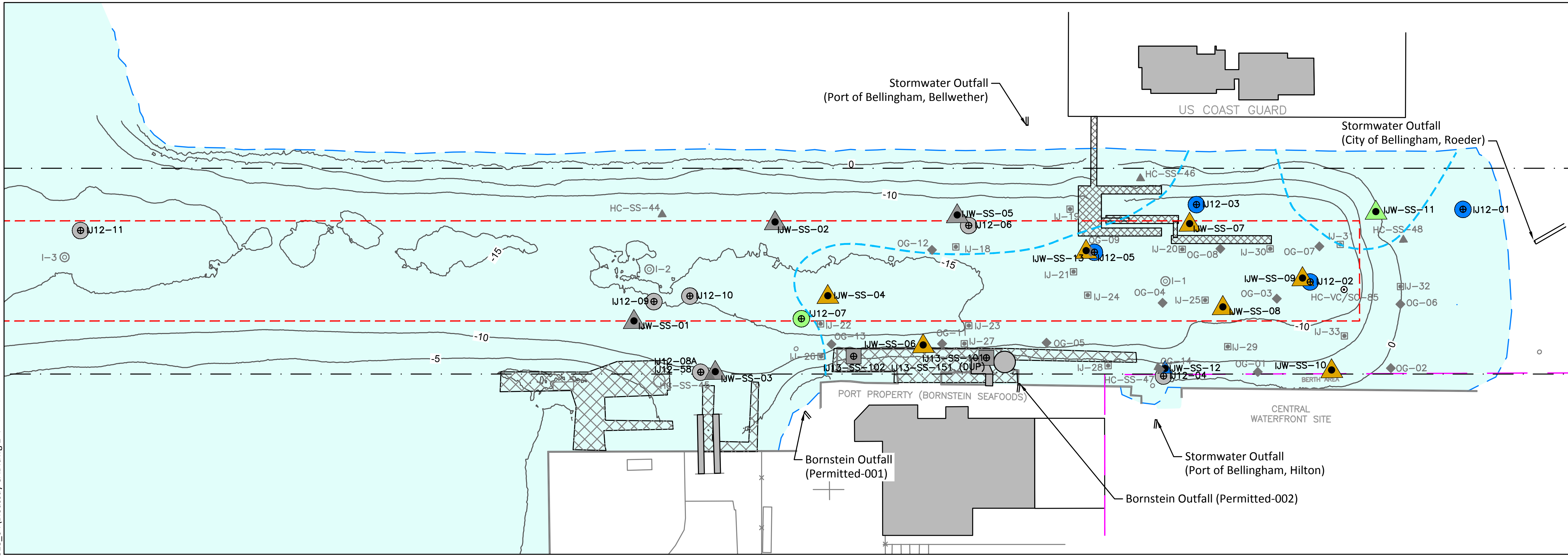
HORIZONTAL DATUM: Washington State Plane North, NAD83.
VERTICAL DATUM: Mean Lower Low Water (MLLW).

NOTES:
1. CSL = Cleanup Screening Level.
2. LAET = Lowest Apparent Effect Threshold
3. SCO = Sediment Cleanup Objective.
4. cPAH concentrations are shown on Figure 2-5.
5. Bathymetric survey from eTrac dated April 5, 2012.

K:\Projects\0007-Port of Bellingham\I & J Waterway RI-FS\0007-RP-032 (Footprint and Exceedances).dwg Plan
Feb 21, 2018 12:18pm chewett

DEPARTMENT OF ECOLOGY State of Washington

Figure 2-3
Surface Sediment Chemical Exceedances
Cleanup Action Plan
I&J Waterway Site
Port of Bellingham



LEGEND:

- Docks or Piers (Over Water Structures)
- Existing Structures
- Existing Shoreline
- -10 Bathymetric Contour (5-foot interval)
- Central Waterfront Site Boundary
- I&J Waterway Boundary
- Federal Channel Boundary
- Area Above Benthic Biological Criteria

RI/FS and Historic Sediment Sampling Station

- HC-SS-47 ▲ Whatcom Waterway Sediment Grab Sample Location (Hart Crowser 1997)
- HC-VC/SC-85 ⊙ Whatcom Waterway Sediment Core (Hart Crowser 1997)
- AN-SS-47 ▲ Bioassay Sample Location (Anchor 2000)
- OG-10 ◆ Surface Sediment Grab Sample Location (ThermoRetec 2001)
- IJ-28 ▣ Subsurface DMMP Composite Sample Location (RETEC 2006)
- IJW-SS-02 ● Surface Sample Location (RETEC 2006)
- I-2 ◎ Subsurface Sample Location (USACE 2011)
- IJ12-10 ⊕ Surface Sediment Sample Location (Anchor QEA 2013)

Biological Effects Criteria

2005/2006	2012	2013	
▲	●		No Exceedances
▲	●		SCO Exceedances
▲	●		CSL Exceedances
▲	●	■	Not Tested

0 100
Scale in Feet

HORIZONTAL DATUM: Washington State Plane North, NAD83.
VERTICAL DATUM: Mean Lower Low Water (MLLW).

NOTES:
1. CSL = Cleanup Screening Level.
2. SCO = Sediment Cleanup Objective.
3. Samples were compared to Carr Inlet reference CR-023.
4. IJ12-08A is IJ12-08 alternative sample location.
5. Bathymetric survey from eTrac dated April 5, 2012.

Figure 2-4
Surface Sediment Biological Exceedances
Cleanup Action Plan
I&J Waterway Site
Port of Bellingham

DEPARTMENT OF ECOLOGY
State of Washington

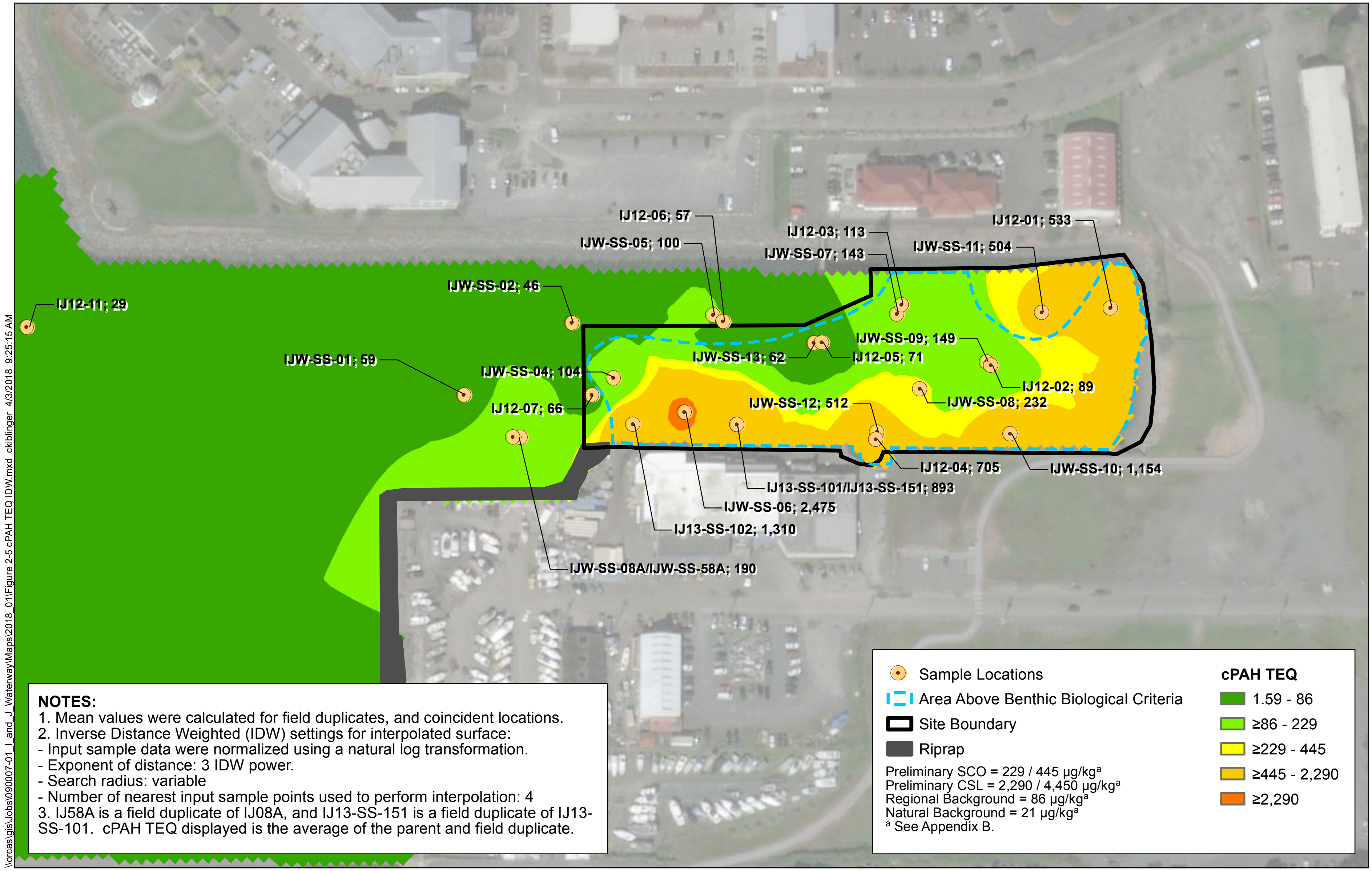
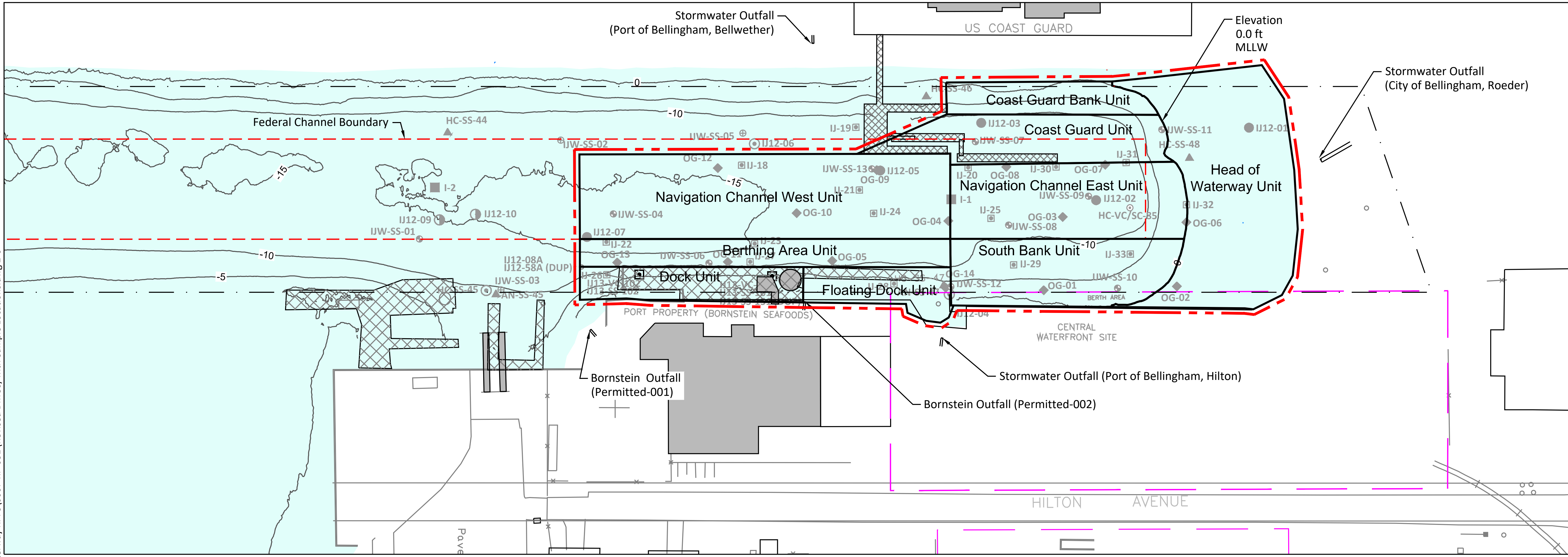


Figure 2-5
Surface Sediment Human and Ecological Health Exceedances
Interpolated Surface Sediment cPAH TEQ Concentrations
Cleanup Action Plan
I&J Waterway Site
Port of Bellingham

DEPARTMENT OF ECOLOGY
State of Washington



LEGEND:

- Docks or Piers (Over Water Structures)
- Existing Structures
- Federal Channel Boundary
- Central Waterfront Site Boundary
- I&J Waterway Boundary
- Bathymetric Contour (5-foot interval)
- Site Boundary

RI/FS Sediment Sampling Station

- Subsurface Sediment Chemistry Sample Location (USACE 2011)
- Surface Sediment Chemistry Sample Location (Anchor QEA 2013)
- Colocated Surface Grab and Core Location (Anchor QEA 2013)
- Surface Sediment Chemistry and Bioassay Sample Location (Anchor QEA 2013)
- Archive Surface Sediment Sample Location (Anchor QEA 2013)
- IJ-28 Subsurface DMMP Composite Sample Location (RETEC 2006)
- IJW-SS-02 Surface Sample Chemistry Location (RETEC 2006)
- IJW-SS-10 Surface Sample Chemistry and Bioassay Location (RETEC 2006)
- HC-VC/SC-85 Whatcom Waterway Sediment Core (Hart Crowser 1997)

Historical Sampling Station

- HC-SS-47 Whatcom Waterway Sediment Grab Sample Location (Hart Crowser 1997)
- AN-SS-47 Bioassay Sample Location (Anchor Environmental 2000)
- OG-10 Surface Sediment Grab Sample Location (ThermoRetec 2001)

0 — 100 Scale in Feet

HORIZONTAL DATUM: Washington State Plane North, NAD83.
VERTICAL DATUM: Mean Lower Low Water (MLLW).

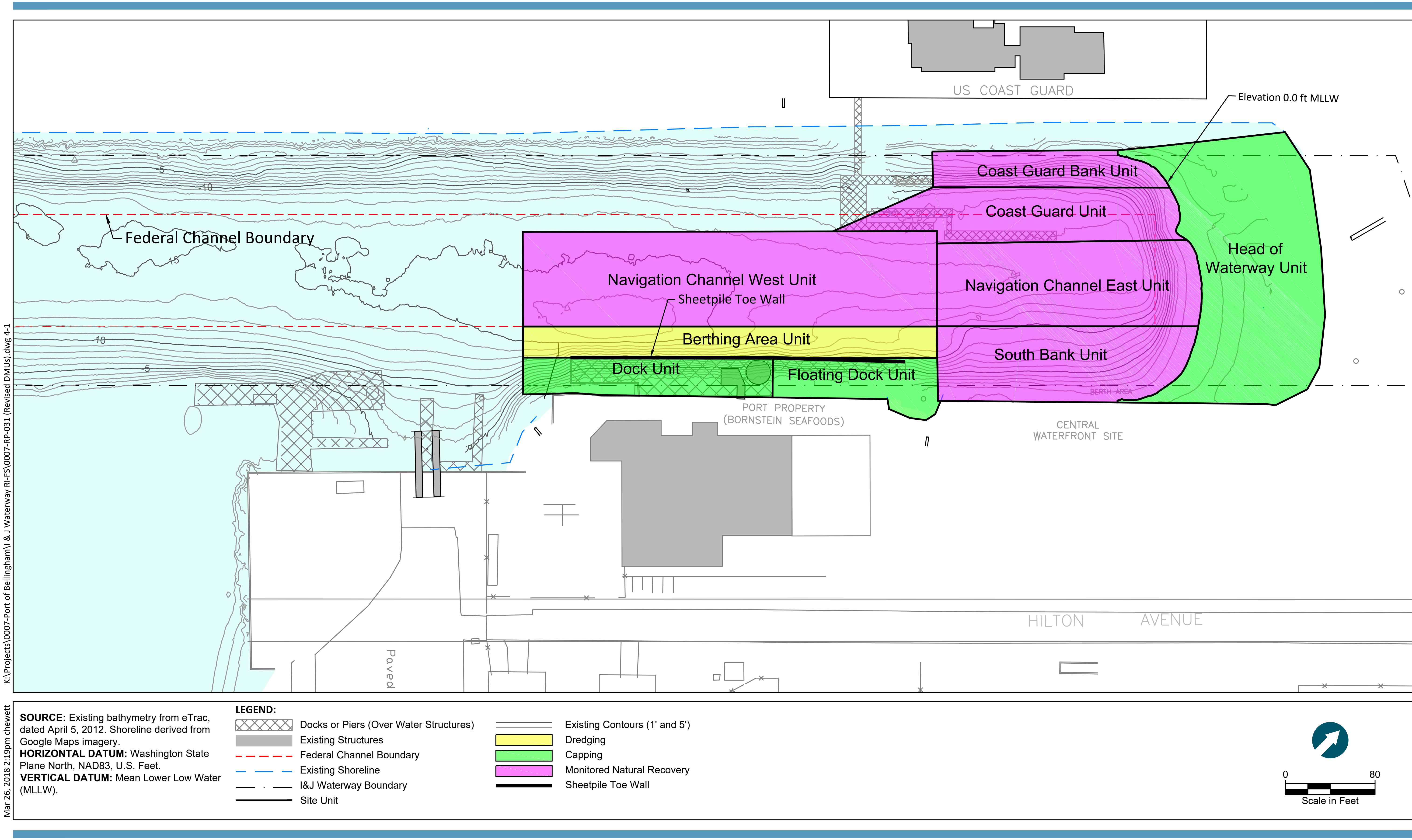
NOTE:

