United States
Environmental Protection
Agency

East Waterway Operable Unit
Harbor Island Superfund Site
Seattle, Washington
(WAD980722839)

Site Information Package for the National Remedy Review Board

Prepared for:
U.S. Environmental Protection Agency
Region 10

Prepared by:

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of Engineers®
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Acronym List

95UCL	95th percentile upper confidence limit
AC	activated carbon
API	Asian or Pacific Islander
ARAR	Applicable or Relevant and Appropriate Requirement
ASAOC	Administrative Settlement Agreement and Order on Consent
BEHP	bis(2-ethylhexyl) phthalate
bgs	below ground surface
BMP	best management practice
BSAF	biota-sediment accumulation factor
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act, as Amended by the Superfund Amendment and Reauthorization Act
CMA	construction management area
COC	contaminant of concern
COPC	contaminant of potential concern
cPAHs	carcinogenic polycyclic aromatic hydrocarbons
CSL	cleanup screening level
CSM	conceptual site model
CSO	combined sewer overflow
cy	cubic yards
DDT	dichlorodiphenyltrichloroethane
DMMP	Washington State Dredged Material Management Program
dw	dry weight
Ecology	Washington State Department of Ecology
ENR	enhanced natural recovery
EPA	United States Environmental Protection Agency
ERA	ecological risk assessment
ESA	Endangered Species Act
ESD	Explanation of Significant Difference
EW	East Waterway
EWG	East Waterway Group
FC	federal candidate species, under the Endangered Species Act
FCo	federal species of concern, under the Endangered Species Act
FE	federal endangered species, under the Endangered Species Act
FS	feasibility study
FT	federal threatened species, under the Endangered Species Act
FWM	food web model
HI	hazard index
HHRA	human health risk assessment
HPAH	high molecular weight PAH
HQ	hazard quotient

LDW	Lower Duwamish Waterway
LOAEL	lowest observed adverse effect level
LPAH	low molecular weight PAH
MIS	multi-increment sampling
MLLW	mean lower low water
MNR	monitored natural recovery
MTCA	Washington State Model Toxics Control Act
NOAA	National Oceanographic and Atmospheric Agency
NOAEL	no observed adverse effect level
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NTCRA	non-time critical removal action
oc	organic carbon (normalization method under SMS)
O&M	operation and maintenance
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PCBs	polychlorinated biphenyls
PQL	practical quantitation limit
PRG	preliminary remediation goal
PRP	potentially responsible party
PTM	particle tracking model
RAL	remedial action level
RAO	remedial action objective
RBTC	risk based threshold concentration
RCRA	Resource Conservation and Recovery Act
RMC	residuals management cover
RME	reasonable maximum exposure
ROD	Record of Decision
SC	state species of concern, for the State of Washington
SCL	sediment cleanup level
SCO	sediment cleanup objective
SD	storm drain
SHNIP	Seattle Harbor Navigation Improvement Project
SMS	Washington State Sediment Management Standards
SQS	Washington State Sediment Quality Standards
SRI	supplemental remedial investigation
SRZ	sediment recovery zone
SS	state sensitive species, for the State of Washington
STER	Sediment Transport and Evaluation Report
SVOC	semi-volatile organic compound
SWAC	surface-area weighted average concentration
T	terminal (e.g. Terminal 18, T-18)

TBT	tributyltin
TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
TEQ	toxic equivalents (for dioxin/furan as 2,3,7,8-TCDD equivalents; for cPAH as benzo[*a*]pyrene equivalents)
TI	technical impracticability
TIN	triangular irregular network
TRV	toxic reference value
TSS	total suspended solids
U&A	usual and accustomed
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
UCL	upper confidence limit
VOC	volatile organic compound
WAC	Washington Administrative Code
WQC	water quality criteria
WQS	water quality standards
WSDOH	Washington State Department of Health
WW	West Waterway
ww	wet weight

A. Summary

1 Site Summary

The East Waterway is an Operable Unit (OU) of the Harbor Island Superfund site and extends along the east side of Harbor Island from Elliott Bay to the southern tip of Harbor Island (Figure A-1). The site is 8,250 ft. long and 750 ft. wide and encompasses 157 acres.

Site Name: East Waterway
Site Location: Seattle, Washington
Site Account Number: TR2B 000DD2 10DGBD00
NPL Listing: Harbor Island Superfund Site
Date Listed: September 8th, 1983

The East Waterway (EW) is located approximately 1 mile south of downtown Seattle, at the confluence of the Duwamish River and Elliott Bay in Puget Sound, Washington (Figure A-2). The EW is part of the greater Green/Duwamish River estuary, which includes the freshwater/saltwater interface extending as far as 10 miles upstream, through the Lower Duwamish Waterway (LDW), from the mouth of the EW at Elliott Bay.

The southern EW boundary is also the northern boundary of the LDW Superfund site. The northern EW study boundary extends along the western pierhead line to the north until water depths reach -60 feet mean lower low water (MLLW). The study boundary follows the approximate upper edge of this naturally occurring slope at about -60 feet MLLW, then turns to perpendicularly intersect the bulkhead along Terminal 46 along the eastern shoreline. The east and west boundaries of the EW are defined as areas below mean higher high water (MHHW; e.g., below +11.4 feet MLLW).

The EW was created during the construction of Harbor Island in the early 1900s to serve developing industries and commerce in Seattle. Historical activities on the waterway have included marine terminals, shipyards, bulk fuel terminals, recycling and scrap metal yards, cement manufacturing, log handing, small boat marinas, boat manufacturing and repair, as well as many other activities. Today, the East Waterway is an active industrial waterway used primarily for container loading and transport. Land use, zoning, and land ownership along the waterway have been consistent with active industrial uses. The sides of the East Waterway contain hardened shorelines with extensive overwater structures, commercial and industrial facilities, and other development.

2 Risk Summary

Due to the historical activities around the waterway, human health and ecological risks from contaminated sediments in the EW persist at levels that warrant action under federal and state laws. Risks to people are highest from eating resident seafood. Lower, but still significant, health risks to people come from sediment contact while clamming and net-fishing. Benthic invertebrates and some resident fish species are also at risk. The primary contaminants of

concern (COCs) contributing to human health and ecological risk in the EW sediments include polychlorinated biphenyls (PCBs), arsenic, dioxins/furans, and carcinogenic polycyclic aromatic hydrocarbons (cPAHs).

2.1 Baseline Human Health Risk Assessment

A baseline human health risk assessment (HHRA) was conducted as part of the supplemental remedial investigation (Windward, 2012b). The HHRA estimated risks people could face from exposure to contaminants in EW sediments, surface water and seafood. Exposures were assumed to occur through consumption of resident seafood harvested from the EW; direct contact with sediment during netfishing, clamming, or habitat restoration; and direct contact with surface water while swimming.

Reasonable maximum exposure (RME) scenarios for seafood consumption were developed for adult and child tribal consumers and also for Asian and Pacific Islanders (API). Total excess cancer risks from RME seafood consumption scenarios are estimated to range from 4×10^{-4} to 1×10^{-3}, Table A-1. In addition, evaluation of non-cancer hazard quotients (HQs) indicate the potential for adverse effects other than cancer associated with seafood consumption. Total PCBs, dioxin/furans, and cPAHs were identified as risk drivers for human health risks.

Direct sediment contact scenarios evaluated in the HHRA included two netfishing scenarios, a habitat restoration worker scenario, and three clamming scenarios. Total excess cancer risks for RME netfishing and clamming scenarios ranged from 7×10^{-6} to 3×10^{-5}, Table A-2. Non-cancer HQs were less than one for all direct contact scenarios. Arsenic and cPAHs were identified as risk drivers.

2.2 Baseline Ecological Risk Assessment

A baseline ecological risk assessment (ERA) was conducted as part of the supplemental remedial investigation (Windward, 2012a). The ERA estimated risks for the benthic invertebrate community and for crab, fish and wildlife species. These receptors may be exposed to contaminants through contact with sediment, water, porewater, or through consumption of prey species found in the EW.

Risks to the benthic community were assessed by comparing surface sediment concentrations to the Washington State Sediment Management Standards (SMS), which are an applicable or relevant and appropriate requirement (ARAR) for the site. Approximately 39% of the site has the potential for minor adverse and 23% of the area is expected to have at least minor adverse effects to the benthic community. 28 SMS chemicals and tributyltin (TBT) were identified as ecological risk drivers, Table A-3.

Risks to crab and fish were below threshold values, with one exception. Risks associated with total PCBs were above the risk threshold for English sole and brown rockfish, and thus total PCBs were identified as an ecological risk driver. No contaminants were found to pose unacceptable risk to crabs, birds, or mammals.

3 Remedial Action Objectives, Remedial Action Levels

The remedial action objectives (RAOs) for the EW describe goals for the protection of human health and the environment. Preliminary remediation goals (PRGs) are the contaminant concentrations or risk levels associated with each RAO that are believed to be sufficient to protect human health and the environment. RAOs developed for the EW are for cleanup of contaminated sediment. Surface water is also a medium of concern, but no active remedial measures are anticipated solely for the water column. RAOs for the EW are as follows:

- **RAO 1:** Reduce risks associated with the consumption of contaminated resident EW fish and shellfish by adults and children with the highest potential exposure to protect human health;
- **RAO 2:** Reduce risks from direct contact (skin contact and incidental ingestion) to contaminated sediment during netfishing and clamming to protect human health;
- **RAO 3:** Reduce to protective levels, risks to benthic invertebrates from exposure to contaminated sediments; and,
- **RAO 4:** Reduce to protective levels, risks to crabs and fish from exposure to contaminated sediment, surface water, and prey.

PRGs were established for each RAO based on the highest of the risk-based threshold concentration (RBTC), background, or practical quantitation limit (PQL). The PRGs for the EW are presented in Table A-4. Remedial action levels (RALs) are contaminant-specific concentrations that trigger the need for remediation. RALs for the EW were designed to achieve the RAOs. Two sets of RALs for total PCBs were used in the development of remedial action alternatives (7.5 and 12 mg/kg organic carbon [OC]). Table A-5 presents a summary of the selected RALs, along with PRGs and RAOs for the site. Note that both the PRGs and RALs for PCBs and TBT are normalized to organic carbon.

4 Description of Alternatives

Ten remedial alternatives were developed and evaluated in the feasibility study (FS), including nine action alternatives and the no action alternative. The alternatives were developed by varying three components:

- The remedial technology assignments in the open-water areas that are generally accessible to barge-mounted construction equipment
- The remedial technology assignments in areas with limited access to construction equipment, such as under piers and low bridges
- The RALs for PCBs that result in variation of the remediation footprint

Table A-6 summarizes the ten alternatives and their technology assignments for each of the three components. All action alternatives rely heavily on removal because the current sediment

bed elevation within most the open-water areas is at the depth needed for navigation, eliminating options such as capping. A range of technologies were evaluated for the limited access areas (under piers and low bridges), which pose a significant technical challenge for cleanup. The range of technologies presented in the alternatives include monitored natural recovery (MNR), enhanced natural recovery (ENR), placement of in-situ treatment material and diver-assisted hydraulic dredging. Table A-7 shows the remediated area, removal volume, total estimated construction cost, and construction timeframe for all the alternatives. The alternatives are described in more detail is Section B-8.

5 Preferred Alternative

The U.S. Environmental Protection Agency (EPA) Region 10's preferred remedy for the EW is a hybrid of Alternatives 2B(12) and 3B(12) (Figure A-3). The 2B/3B(12) alternative provides a highly permanent remedy that is consistent with future uses of the open-water areas and provides treatment for areas that are not readily accessible for removal. The 2B/3B(12) hybrid achieves the RAOs at the completion of the construction timeframe of 10 years and the estimated cost of $290 million represents an intermediate cost, relative to the other active remedial alternatives (range: $256 million to $411 million).

Key elements of the Preferred Alternative are described below.

1. Main Channel Area: The Preferred Alternative relies primarily on dredging in the main channel area. Dredging removes the greatest mass of contaminants, is highly permanent, provides greater certainty in future remedy performance and is compatible with the current and future use of the waterway. In the limited areas where full dredging is infeasible, partial dredging and engineered caps is proposed. A 10-cm residual management cover layer will be applied following removal.
2. Sill Reach: For the shallow sill reach at the south end of the site, a 9-inch ENR sand/gravel layer is proposed because overwater structures present significant challenges to dredging and this area is not used for navigation.
3. Under-Pier Areas: In-situ treatment (most likely with activated carbon) will be used to address under-pier hot spots followed by the application of an ENR layer.

The Preferred Alternative addresses all areas with PCB concentrations greater than 12 mg/kg OC. Of the 157 acres in the EW, the preferred remedy assignments are as follows:

- **99 acres** for sediment removal from open-water areas
- **7 acres of partial removal and cap** where the depth of contamination makes full removal impractical
- **3 acres** of ENR placement in the Sill Reach
- **34 acres** of unremediated open water area
- **12 acres** of in-situ treatment in underpier areas

- **36 acres** of unremediated underpier area

The total dredging volume is estimated at 960,000 cubic yards of contaminated sediment would be removed and disposed of in an upland landfill. The total cost of the 2B/3B(12) alternative would be $290 million. The distribution of costs are as follows:

Preconstruction/Planning/Mobilization	10%
Sediment Removal	9%
Sediment Disposal	34%
Underpier In-situ/ENR/Sand Cover Layers	6%
Contingency and Taxes	35%
Post Construction/Long-term Monitoring	6%

Areas, volumes and costs will be modified in the design phase based on additional sampling and verification of the natural recovery model. Alternative 2B/3B(12) also includes long-term monitoring, and institutional controls to further reduce exposures, including waterway/land use restrictions as needed to protect caps and ENR areas, and fish consumption advisories. EPA will require monitoring and bets management practices (BMPs) to manage dredge and other construction-related releases, and will evaluate performance data and make necessary adjustments.

The preferred alternative employs the most reliable remedial technology (removal) for all open water areas and results in lower residual risk than for alternatives employing ENR and capping. With removal, there is also a reduced potential for resuspension due to vessel scour and the remedy is compatible with future uses of the waterway (e.g. channel deepening). Alternatives that rely on ENR or capping are considered less reliable over the long-term and may be inconsistent with maintaining or deepening the navigational channels.

6 Stakeholder views

State – Washington State Department of Ecology (Ecology) has been actively involved in the interpretation and application of state SMS regulation, as well as coordinating cleanup activities in adjacent properties. The State is also the lead agency for source control for upstream sources (Green River and Duwamish River).

Tribes – The EW is within the usual and accustomed (U&A) fishing area for the Muckleshoot Indian Tribe and the Suquamish Tribe. Both tribes operate commercial and ceremonial fin-fish and shellfish fisheries in the waterway. The Tribes have been consulted throughout the process. Estimates of human health risk have been based on tribal subsistence fish consumption and net-fishing exposures scenarios. The Tribes support the cleanup provided is consistent with the continued support of the tribal fisheries.

Local Government – King County, City of Seattle and Port of Seattle comprise the East Waterway Group (EWG) and have been conducted the supplemental remedial investigation (SRI) and FS. The EWG will continue to be involved with the project and will conduct the pre-design sampling and analysis.

Industry – The Port of Seattle is the primary land owner in the areas adjacent to the EW. There is general support for the project among the businesses and users of the waterway. The potential for waterway use restrictions are likely to the biggest concern, including the potential economic impacts during construction.

US Fish and Wildlife Service – the Site provides habitat for fish species that are protected under the Endangered Species Act (ESA).

B. Detailed Information

1 Site Name, Location, and Brief Description

1.1 Site Summary

The East Waterway is located at the confluence of the Duwamish River and Elliott Bay in Puget Sound, Seattle, Washington (Figure B-1). The EW is one of seven OUs of the Harbor Island Superfund Site and extends along the east side of Harbor Island from Elliott Bay to the southern tip of Harbor Island. The EW OU is 8,250 feet long and approximately 750 feet wide and encompasses 157 acres.

The Green/Duwamish River drains approximately 362,000 acres of the Green/Duwamish watershed, flowing northward to its terminus in Puget Sound at Elliott Bay. In the early 1900s the last six miles of the river were straightened and channelized into a commercial waterway. The LDW comprises the upper 4.5 miles from the turning basin to the south end of Harbor Island, a man-made island constructed as part of the LDW channelization (Figure B-2). At Harbor Island, the Duwamish River splits into the EW and the West Waterway (WW). The EW and WW extend from the southern end of Harbor Island to the island's northern end at Elliott Bay. The EW runs along the eastern shore of Harbor Island.

The EW is one of seven operable units of the Harbor Island Superfund site (Figure B-3). The EW is located immediately downstream from, and adjacent to, the LDW Superfund site. The southern EW study boundary is located at the southern end of Harbor Island and is also the northern study area boundary of the LDW Superfund site. The northern EW study boundary extends along the western shoreline to the north until water depths reach -60 feet MLLW in Elliott Bay. The east and west boundaries of the EW are defined as areas below mean higher high water, which is equivalent to +11.4 feet MLLW. The EW is approximately 8,250 feet long and for most of its length is 750 feet wide. It is channelized and has a south-to-north orientation.

For the purposes of the SRI/FS, the EW was divided into four main reaches: the Deep Main Body Reach, the Shallow Main Body Reach, the Sill Reach, and the Junction Reach (Figure B-4). The waterway also contains a federal navigation channel for much of its length. Within the Deep Main Body, the federal navigation channel is authorized to a depth of -51 ft MLLW along the northern and western portion of the waterway. Within the Shallow Main Body Reach, the navigation channel is authorized to a depth of -34 ft MLLW along the middle portion of the waterway (Figures B-5 and B-6). The shallow Sill Reach is located underneath several bridges and mudline elevations are between -13 and -6 feet MLLW. The Junction Reach define the southern boundary of the site and includes mudline elevations near -25 feet MLLW. EW

includes two slips along the eastern side, Slips 27 and 36 (Figure B-4). A shallow area exists adjacent to Slip 27, and is referred to as the "Mound Area".