1. Bathymetric survey from eTrac dated April 5, 2012.

Apr 03, 2018 8:48am chewett K:\Projects\0007-Port of Bellingham\I & J Waterway RI-FS\0007-RP-031 (Revised DMUs) with Sample Locations.dwg 2-6

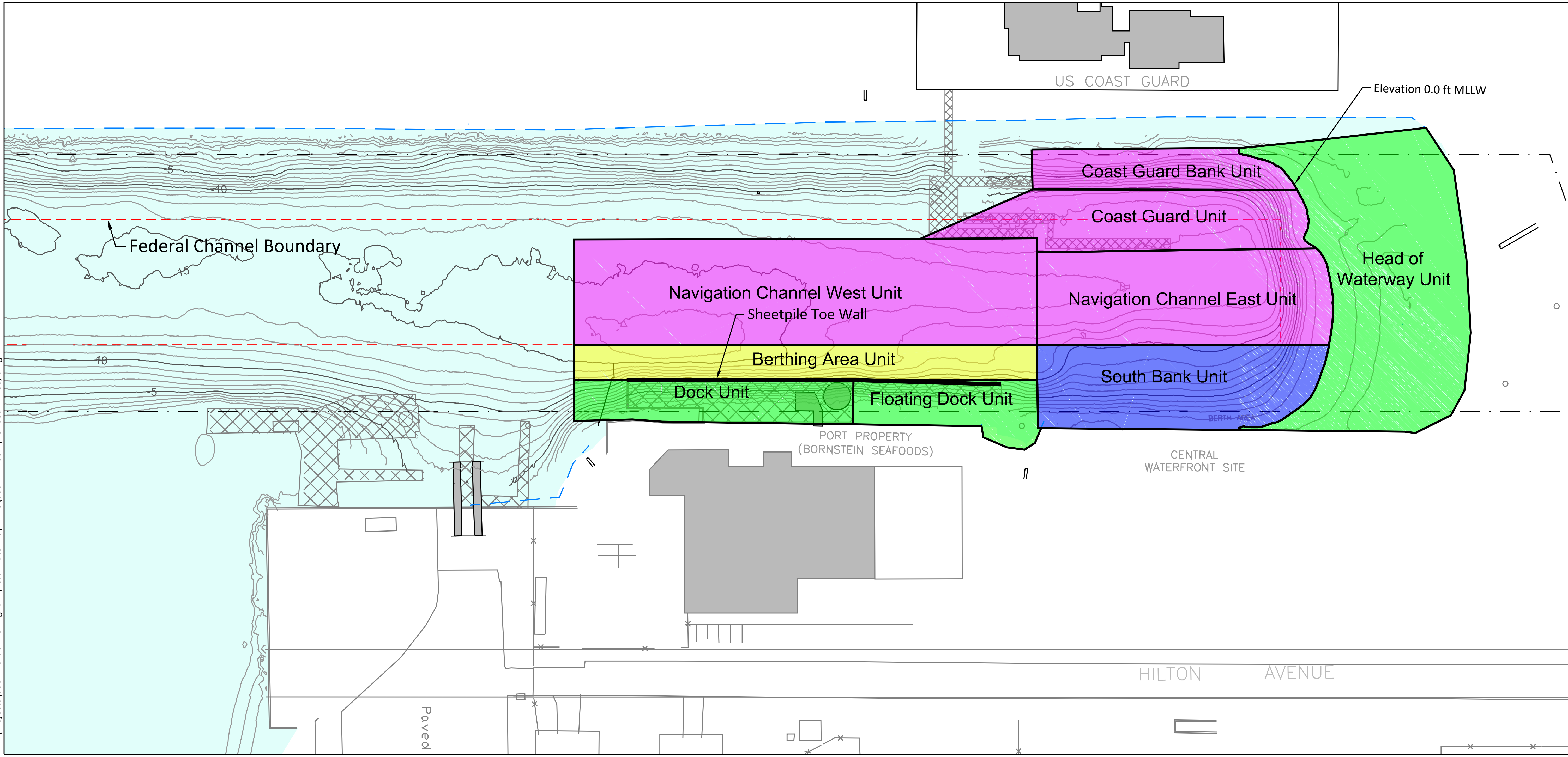
DEPARTMENT OF ECOLOGY State of Washington

Figure 2-6
Site Units
Cleanup Action Plan
I&J Waterway Site
Port of Bellingham



DEPARTMENT OF ECOLOGY State of Washington

Figure 4-1
Alternative 1
Cleanup Action Plan
I&J Waterway Site
Port of Bellingham



K:\Projects\0007-Port of Bellingham\I & J Waterway RI-FS\0007-RP-031 (Revised DMUs).dwg 4-2

Mar 26, 2018 2:19pm chewett

SOURCE: Existing bathymetry from eTrac, dated April 5, 2012. Shoreline derived from Google Maps imagery.
HORIZONTAL DATUM: Washington State Plane North, NAD83, U.S. Feet.
VERTICAL DATUM: Mean Lower Low Water (MLLW).

LEGEND:

- Docks or Piers (Over Water Structures)
- Existing Structures
- Federal Channel Boundary
- Existing Shoreline
- I&J Waterway Boundary
- Site Unit
- Existing Contours (1' and 5')
- Dredging
- Capping
- Enhanced Natural Recovery
- Monitored Natural Recovery
- Sheetpile Toe Wall

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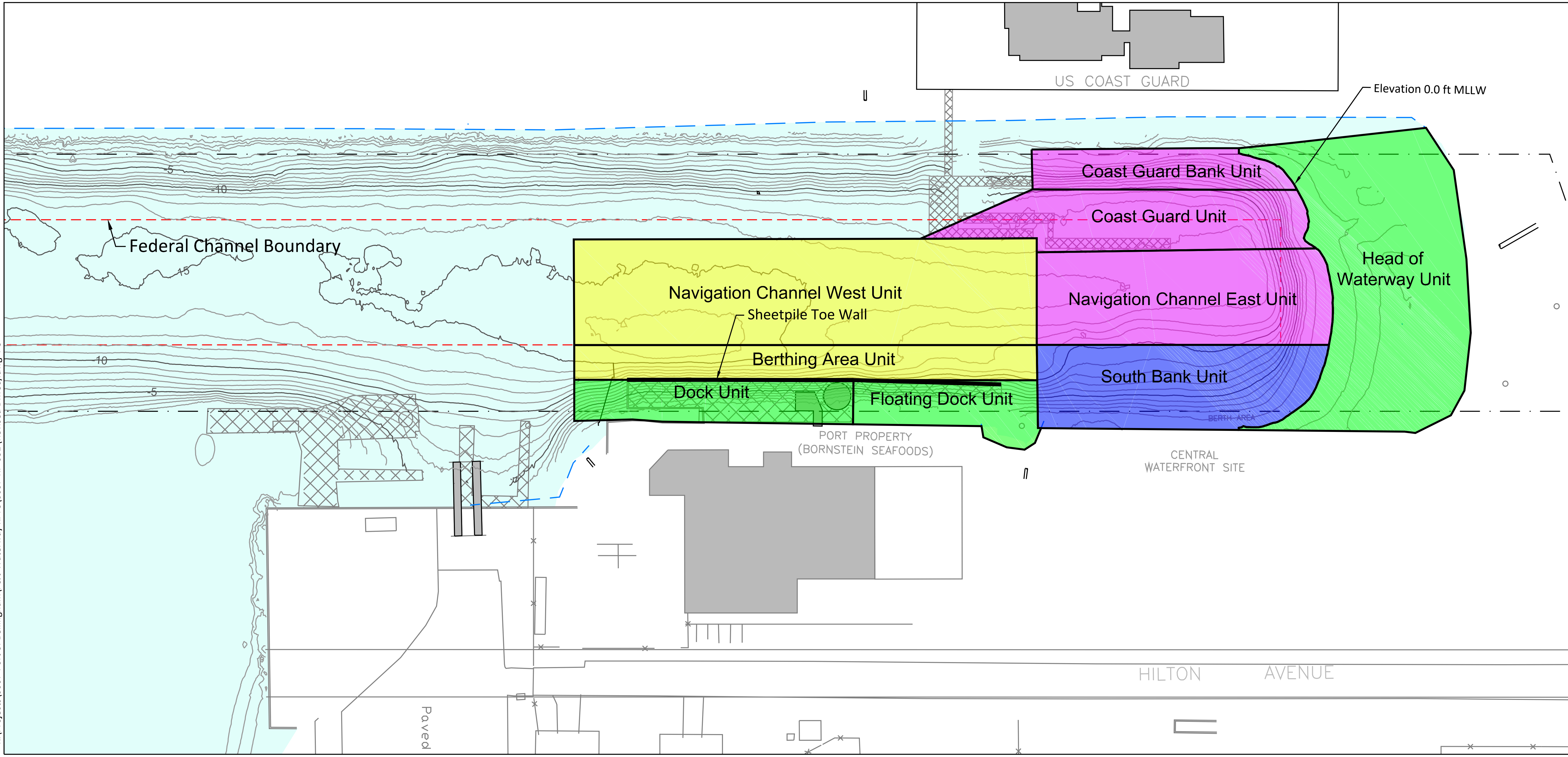
State of Washington

Figure 4-2
Alternative 2
Cleanup Action Plan
I & J Waterway Site
Port of Bellingham



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Mar 26, 2018 2:19pm chewett

SOURCE: Existing bathymetry from eTrac, dated April 5, 2012. Shoreline derived from Google Maps imagery.
HORIZONTAL DATUM: Washington State Plane North, NAD83, U.S. Feet.
VERTICAL DATUM: Mean Lower Low Water (MLLW).

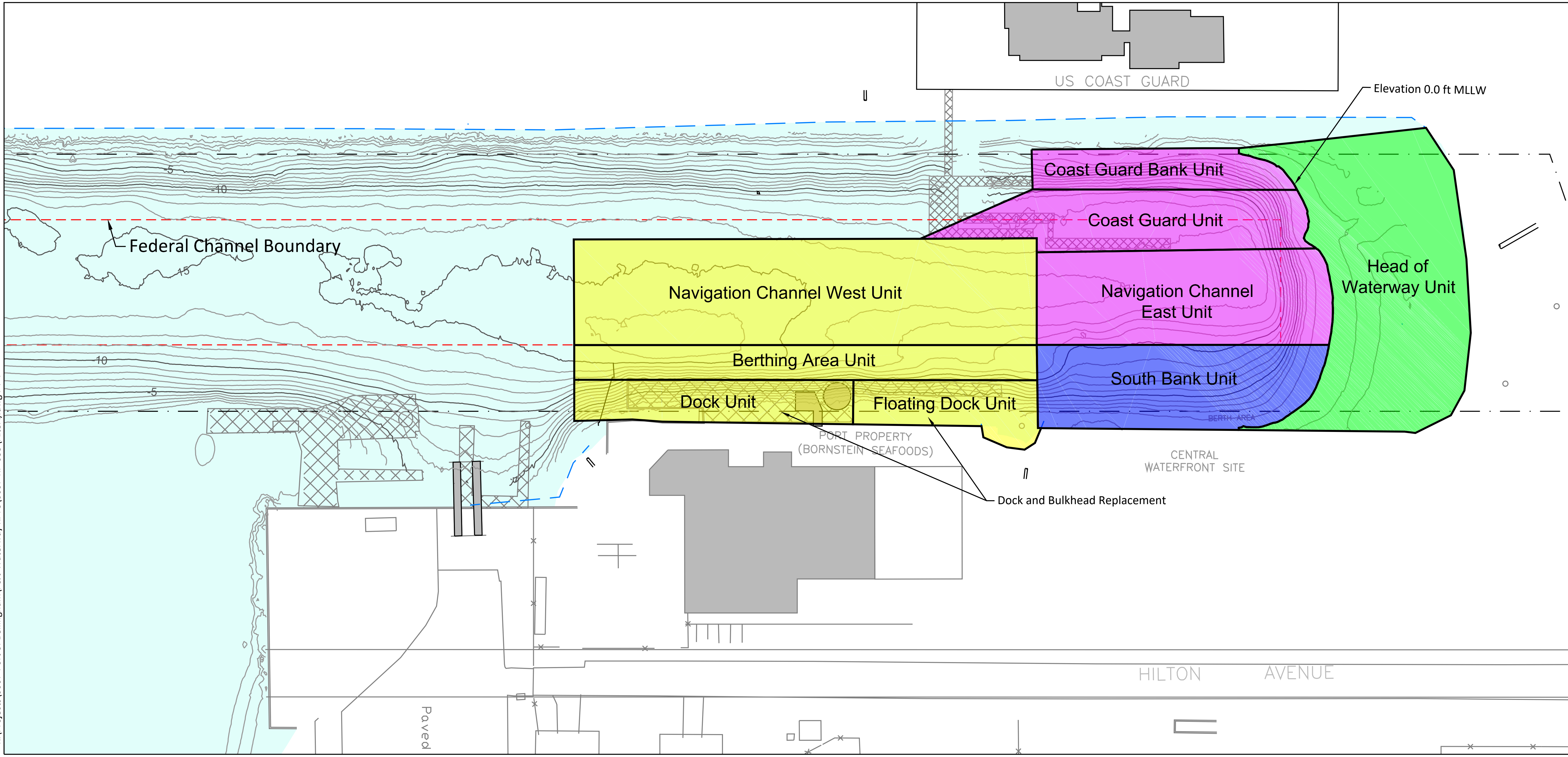
LEGEND:

- Docks or Piers (Over Water Structures)
- Existing Structures
- Federal Channel Boundary
- Existing Shoreline
- I&J Waterway Boundary
- Site Unit
- Existing Contours (1' and 5')
- Dredging
- Capping
- Enhanced Natural Recovery
- Monitored Natural Recovery
- Sheetpile Toe Wall

0 80
Scale in Feet

DEPARTMENT OF ECOLOGY
State of Washington

Figure 4-3
Alternative 3
Cleanup Action Plan
I & J Waterway Site
Port of Bellingham



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Mar 26, 2018 2:18pm chewett

SOURCE: Existing bathymetry from eTrac, dated April 5, 2012. Shoreline derived from Google Maps imagery.
HORIZONTAL DATUM: Washington State Plane North, NAD83, U.S. Feet.
VERTICAL DATUM: Mean Lower Low Water (MLLW).