Outside of the navigation channel, sloped subtidal embankments have been created by the navigation channel deepening, with the shoreline dominated by bulkheads, rip-rap, and piers. Throughout the entire length of the EW, approximately 60% of the shoreline contains over-water piers (aprons) above riprapped slopes (Figure B-7). Another 30% contains exposed shoreline, nearly all of which is armored with riprap. The remaining 10% is comprised of steel sheetpile bulkheads. There are unarmored intertidal areas in portions of the eastern shoreline near the Spokane Street Bridge (Figure B-8). Four bridge structures transect the EW at the southern end of the site in the Spokane Street Bridge corridor. A communication cable crosses the EW between Terminal 18 (T-18) and the northern portion of Terminal 30 (T-30) (Figure B-4). This cable was originally buried between -61 and -66 feet MLLW in 1972 in an armored trench. Mudline elevations in the footprint of the cable crossing range from -53 to -59 feet MLLW.

The EW is an active industrial waterway used primarily for commercial vessel traffic, container loading at marine terminals, and, to a lesser extent, recreational watercraft. Vessels include deep-draft container ships, tugs, as well as smaller commercial vessels. While the EW supports considerable commercial navigation, it is also part of the Muckleshoot Indian Tribe's and Suquamish Tribe's U&A fishing area. The U&A area provides these Tribes with treaty protected uses including a commercial fishery for salmon as well as ceremonial and subsistence shellfish harvest. Within the EW there are limited recreational activities that include boating, kayaking, fishing, and beach play. There is one public park, Jack Perry Memorial Park and a public fishing pier in the southern portion of the waterway (Figure B-8). The EW, which connects Puget Sound to the Green River, is also an important migratory pathway for salmon and provides habitat for rockfish and other marine fish and small mammals.

The U.S. Army Corps of Engineers has established a measurement system along the length of the western berth face, comprised of "stationing" or "station markers." The system is measured in feet from the northern end of Harbor Island (Station 0) to near the southern end of the EW (Station 7700) and is used by the Port to define the extents of the berths. The station markers are shown on Figure B-4 and are used as reference points within this document.

2 Site History and Enforcement Activities

The following section provides a brief summary of the site history and significant enforcement activities.

2.1 Site History

The East Waterway has been an active port and marine shipping terminal since it was created by dredging and filling activities at the mouth of the Duwamish River and Elliott Bay in the early 1900s. Channel dredging and filling from 1903 to 1905 created the EW, which provided fill material for construction of the upland areas to the west and east (Figure B-9a). By 1909, Harbor Island and the land east of the EW was created using dredge fill removed from the Duwamish River estuary or sluiced from Seattle regrade projects. At this time, the extent of Harbor Island was approximately 350 acres and included 5 to 15 feet of placed fill. Upstream of Harbor Island, the Duwamish River was straightened and deepened starting in 1913 to allow navigation of ocean-going vessels upriver of Elliott Bay (HistoryLink, 2001).

The EW was initially dredged to a minimum navigable depth of -30 to -40 ft MLLW and widened to 750 ft. Based on historical U.S. Army Corps of Engineers (USACE) maps, a turning basin was created along the southeastern edge of the EW between approximately Stations 5200 to 6100 (Figure B-9b,c). The turning basin was dredged from -30 to -40 ft MLLW to -54 ft MLLW in 1918 to correspond with the deeper elevations maintained in the Main Body Reach at that time. The turning basin was filled in 1972 and no longer exists (Figure B-9d). In addition to the turning basin, two slips were dredged along the eastern shore to -28 ft MLLW (currently Slip 27) and -30 ft MLLW (formerly Slip 30). Slip 30 was filled in 1981 and no longer exists (Figure B-9d).

In 1919, the EW, WW, and LDW were authorized as federal navigation channels by Congress (March 2, 1919). The EW was maintained at -40 ft MLLW along most of the 750-ft-wide portion in the mid-1920s. Slip 36 was constructed in 1927 and originally dredged to -35 ft MLLW. That same year, the Port of Seattle first converted areas to container use on portions of T-18 and along T-25. Additional areas were converted to container use in the 1980s, including areas along T-18 and T-30.

The federal navigation channel in the EW currently extends from Station 0 to the Spokane Street Bridge, which is approximately Station 6840. Major channel deepening and maintenance projects since 2000 are shown in Figure B-10 and summarized in Table B-1.

Activities at the waterway have included marine terminals, shipyards, bulk fuel terminals, recycling and scrap metal yards, cement manufacturing, log handing, small boat marinas, boat manufacturing and repair, and many others. The EW is an active industrial waterway used primarily for container loading and transport. Land use, zoning, and land ownership along the EW have been consistent with active industrial uses. The sides of the EW contain hardened shorelines with extensive overwater structures, commercial and industrial facilities, and other development. Thirty-nine outfalls discharge into the EW, including 36 storm drains (SDs), one combined sewer overflow (CSO), and two combined CSO/SDs. The two outfalls that are shared by separated storm drains and CSOs are the Hinds and Lander CSO/SDs. These CSO/SD outfalls

and the Hanford CSO outfall discharge along the eastern shoreline of the EW. The stormwater-only outfalls are located along both sides of the waterway.

2.2 Remedial Actions

Port of Seattle conducted a non-time critical removal action for highly contaminated sediments on the East Waterway that covered two dredge seasons from 2004-2006 (Figure B-10). The removal action, termed "Phase 1", was implemented under the authority of an Action Memorandum. The following actions were completed under the Action Memorandum:

- Dredging 180,000 cubic yards (cy) of contaminated sediment unsuitable for open-water disposal and 67,000 cy of sediment suitable for open-water disposal.
- De-watering sediments not suitable for open-water disposal at an upland staging area and disposing of the de-watered sediments at an upland landfill.

Following the Phase 1 removal, the remaining sediment did not meet the State of Washington Sediment Quality Standards (SQS). In order to protect benthic organisms from residual contamination, a six-inch layer of clean sand was placed over the dredged surface. An SRI/FS was then initiated for the entire East Waterway.

3 Scope and Role of Operable Unit or Response Actions

The EW is one of seven operable units in the Harbor Island Superfund Site. Since being placed on the EPA's National Priorities List (NPL) in 1983, remedial actions have been completed in each of the adjacent upland OUs. The EW remains as the final OU of the Harbor Island Superfund Site for which EPA has not made a cleanup decision. Region 10 is preparing the proposed plan to address contaminated sediments in the EW. The Region's goal is to implement remedies that are cost effective and protective in the long term while supporting reasonable future uses of the waterway, including subsistence fishing and commercial navigation. In open-water areas, this will require dredging throughout much of the waterway to ensure that future navigation is not impeded. In portions of the waterway where access is limited (underneath overwater structures, such as piers and low bridges) enhanced natural recovery and in-situ treatment of contaminated sediments is recommended.

In 2006, the Port of Seattle under the authority of EPA completed a non-time critical removal action (NTCRA), dredging 273,000 cy of contaminated sediment from a portion of the federally authorized navigation channel. In October 2006, the potentially responsible parties (PRPs) formed a group called the East Waterway Group (EWG), consisting of the City of Seattle, King County, and the Port of Seattle. The EWG signed an Administrative Settlement Agreement and Order on Consent (ASAOC) with EPA to conduct an SRI/FS for the EW (EPA, 2006) under the Comprehensive Environmental Response, Compensation, and Liability Act, as Amended by the Superfund Amendment and Reauthorization Act (CERCLA).

The SRI, completed in 2014 (Windward & Anchor QEA, 2014), indicated that contaminated sediments in the EW exceeded SMS and represent a significant human health and ecological risk. In particular, risks to subsistence fishers exposed to EW contaminants from the consumption of contaminated seafood and from direct contact with sediments during net-fishing exceed the EPA acceptable risk levels. This has resulted in fish advisories for subsistence fishing in the waterway. Ecological risks were found for the benthic community and fish.

The FS, completed in February 2018, identified nine cleanup alternatives with costs ranging from $950,000 to $411,000,000. EPA Region 10's preferred remedy is a combination of two alternatives identified in the FS that provides a highly permanent remedy that is consistent with future uses of the open-water areas and provides a treatment remedy for areas that are not readily accessible for removal.

EPA Region 10 is planning to release a proposed plan in summer 2018 followed by a Record of Decision (ROD) specific to the EW operable unit in 2019.