LEGEND:

- Docks or Piers (Over Water Structures)
- Existing Structures
- Federal Channel Boundary
- Existing Shoreline
- I&J Waterway Boundary
- Existing Contours
- Site Unit
- Dredging
- Capping
- Enhanced Natural Recovery
- Monitored Natural Recovery
- Sheetpile Toe Wall

0 150
Scale in Feet

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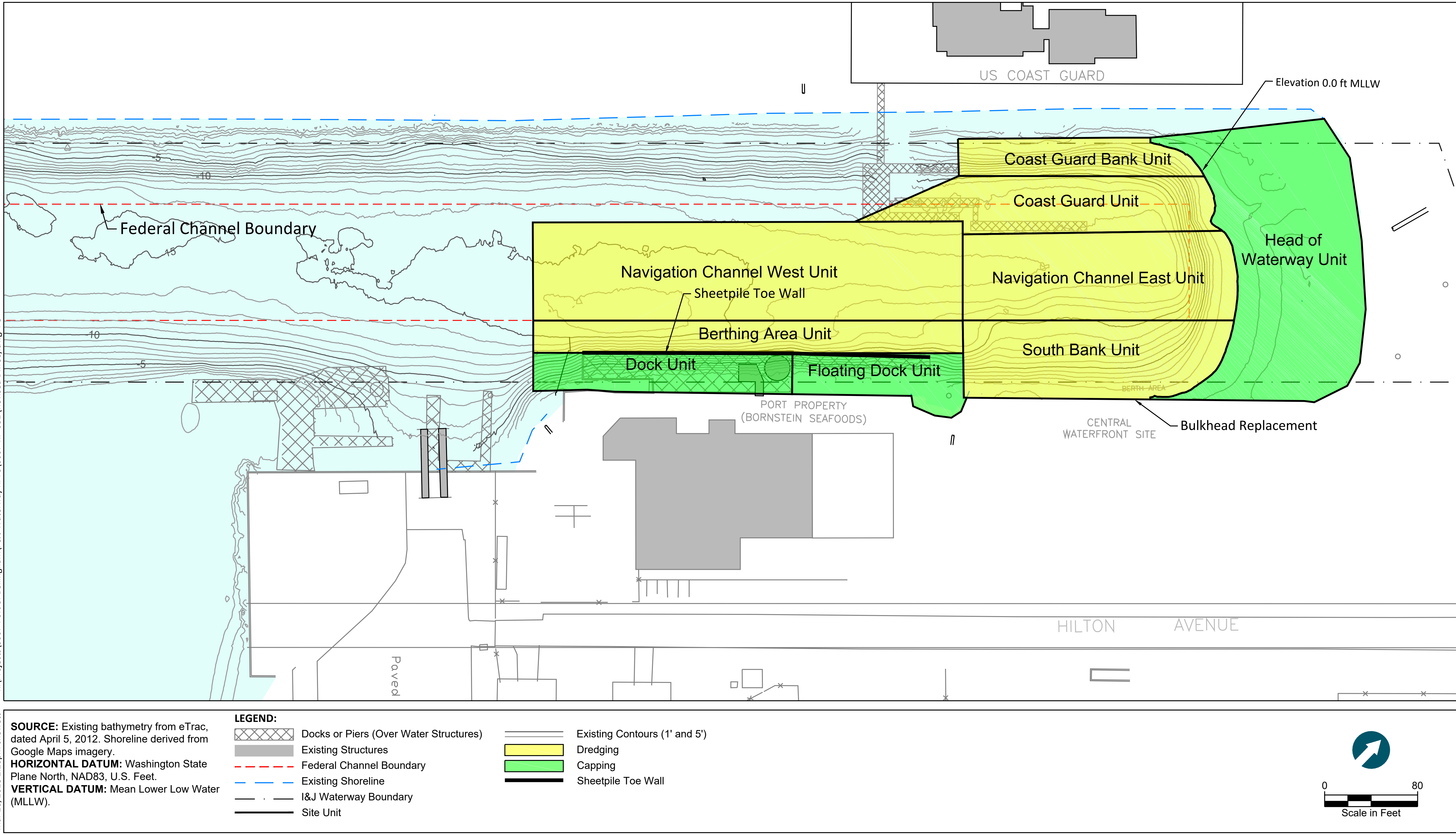
State of Washington

Figure 4-4
Alternative 4
Cleanup Action Plan
I&J Waterway Site
Port of Bellingham



SOURCE: Existing bathymetry from eTrac, dated April 5, 2012. Shoreline derived from Google Maps imagery.
HORIZONTAL DATUM: Washington State Plane North, NAD83, U.S. Feet.
VERTICAL DATUM: Mean Lower Low Water (MLLW).

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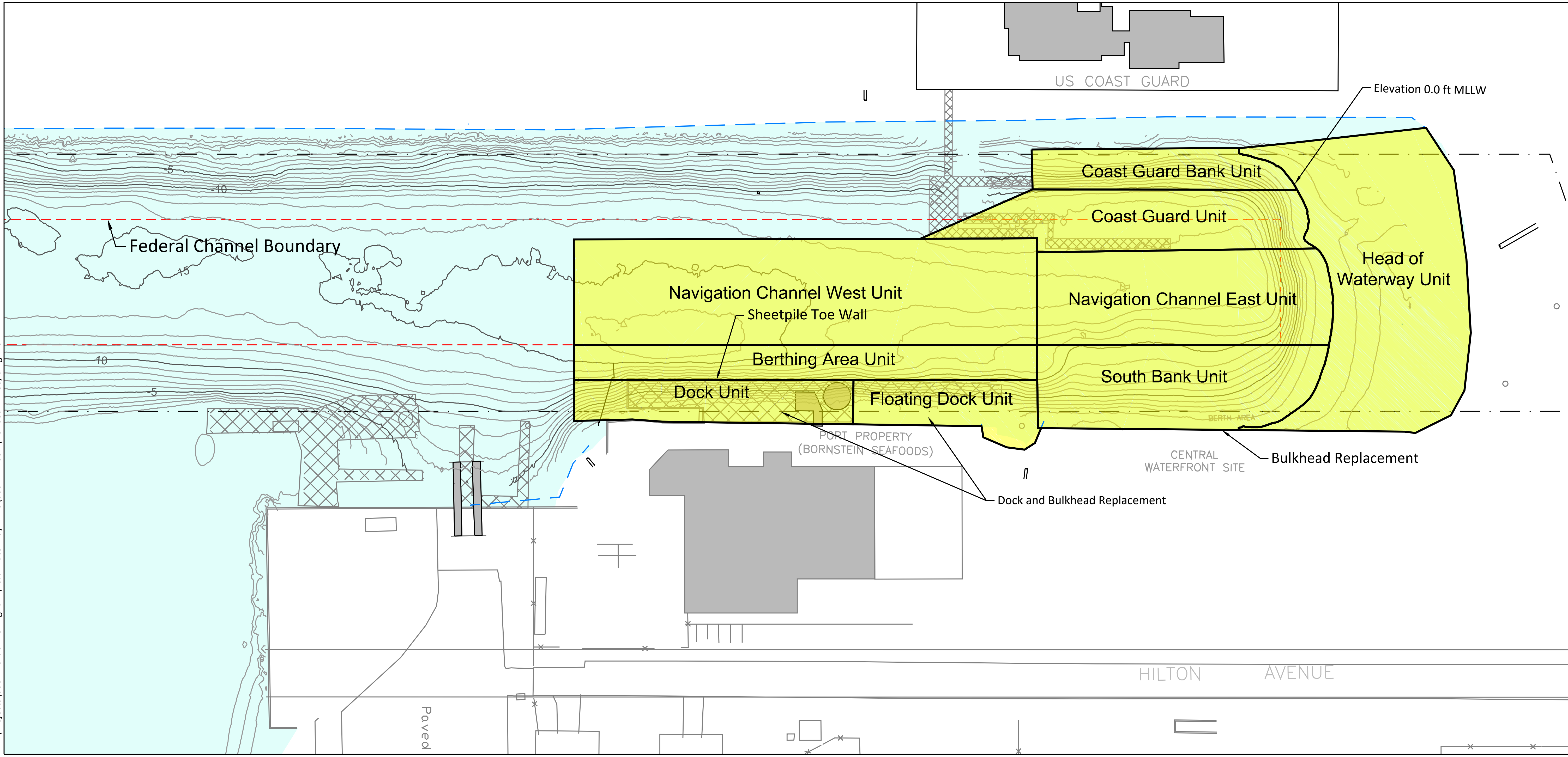
Figure 4-5
Alternative 5
Cleanup Action Plan
I & J Waterway Site
Port of Bellingham



SOURCE: Existing bathymetry from eTrac, dated April 5, 2012. Shoreline derived from Google Maps imagery.
HORIZONTAL DATUM: Washington State Plane North, NAD83, U.S. Feet.
VERTICAL DATUM: Mean Lower Low Water (MLLW).

LEGEND:
- Docks or Piers (Over Water Structures)
- Existing Structures
- Federal Channel Boundary
- Existing Shoreline
- I&J Waterway Boundary
- Site Unit
- Existing Contours (1' and 5')
- Dredging
- Sheetpile Toe Wall

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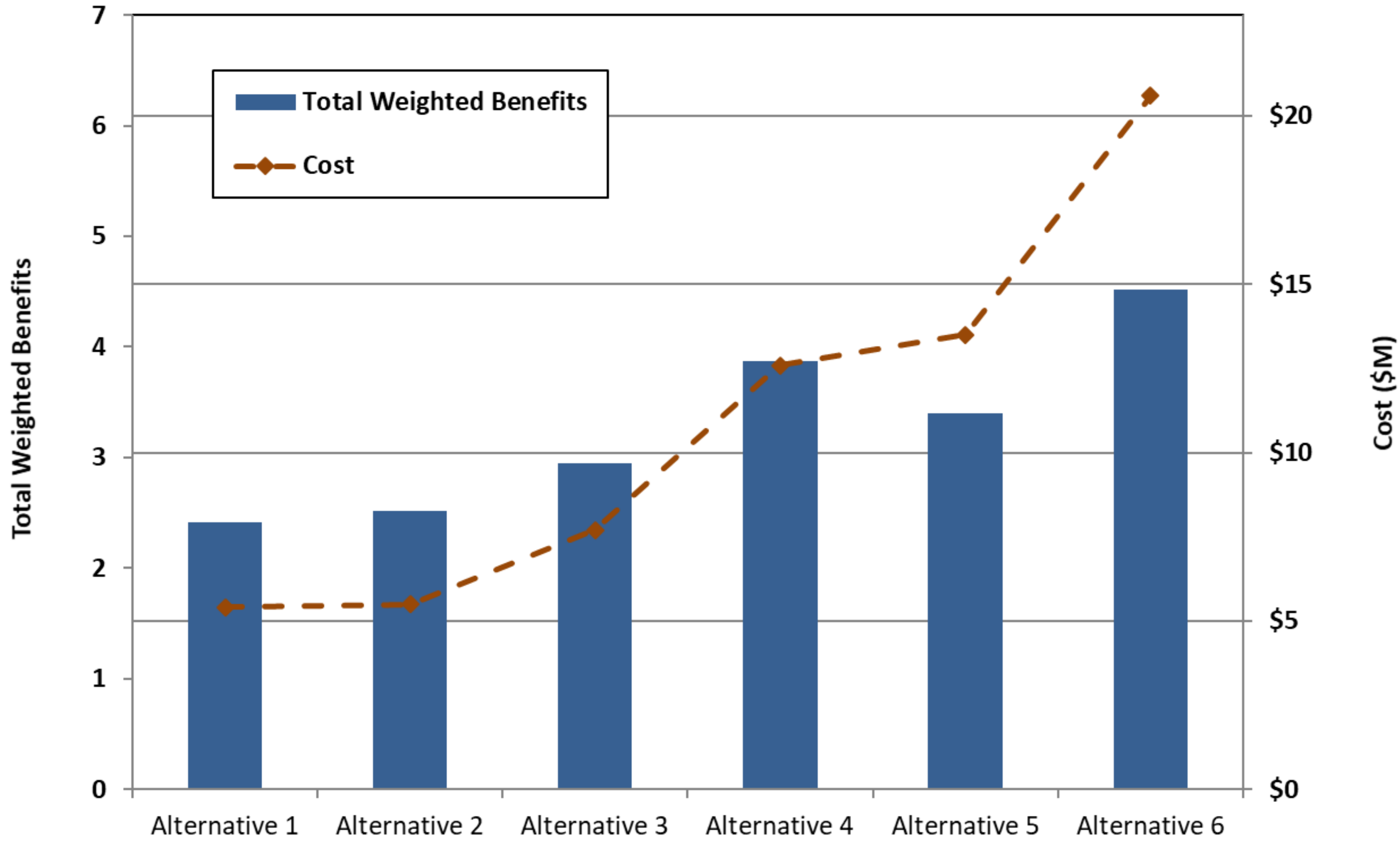
Mar 26, 2018 2:21pm chewett

DEPARTMENT OF ECOLOGY State of Washington

Figure 4-6
Alternative 6
Cleanup Action Plan
I&J Waterway Site
Port of Bellingham



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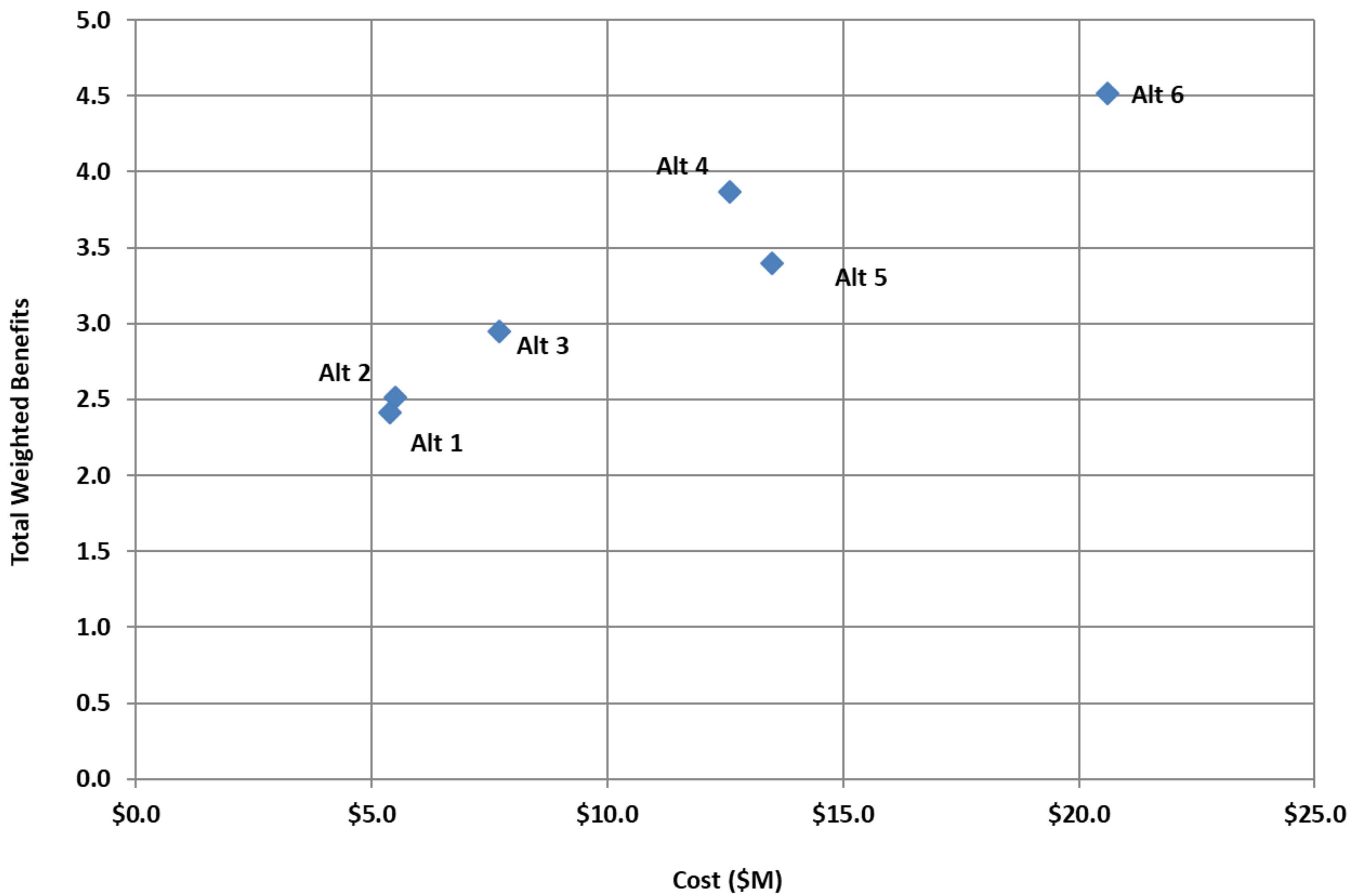
DEPARTMENT OF ECOLOGY State of Washington

Figure 5-1
Disproportionate Cost Analysis Summary – Bar Chart
Cleanup Action Plan
I&J Waterway Site
Port of Bellingham



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DEPARTMENT OF ECOLOGY State of Washington

Figure 5-2
Disproportionate Cost Analysis Summary – Scatter Plot
Cleanup Action Plan
I&J Waterway Site
Port of Bellingham

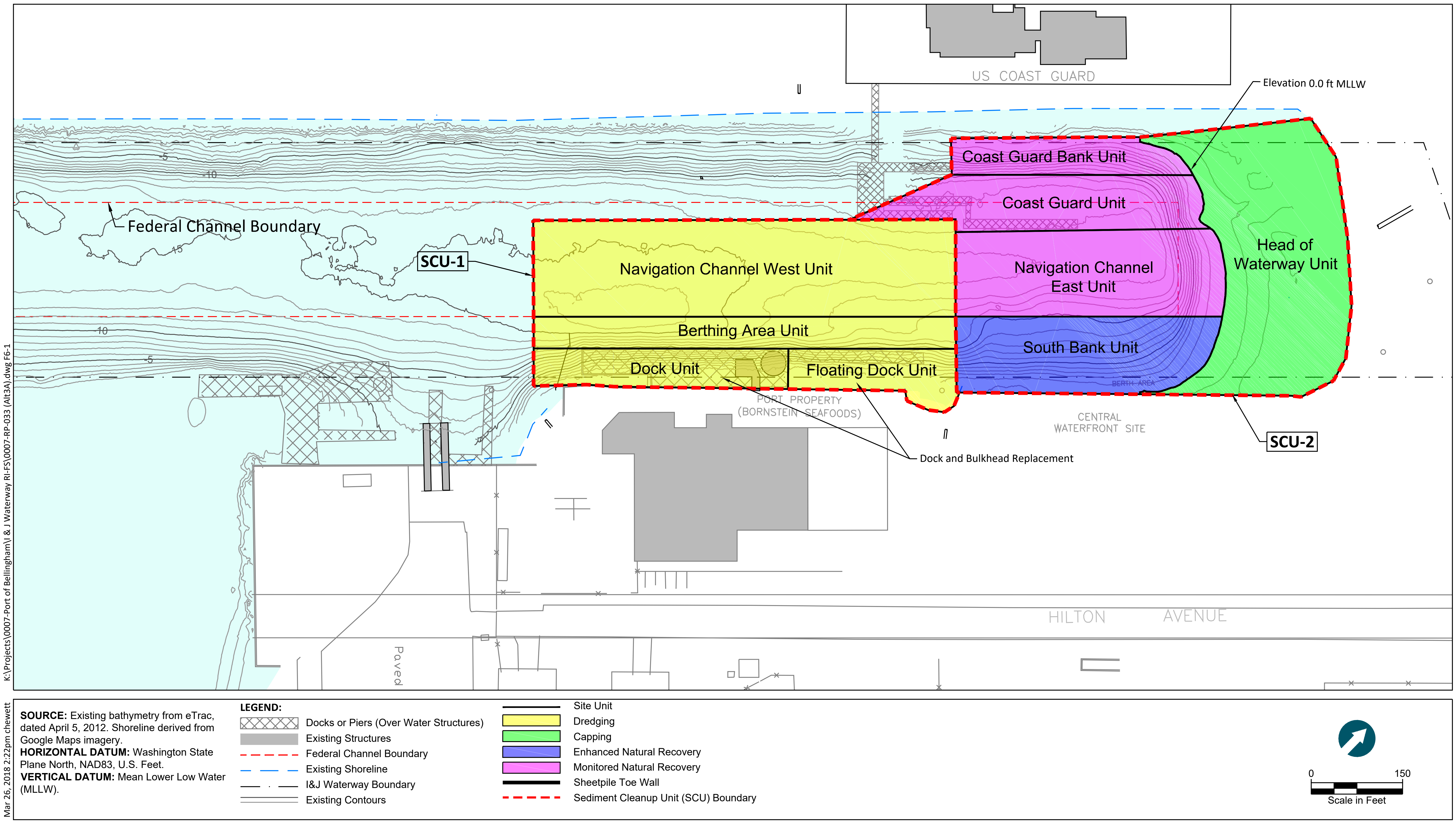


Figure 6-1
Proposed Cleanup Action
Cleanup Action Plan
I&J Waterway Site
Port of Bellingham

DEPARTMENT OF ECOLOGY
State of Washington

Appendix A
Memorandum re: I&J Waterway Site-Specific Nickel AET

720 Olive Way, Suite 1900
Seattle, Washington 98101
206.287.9130

Memorandum

March 24, 2017

To: Lucy McInerney, Washington State Department of Ecology

From: Dan Berlin, Ariel Blanc, Mark Larsen, and Dan Hennessy, Anchor QEA, LLC

cc: Peter Adolphson, Washington State Department of Ecology

Re: I&J Waterway Site-Specific Nickel AET

Introduction

This memorandum details the methods used to develop a site-specific apparent effects threshold (AET) for nickel in I&J Waterway (Site) surface sediments. Nickel was detected in all I&J Waterway Remedial Investigation (RI) surface sediment samples collected in 2005, 2012, and 2013 (Anchor QEA 2015). Sediments near the head of the Waterway contain the highest level of nickel concentrations at the Site, which is adjacent to the former upland Olivine Corporation facility. The primary source of nickel within Site surface sediments is historical activities at the facility, which operated a rock crushing plant for the mineral olivine. Nickel is a constituent within olivine ore and was periodically released to the Waterway through dust and wastewater (Anchor QEA 2015).

During the RI studies, bioassay testing was performed on 14 surface sediment samples in 2005/2006 and 2012. Bioassay testing included the 10-day acute toxicity amphipod test, larval development test, and the 20-day juvenile polychaete chronic toxicity tests consistent with the Sediment Management Standards (SMS; Ecology 2013). The larval normal survivorship endpoint was the most sensitive of the bioassays performed. Twelve[1] of the 14 synoptic samples had sediment cleanup objective (SCO)[2] or cleanup screening level (CSL) larval bioassay criteria exceedances, while only 1 of the 12 samples had chemical concentrations above promulgated SMS chemistry criteria (IJW-SS-06), indicating that toxicity could potentially be attributable to parameters without criteria (e.g., nickel) or synergistic effects between multiple chemicals (Table 1). Because nickel does not have an SMS chemical criterion, the RI/FS compared nickel concentrations to the former Dredged Material Management Program screening level of 140 milligrams per kilogram (mg/kg). However, Ecology has indicated that a site-specific AET would be most appropriate to establish a site-specific numeric criterion for nickel.

This memorandum describes methods to derive the site-specific AET to identify a nickel concentration above which adverse biological effects would be expected to occur. It also characterizes the relationship between chemical concentrations and bioassay performance for the larval development test using regression analysis. This assessment suggests a potential relationship between bioassay performance and nickel.

[1] Includes sample IJW-SS-12, which exceeded the SCO numeric criteria but was not statistically different from the reference
[2] Or former sediment quality standards (SQS) for 2005/2006 bioassay criteria.

Site-Specific Nickel Apparent Effects Threshold

A site-specific AET for nickel was developed for larval bioassay performance using Washington State Department of Ecology (Ecology) methods (Gries and Waldow 1996). Thirteen synoptic samples were used to develop the nickel AET. Sample IJW-SS-06 was excluded because of multiple SMS chemical criteria exceedances. The samples without a larval bioassay criteria exceedance ("No Hit") were ranked. Consistent with Ecology methods, the "No Hit" sample with the highest nickel concentration was identified as the AET. Sample IJ-SS-11 had a nickel concentration of 211 mg/kg and no larval or other bioassay criteria exceedances. Two larval bioassay criteria exceedances ("Hits") had greater nickel concentrations than the AET. This is consistent with the AET development methods that at least one "Hit" sample has a higher concentration than the AET, to confirm the AET. The AET of 211 mg/kg was not considered "chemically anomalous," greater or equal to three times the next highest "No Hit" sample (123 mg/kg; Gries and Waldow 1996) and, therefore, meets the criteria for establishing the site-specific AET. Figure 1 shows the ranked Site synoptic samples and the site-specific AET.

Regression Analysis

The relationship between sediment chemical concentrations and larval bioassay performance was further explored using multiple regression analysis. To assess potential chemicals contributing to larval toxicity, nickel and all chemicals with detected concentrations of at least half of the SCO chemical criteria were selected for evaluation against synoptic larval bioassay results. Data selection was refined by removing non-detect data from the data set, chemicals without five detected samples (minimum number of samples required for the analysis), and the results for sample IJW-SS-06, which contained concentrations of nine chemicals above SMS chemical criteria. The multiple regression analysis included: nickel, mercury, benzyl alcohol, bis(2-ethylhexyl)phthalate, chrysene, and fluoranthene. Chemical data were evaluated using dry weight and organic carbon (OC)-normalized concentrations.

Multiple linear regression analysis of the data set was performed with JMP® 12. Correlations were evaluated using the Spearman's Rho (ρ), a nonparametric rank correlation coefficient that ranges from -1 to 1, and significance testing. The strength of a correlation is indicated by the closeness of the Spearman's ρ to ±1. A Spearman's ρ of 0 would indicate no association, and a Spearman's ρ of -1 or 1, would indicate a perfect negative or positive correlation, respectively. A negative relationship indicates higher concentrations and lower larval normal survivorship.

The Spearman's ρ and significance testing for the multiple regression analysis is shown in Figure 2. Mercury exhibited a significant relationship with bioassay performance ($\rho = -0.6751$, $p = 0.0113$) and nickel, chrysene and fluoranthene exhibited negative, non-significant relationships ($-0.0220 \leq \rho \leq -0.0769$). Benzyl alcohol and bis(2-ethylhexyl)phthalate exhibited a positive non-significant relationship and were not further evaluated.

Metals bioavailability in sediments can be effected by OC (USEPA 2005). A multiple linear regression analysis was also conducted with metals expressed on an OC-normalized basis to estimate bioavailability. The Spearman's ρ and significance testing for the multiple regression analysis is shown in Figure 2. Mercury ($\rho = -0.6658$, $p = 0.0130$) and nickel ($\rho = -0.4396$, $p = 0.1329$) exhibited the strongest negative relationships with bioassay performance.

While the mercury correlation was the strongest, data from the adjacent Whatcom Waterway site suggest that mercury would not drive toxicity at I&J Waterway. Synoptic surface sediment mercury and larval bioassay data from Whatcom Waterway studies in 2002, 2008 and 2016 were used to develop a Whatcom Waterway site-specific mercury AET. No toxicity was observed in any of the samples, including the sample with the maximum mercury concentration of 2.55 mg/kg. This concentration would be the site-specific AET (>2.55 mg/kg), as shown in Figure 3. I&J Waterway samples used in the regression analysis had concentrations less than or equal to 0.4 mg/kg, which were less than the SCO chemical criteria (0.41 mg/kg) and several times less than the Whatcom Waterway AET, suggesting that mercury did not drive larval toxicity.

If mercury is removed from consideration, nickel exhibits the strongest relationship, with a stronger probability ($p = 0.1329$) than the individual polycyclic aromatic hydrocarbons included in the multiple regression analysis. This indicates an 87% confidence that the correlation did not arise by chance and is different from $\rho = 0$ (no relationship).

The relationship between higher sediment nickel concentrations and lower larval bioassay performance is supported by the multiple linear regression analysis performed with nickel expressed on an OC-normalized basis.

Ammonia and Sulfide Considerations

Additional evaluation was conducted to assess the potential contribution of ammonia and sulfide to larval toxicity, as suggested by Spadaro et al. (2015). Total ammonia and total sulfide were measured in overlying water for the larval bioassays performed in 2006[3] and 2012[4]. Ammonia concentrations from the 2006 and 2012 test samples (0.018 milligrams per liter [mg/L] to 0.392 mg/L) were several times lower than the 2012 ammonia reference-toxicant test no-observed-effects-concentration (1.52 mg/L) and were also less than ammonia measured in the 2012 control sample (0.554 mg/L), which met the SMS control performance standard for normal survival. Together, this information suggests that ammonia was not driving toxicity observed in the larval development test.

Total sulfide concentrations measured in 2012 test samples (0.118 mg/L to 0.183 mg/L) were less than the 2012 reference sample (CR-023; 0.359 mg/L), which met the SMS reference performance standard for normal survival, indicating that sulfide was unlikely contributing to toxicity in 2012

[3] Measured at initiation and day 2 of the test.
[4] Measured at test initiation.

samples. Sulfide measured in 2006 samples were not detected above 0.2 mg/L in any sample except for samples IJW-SS-06 (0.69 mg/L) and IJW-SS-13 (0.78 mg/L), which were similar to reference sample IJW-RR-01 (0.71 mg/L). The reference met the SMS reference performance standard for normal survival. It is unknown if sulfide contributed to larval toxicity in sample IJW-SS-06 (which contained exceedances of eight SCO chemical criteria and one CSL chemical criterion) and sample IJW-SS-13 (which contained a nickel concentration of 133 mg/kg). The information suggests that sulfide was not driving toxicity observed in nearly all of the 2006 samples.

Conclusion

A site-specific nickel larval bioassay AET of 211 mg/kg was developed for Site sediments, using synoptic data and Ecology methods. Multiple regression analysis was conducted to further explore the relationship between larval development bioassay performance and sediment contaminants. Nickel exhibited a strong relationship with larval bioassay performance on an OC-normalized basis. Other potential factors, such as mercury, ammonia, and sulfide, were not likely to have contributed to larval toxicity based on a site-specific AET evaluation for Whatcom Waterway bioassay performance (mercury) and on lower overlying water measurements during bioassay testing (sulfide and ammonia). The regression analysis suggests a relationship between nickel and larval bioassay response and supports the development of the site-specific nickel AET.

References

Anchor QEA, LLC, 2015. *Remedial Investigation and Feasibility Study Report I&J Waterway Site.* Prepared for the Port of Bellingham. January 2015.

Ecology (Washington State Department of Ecology), 2013. *Sediment Management Standards - Chapter 173-204 WAC. Final Rule*. Washington State Department of Ecology. February 22, 2013.

Gries, T.H. and K.H. Waldow, 1996. *Draft Progress Re-evaluating Puget Sound Apparent Effects Thresholds (AETs) Volume I: 1994 Amphipod and Echinoderm Larval AETs.* For Puget Sound Dredged Disposal Analysis (PSSDA). April 1996.

Spadaro, P., A. Hackett, J. Dittman, and D. Profusek, 2015. *Evaluation of Nickel Concentrations in Sediment near the Former Olivine Site, I&J Waterway, Port of Bellingham Washington.* July 14, 2015.

USEPA (U.S. Environmental Protection Agency), 2005. *Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Metals Mixtures (Cadmium, Copper, Lead, Nickel, Silver, and Zinc)*. Office of Research and Development. USEPA 600-R-02-011. January 2005.

Table

Table 1

I&J Waterway Surface Sediment Chemical Criteria Exceedances and Biological Testing Results

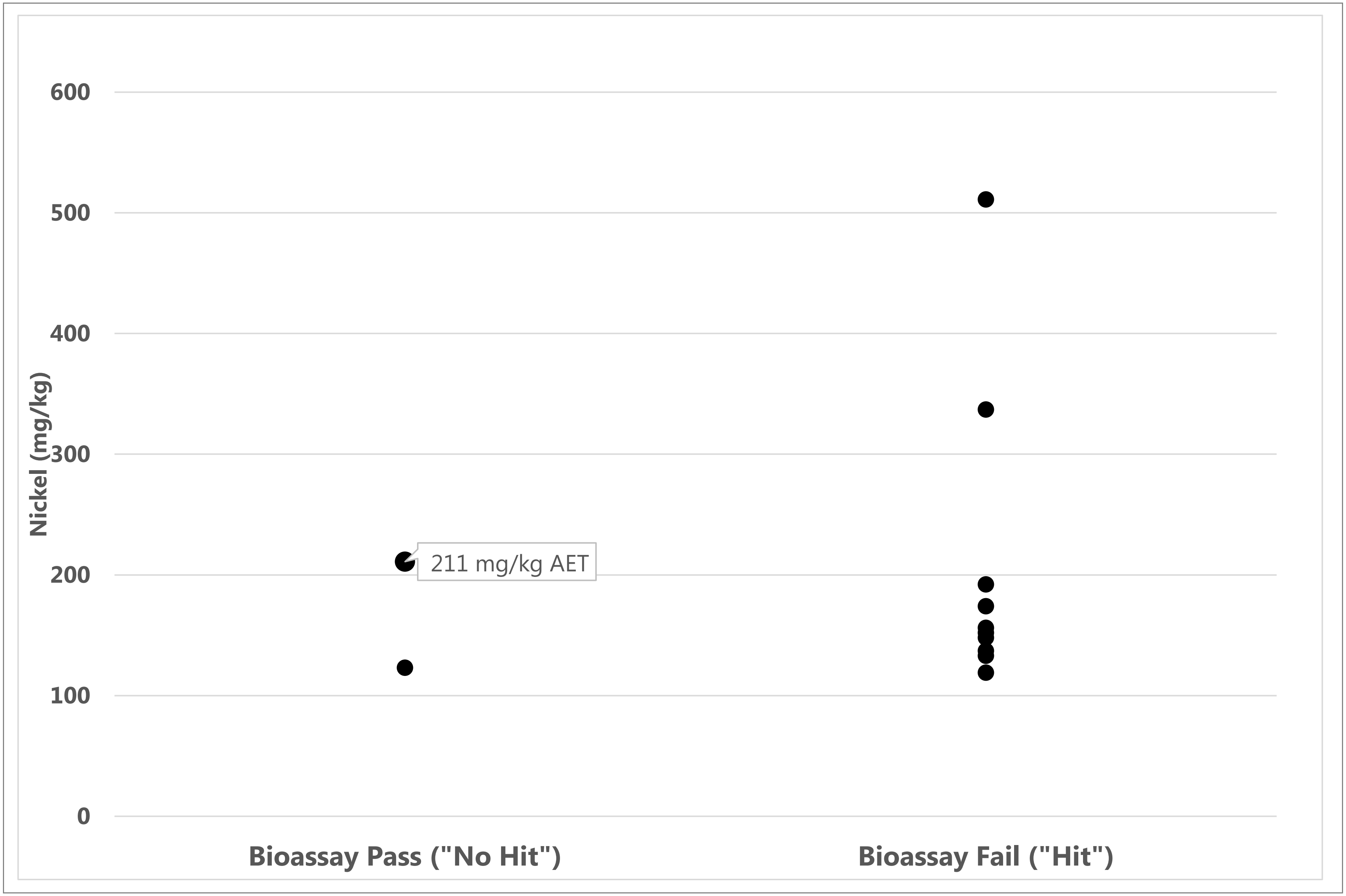
Station ID	Chemical Criteria Exceedances[1]	Nickel (mg/kg)	SCO/CSL Biological Criteria (Pass/Fail)[2]
2005/2006 Biological Testing			
IJW-SS-04	No SMS criteria exceedances	119	CSL Fail (larval)
IJW-SS-06	Acenaphthene, bis(2-ethylhexyl)phthalate, chrysene, dibenzo(a,h)anthracene, dibenzofuran, fluoranthene, fluorene, phenanthrene, and total HPAH	57	SCO Fail (juvenile polychaete) and CSL Fail (larval)
IJW-SS-07	No SMS criteria exceedances	174	CSL Fail (larval)
IJW-SS-08	No SMS criteria exceedances	156	CSL Fail (larval)
IJW-SS-09	No SMS criteria exceedances	192	CSL Fail (larval)
IJW-SS-10	No SMS criteria exceedances	511	CSL Fail (larval)
IJW-SS-11	No SMS criteria exceedances	211	Pass
IJW-SS-12	No SMS criteria exceedances	152	SCO Fail (juvenile polychaete and larval[3])
IJW-SS-13	No SMS criteria exceedances	133	CSL Fail (larval)
2012 Biological Testing			
IJ12-01	No SMS criteria exceedances	337	SCO Fail (larval)
IJ12-02	No SMS criteria exceedances	148	SCO Fail (larval)
IJ12-03	No SMS criteria exceedances	140	SCO Fail (larval)
IJ12-05	No SMS criteria exceedances	137	SCO Fail (larval)
IJ12-07	No SMS criteria exceedances	123	Pass