4 Site Characteristics

The EW is a channelized portion of the Duwamish River delta. It is located at the north end of the greater Duwamish Valley (Figure B-2), and rests in a north-south trending, glacially scoured trough bounded by glacial drift uplands deposited during repeated Pleistocene glaciations (approximately 15,000 years ago). The trough contains post-glacial alluvium up to 200 ft thick (Weston, 1993) and includes the waters of the Duwamish River, EW, and WW. The EW was formed during the construction of Harbor Island, with both the eastern and western shorelines constructed with fill material.

The EW is influenced by the freshwater flows from the Green/Duwamish River and the tidal conditions of Elliott Bay (Anchor and Windward, 2008a). The freshwater input from the Green/Duwamish River system flows over the saline waters from Elliott Bay, producing two layer flow in the EW of saltwater at the bottom and a thin surface layer of slightly lower salinity water (Figure B-11). These conditions influence the hydrodynamic and sediment transport processes in the waterway (Anchor QEA and CHE, 2012).

The mudline elevation of the EW varies from approximately -40 to -60 ft MLLW in the 750-foot-wide portion of the waterway (Figures B-5 and B-6). Mudline elevations increase to between -13 and -6 ft MLLW in the vicinity of Spokane Street Bridge and the West Seattle Bridge. The shallow water depths associated with this “sill” along the Spokane Street corridor form a physical barrier that generally causes a larger fraction of the total riverine flow to pass through the WW. The presence of the bridges along the Spokane Street corridor also prohibits any type of boat passage, except at low tide by small, shallow-draft boats (e.g., kayaks and skiffs). There are also two slips present along the eastern side of the EW; Slip 27 and Slip 36. Currently, berths are maintained along Terminals 18, 30, and 25 and in portions of Slips 27 and 36 (Figure B-3).

For the purposes of site management, three reaches have been identified in the EW, including the Junction Reach (Station 7200 to 7650), Sill Reach (Station 6800 to 7200), and Main Body Reach (Station 0 to 6800; Figure B-4). The Main Body Reach has been further subdivided into two sections: the Deep Main Body Reach (Station 0 to 4950) and the Shallow Main Body Reach (Station 4950 to 6800), which is located south of regular historical maintenance dredging activities. The Junction, Sill, Shallow Main Body, and Deep Main Body Reach are referred to throughout this document.

4.1.1 Geology and Sediment Characteristics

Three stratigraphic units were encountered in EW sediment cores and were identified primarily by density, color, sediment type, texture, and fill horizons (e.g., sand cover). Other information used to delineate these units included presence of anthropogenic or engineered materials, bathymetry, proximity to shoreline, and dredge events.

The three stratigraphic units in the EW are comprised of recent silts overlying alluvial, deltaic sediments. These, in turn, overlie deeper alluvial, deltaic deposits associated with early and pre-

industrial time periods. In some areas, dredging and site use have altered the depths at which these units outcrop compared to initial deposition. For example, the deeper alluvial, deltaic deposits outcrop at the surface in several cores collected from the Deep Main Body Reach.

The primary stratigraphic units are described in detail below, from top (i.e., mudline) to bottom of core.

- **Recent –** This upper unit consisted of recently deposited material dominated by unconsolidated organic silt and inorganic silt. The surface fraction of silt often contained fine sand and gravel. This material was characterized by higher moisture content, soft to medium stiff density, smooth and homogenous texture, and higher visible organic matter compared with the underlying materials. Shell fragments, decomposed wood, and anthropogenic materials were often present scattered vertically throughout the unit (rather than in distinct layers as is common in lower units). A hydrogen sulfide odor was common. The Recent unit was encountered between 0 and 10 ft below mudline.
- **Upper Alluvium/Transition –** This middle unit formed a transitional bed between Recent and Lower Alluvium units. The Upper Alluvium unit had characteristics that were often a mix of the units lying above and below it. It consisted of a mixture of silty sand and sandy silt matrices with a higher density and a higher percentage of sand compared with the Recent unit. Pockets of inorganic and organic silt, layers of decomposed wood, and shell fragments were often present. The Upper Alluvium unit was encountered between 0 and 9 ft below mudline.
- **Lower Alluvium/Native –** This basal unit was predominantly a sand matrix with laminated and stratified beds of slightly silty to silty sand, and silt. The sand matrix consisted of multicolored grains of red, beige, black, white, and gray. Layers of un-decomposed wood and shells were often present in the matrix. The Lower Alluvium sand unit typically graded to stiff, inorganic silt as depth increased. This unit was encountered between 0 and 13 ft below mudline.

In addition to the primary stratigraphic units, three veneers overlie the existing sediment stratigraphy in discrete locations. These veneers are described below.

- **Engineered Fill** – This layer was present in close proximity to the shoreline. The composition of Engineered Fill was dominated by light to dark gray, sub-rounded, gravelly sand and sandy gravel. Gravel and cobbles were up to 3 inches in diameter. Engineered Fill is found in areas with developmental activities associated with slope and keyway armoring.
- **Anthropogenic Fill** – This layer was also present in close proximity to the shoreline. The composition of Anthropogenic Fill is gray to black, sub-rounded gravelly sand to coarse gravel. Anthropogenic Fill is found in areas without development activities that occur on the slope.

- **Sand Cover –** The sand cover was placed between Stations 3000 to 4900 during the Phase 1 removal, which was completed in 2005 (Anchor and Windward, 2005). The extent of this boundary is shown in Figure B-10. Sand cover is present within the top 1 ft of cores collected from this area. The sand cover is primarily very fine to very coarse-grained brown sand that was distinctly different in appearance from other strata within the EW as a result of color and sorting.

Nearshore Structures and Underpier Areas

Most of the shoreline (61%) is covered by wharves with engineered riprap slopes, approximately 30% is covered with armored riprap with no wharf structures, and the remaining shoreline is predominantly characterized as bulkhead (Figure B-7). Areas under the piers downslope from the bulkheads are typically engineered riprap slopes to approximately -50 ft MLLW (with some areas to -40 ft MLLW). The pilings supporting the wharves along the underpier slope typically extend 25 ft below the riprap surface. The fender piles along the pierface typically extend to a depth of -76 ft MLLW (25 ft below mudline) (Figure B-12). The shoreline within Slip 27 and Slip 36 is predominantly armored riprap with extensive pier structures, although the southern shore of Slip 27 has an adjacent intertidal bench. A limited number of small intertidal beaches are present above the riprap slopes in locations along the eastern shoreline of the waterway, including the head of Slip 27.

Areas under piers, docks, and aprons are referred to collectively as "underpier areas". Underpier areas are in general depositional, with sediment accretion being dependent upon the substrate and the bank slope below the overwater structures (Figure B-13). The typical thickness of underpier sediments in the EW is approximately 2 feet based on probing data, which equates to approximately 53,000 cubic yards of underpier sediments. While underpier sediments represent a smaller volume of sediment compared to the channel areas, they have elevated concentrations of COCs and can be scoured and resuspended by propwash. In the sediment transport evaluation model, an estimated 25% of the total volume of underpier sediments was assumed to mix with the open-water areas every five years.

4.1.2 Hydrodynamic Processes and Sediment Transport

The physical conceptual site model (CSM) developed for the site includes site-specific empirical data and output from hydrodynamic, sediment deposition, and propeller wash (propwash) modeling as presented in the Sediment Transport Evaluation Report (STER; Anchor QEA and CHE, 2012) and summarized in the SRI (Windward and Anchor QEA, 2014). Empirical data collected as part of this work includes tidal elevations from Elliott Bay and the EW, flow data from the Green/Duwamish River velocity and salinity profile measurements south and north of the Spokane Street Corridor and within the main body of the EW, sedimentation data from the EW, and in-situ measurements of critical shear stress in the EW. Model output included predictions of current velocities, salinities, and suspended solids for average and high-flow events within the EW (hydrodynamic model), predictions of annual average initial deposition

patterns from lateral sources within the EW (particle tracking model [PTM]), and near-bottom current velocities due to vessel operations (from propwash) within the EW.

Hydrodynamic circulation in the EW is controlled by tidal exchange with Elliott Bay from the north and freshwater inflow from the Green/Duwamish River from the south. SD and CSO inflows from the directly contributing drainage basins have a negligible influence on large-scale circulation in the EW. Water circulation within the EW can be generally described as two-layer flow. Marine waters extend upstream from Elliot Bay, through the EW and into the LDW. A thin layer of fresher surface water flows from the Green/Duwamish River system (Figure B-11). While the depth of the salinity gradient can vary with surface flow volumes, the majority of the water column remains saline even under the 100-year flow conditions (as predicted by the hydrodynamic model).

In general, as riverine inflow increases, predicted surface velocities within the EW increase; however, near-bed velocities remain relatively constant over the range of river flows. Average near-bed flow is 5 cm/s with maximum near-bed velocities ranging from 18 to 28 cm/s during high river flow. Surface velocities are more variable, with average surface velocities ranging from 20 to 25 cm/s and maximum surface velocities ranging from 90 to 95 cm/s (2- to 100-year flows, respectively).

Flow from the LDW is split by Harbor Island into the EW and WW. During normal flow events (annual average) flow is divided equally between the two waterways. However, during flow events of 2-year or greater, only 30% of the flow moves through the EW. This is in part due to constrictions (both width and depth) at the Junction and Sill reaches (Anchor QEA and CHE, 2012).

Figure B-14 presents a graphical summary of the sediment transport processes within the EW. Sediment sources to the EW include the upstream sources (Green River, LDW bed and bank sediments, and LDW lateral load sediments), downstream sources (Elliott Bay), and local sources (lateral sources that drain directly to the EW). Based on sediment transport models and geochronology cores, the EW is generally considered to be net depositional, with an average net sedimentation rate of 0.5 cm/yr. The majority of the Shallow Main Body Reach (between Stations 5000 and 6800) and the interior of Slip 27 are considered to be net depositional with deposition rates ranging from 0.2 to greater than 2.0 cm/yr (Table B-2). The Deep Main Body Reach (Stations 0 to 5000), including the mouth of Slip 36, appears to be net depositional; however, net deposition is near zero in selected areas that are influenced by propwash scour. In the Sill and Junction Reaches, geochronology cores were not retrieved due to consolidated sand and gravel surface sediments. This result indicates that the Sill and Junction Reaches may not be net depositional.

Results of the LDW sediment transport modeling (QEA, 2008) and the PTM of EW lateral loads suggest that 99% of the sediment load entering the EW originates in the Green River, approximately 0.7% is from the LDW (bed sediments and lateral loads), and less than 0.3% is from lateral loads within the EW itself (Anchor QEA and CHE, 2012). Contributions of sediment from Elliot Bay are negligible. Comparisons of sediment input/output and geochronology cores

indicate that approximately 25% to 60% of the incoming sediment load deposits in the EW, with 40% to 75% of the incoming load predicted to leave the EW. Initial mass deposition patterns within the EW from local lateral sources (evaluated through PTM) show the majority of initial deposition occurs close to the outfall locations (Figure B-15), with net deposition rates of less than 0.2 cm/yr. Nearly 100% of sediment from the Green River and LDW (bed sediments and lateral loads) consist of silts and clays.

Riverine and tidal currents in the EW are not expected to cause significant erosion of bedded sediments. Based on the STER (Anchor QEA and CHE, 2012), the maximum predicted bed shear stress during a 100-year high-flow event was modeled to be less than the mean critical shear stress of the bed sediments (estimated from site-specific SEDflume data). However, erosional forces associated with propwash were predicted to exceed the critical sheer stress of bedded sediments in portions of the Deep Main Body Reach (north of Station 4200). Consequently, these areas are likely subject to episodic and localized erosion and re-suspension of bed sediments due to propwash. The remainder of the Deep Main Body Reach (between Stations 4200 and 4900), the Shallow Main Body Reach, and the Junction Reach are also subject to impacts from vessel operations; however, the vessels that operate in these areas are smaller in size and operate less frequently than in the Deep Main Body Reach (north of Station 4200). Therefore, these areas may be subject to occasional erosion or re-suspension of surface sediments due to propwash.

4.1.3 Land Use Setting

The EW is an active port, serving as one of Seattle's primary deep-water terminals. Current land use, zoning requirements, and land ownership within most of this waterway are consistent with the characteristics of an active industrial port. Both the eastern and western shorelines are largely owned by the Port of Seattle (Figure B-16) and are used primarily as a marine terminal and other associated marine industries. The sides of the EW contain hardened shorelines with extensive overwater structures, commercial and industrial facilities, and other development.

There are no residential areas immediately adjacent to the EW; however, there is Jack Perry Memorial Park on the eastern shore near Slip 36 and two public fishing piers at the southern end of the waterway (Figure B-8). The EW is also used for various recreational activities such as boating, kayaking, fishing, and beach play.

The EW is part of the usual and accustomed fishing areas for two federally recognized tribes (the Muckleshoot Indian Tribe and the Suquamish Tribe) and is used for commercial, ceremonial, and subsistence fisheries for salmon. The Asian and Pacific Islander community conducts subsistence fisheries on the waterway as well, harvesting both intertidal species as well as fish for consumption.

Further discussion regarding current and future land use is presented in Section 5.

4.1.4 Natural Resources

The aquatic habitats in the EW include intertidal and subtidal substrates (typically mud, sand, gravel, cobble, or riprap) and the overlying water column. The majority of the EW is subtidal with relatively little shallow subtidal and intertidal habitat which is found primarily in the Junction/Sill reach, within Slip 27, and south of Slip 36. The benthic invertebrate community in the EW is typical of Puget Sound and is comprised of a variety of species from diverse phyla (e.g., Mollusca, Arthropoda, Annelida, and Echinodermata) and includes several resource species, including Dungeness crab and clams. There are demersal, benthopelagic, and pelagic fish species in the EW, including both resident (e.g. Brown rockfish) and migratory species (e.g. salmon). While there is relatively little EW-specific information on wildlife populations, marine mammals, semi-aquatic mammals (e.g. River otter), and sea birds are found in the EW.

Sixteen aquatic and aquatic-dependent species reported in the vicinity of Elliott Bay area are listed either under Endangered Species Act as candidate species (FC), threatened species (FT), endangered species (FE), or species of concern (FCo) or by the State of Washington as species of concern (SC) or state sensitive species (SS):

- Bull trout — Salvelinus confluentes — FT, SC
- Chinook salmon — Oncorhynchus tshawytscha — FT, SC
- Coho salmon — Oncorhynchus kisutch — FC
- Pacific cod — Gadus microcephalus — FCo, SC
- Pacific herring — *Clupea pallasi* — FCo, SC
- River lamprey — *Lampetra ayresi* — FCo, SC
- Brown rockfish — *Sebastes auriculatus* — FCo, SC
- Steelhead salmon — Oncorhynchus mykiss — FT
- Walleye pollock — *Theragra chalcogramma* — FCo, SC
- Bald Eagle — Haliaeetus luecocephalus — FCo, SS
- Common loon — *Gavia immer* — SS
- Common murre — *Uria aalge* — SC
- Merlin — Falco columbarius — SC
- Peregrine falcon — *Falco peregrinus* — FCo, SS
- Western grebe — Aechmophorus occidentalis — SC
- Orca whale — *Orcinus orca* — FE, SE

Of these species, Chinook salmon, coho salmon, steelhead salmon, brown rockfish, bald eagle, western grebe, and Pacific herring are commonly observed in the EW. Species that were considered as receptors of concern in the ecological risk assessment are listed in Table B-3.

The Washington State Department of Health (WSDOH) has issued health advisories for resident fish and shellfish in the EW, warning the public that any level of seafood consumption from the EW is unsafe because of elevated total PCB concentrations in these species. WSDOH's Office of Food Safety and Shellfish, and the Seattle, and King County Departments of Public Health also advise against the consumption of bivalves (i.e., clams, mussels, and oysters) from all of King County, including the EW, because of pollution concerns.

4.2 Conceptual Site Model

4.2.1 Historical and Ongoing Sources of Contamination

Early industrial and commercial use of these areas consisted of fish processing facilities, shipyards, petroleum tank farms, flour mills, and lumber yards. Industrial and commercial use continued after the 1940s on both sides of the EW, including oil terminals, shipyards, rail transfer terminals, cold storage, lumber yards, and sand and gravel transfer stations. During the 1970s and 1980s, significant shoreline areas along both the west and east sides of the EW were transitioned into shipping terminals and container storage. (Windward and Anchor QEA, 2014)

Historical direct sources to the EW have included include the following activities:

- Shipyards and shipping facilities, marine vessel repair, and maintenance
- Marinas and cruise ship terminals
- U.S. Coast Guard Station
- Bulk fuel terminals
- Metal smelters and iron works
- Metal salvage and recycling
- Wire rope/mesh manufacture, storage, and shipping
- Lumber mills, log storage, and transfer
- Paper recycling and transfer
- Ink distribution facility
- Electrical lamp manufacture
- Shipping terminals and container storage

Historical regional air emissions that may have contributed to sediment contamination include smelter facilities, petroleum combustion, home heating systems (e.g., coal, wood stoves, and natural gas), marine shipping, and industrial facilities, cement manufacturing plants, and other industrial and urban practices.

Prior to 1958, local sewer systems along the waterway discharged raw sewage and mixed industrial wastes directly into the EW and LDW. A combined storm/sanitary sewer system for the waterway was implemented in 1958. By 1969, large portions of the public and private sewer lines were connected into the sewer system. However, CSOs were still necessary to prevent wastewater from backing up into homes and businesses during extreme rainfall events.

Episodic releases from the CSO to the EW occur at the current King County and City of Seattle CSO locations (Figure B-4).

In addition to direct discharge of historical sanitary and industrial wastewater to the EW, historical flows of surface water and suspended sediment contaminated from historical practices have likely been transported to the EW from the Green/Duwamish River and Elliott Bay.