Notes:

1. Chemical criteria used were the Sediment Cleanup Objective for chemicals with Sediment Management Standards benthic criteria.
2. Refer to Remedial Investigation text for a description of bioassay testing.
3. Larval bioassay failed SCO (former SQS) numeric criteria but was not statistically different from the reference.

CSL: Cleanup Screening Level
HPAH: high-molecular-weight polycyclic aromatic hydrocarbon
mg/kg: milligram per kilogram
SCO: Sediment Cleanup Objective
SQS: Sediment Quality Standards

Figures



ANCHOR QEA

Figure 1
I&J Waterway Site-specific Larval Bioassay Nickel AET

SCO Basis (metals and benzyl alcohol dry weight, organics OC-normalized)

Multivariate

Nonparametric: Spearman's ρ

Variable	by Variable	Spearman ρ	Prob>|ρ|	-.8 -.6 -.4 -.2 0 .2 .4 .6 .8
Nickel_mg/kg_result_text	Mercury_mg/kg_result_text	-0.4994	0.0823	
Benzyl alcohol_ug/kg_result_text	Mercury_mg/kg_result_text	-0.4617	0.4338	
Benzyl alcohol_ug/kg_result_text	Nickel_mg/kg_result_text	-0.3000	0.6238	
bis(2-Ethylhexyl)phthalate_mg/kg-OC_result_text	Mercury_mg/kg_result_text	-0.2439	0.4971	
bis(2-Ethylhexyl)phthalate_mg/kg-OC_result_text	Nickel_mg/kg_result_text	0.0909	0.8028	
bis(2-Ethylhexyl)phthalate_mg/kg-OC_result_text	Benzyl alcohol_ug/kg_result_text	-1.0000	.	
Chrysene_mg/kg-OC_result_text	Mercury_mg/kg_result_text	-0.4101	0.1640	
Chrysene_mg/kg-OC_result_text	Nickel_mg/kg_result_text	0.7308	0.0045*	
Chrysene_mg/kg-OC_result_text	Benzyl alcohol_ug/kg_result_text	0.1000	0.8729	
Chrysene_mg/kg-OC_result_text	bis(2-Ethylhexyl)phthalate_mg/kg-OC_result_text	0.2606	0.4671	
Fluoranthene_mg/kg-OC_result_text	Mercury_mg/kg_result_text	-0.4240	0.1487	
Fluoranthene_mg/kg-OC_result_text	Nickel_mg/kg_result_text	0.7143	0.0061*	
Fluoranthene_mg/kg-OC_result_text	Benzyl alcohol_ug/kg_result_text	0.7000	0.1881	
Fluoranthene_mg/kg-OC_result_text	bis(2-Ethylhexyl)phthalate_mg/kg-OC_result_text	0.2364	0.5109	
Fluoranthene_mg/kg-OC_result_text	Chrysene_mg/kg-OC_result_text	0.9286	<.0001*	
Larval Bioassay % Normal Survivorship	Mercury_mg/kg_result_text	-0.6751	0.0113*	
Larval Bioassay % Normal Survivorship	Nickel_mg/kg_result_text	-0.0769	0.8028	
Larval Bioassay % Normal Survivorship	Benzyl alcohol_ug/kg_result_text	0.2000	0.7471	
Larval Bioassay % Normal Survivorship	bis(2-Ethylhexyl)phthalate_mg/kg-OC_result_text	0.5394	0.1076	
Larval Bioassay % Normal Survivorship	Chrysene_mg/kg-OC_result_text	-0.0220	0.9432	
Larval Bioassay % Normal Survivorship	Fluoranthene_mg/kg-OC_result_text	-0.0714	0.8166	

Metals and Organics OC-normalized

Multivariate

Nonparametric: Spearman's ρ

Variable	by Variable	Spearman ρ	Prob>|ρ|	-.8 -.6 -.4 -.2 0 .2 .4 .6 .8
Nickel_mg/kg-OC_result_text	Mercury_mg/kg-OC_result_text	0.0358	0.9077	
Benzyl alcohol_ug/kg_result_text	Mercury_mg/kg-OC_result_text	-0.1000	0.8729	
Benzyl alcohol_ug/kg_result_text	Nickel_mg/kg-OC_result_text	0.1000	0.8729	
bis(2-Ethylhexyl)phthalate_mg/kg-OC_result_text	Mercury_mg/kg-OC_result_text	-0.2796	0.4339	
bis(2-Ethylhexyl)phthalate_mg/kg-OC_result_text	Nickel_mg/kg-OC_result_text	-0.1394	0.7009	
bis(2-Ethylhexyl)phthalate_mg/kg-OC_result_text	Benzyl alcohol_ug/kg_result_text	-1.0000	.	
Chrysene_mg/kg-OC_result_text	Mercury_mg/kg-OC_result_text	-0.4044	0.1705	
Chrysene_mg/kg-OC_result_text	Nickel_mg/kg-OC_result_text	0.4505	0.1223	
Chrysene_mg/kg-OC_result_text	Benzyl alcohol_ug/kg_result_text	0.1000	0.8729	
Chrysene_mg/kg-OC_result_text	bis(2-Ethylhexyl)phthalate_mg/kg-OC_result_text	0.2606	0.4671	
Fluoranthene_mg/kg-OC_result_text	Mercury_mg/kg-OC_result_text	-0.4044	0.1705	
Fluoranthene_mg/kg-OC_result_text	Nickel_mg/kg-OC_result_text	0.4835	0.0941	
Fluoranthene_mg/kg-OC_result_text	Benzyl alcohol_ug/kg_result_text	0.7000	0.1881	
Fluoranthene_mg/kg-OC_result_text	bis(2-Ethylhexyl)phthalate_mg/kg-OC_result_text	0.2364	0.5109	
Fluoranthene_mg/kg-OC_result_text	Chrysene_mg/kg-OC_result_text	0.9286	<.0001*	
Larval Bioassay % Normal Survivorship	Mercury_mg/kg-OC_result_text	-0.6658	0.0130*	
Larval Bioassay % Normal Survivorship	Nickel_mg/kg-OC_result_text	-0.4396	0.1329	
Larval Bioassay % Normal Survivorship	Benzyl alcohol_ug/kg_result_text	0.2000	0.7471	
Larval Bioassay % Normal Survivorship	bis(2-Ethylhexyl)phthalate_mg/kg-OC_result_text	0.5394	0.1076	
Larval Bioassay % Normal Survivorship	Chrysene_mg/kg-OC_result_text	-0.0220	0.9432	
Larval Bioassay % Normal Survivorship	Fluoranthene_mg/kg-OC_result_text	-0.0714	0.8166	

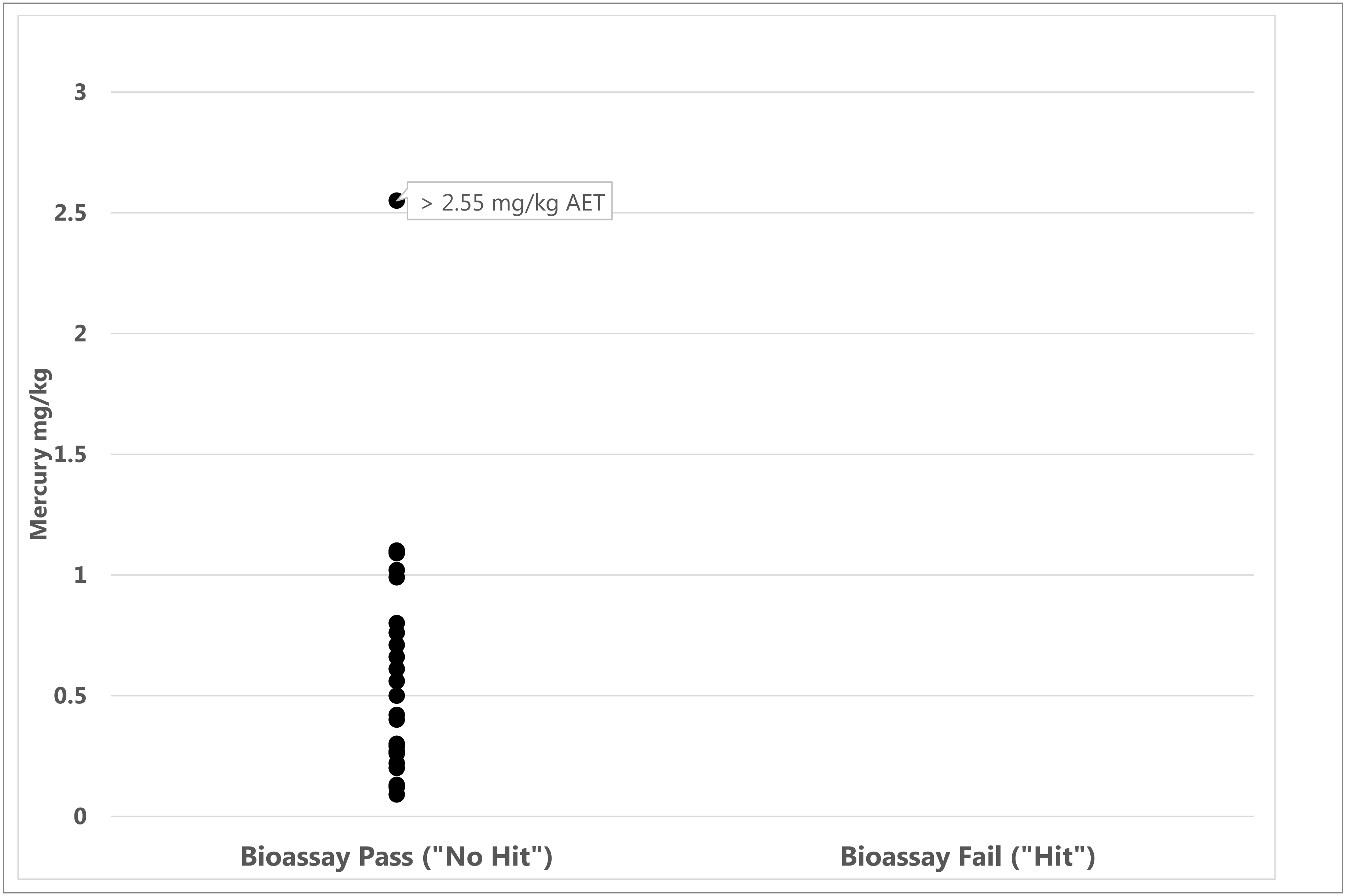


Figure 3
Whatcom Waterway Site-specific Larval Bioassay Mercury AET

Appendix B
Preliminary Human Health SCO and CSL Development

TABLE OF CONTENTS

CHARTS

TABLES

ABBREVIATIONS

ADAF	age-dependent adjustment factor
BSAF	biota-sediment accumulation factors
bw	body weight
CAP	Cleanup Action Plan
CLARC	Cleanup Levels and Risk Calculations
cm^2	square centimeter
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CPF	cancer potency factor
COC	constituent of concern
CSL	Cleanup Screening Level
DF	diet fractions
DMMP	Dredged Material Management Program
Ecology	Washington State Department of Ecology
ELCR	Excess Lifetime Cancer Risk
ELS	early life stage
EPA	U.S. Environmental Protection Agency
ERDC	USACE Environmental Research Development Center
ESA	Endangered Species Act
FS	Feasibility Study
g	gram
g/day	gram per day
HI	hazard index
HQ	hazard quotient
g/g	gram per gram
kg	kilogram
km^2	square kilometer
Koc	organic carbon-water partitioning coefficient
mg/kg	milligram per kilogram
MLLW	mean lower low water
MTCA	Model Toxics Control Act
OC	organic carbon
ODEQ	Oregon Department of Environmental Quality
ORD	EPA Office of Research and Development
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyls
PQL	practical quantitation limit

RBC	risk-based concentration
RfD	reference dose
RI	Remedial Investigation
RME	reasonable maximum exposure
RSET	Regional Sediment Evaluation Team
SCL	sediment cleanup level
SCO	Sediment Cleanup Objective
SCUM II	Sediment Cleanup Users Manual II
Site	I&J Waterway Site
SMS	Sediment Management Standards
SUF	site use factor
TCDD	tetrachlorodibenzodioxin
TEF	toxic equivalency factor
TEQ	toxic equivalents quotient
TTL	target tissue level
USACE	U.S. Army Corps of Engineers
UTL	upper tolerance limit
WAC	Washington Administrative Code
WES	Waterway Experiment Station

1 Introduction

This appendix presents the development of human health risk-based concentrations (RBCs) for the I&J Waterway Site (Site). These human health RBCs contribute to the selection of the Sediment Cleanup Objective (SCO) and Cleanup Screening Level (CSL) described in Section 3 of the Cleanup Action Plan (CAP). This appendix also identifies natural background, regional background, and practical quantitation limits (PQLs), which also contribute to selection of the SCO and CSL. Human health SCO and CSL were developed in the Remedial Investigation/Feasibility Study (RI/FS) for carcinogenic polycyclic aromatic hydrocarbons (cPAHs), but the following new information requires revision of that work:

- Determination of a regional background cPAH concentration of 86 µg TEQ/kg in Bellingham Bay (Ecology 2015)
- Change in cancer potency factor for benzo(a)pyrene from 7.3 $(mg/kg\text{-}day)^{-1}$ to 1 $(mg/kg\text{-}day)^{-1}$ (EPA 2017)
- Consideration of early life stage (ELS) exposure to mutagenic chemicals in risk-calculations

For the ELS exposure, the RBC methodology used in this appendix is preliminary because the Washington State Department of Ecology (Ecology) plans to perform a broader evaluation of the issue. The future implementation stage of the Site cleanup will define final RBCs. Both standard RBCs and preliminary ELS-based RBCs are developed in this appendix for cPAHs.

Sediment sites are regulated by the Sediment Management Standards (SMS; Washington Administrative Code [WAC] 173-204). The revised SMS rule was implemented on September 1, 2013 (Ecology 2013) and includes specific requirements for the protection of both human health and the environment. The SMS rule includes specific procedures to determine human health risk-based SCOs and CSLs to address the bioaccumulative (seafood consumption) and direct contact exposure pathways (WAC 173-204-560). Under SMS, the derivation of human health sediment RBCs is a component of the overall sediment cleanup level (SCL) development. The SMS permits site risk-based cleanup standards within a range of 1 in 100,000 (1×10^{-5}) to 1 in 1 million (1×10^{-6}) excess lifetime cancer risk (ELCR) levels for all individual carcinogens, and a total ELCR risk of 1×10^{-5} for all carcinogens (total risk from multiple contaminants). For non-carcinogenic chemicals, a hazard quotient (HQ) of 1 is used to develop cleanup standards. If a site has multiple non-carcinogens with similar types of toxicity, the cleanup standards may be adjusted downwards in accordance with WAC 173-340-708, or other approved methods to ensure protectiveness at a hazard index (HI) of 1.