4.2.1.1 Potential Ongoing Sources

The potential ongoing sources and pathways to the EW are summarized in Table B-4 and include the following:

- Direct discharge into the EW (e.g., CSOs, stormwater, or sheetflow from properties immediately adjacent to the waterway)
- Groundwater discharge (including tidally influenced groundwater discharge)
- Bank erosion
- Atmospheric deposition
- Spills and/or leaks to the ground, surface water, or directly into the EW
- Abrasion and leaching of treated-wood structures
- Surface water inputs and sediment transport from upstream sources

Direct Discharge Systems and Sheetflow

In general, direct discharge systems to the EW include municipal and other publicly owned drainage systems, privately owned and managed storm drains, and sanitary/combined sewer systems via CSOs. In addition to direct discharges, some small percentage of stormwater also enters the EW from adjacent properties via sheetflow. Based on the PTM, less than 0.3% of the solids input into the EW are predicted to come from direct discharges from EW drainage basins.

Stormwater is conveyed to the EW by storm drains and CSO systems (Figure B-4). Public storm drains are owned and operated by the City or the Port and are covered under their respective National Pollutant Discharge Elimination System (NPDES) municipal stormwater permits and Port tenant industrial permits, where applicable. The U.S. Coast Guard (USCG) facility (around Slip 36) has coverage under a federal multi-sector general permit. All other drainage systems are classified as private (i.e., outfalls not owned by the Port, City, or USCG).

CSO discharges can occur during heavy rainfall when the CSO system capacity is insufficient to transport the volume of both sanitary wastewater and stormwater flows to the wastewater treatment plant. When this capacity is exceeded, excess flow is discharged to the EW through an overflow structure or relief point. CSOs consist of a combination of untreated municipal and industrial wastewater and stormwater runoff.

Sheetflow includes surface water runoff that directly enters the EW from berth aprons, deck drains, bridges, and areas immediately adjacent to the EW during rain events. In areas lacking stormwater collection systems potential sources such as contaminated soils or contaminants improperly stored either as raw or as waste materials could be carried directly over these surfaces to the EW.

Groundwater Discharge

Groundwater flow in the surrounding basin is generally towards the EW, although the direction varies locally depending on the nature of subsurface materials, hydrostratigraphy, and proximity to the EW. Near the EW, tidal action also influences groundwater flow directions, rates, and water quality.

Extensive nearshore groundwater and seep information is available for nearshore cleanup sites throughout the EW. These data were developed during previous investigations and cleanup activities. In general, COC concentrations were similar to or below reference values. While there have been some discrete detections of metals (zinc, arsenic, and mercury) and PAHs that were above groundwater reference values, they have not been directly linked to sediment contamination. Groundwater monitoring is ongoing to confirm the absence of groundwater sources to EW sediments.

Bank Erosion

Unprotected bank soils can be susceptible to erosion through surface water runoff, wind waves, and the action of vessel wakes and propwash. If shoreline soils are contaminated, erosion can represent a complete pathway of pollutants to the EW. Currently, nearly all of the EW shoreline is armored with constructed steel, wood, and concrete bulkheads; sheetpile walls; and riprap revetments, which reduce the potential for bank erosion.

Atmospheric Deposition

Chemicals are emitted to the air from both point and non-point sources. Point sources include emissions from various stationary industrial facilities (EPA, 2001). Non-point sources include emissions from mobile sources such as motor vehicles, marine vessels, and trains, as well as emissions from common materials (e.g., off-gassing from plastics) and road dust resulting from urban traffic. Atmospheric deposits that may act as sources are primarily addressed through the stormwater and upstream watershed pathways.

Spills and Leaks

Spills and leaks, containing chemical contamination, to soil, impervious surfaces (pavement or pier decking), or surface water are a potentially complete pathway to the EW. Spills occurring in upland areas are incorporated into the direct discharge pathways (storm drain and CSO). Spills in the EW are managed under existing spill prevention and response programs.

Abrasion, Leaching, or Decomposition of Treated-wood Structures

Historically, pilings and other wooden structures treated with creosote or other preservatives were commonly used as part of navigation or berthing improvements and marine structures. Currently, numerous old pilings exist in the Former Pier 24 Piling Field. Treated-wood structures are a potential source of contaminants, which can be released to sediments by abrasion or leaching pathways. Studies at other sites in the region indicate that the impact of treated-wood structures on sediments tends to be localized and results in steep concentration gradients of contaminants in sediments within a few feet from structures (e.g., Goyette and Brooks 1998; Poston 2001; Weston and Pascoe 2006). Although abrasion and leaching of pilings are not accounted for in the sediment transport evaluation, the FS baseline dataset shows patterns that are consistent with these findings. Piling removal programs have been conducted in the EW, reducing this pathway.

Transport of Surface Water and Sediment

Surface water inputs and suspended sediment are transported to the EW from upstream through the Green/Duwamish River and the LDW Superfund Site, and from Elliott Bay. The input amounts and types vary greatly during the year. Contaminants (both dissolved and particulate) released from outside of the EW drainage basins have the potential to enter the EW through transport of sediments and water from upriver or, to a lesser extent, Elliott Bay.

Based on the PTM, the solids mass contribution to the EW from lateral sources (mass of sediment that settles within the EW) is estimated between 45 and 114 metric tons per year. The contribution of solids from lateral sources to sediment accumulation declines quickly with increasing distance from the outfall location with relatively little deposition occurring in much of the deeper areas of the Main Body, Sill, and Junction Reaches. Generally, coarser sediment size fractions (sands) settle quite close to outfall locations, whereas silts and clays tend to settle farther away from their source or are transported out of the EW.

4.2.2 Source Control

Understanding ongoing sources of contamination and their potential impact to EW sediments is an important consideration for the cleanup of the EW. As such, an extensive source control evaluation was conducted as part of the SRI/FS process. The Source Control Evaluation Approach Memorandum (Anchor and Windward, 2008b) described the source control evaluation process and strategy.

Source control has been ongoing throughout the watershed. The majority of the source control has been performed under CERCLA, NPDES, and the Washington State Model Toxics Control Act (MTCA) for state-led upland cleanup sites adjacent to the EW. These programs enforce federal and state standards, and incorporate reporting and review cycles for transparency, corrective action, and adaptive management. A summary of each source control-related program and how it relates to the source control strategy is provided below.

East Waterway Source Tracing Activities: The City, County, and Port conduct source tracing and identification sampling to support the EW source control efforts. Source tracing sampling, including evaluations of total suspended solids, and contaminant concentrations in storm drain and CSO solids is designed to identify potential sources by strategically collecting samples at key locations within the storm drainage and combined sewer service areas. Source tracing and source control efforts will continue through remedy implementation to minimize potential recontamination from direct discharges from stormwater outfalls and CSOs.

Operations and Maintenance (O&M) Programs: The County, City, and Port each implement operation and maintenance program for drainage and wastewater systems. Catch basins in the drainage system are inspected annually and cleaned when there is excessive sediment accumulation, preventative maintenance programs, and working with businesses/tenants to implement BMPs to limit inputs to drainage systems.

CSO Control Programs: CSO control programs by the County and City under the NPDES program (and consent decrees) has reduced the number of CSO connections to the EW and the number of events and event volumes. Under permits, the County and City provide the State monthly monitoring reports that include number of events and volumes and discuss efforts to reduce CSO discharges. In addition, long-term CSO reduction plans are required, including implementation of further controls on released volumes, decreased released solids and floatables, and O&M programs.

Compliance and Inspection Programs: The Port, County, and City conduct various inspections/site assessments, based on their applicable regulatory authority, to enhance or assess compliance of permitted dischargers. The programs inspect industrial waste systems, identify and prioritize site for actions, including on-site storm drains that require cleaning, appropriate spill prevention/control programs, and proper training. These programs will continue during and after remediation. The continued inspection and assessment of businesses and tenants operating in the EW basin to enforce or enhance compliance with source control requirements through the implementation of appropriate BMPs reduces recontamination potential.

NPDES: NPDES discharges are generally administered by Ecology, although USCG discharges are administered federally. NPDES-permitted discharges to the EW include industrial and municipal stormwater, stormwater originating from certain construction projects, and County and City CSOs. Regular monitoring and reporting is conducted as part of these programs. The continued implementation of permitted discharges requires the integration of pollutant-reducing BMPs.

Municipal Stormwater Management: Both the City's and the Port's municipal stormwater permits require development of a stormwater management plan to meet Clean Water Act and state water quality requirements. These programs include source control and pollution prevention, for existing and new development, the implementation of BMPs for new construction, including programs to detect, remove and prevent illicit connections to storm drain systems. The Port of Seattle requires compliance with O&M for all tenants.

Site Cleanup and Associated Programs: Upland soil and groundwater adjacent to the EW have been cleaned up and are monitored under Ecology-administered (MTCA) and EPA-administered

(CERCLA) programs. Completion of groundwater monitoring programs will verify the protectiveness of upland remedies at state and federal cleanup sites with respect to EW sediment recontamination. Further evaluation of USCG property bank soil and groundwater quality will minimize the recontamination potential in the EW sediments in this area.