The human health risk-based SCO is the lowest sediment RBC developed from the 1×10^{-6} ELCR[1] threshold and/or a HQ of 1.[2] The human health risk-based CSL is the lowest sediment RBC

[1] Or $1\text{x}10^{-5}$ for multiple carcinogens
[2] Or an HI of 1 for multiple non-carcinogens

corresponding to a 1×10^{-5} ELCR threshold and/or a HQ of 1.[2] The final SCO and CSL are determined based on the highest of the 1) lowest appropriate RBCs for protection of human health, benthic organisms (WAC 173-204-320 and WAC 173-204-562 for SCO and CSL, respectively), or ecological receptors; 2) background; and 3) PQLs.

The SCO defines the lower bound of a sediment cleanup level and the CSL defines the upper bound. The SCL may be adjusted upward from the SCO, if the SCO is not technically possible to achieve considering net environmental effects on the aquatic environment, natural resources, and habitat. However, the SCL may not be adjusted upward above the CSL (WAC 173-204-560).

As described in SMS and the Sediment Cleanup Users Manual II (SCUM II) (Ecology 2017) guidance document, the steps for developing human health risk-based CSL and SCO for I&J Waterway are as follows:

- Identify Site bioaccumulative chemicals requiring RBC development (Ecology 2017).
- Identify potential exposure pathways and the reasonable maximum exposure (RME) scenario (WAC 173-204-561(2)).
- Calculate carcinogenic sediment RBCs at $1\text{x}10^{-6}$ (SCO) and $1\text{x}10^{-5}$ (CSL) and non-carcinogenic RBCs using a HQ of 1.[1]
- Determine natural background.
- Determine the PQL.
- Determine regional background.

This document is generally organized according to these steps and includes the following sections:

- Section 2 identifies Site bioaccumulative chemicals requiring development of bioaccumulative exposure pathway (seafood consumption) RBC.
- Section 3 identifies complete Site exposure pathways and discusses RME scenarios.
- Section 4 includes components of SCO development. This section provides equations for calculating RBCs for the exposure scenarios and discusses natural background and PQLs.
- Section 5 includes components of CSL development. This section discusses RBCs and PQLs and presents the Bellingham Bay regional background values calculated by Ecology for cPAH toxic equivalents quotient (TEQ) and total dioxin/furan TEQ.

2 Identification of Site Bioaccumulative Chemicals of Potential Concern

I&J Waterway sediment samples collected in 2005/2006, 2012, and 2013 were used to determine Site bioaccumulative chemicals requiring RBC development. Bioaccumulative chemicals detected in at least one Site surface sediment sample included arsenic, cadmium, lead, mercury, total polychlorinated biphenyls (PCB) Aroclors, polycyclic aromatic hydrocarbons (PAHs), pentachlorophenol, and total dioxin/furan TEQ. The frequency of detection, temporal and spatial chemical concentration patterns, and current and historical Site activities were considered to determine which of these chemicals could be considered Site related.

Bioaccumulative chemicals that could be potentially Site related include a number of PAHs, which were developed into RBCs for cPAHs. The other bioaccumulative chemicals are not considered Site-related because they are not specifically associated with historical or current Site uses and/or have low detection frequencies. Dioxin/furan was not retained as a constituent of concern (COC) because congener profiles suggest no Site-associated release/activity and Site sediments are similar to Bellingham Bay profiles. As shown in Appendix E of the RI/FS, dioxin/furan congener profiles from sediment at the Site are similar to sediment samples collected by the U.S. Army Corps of Engineers (USACE) in 2012 that extend to the end of the I&J Waterway, up to approximately 2,000 feet from the Site into Bellingham Bay. As presented in the RI/FS, congener patterns in Site sediment resemble profiles associated with typical urban inputs, such as automobile and diesel emissions, which is typical in urban areas with stormwater runoff from commercial and industrial areas. Areas with elevated dioxin/furan concentrations that are co-located with Site COCs will be addressed as part of Site remediation.

2.1 cPAHs

PAHs are a group of structurally similar planar compounds. Seven of the 16 PAHs tested under SMS have been identified as probable human carcinogens (cPAH). The U.S. Environmental Protection Agency (EPA) considers cPAHs to be mutagenic carcinogens (EPA 2005) and, although not currently required in SMS or the Model Toxics Control Act (MTCA), ELS adjustments were incorporated into the risk assessment, and preliminary ELS-based RBCs were determined. Evaluation of cPAH under MTCA occurs by multiplying the individual cPAH by their respective benzo(a)pyrene toxic equivalency factors (TEF; CalEPA 2005) and summing these TEQs into a total cPAH TEQ (WAC 173-340-708(e)). While non-carcinogenic PAHs co-occur with the cPAH at the Site, the cPAH exhibit higher potential risk to human health than do the non-carcinogenic PAHs. For this reason, Site remediation to risk-based bioaccumulative cleanup levels developed for cPAHs will be protective of risk from other bioaccumulative non-carcinogenic PAHs.

3 Exposure Pathways and Reasonable Maximum Exposure Scenarios

RBCs have been calculated for Site exposure pathways for both carcinogenic and non-carcinogenic risk, as applicable. This section describes the exposure pathways used to calculate the RBCs.

Two likely exposure pathways were identified for the Site based on current and potential future Site uses:

- Ingestion of fish and shellfish that have bioaccumulated chemicals from the Site.
- Direct contact (incidental sediment ingestion and dermal contact) with chemicals in Site sediments during recreational beach use.

The RME scenario refers to the highest exposure for human health risk that is reasonably expected to occur at a site under current and potential future land use (WAC 173-204-561(2)(b)). Three RME scenarios were developed to address these exposure pathways:

- Tribal seafood ingestion of fish and shellfish (seafood consumption)
  - Age 0 to 70 years old
- Adult direct contact and incidental ingestion RME clamming
  - Age 0 to 70 years old
- Child direct contact and incidental ingestion RME beach play
  - Age 0 to 6 years old

These RME scenarios were developed for the Study Area based on Ecology guidance (Ecology 2017). The pathways are considered complete and are shown in the Conceptual Site Model (Figure 7-2).

3.1 Seafood Consumption Scenario

Development of the sediment cPAH RBC that would be protective of tribal RME seafood consumption from the Site was calculated using Ecology's default equation (Ecology 2017), and a combination of Ecology's default input parameters (e.g., exposure frequency, exposure duration) and Site-specific input parameters (e.g., seafood ingestion rates, site use factors). The RBC developed is the concentration in sediment at and below which chemicals would not be expected to accumulate in seafood tissue to levels presenting potential unacceptable ELCR to human consumers under RME conditions. The equation and Site-specific parameters used for calculating the seafood consumption cPAH RBC are presented in Section 4.1.1. For the preliminary ELS-based RBCs, the fish consumption dose for children (0 to 6 years old) was assumed to be 40% of the adult value, based on recommendations in the *Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia* (EPA 2007).

3.2 Sediment Direct Contact and Incidental Ingestion Scenario

The direct contact and incidental ingestion exposure pathways were evaluated through the adult clamming and the child beach play scenarios. These scenarios were used to derive RBCs for adult and child recreational activities in the intertidal area of the Site (-4 feet to 11 feet mean lower low water [MLLW]). RBCs protective of the direct contact and incidental ingestion scenarios were calculated using Ecology's default equations (Ecology 2017), and a combination of Ecology's default input parameters (e.g., body weight, exposure duration) and Site-specific input parameters (e.g., exposure frequency). RBCs were developed for cPAHs in addition to other SMS chemicals if toxicity data (cancer potency factor [CPF] and/or reference dose [RfD]) were available in Ecology's Cleanup Levels and Risk Calculations (CLARC) database (Ecology 2017). For a given chemical, carcinogenic and/or non-carcinogenic RBCs were developed based on the chemical's toxicological mechanisms of action. The direct contact and incidental ingestion equations and Site-specific parameters used for calculating the RBCs are presented in Section 4.1.2.

3.3 Ecological Receptors

Ecological risk from bioaccumulative chemicals is also considered in the development of SCO and CSL for a site (Ecology 2017). Higher trophic-level aquatic dependent organisms such as Great Blue Heron (*Ardea herodias*) or Harbor Seals (*Phoca vituluna*) could potentially forage on prey species that have bioaccumulated chemicals from the Site. PAHs were the only chemicals identified as Site-related bioaccumulative chemicals of potential concern. The other bioaccumulative chemicals (arsenic, cadmium, lead, mercury, PCB, pentachlorophenol, and total dioxin/furan) were excluded from further ecological evaluation based on frequency of detection, temporal and spatial chemical concentration patterns, and knowledge of current and historical Site activities.

The Site mean concentrations of the bioaccumulative metals cadmium and lead in surface sediments were at or below natural background (Ecology 2017) concentrations, while arsenic and mercury concentrations were slightly above natural background. Arsenic and mercury are not associated with any known Site release/activity and elevated areas are co-located with Site COCs that will be addressed as part of Site remediation. These chemicals are therefore not considered Site bioaccumulative chemicals of concern.

Pentachlorophenol and PCB had low detection frequencies in Site samples, there is no known Site-related release/activity, and samples with detections are located in areas targeted for remediation of Site COCs. These chemicals are therefore not considered Site bioaccumulative chemicals of concern.

Dioxin/furan tends to be present in higher concentrations throughout Bellingham Bay and in other urban areas in Puget Sound. As discussed previously, dioxin/furan was not retained as a COC because congener profiles suggest no Site-associated release/activity and Site sediments are similar to Bellingham Bay profiles. Areas with elevated dioxin/furan concentrations that are co-located with Site COCs will be addressed as part of Site remediation.

The cPAH RBC developed for human health is anticipated to be adequately protective of aquatic dependent wildlife that may be exposed to bioaccumulative chemicals (through foraging) at the Site, which may include otters or seals. Human and aquatic-dependent wildlife bioaccumulative chemical target tissue levels (TTLs) have been developed and are presented in several documents, including the SCUM II (Ecology 2017), the *Sediment Evaluation Framework for the Pacific Northwest* (RSET 2009), and the *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment* (ODEQ 2007). The TTLs represent the prey tissue concentrations considered protective of human health and aquatic dependent wildlife. The compilation of available TTLs are included in Table B-1. Comparison of the human and aquatic-life dependent wildlife TTLs demonstrates that RBCs developed for human health would also be protective of aquatic-dependent wildlife. The available human TTLs for metals, PAHs, PCB, pentachlorophenol, and dioxin/furan TEQ are generally several orders of magnitude less than the aquatic dependent wildlife TTLs (for those chemicals where both are presented)[3], indicating that the sediment concentrations corresponding to the human TTL would be inclusively protective of aquatic-dependent wildlife. While no aquatic life dependent cPAH TTL is available to compare to the human TTL, Ecology has not identified cPAH or benzo(a)pyrene (as a surrogate) as a chemical that may pose a risk to aquatic dependent receptors at levels lower than may present an unacceptable risk to human health (Ecology 2017). Elevated concentrations of non-carcinogen PAH and other bioaccumulative chemicals collocated with cPAH in Site sediments will be addressed with remedies developed for cPAH. For these reasons, it is expected that the cPAH RBC developed for the human health RME seafood consumption scenario will also be protective of exposure of aquatic dependent wildlife foraging at the Site.

[3] The fluoranthene nearshore Endangered Species Act (ESA) aquatic-dependent wildlife TTL is slightly lower than the human TTL presented in the *Sediment Evaluation Framework for the Pacific Northwest* (RSET 2009). However, the RSET (2009) population-level aquatic dependent wildlife TTL is greater than the human TTL. Because individual ESA species are not receptors of concern at the I&J Waterway Site, the population-level TTLs are a more appropriate benchmark for comparison to the human health TTLs. Further, the aquatic-dependent TTLs were based on mink, which is not present in the I&J Waterway Site. RSET (2009) also presents population-level TTLs for sea otter and harbor seal, two aquatic dependent wildlife species that have a greater potential to use the I&J Waterway Site. The RSET (2009) TTLs for otter and seal are greater than the mink TTL.

4 SCO Development

For a given chemical, the SCO is determined based on the highest of the following:

- The lowest appropriate RBCs for protection of human health for the 1×10^{-6} ELCR threshold and/or a HQ of 1, benthic organisms (WAC 173-204-320 for SCO), or ecological receptors
- Background
- PQLs

4.1 Risk-based Levels

Carcinogenic ELCR and non-carcinogenic health effects were evaluated separately because of differences in assumptions about the mechanism of these toxic effects. The toxicity values used to evaluate exposure to chemicals with non-carcinogenic and carcinogenic effects are RfDs and the CPFs, respectively. All toxicity values were taken from the CLARC database (Ecology 2012) unless otherwise specified.

Carcinogenic chemicals are assumed to have no threshold for carcinogenicity. Carcinogenic risks are presented as the chance of contracting cancer over a 75-year lifetime due to Site-related exposure. These risks are considered by the EPA to be excess cancer risks that are in addition to the national rates of cancer for the general population. Carcinogenic-based sediment screening values were calculated using $1x10^{-6}$ cancer risk, consistent with SMS guidance for developing human health-based SCO.

Preliminary ELS-based RBCs were also developed for comparison to standard RBCs to account for the mutagenic effect of cPAH (EPA 2005). cPAH mutagenicity was addressed by using default age-dependent adjustment factors to modify the total dose for the ELS age cohorts.

Chemicals exhibiting non-carcinogenic health effects are considered threshold chemicals, indicating that a critical chemical dose must be exceeded before adverse health effects occur. The potential for non-carcinogenic health effects to occur from exposure to a chemical is represented by the ratio of the estimated chemical intake to the RfD, and is expressed as a HQ. Exposures resulting in a HQ less than or equal to 1 are unlikely to result in non-carcinogenic adverse health effects.

4.1.1 Seafood Consumption Risk Levels

The cPAH TEQ sediment RBC for the seafood consumption pathway was calculated using Equations 1 through 1.4 shown in the following paragraphs. The individual PAHs comprising the cPAH TEQ have unique biota sediment accumulation factors (BSAF) and relative potencies and are present in Site sediments in varying concentrations. To calculate a cPAH TEQ RBC for the Site, the default equation

(Ecology 2017) was re-arranged to first calculate the current total cPAH TEQ ELCR from the mean[4] individual cPAH concentrations. The current mean Site sediment concentrations were then multiplied by the target ELCR ($1x10^{-6}$ for the SCO) and divided by the current total cPAH TEQ ELCR. This resulted in individual PAH sediment values with ELCRs that sum to the target ELCR ($1x10^{-6}$). The protective sediment concentrations for the individual PAH were then adjusted by their respective TEFs and summed to express the protective sediment concentration in terms of cPAH TEQ.

Equation 1

$$RBC_{cPAH\ TEQ} = \sum_{a=1}^{g} \left[\left(\frac{Csed_a \times ELCR_{Target}}{ELCR_{cPAH\ TEQ}} \right) \times TEF_a \right]$$

Equation 1.1

$$ELCR_{cPAH\ TEQ} = \sum_{a=1}^{g} ELCR_a$$

Equation 1.2.1

$$ELCR_a = CPFo_a \times CDI_a$$

For cPAHs, which have been identified as having a mutagenic mode of action, dose estimates were adjusted upwards in the risk calculation in the following manner to account for potential greater susceptibility of children from 0 to 16 years of age compared with older children and adults (Chart 1):

Chart 1
ELS Age Dependent Adjustment Factors and Exposure Durations (EPA 2005)

Age Group	Age Dependent Adjustment Factor (ADAF; unitless)	Exposure Duration (years)
<2 yrs	10	2
2 to <6 yrs	3	4
6 to <16 yrs	3	10
16 to 70 yrs	1	54

4 The cPAH averages were calculated from all waterway samples with the exception of sample IJ12-11, which was located outside of the Site. The cPAH averages were calculated after first averaging parent and field duplicates. Average benzo(b)fluoranthene and benzo(k)fluoranthene concentrations were calculated from samples collected in 2005/2006.

Equation 1.2.2

$$ELCR_{a(0-70)} = CPFo_a \times \left(\left[CDI_{a(0-2)} \times \frac{2}{70} \times 10\right] + \left[CDI_{a(2-6)} \times \frac{4}{70} \times 3\right] + \left[CDI_{a(6-16)} \times \frac{10}{70} \times 3\right] + \left[CDI_{a(16-70)} \times \frac{54}{70} \times 1\right]\right)$$

Equation 1.3

$$CDI_a = \sum_{k=1}^{m} \left(\frac{C_{a,k} \times FCR_k \times EF \times ED \times FDF_k \times SUF_k \times UCF}{AT_{cr} \times BW}\right)$$

Equation 1.4

$$C_{a,k} = SL_k \times BSAF_{a,k} \times CsedOC_a$$

where:

AT_{cr}	=	Cancer averaging time (days)
$BSAF_{a,k}$	=	Biota sediment accumulation factor of a^{th} individual cPAH for k^{th} seafood type (grams organic carbon [g-OC]/grams lipid [g-lipid])
BW	=	Body weight (kilograms [kg])
$C_{a,k}$	=	Tissue concentration of a^{th} individual cPAH in k^{th} seafood type (milligrams per kilogram [mg/kg])
$Csed_a$	=	Average Site concentration of a^{th} individual cPAH (mg/kg)
$CsedOC_a$	=	Average Site organic carbon normalized concentration a^{th} individual cPAH (mg/kg-OC)
CDI_a	=	Chronic daily intake of a^{th} individual cPAH (mg/kg-day)
$CPFo_a$	=	Oral cancer potency factor of a^{th} individual cPAH (mg/kg-day)-1
$ELCR_a$	=	Excess lifetime cancer risk for a^{th} individual cPAH (unitless)
$ELCR_{cPAH\ TEQ}$	=	Current Site cPAH TEQ excess lifetime cancer risk (unitless)
$ELCR_{Target}$	=	Target total excess lifetime cancer risk (1×10^{-6}, unitless)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
FCR_k	=	Consumption rate of k^{th} seafood type (g/day)
FDF_k	=	Diet fraction of k^{th} seafood type (proportion)
$RBC_{cPAH\ TEQ}$	=	Sediment cPAH TEQ risk-based concentration (mg/kg)
SL_k	=	Lipid fraction of k^{th} seafood type (gram per gram [g/g])
SUF_k	=	Site use factor of k^{th} seafood type (proportion)
TEF_a	=	Toxicity equivalency factor of a^{th} individual cPAH (unitless)
UCF	=	Conversion factor (0.001 kg/g)

Values for each of the listed parameters are presented in Table B-2a and B-2b. The cPAH TEQ standard RBC and preliminary ELS-based RBC is presented in Table B-4.

4.1.1.1 Site-specific Parameters

The Site-specific parameters used in the seafood consumption risk equation are described below. The Ecology default values for all other parameters were used. All parameters used are included in Tables B-2a and B-2b.

4.1.1.1.1 Seafood Consumption Rates, Diet Fraction, and Site Use Factors

Fish and shellfish consumption rates for shellfish, crabs, and bottomfish were 38.5 grams per day (g/day), 23.4 g/day, and 7.8 g/day, respectively, based on the 90th percentile rates from the Tulalip Tribe Seafood Consumption study and an average Tulalip tribal member adult body weight[5] of 81.8 kg (Toy et al. 1996) for use in developing the cPAH TEQ RBC. The consumption rates used for the I&J Waterway Site were 45 g/day for clam, 27.3 g/day for crabs, and 9.1 g/day for fish. Mobile crabs and bottomfish that could be potentially caught in I&J Waterway were assumed to have a 10-square kilometer (km^2) unconstrained home range. The I&J Waterway Site consists of 0.016-km^2 area, or 0.2% of the 10-km^2 home range. Crab and fish would therefore be expected to utilize I&J Waterway for only a small portion of the time, given the relatively small area of the Site compared to the home range. The RBC was developed for the Site using crab and fish site use factors (SUF) of 0.01 and the Ecology default diet fractions (DF) of 1.

I&J Waterway has a small beach (approximately 250 feet by 155 feet; -4 feet MLLW to the vegetated berm) at the head of the Waterway. While it is possible that the relatively small intertidal area could support a limited clam population, shellfish densities are low along the eastern shore of Bellingham Bay and geoduck do not occur in I&J Waterway (discussed in Section 3.2.2 of the RI). Because of the constrained clam habitat in I&J Waterway, a clam DF of 0.1 was used. Clams are sessile organisms and therefore a SUF of 1.0 was used.

4.1.1.1.2 Cancer Potency Factors

To be consistent with the MTCA cPAH TEQ approach, the individual cPAH CPFs were calculated by adjusting the benzo(a)pyrene CPF (1 $[mg/kg\text{-}day]^{-1}$) by the individual cPAH TEF. The cPAH-specific CPFs are included in Chart 2.

[5] Weighted average of female and male adult tribal members.

Chart 2
Model Toxics Control Act cPAH Toxicity Equivalency Factor and Adjusted Cancer Potency Factor

Chemical	CAS Number	TEF	CPF $(mg/kg\text{-}day)^{-1}$
Benz[a]anthracene	56-55-3	0.1	0.1
Benzo[a]pyrene	50-32-8	1	1
Benzo[b]fluoranthene	205-99-2	0.1	0.1
Benzo[k]fluoranthene	207-08-9	0.1	0.1
Chrysene	218-01-9	0.01	0.01
Dibenz[a,h]anthracene	53-70-3	0.1	0.1
Indeno[1,2,3-cd]pyrene	193-39-5	0.1	0.1

Notes:
CPF: Cancer potency factor
mg/kg-day: milligrams per kilogram per day
TEF: toxic equivalency factor

4.1.1.1.3 Biota-Sediment Accumulation Factors

The extent of aquatic biota non-polar chemical bioaccumulation from sediment is typically expressed using BSAF. BSAF is the ratio between the concentration of a nonpolar organic chemical in the total extractable lipids of an organism (normalized to the lipid fraction), to the concentration in sediment normalized to the organic carbon content of sediment.

The BSAF that were used to model clam, crab, and bottomfish tissue concentrations were developed using BSAF data from the following two sources:

- EPA Office of Research and Development (ORD) BSAF database of synoptic tissue and sediment data from a subset of national Superfund sites
- USACE Environmental Research Development Center (ERDC) BSAF database (USACE 2013) of literature-reported studies

Selection of records within these databases was based on the following guidelines:

- ERDC data must have variance estimate to be selected
- Basis must be known
- Conversion between wet or dry weight basis is assumed to be 80% tissue moisture or 60% sediment moisture content

The clam BSAF used for this analysis were derived from the clam and oyster species included in the databases, including hard clam (*Mercenaria mercenaria* and *Pitar morrhuana*), macoma clam (*Macoma nasuta*), venus clam (*Venerupis philippinarum*), asian clam (*Potamocorbula amurensis*), and eastern oyster (*Crossostrea virginica*). The brackish water clam (*Rangia cuneata*) BSAF were excluded due to potential data quality issues. An outlier evaluation was conducted using the distribution platform in JMP software. An outlier boxplot evaluation was conducted and outliers from both the high and low tails were identified. Outliers were removed from the dataset. The final dataset included 160 individual clam and oyster BSAF. The individual cPAH BSAF values were derived as the mean value from all clam and oyster species. Each final cPAH BSAF was based on the mean of a minimum of 11 individual values. Sufficient individual BSAF values for benzo(b)fluoranthene and benzo(k)fluoranthene were not available in the ORD or ERDC databases, so the evaluation of these BSAF values were selected on the basis of the organic carbon-water partitioning coefficient (Koc) values reported by EPA (2003). The cPAH compound with the closest matching Koc for benzo(b)fluoranthene and benzo(k)fluoranthene was benzo(a)pyrene. Therefore, the BSAF for these compounds were set equal to the BSAF for benzo(a)pyrene. The Koc and literature-derived BSAF are provided in Table B-2b.

The databases did not include whole-body BSAF for bottomfish species inhabiting Bellingham Bay. As an alternative, whole-body BSAF for other demersal fish were used, including brown bullhead (*Ictalurus nebulosus*), channel catfish (*Ictalurus punctatus*), common carp (*Cyprinus carpio*), and white sucker (*Catostomus commersoni*). An outlier evaluation was conducted using the distribution platform in JMP software. An outlier boxplot evaluation was conducted and outliers from both the high and low tails were identified. Outliers were removed from the dataset. The final dataset included 80 individual BSAF for cPAH. The individual cPAH chemical-specific BSAF values were derived as the mean value from all bottomfish specifies. Each final chemical BSAF was based on the mean of a minimum of 10 individual bottomfish values.

No Pacific crab species BSAF data were available from the databases. Limited (one to six BSAF per chemical) BSAF are available for other crustacean species, including crayfish and fiddler crab. Due to limited available data and potential data quality issues, these BSAF were not used. The individual cPAH BSAF developed for bottomfish were used as a surrogate. Similar to bottomfish, crabs have enzymes capable of metabolizing PAH; however, they metabolize PAH less efficiently than bottomfish (Stegeman and Lech 1991). A safety factor of 5 was applied to the bottomfish BSAF to account for this uncertainty.

4.1.1.1.4 Seafood Lipid Content

Lipid data for marine/estuarine mollusks, bottom feeding fish, and crab were obtained from the tissue lipid summary provided by the USACE Waterway Experiment Station (WES) BSAF database. The WES database summarizes lipid data for different species groups (e.g., bottom feeding fish, marine crustaceans, and marine mollusks). The lipid data selected were based on average whole-body wet weight measurements that were reviewed for data quality and designated as useable by WES. The average percent lipid content for marine/estuarine mollusks, marine crustaceans, and bottom feeding fish were 1.42, 2.45, and 3.84, respectively. These values were used for modeling clam, crab, and bottomfish tissue cPAH concentrations using Equation 1.4.

4.1.1.1.5 Sediment Fraction Organic Carbon

The sediment fraction organic carbon used was the mean of Site surface samples with the exception of sample IJ12-11, which was located outside of the Site. The Site mean was calculated after first averaging the parent and field duplicate samples. The Site mean fraction organic carbon was 0.028 g/g.

4.1.2 Incidental Ingestion and Dermal Contact Risk Levels

For the incidental ingestion and dermal contact pathways, Equations 2 and 3 (Ecology 2017) were used to calculate the carcinogenic and non-carcinogenic sediment RBCs, respectively. The preliminary ELS-based RBC was calculated in a manner similar to that for fish ingestion, by calculating the dose and RBC separately for the different age cohorts (see Chart 1). The direct contact RBC was calculated by dividing the age-specific unadjusted RBC by the appropriate ADAF and taking the harmonic mean of the age groups in the scenario. For example, the adult clamming ELS adjusted RBC is the harmonic mean of the ADAF-adjusted RBC for each the four age cohorts (Chart 1).

Equation 2

$$RBC_{cancer} = \left(\frac{CR \times BW \times AT_{cr}}{EF \times ED \times \left[\left(\frac{IR \times AB \times CPFo}{UCF} \right) + \left(\frac{SA \times AF \times ABS \times CPFd}{UCF} \right) \right]} \right)$$

where:

AB	=	Gastrointestinal absorption fraction (unitless)
ABS	=	Dermal absorption fraction (unitless)
AF	=	Sediment to skin adherence factor (mg/kg^2-day)
AT_{cr}	=	Cancer averaging time (days)
BW	=	Body weight (kg)
CPFo	=	Oral cancer potency factor (mg/kg-day^{-1})
CPFd	=	Dermal cancer potency factor (mg/kg-day^{-1})
CR	=	Cancer risk (unitless)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
IR	=	Ingestion rate (mg/day)
RBC_{cancer}	=	Risk-based concentration for carcinogenic mechanism of toxicity (mg/kg)
SA	=	Dermal surface area (square centimeter [cm^2])
UCF	=	Conversion factor (1,000,000 mg/kg)

Equation 3

$$RBC_{Noncancer} = \left(\frac{HQ \times BW \times AT_{nc}}{EF \times ED \times \left[\left(\left(\frac{1}{RfDo} \right) \times \left(\frac{IR \times AB}{UCF} \right) \right) + \left(\left(\frac{1}{RfDd} \right) \times \left(\frac{SA \times AF \times ABS}{UCF} \right) \right) \right]} \right)$$

where:

AB	=	Gastrointestinal absorption fraction (unitless)
ABS	=	Dermal absorption fraction (unitless)
AF	=	Sediment to skin adherence factor (mg/kg^2-day)
AT_{nc}	=	Noncancer averaging time (days)
BW	=	Body weight (kg)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
HQ	=	Hazard Quotient (1 unitless)
IR	=	Ingestion rate (mg/day)
$RBC_{noncancer}$	=	Risk-based concentration for non-carcinogenic mechanism of toxicity (mg/kg)
RfDd	=	Dermal reference dose (mg/kg-day)
RfDo	=	Oral reference dose (mg/kg-day)
SA	=	Dermal surface area (cm^2)
UCF	=	Conversion factor (1,000,000 mg/kg)

Values for each of the listed parameters are presented in Table B-3. The benzo(a)pyrene and 2,3,7,8-tetrachlorodibenzodioxin (TCDD) CPFs were used to calculate the direct contact and incidental ingestion RBCs for cPAH TEQ and total dioxin/furan TEQ, respectively. The RBCs are presented in Table B-4.

4.1.2.1 Site-specific Parameters

The Site-specific parameter used in the incidental ingestion and dermal contact risk equations is described below. The Ecology default values were used for the other parameters. All parameters used are included in Table B-3.

4.1.2.1.1 Clamming Exposure Frequency

Section 4.1.1.1.1 above describes the Site habitat limitations prohibiting a clam diet fraction equivalent to the Ecology default value of 1. For the seafood consumption exposure pathway, it was estimated that the I&J Waterway beach could potentially support approximately 0.1 of the clam diet fraction (28.4 g/day, 365 days/year). For the dermal contact and incidental ingestion adult clamming scenario, this assumption was converted to terms of days per year (i.e., the Site could support a clam diet fraction of 1, 36.5 days of the year). This value was conservatively adjusted by two with the assumption that an adult clammer could potentially collect half of their daily take on any given day. A Site-specific exposure frequency of 74 days/year was used for the clamming exposure pathway.

4.2 PQL

SMS allows consideration of the PQL in establishing the SCLs when a COC concentration determined to be protective cannot be reliably detected using state-of-the-art currently available analytical instruments and methods (WAC 173-204-505(15)). In simpler terms, the PQL is the minimum concentration for an analyte that can be reported with a high degree of certainty. If natural background or the risk-based SCO is below the concentration at which a contaminant can be reliably quantified, then the SCO for that contaminant may default to the analytical PQL. MTCA defines the PQL as the following:

> *…the lowest concentration that can be reliably measured within specified limits of precision, accuracy, representativeness, completeness, and comparability during routine laboratory operating conditions, using department approved methods (WAC 173-340-200).*

Table B-4 includes the specific PQLs. These PQLs are based on specific reporting limits at the I&J Waterway Site and recommended PQLs in the SCUM II guidance (Ecology 2017).

4.3 Natural Background

Natural background values were adopted from the SCUM II Table 11-1 (Ecology 2017). These natural background concentrations were derived as the 90/90 upper tolerance limit (UTL) of the Dredged Material Management Program (DMMP) OSV Bold Survey data (DMMP 2009) and additional datasets selected by Ecology (collectively referred to as the "BOLD Plus" dataset; Ecology 2017). The natural background total cPAH TEQ concentration is 16 μg TEQ/kg, as shown in Table B-4.

5 CSL Development

For a given chemical, the CSL is based on the highest of the following:

- The lowest appropriate RBCs for protection of human health corresponding to a 1×10^{-5} ELCR threshold and/or a HQ of 1, benthic organisms (WAC 173-204-562 for CSL), or ecological receptors
- Regional background
- PQLs

5.1 Risk-based Levels

The methods for developing human health CSL RBC were similar to methods used to calculate SCO RBCs as described in Section 4, with the exception that a target cancer risk of $1x10^{-5}$ is used for carcinogenic chemicals instead of $1x10^{-6}$. A HQ of 1 is used for development of both the SCO and CSL RBC, and the RBCs for non-carcinogens will therefore be the same for the SCO and CSL. The CSL RBCs are included in Table B-4.

5.2 PQL

The PQLs are described in Section 4.3. The PQLs are the same for the development of both the SCO and CSL.

5.3 Regional Background

Ecology recognizes that natural and man-made hazardous substance concentrations can occur at a site in excess of natural background concentrations but are not the result of controllable local Site-related releases. The SMS defines the term "regional background" as concentrations that are consistently present in the environment in the vicinity of a site that are attributable to "diffuse nonpoint sources, such as atmospheric deposition or storm water, not attributable to a specific source or release." SMS allows upward adjustment of cleanup levels to regional background.