Upstream sediments have been, and will be, cleaned up under CERCLA, MTCA, and Resource Conservation and Recovery Act (RCRA) administration. The LDW cleanup and source control activities may reduce the potential for recontamination of EW sediments from ongoing upstream inputs. Timing of the LDW cleanup will be considered as part of source control sufficiency for the EW.

Spill Response: Ecology, USCG, the Port, and Seattle Public Utilities maintain spill response programs that support source control efforts in the EW. Ongoing operation of spill prevention and response programs within the EW and its drainage basins reduces recontamination risks.

Air Quality Programs: Numerous state, federal, and local programs exist to evaluate air quality and control potential air pollution sources. Air quality and atmospheric deposition information has been collected in the vicinity of the EW by several groups, including the Puget Sound Clean Air Agency, Ecology, and the County. If additional information is collected in the future, it will supplement existing information.

Other Programs: Bank erosion and abrasion and leaching of treated-wood structures pathways will be addressed directly during cleanup. Both of these potential sources are located within the limits of the EW and will be evaluated as part of remedial design. Bank stability is an important component of dredging and capping design and will be addressed as part of geotechnical analysis. The impact of treated-wood structures within the EW (e.g., the Former Pier 24 Piling Field) will be evaluated during design and addressed as necessary by the selected alternative. Some piling removal has already been performed by individual parties in the EW, including as part of a DNR program for the removal of creosote-treated structures. Ongoing treatment, replacement, and/or removal of treated wood structures located within the EW as needed during redevelopment reduces the potential for recontamination from these sources.

4.2.3 Nature and Extent of Contamination

Prior to the SRI investigations, 13 studies were identified with EW surface sediment data and nine studies were identified with subsurface data for EW. There was very little pre-existing tissue data for EW. The data collection studies for the SRI included the collection of approximately 500 additional samples to characterize chemical contamination in the following media:

- Surface sediment (top 10 cm)
- Subsurface sediment (below the top 10 cm)
- Fish, clam, mussel, shrimp, and crab tissue
- Benthic invertebrate tissue (organisms living in and on the sediment)
- Surface water
- Porewater

The primary risk drivers for human health and ecological risk are PCBs, arsenic, cPAHs, dioxins and furans, and TBT. In addition, 29 other chemicals were identified as COCs for benthic invertebrates because detected concentrations of these 29 chemicals exceeded the SMS SQS at one or more locations. The following discussion focuses on the distribution of the primary risk drivers, as well as a discussion areas with SMS exceedances.

4.2.3.1 Surface Sediment

The surface sediment baseline dataset analyzed in the FS consists of 334 individual surface sediment samples from the EW SRI dataset, plus an additional 8 surface sediment samples collected from Slip 36 (USCG) in November 2014.[1]

Total PCB concentrations and mercury concentrations in surface sediment exceeded the SQS at the greatest number of locations. Table B-5 summarizes average concentrations, maximum detections, and detection frequencies of COCs identified as human health risk drivers. The distributions of risk driver COCs in sediment are discussed below and summarized in Figure B-17. More detailed figures with station locations, concentration ranges, and concentrations by depth are presented in Figures B-18 through B-20. Thiessen polygons were used to spatially represent results from specific point locations.[2]

PCBs are widely distributed in surface sediment throughout the EW. Total PCBs were detected in 95% of the 248 surface sediment samples analyzed for the FS dataset, at concentrations ranging from 6 to 8,400 µg/kg dry weight (dw), with a mean concentration of 490 µg/kg dw and a surface-weighted average concentration (SWAC) of 460 µg/kg dw (Figures B-18a through B-18c). While the Thiesson polygons show some areas with notably higher concentrations of PCBs (sediment in and around Slip 27, the Sill Reach near the Spokane Street Bridge, and the general area of the cable crossing), data for individual points show that PCBs are distributed throughout much of the waterway. Note that PCBs are reported here as dry weight and are not carbon normalized; whereas the PRG and RAL for PCBs is carbon normalized. For comparison, the dry weight equivalent of the proposed RAL of 12 mg/kg OC is 192 mg/kg dw.

cPAHs, reported as benzo[*a*]pyrene toxic equivalents (TEQ), were found throughout the waterway, with concentrations ranging from 15 to 68,000 µg TEQ/kg dw, with a mean concentration of 1,600 µg TEQ/kg dw and a SWAC of 680 µg TEQ/kg dw (Table B-5). cPAHs were also measured in four intertidal multi-increment sampling (MIS) composite samples (encompassing all intertidal areas with clams) and 15 intertidal composite samples created to characterize cPAHs in each intertidal sampling area (Figures B-19a through B19c). cPAHs were

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1 These additional locations were sampled after the risk assessments (Windward, 2012a; 2012b), initial EW FS modeling work, and source and pathway characterization data cutoff of August 2010. However, they are included in the statistical summaries of contamination in FS Section 2 and have been used to expand the remediation footprint in FS Section 6.

2 Dioxin and furan TEQ and TBT concentrations are not represented on figures as Thiessen polygons, but as individual points due the smaller size of these datasets. During remedial design, additional samples may be collected and tested where dioxin and furan information is limited.

detected in all 15 of the surface sediment intertidal composite samples, with concentrations ranging from 18 to 17,000 µg TEQ/kg dw. For cPAHs, there were three locations with notably elevated concentrations: the intertidal sediments among the creosoted pilings at Pier 24, sediments in the vicinity of the USCG piers, and immediately offshore of the former GATX facility.

Arsenic was detected in 71% of the 239 surface sediment grab samples analyzed for the FS dataset. Arsenic concentration results range from 2.3 to 250 mg/kg dw with a mean concentration of 11.0, and a SWAC of 9.0 mg/kg dw (Table B-5, Figures B-20a through B-20c). In general, arsenic concentrations throughout the water way were between 2.3 and 15 mg/kg dw, with higher concentrations found in the southern waterway. The highest concentrations of arsenic were observed in sediments near the USCG Station piers.

Dioxins/furans, reported as 2,3,7,8-TCDD toxic equivalents (TEQ), were measured in subtidal composite sediment samples created for 13 subareas throughout the waterway and in four intertidal MIS composite sediment samples. Dioxins/furans were detected in all 13 subtidal composite samples with concentrations ranging from 4.0 to 31 ng TEQ/kg dw, and in all four intertidal MIS composite samples with concentrations ranging from 9.2 to 13.8 ng TEQ/kg dw. In addition, 19 individual surface sediment grab samples were analyzed for dioxins/furans. Dioxins/furans were detected in all 19 grab samples with concentrations ranging from 2.8 to 71 ng TEQ/kg dw (Table B-5 and Figure B-21). Areas with higher concentrations of dioxins/furans were in the southwestern portion of the waterway and Slip 27 (Figures B-17 and B-21).

Table B-6 presents a summary of chemicals detected in surface sediment samples relative to numerical chemical SMS criteria to evaluate potential risk to benthic organisms. The SMS criteria uses two values: the sediment quality standard (SQS; WAC 173-204-320) and the cleanup screening level (CSL; WAC 173-204-562). The SQS criteria represent numerical chemical concentrations below which sediment is designated as having met the State's standard for sediment quality. The CSL criteria represent chemical concentrations at which minor adverse effects on biological resources are expected to occur. At chemical concentrations above the SQS but below the CSL, sediment is designated as having the potential for minor adverse effect on biological resources. To facilitate the evaluation of SMS exceedances, Table B-6 presents an exceedance factor (EF), which is the ratio of the maximum detected concentration of a chemical to the sediment criteria.

In surface sediment, 175 locations (out of 251 in the FS dataset, or 70%) throughout the waterway had one or more exceedance of the chemical SQS. Total PCBs most frequently exceeded its SQS or CSL criterion (65%), followed by mercury (21%), and 1,4-dichlorobenzene (13%). All other detected chemicals exceeded their respective SQS or CSL criteria in less than 10% of the samples. Twenty-four contaminants exceeded their respective CSL in at least one sample, with total PCBs being the most frequently detected above its CSL criterion (23 of 248 locations, or 9.3%) followed by acenaphthene (13 of 248 locations, or 5.2%) and mercury (10 of 247 locations, or 4.0%); all other contaminants were detected above their respective CSL criterion in less than 4% of the samples.

Three studies have conducted sediment toxicity tests (bioassays) in EW. First, there were six sample locations tested as part of post-dredge monitoring conducted in 2000 (Windward, 2001). Second, as part of an EW-wide nature and extent evaluation in 2001, 34 sediment samples collected throughout EW were submitted for toxicity testing. The majority of these samples were located in the northern portion of the deep main body in the vicinity of the area that was dredged in 1999. And third, as part of the EW SRI surface sediment characterization in 2009, 11 sediment samples were submitted for toxicity testing.