Since completion of the RI/FS, Ecology collected sediment data and calculated a regional background concentration of cPAHs in Bellingham Bay (Ecology 2015) using the 90/90 upper threshold limit (UTL). The regional background total cPAH TEQ concentration is 86 µg TEQ/kg, as shown in Table B-4.

6 Summary

The human health RBCs derived following methods described in this appendix, natural and regional background values, and PQLs are included in Table B-4. These values are referenced in Section 2 of the draft CAP in the screening of Site sediments and determination of Site COCs and in Section 3 of the draft CAP in the development of cleanup standards.

7 References

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Tables

Table B-1

Human and Wildlife Target Tissue Levels (mg/kg wet weight)

	SCUM II[c]		Sediment Evaluation Framework for the Pacific Northwest [d]			Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment[e]				
Bioaccumulative Chemical	**Aquatic-dependent Wildlife**	**Human**	**Nearshore ESA Aquatic-dependent Wildlife**	**Nearshore Population Aquatic-dependent Wildlife**	**Human Health[a]**	**Bird Individuals**	**Bird Populations**	**Mammals Individuals**	**Mammal Population**	**Human Health[b]**
Metals										
Arsenic	2.7	0.000115	2.7	14	0.00008	13	64	7.6	38	0.00076
Cadmium		0.162				8.4	42	5.6	28	0.49
Chromium										
Copper										
Lead	2		2	10		9.3	46	34	170	0.5
Mercury	0.02		0.02	0.03	0.012	0.074	0.15	0.12	0.2	0.049
Nickel										
Silver										
Zinc										
PAH										
2-Methylnaphthalene										
Acenaphthene										
Acenaphthylene										
Anthracene										
Benz(a)anthracene										
Benzo(a)pyrene										
Benzo(g,h,i)perylene										
Benzo[b]fluoranthene										
Benzo[k]fluoranthene										
Benzofluoranthenes (total)										
Chrysene										
Dibenzo(a,h)anthracene										
Fluoranthene	3.8	0.00433	3.8	19	4.8			190	950	20
Fluorene	410	0.00433	410	2,000	4.8					
Indeno(1,2,3-cd)pyrene										
Naphthalene										
Phenanthrene										
Pyrene	3.8	0.00577	3.8	19	3.6			9,500	47,000	15
cPAH TEQ		2.37E-05								
PCB										
Total Aroclors	0.04	8.65E-05	0.04	0.18	0.00006	1.1	3.4	0.88	1.7	0.00057
Phenols										
Pentachlorophenol	8.1	0.00577	8.1	41	0.001			0.18	1.8	0.0096
Dioxin/furans										
Dioxin/furan TEQ	5.00E-07	1.15E-09	5.00E-07	8.50E-06	9.20E-10	8.00E-06	4.00E-05	5.80E-07	1.60E-05	7.60E-09

Notes:

a. TTL3 protective of high-end tribal consumption

b. Lower of carcinogen or non-carcinogen Subsistance Tribal

c. Ecology 2013b

d. RSET 2009

e. ODEQ 2007

ESA: Endangered Species Act

cPAH: carcinogenic polycyclic aromatic hydrocarbon

PAH: polycyclic aromatic hydrocarbon

PCB: polychlorinated biphenyls

SCUM II: Sediment Cleanup Users Manual II

TEQ: toxic equivalents quotient

Table B-2a
Seafood Consumption RBC Equation Parameters

Parameter Abbreviation	Parameter Name	Value	Units	Source
$AT_{C(FC)}$	Averaging Time Carcinogen (fish consumption)	27,375	days	Ecology 2013b default
BSAF	Biota-Sediment Accumulation Factor	See Table B-2b	g-OC/g-lipid	ORD and ERDC databases (see Section 4.1.1.1.3)
$BW_{Adult-FC}$	Body Weight Adult (fish consumption)	81.8	kg	Weighted average (male and female) Tulalip adult body weight (Toy et al. 1996)
CPFo	Cancer Potency Factor (oral)	See Table B-2b	$mg/kg\text{-}day^{-1}$	CLARC (see Section 4.1.1.1.2)
CR	Cancer Risk for Individual Carcinogens	1.00E-06	unitless	Ecology 2013b default
ED_{FC}	Exposure Duration Fish Consumption	70	years	Ecology 2013b default
EF_{FC}	Exposure Frequency Fish Consumption	365	days/year	Ecology 2013b default
$FCR_{(clam)}$	Fish/Shellfish Consumption Rate (clam)	45	grams/day	Whatcom Waterway RI (Hart Crowser 2000) consumption rate adjusted for an 81.8 kg adult
$FCR_{(crab)}$	Fish/Shellfish Consumption Rate (crab)	27.3	grams/day	Whatcom Waterway RI (Hart Crowser 2000) consumption rate adjusted for an 81.8 kg adult
$FCR_{(fish)}$	Fish/Shellfish Consumption Rate (fish)	9.1	grams/day	Whatcom Waterway RI (Hart Crowser 2000) consumption rate adjusted for an 81.8 kg adult
$FDF_{(clam)}$	Fish/Shellfish Diet Fraction (clam)	0.1	proportion	Site specific - limited intertidal clam habitat (see Section 4.1.1.1.1)
$FDF_{(crab)}$	Fish/Shellfish Diet Fraction (crab)	1	proportion	Ecology 2013b default
$FDF_{(fish)}$	Fish/Shellfish Diet Fraction (fish)	1	proportion	Ecology 2013b default
$SUF_{(clam)}$	Site Use Factor (clam)	1	proportion	SCUM II Table 9-1 (Ecology policy, may be adjsuted based on site-specific data)
$SUF_{(crab)}$	Site Use Factor (crab)	0.01	proportion	Site specific. Based on the Site Area (0.016 km^2). Rounded up to 0.01 proportion of 10 km^2 home range.
$SUF_{(fish)}$	Site Use Factor (fish)	0.01	proportion	Site specific. Based on the Site Area (0.016 km^2). Rounded up to 0.01 proportion of 10 km^2 home range.
Sfoc	Fraction of Organic Carbon in Sediment	0.028	gram/gram	Average of site surface samples (excluding IJ12-11). Field Duplicates averaged before calculating site average

Table B-2a
Seafood Consumption RBC Equation Parameters

Parameter Abbreviation	Parameter Name	Value	Units	Source
$SL_{(clam)}$	Fish/Shellfish Lipid Fraction (clam)	0.01419	gram/gram	WES (see Section 4.1.1.1.4)
$SL_{(crab)}$	Fish/Shellfish Lipid Fraction (crab)	0.02447	gram/gram	WES (see Section 4.1.1.1.4)
$SL_{(fish)}$	Fish/Shellfish Lipid Fraction (fish)	0.0384	gram/gram	WES (see Section 4.1.1.1.4)
$UCF_{(CDI\text{-}calculation)}$	Unit Conversion Factor	0.001	kg/gram	

Notes:

CLARC: Cleanup Levels and Risk Calculations

ERDC: USACE Environmental Research Development Center

g: gram

kg: kilogram

kg/g: kilogram per gram

km^2: square kilometer

mg/kg: milligram per kilogram

OC: organic carbon

ORD: EPA Office of Research and Development

RBC: risk-based concentration

RI: Remedial Investigation

SCUM II: Sediment Cleanup Users Manual II

WES: Waterway Experiment Station

Table B-2b
Seafood Consumption cPAH RBC Chemical-specific Parameters

Chemical	CAS number	TEF	CPF (mg/kg-day)$^{-1}$	Log10 Koc[a]	Clam BSAF (g-OC/g lipid)	Crab BSAF (g-OC/g lipid)	Bottomfish BSAF (g-OC/g lipid)	Average I&J Waterway Surface Sediment (Csed) (mg/kg)
Benz(a)anthracene	56-55-3	0.1	0.1	5.577	0.1727	0.0061	0.0012	0.421
Benzo(a)pyrene	50-32-8	1	1	6.003	0.0771	0.0048	0.0010	0.289
Benzo(b)fluoranthene	205-99-2	0.1	0.1	6.16	0.0771	0.0061	0.0012	0.428
Benzo(k)fluoranthene	207-08-9	0.1	0.1	6.184	0.0771	0.0056	0.0011	0.383
Chrysene	218-01-9	0.01	0.01	5.616	0.2651	0.0075	0.0015	0.735
Dibenz(a,h)anthracene	53-70-3	0.1	0.1	6.599	0.0297	0.0065	0.0013	0.065
Indeno(1,2,3-cd)pyrene	193-39-5	0.1	0.1	6.608	0.0421	0.0055	0.0011	0.116

Notes:

a. EPA (2003; Table 3-4). Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: PAH Mixtures. EPA-600-R-02-013.

BSAF: biota-sediment accumulation factors

cPAH: carcinogenic polycyclic aromatic hydrocarbon

CPF: cancer potency factor

g: gram

Koc: organic carbon - water partitioning coefficient

mg/kg: milligram per kilogram

OC: organic carbon

RBC: risk-based concentration

TEF: toxic equivalency factor

Table B-3
Direct Contact RBC Equation Parameters

Parameter Abbreviation	Parameter Name	Value	Units	Source
AB	Gastrointestinal Absorption Fraction (soil)	1 0.6 for mixtures of dioxins/furans	unitless	Ecology 2013b defaults (WAC 173-340-735 ((Equation 745-5))
ABS	Dermal Absorption Fraction	0.01 for inorganic hazardous substances 0.03 for dioxins/furans 0.1 for other organic hazardous substances	unitless	Ecology 2013b defaults (WAC 173-340-735 ((Equation 745-5))
AF_{Child}	Sediment to Skin Adherence Factor Child	0.2	mg/cm^2-day	Ecology 2013b default
$AF_{Adult\ (CD)}$	Sediment to Skin Adherence Factor Adult Clam Digging	0.6	mg/cm^2-day	Ecology 2013b default
$AT_{C(Inc+Derm)}$	Averaging Time Cancer (incidental ingestion and dermal contact) Child or Adult	27,375	days	Ecology 2013b default
$AT_{NC(Inc+Derm)\ Adult(CD)}$	Averaging Time Non-cancer (incidental ingestion and dermal contact) Adult Clam Digging	25,550	days	Based on a 70-year exposure duration
$AT_{NC(Inc+Derm)\ Child}$	Averaging Time Non-cancer (incidental ingestion and dermal contact) Child	2,190	days	Ecology 2013b default
BW_{Child}	Body weight Child	16	kg	Ecology 2013b default
$BW_{Adult-CD}$	Body weight Adult (clam digging)	70	kg	Ecology 2013b default
CPFd	Cancer Potency Factor (dermal)	chemical specific	$mg/kg\text{-}day^{-1}$	Calculated (CPFo/GI)
CPFo	Cancer Potency Factor (oral)	chemical specific	$mg/kg\text{-}day^{-1}$	CLARC Database
CR	Cancer Risk for individual carcinogens	1.00E-06	unitless	Ecology 2013b default
$ED_{(Inc+Derm)Adult(CD)}$	Exposure Duration (incidental ingestion and dermal contact) Adult Clam Digging	70	years	Ecology 2013b default
$ED_{(Inc+Derm)Child}$	Exposure Duration (incidental ingestion and dermal contact) Child	6	years	Ecology 2013b default
$EF_{(Inc+Derm)Adult\ (CD)}$	Exposure Frequency (incidental ingestion and dermal contact) Adult Clam Digging	74	days/year	I&J Site-specific value based on limited clam habitat (see Section 4.1.2.1.1)
$EF_{(Inc+Derm)Child}$	Exposure Frequency (incidental ingestion and dermal contact) Child	41	days/year	Ecology 2013b default

Table B-3
Direct Contact RBC Equation Parameters

Parameter Abbreviation	Parameter Name	Value	Units	Source
GI	Gastrointestinal Absorption Fraction	0.2 for inorganic hazardous substances 0.8 for dioxins/furans 0.5 for other organic hazardous substances	unitless	Ecology 2013b defaults (WAC 173-340-745 (Equation 745-5))
HQ	Hazard Quotient	1	unitless	Ecology 2013b default
$IR_{Adult\ (CD)}$	Ingestion Rate (Sediment) Adult Clam Digging	100	mg/day	Ecology 2013b default
IR_{Child}	Ingestion Rate (Sediment) Child	200	mg/day	Ecology 2013b default
RfDd	Reference Dose (dermal)	chemical specific	mg/kg-day	Calculated (RfDo*GI)
RfDo	Reference Dose (oral)	chemical specific	mg/kg-day	CLARC Database[a]
SA_{Adult}	Dermal Surface Area Adult	3,160	cm^2	Ecology 2013b default
SA_{Child}	Dermal Surface Area Child	2,200	cm^2	Ecology 2013b default
$UCF_{(Inc+Derm)}$	Unit Conversion Factor (incidental ingestion and dermal contact)	1,000,000	mg/kg	Ecology 2013b default

Notes:

a. The dioxin/furan RfDo is from the EPA Integrated Risk Information System.
http://cfpub.epa.gov/ncea/iris/index.cfm?fuseaction=iris.showQuickView&substance_nmbr=1024

CLARC: Cleanup Levels and Risk Calculations

cm^2: square centimeter

kg: kilogram

mg/day: milligram per day

mg/cm^2-day: milligram per square centimeter per day

mg/kg-day: milligram per kilogram per day

WAC: Washington Administrative Code

Table B-4

Preliminary Human Health Risk-Based SCO and CSL

Analyte	CAS Number	Protection of Human Health								Natural Background[c] (mg/kg-dw)	Regional Background (Bellingham Bay) (mg/kg-dw)	Applicable PQL[a] (mg/kg-dw)
		Via Seafood Consumption (bioaccumulative chemicals)		Via Direct Contact								
				Clamming (Adult) (mg/kg-dw)			Beach Play (Child) (mg/kg-dw)					
		Carcinogenic		Carcinogenic		Non-carcinogenic	Carcinogenic		Non-carcinogenic			
		10-6, SCO_{HH}	10-5, SCO_{HH}	10-6, SCO_{HH}	10-5, SCO_{HH}	HQ=1, SCO_{HH} and CSL_{HH}	10-6, SCO_{HH}	10-5, SCO_{HH}	HQ=1, SCO_{HH} and CSL_{HH}	SCO_{NB}	CSL_{RB}	SCO_{PQL} and CSL_{PQL}
Carcinogenic Polycyclic Aromatic Hydrocarbons												
Benz(a)anthracene	56-55-3	--[b]	--[b]	--[b]	--[b]	--	--[b]	--[b]	--	--	--	0.433
Benzo(a)pyrene	50-32-8	--[b]	--[b]	--[b]	--[b]	--	--[b]	--[b]	--	--	--	0.533
Benzo(g,h,i)perylene	191-24-2	--[b]	--[b]	--[b]	--[b]	--	--[b]	--[b]	--	--	--	0.223
Benzo[b]fluoranthene	205-99-2	--[b]	--[b]	--[b]	--[b]	--	--[b]	--[b]	--	--	--	--
Benzo[k]fluoranthene	207-08-9	--[b]	--[b]	--[b]	--[b]	--	--[b]	--[b]	--	--	--	--
Benzofluoranthenes (total)		--[b]	--[b]	--[b]	--[b]	--	--	--	--	--	--	1.067
Chrysene	218-01-9	--[b]	--[b]	--[b]	--[b]	--	--[b]	--[b]	--	--	--	0.467
Dibenzo(a,h)anthracene	53-70-3	--[b]	--[b]	--[b]	--[b]	--	--[b]	--[b]	--	--	--	0.077
Indeno(1,2,3-cd)pyrene	193-39-5	--[b]	--[b]	--[b]	--[b]	--	--[b]	--[b]	--	--	--	0.2
cPAH TEQ (U=1/2)	cPAH TEQ	0.445	4.45	0.80	8.0	--	6.21	62.1	--	0.016	0.086	0.009
cPAH TEQ (U=1/2) with ELS adjustment	cPAH TEQ - ELS	0.229	2.29	0.45	4.5	--	1.16	11.6	--	0.016	0.086	0.009
Dioxins/Furans												
Total Dioxin/Furan TEQ (U=1/2)	1746-01-6	--	--	0.000019	0.00019	0.0018	0.000087	0.00087	0.00073	0.0000036	0.000015	0.000005

Notes:

Standard RBC

Preliminary ELS-based RBC

a. PQLs are based on specific reporting limits at the I&J Waterway Site and recommended PQLs in the SCUM II Guidance (Ecology 2017)

b. Evaluated as cPAH TEQ

c. Natural Background values are from SCUM II Table 11-1 (Ecology 2013b)

cPAH: carcinogenic polycyclic aromatic hydrocarbon

CSL: Cleanup Screening Level

mg/kg-dw: milligram per kilogram dry weight

PQL: practical quantitation limit

SCO: Sediment Cleanup Objective

TEQ: toxic equivalents quotient