In total, 51 surface sediment bioassay samples from the three studies met acceptance criteria and were analyzed in the SRI. Three types of bioassays were included: the acute (10-day) amphipod survival test using the amphipod *Eohaustorius estuarius*, the acute (48-hour) bivalve larvae normal survival test using the blue mussel *Mytilus galloprovincialis*, and the chronic (20-day) juvenile polychaete survival and growth test using *Neanthes arenaceodentata*.

Using the final SMS designation based on both sediment chemistry and toxicity test results, approximately 39% of the EW is designated as having no adverse effects to benthic community (all less than SQS), while approximately 23% is expected to have minor adverse effects (greater than or equal to CSL). Approximately 38% of the area was between the SQS and the CSL and is generally interpreted as having a potential for minor adverse effects on the benthic community (Figure B-17).

4.2.3.2 Subsurface Sediment

The subsurface sediment baseline dataset analyzed in the FS includes 346 subsurface samples from 146 cores. Data from the sediment cores is shown in Figures B-18 through B-21. A total of 214 samples (from 67 cores) were collected during site-wide investigations, including the SRI subsurface sediment sampling in 2010. The remaining 132 samples (from 79 cores) were collected to characterize sediment quality in potential dredging areas that were ultimately not dredged. The chemical concentrations observed at different depth below the sediment surface are shown in the surface distribution figures cited in the previous section.

In general, elevated subsurface contaminant concentrations were co-located with areas of elevated surface sediment concentrations. The majority of locations had the highest concentrations at the surface, with the exception of Slip 27 which had generally higher subsurface sediment contaminant concentrations compared to the surface sediment concentrations. Additionally, the shallow main body area had higher subsurface sediment concentrations of total PCBs and mercury relative to the surface sediment concentrations of these contaminants in that area. The analysis of vertical patterns of chemicals in subsurface sediment showed that the areas with elevated contaminant concentrations at depth were found in areas that have not been recently dredged.

Overall, 95% of the cores collected from the EW during SRI sampling events had contaminant concentrations that were less than the SQS in the lowest interval of the core that was analyzed, indicating that the vertical extent of sediment contamination has been characterized. In the cores where the lower alluvium was analyzed (74% of the cores), three locations had SQS exceedances in that zone; although the FS concludes that exceedances at depth at these

locations were likely due to inclusion of transitional or contact layer material from the upper unit.

4.2.3.3 Tissue

Tissue data included samples of English sole, shiner surfperch, brown rockfish, juvenile Chinook salmon, red rock and Dungeness crabs, intertidal clams, mussels, geoducks, shrimp, and small benthic invertebrates that live in or on the sediment, such as amphipods and marine worms. These species were selected because they were either known or assumed to be representative of species that could be consumed by people, fish, or aquatic-dependent wildlife within the EW or they were identified as important ecological receptors of concern. Tissue data were used to evaluate risks to human health and ecological receptors in the HHRA (Windward, 2012b) and ERA (Windward, 2012a), respectively. Summary statistics for tissue by species and chemical are shown in Table B-7.

Mean total PCB concentrations were highest for fish tissues including brown rockfish, English sole, and shiner surfperch (Table B-7). Mean total PCB concentrations were lowest for the shellfish tissues (geoducks, mussels, and intertidal clams). Mean dioxin and furan concentrations were also highest in the fish tissues and lowest in the shellfish tissues. Mean cPAH concentrations were highest in clams, mussels, and benthic invertebrates. Inorganic arsenic concentrations were highest for intertidal clams and other shellfish tissues (geoducks and mussels). TBT concentrations were highest in brown rockfish and benthic invertebrates.

4.2.3.4 Water

Contaminant concentrations in surface water and porewater were also summarized in the SRI. Surface water grab samples were collected along a transect in the EW (at Station 4950) by King County between October 1996 and June 1997 and analyzed for conventional parameters, metals and semi-volatile organic compounds (SVOCs). Surface water sampling was also conducted in 2008 and 2009 as part of the SRI. 59 samples were collected from 5 locations throughout the waterway during the wet season, the dry season, and a large storm event. These samples were analyzed for conventional parameters, metals, SVOCs, and PCB congeners. The metals concentrations in the two datasets were similar. SVOCs were not detected in the King County samples, but were detected in the SRI dataset, likely due to improved analytical sensitivity in the analyses conducted for the SRI.

Total PCB concentrations in whole-water samples ranged from 0.068 to 5.83 ng/L with a mean concentration of 1.31 ng/L. cPAHs were infrequently detected in surface water samples (4 out of 59 samples) with concentrations ranging from 0.0091 to 0.011 µg TEQ/L. Dissolved surface water arsenic concentrations ranged from 0.43 to 1.43 µg/L. Finally, TBT was detected in 1 out of 59 samples with a concentration of 0.01 µg/L.

Porewater data were collected from subtidal surface and subsurface sediments for the analysis of TBT primarily in samples collected for dredge material characterization and post-dredge monitoring studies. TBT was detected in 83 out of 99 samples with concentrations ranging from 0.019 to 28 µg/L. In addition, 13 porewater samples were collected from two intertidal areas

for the analysis of volatile organic compounds (VOCs). Naphthalene was detected in two samples, benzene was detected in two samples, and *cis*-1,2-dichloroethene was detected in one sample.

4.2.4 Contaminant Changes through Time

No assessments of changes in surface sediment contaminant concentrations with time were made for the EW as part of the SRI or FS to support natural recovery. Review of the SRI baseline dataset showed that there is very little surface sediment data from locations that have been re-occupied. The majority of locations that have been sampled multiple times are from post-dredge monitoring in the Phase 1 dredging area. Dredging and an unknown amount of sediment mixing due to propwash from vessel traffic are complicating factors in assessing contaminant changes with time within the EW.

4.2.4.1 Sediment Chemistry in Phase 1 Dredge Area

The Phase 1 dredge area is the only area within EW with two sets of surface sediment chemistry data. This area was dredged in 2004-2005. Following the completion of dredging (February 1, 2005), the exposed sediment surface was sampled in order to identify if areas had contaminant concentrations above the SQS. The area with sediment concentrations above the SQS was immediately dredged a second time (February 3 to 25, 2005) to remove an additional foot of material and then covered with a 1-ft thick layer of sand cover material (March 1 to 15, 2005).

Pre-sand placement sediment samples were collected following the removal of the additional foot of material and analyzed for the analytes that exceeded the SMS in the post-dredge surface (metals, mercury, SVOCs, and PCBs). Mercury and total PCBs were the contaminants that exceeded the SQS and CSL in the greatest number of samples.

The surface sediments on and near the sand cover area were then sampled for 3 years (2006-2008) following the placement of the sand cover material and the resulting data represents the current surface sediment conditions. The SQS exceedances for the current surface sediment data were compared with the surface sediment data prior to the placement of sand cover material (i.e., pre-sand placement sediment). The current surface sediment has fewer exceedances of the CSL than was seen in the pre-sand placement samples. In general, concentrations of SMS chemicals of concern remained below SQS levels. Six locations had CSL exceedances in the current sediment surface for total PCBs, 1,4-dichlorobenzene, and bis(2-ethylhexyl) phthalate (BEHP). These locations were not associated with historic SMS for 1,4-dichlorobenzene and BEHP. However, SMS exceedances for total PCBs were observed in pre-sand placement locations located near two locations (EW-RM-34 and EW-RM-32) that exceed the SQS and CSL for total PCBs, respectively.

4.3 Exposure CSM

The exposure CSM includes contaminant sources, transport mechanisms, exposure pathways, exposure routes, and potentially exposed receptors. Figures B-22 present the exposure

pathways for humans, and Figure B-23 and B-24 presents the exposure pathways for ecological receptors.

For the HHRA, the CSM describes scenarios under which people could be exposed to contaminants in EW seafood tissue, sediment, or surface water. Exposure scenarios were selected for consistency with the LDW HHRA (Windward, 2007) and through input from EPA and various site users, including the Muckleshoot Indian Tribe and the Suquamish Tribe. The primary exposure pathways included dietary exposure, direct contact with sediment, and direct contact with surface water and are described as follows.

For humans, dietary exposure of contaminants is primarily associated with ingestion of contaminated seafood, such as fish, crabs, clams, and smaller invertebrates. For the purposes of the EW risk assessments, consumption rates for humans were estimated for various scenarios based on seafood consumption rates developed for adult and child consumers in King County or Puget Sound. Separate human health risk assessments were conducted for the AP) community and for Tribal subsistence fishers.

Human exposure to chemicals in contaminated sediment through direct contact is primarily through dermal adsorption and incidental ingestion of sediment. The HHRA evaluated several scenarios for this pathway, including netfishing, habitat restoration work, and clamming, where people would come into direct contact with sediment.

People are exposed to chemicals in surface water when swimming through direct contact (dermal adsorption and incidental ingestion of surface water). Exposure to surface water in the EW was assessed for swimming exposure based on the adult swimming scenarios presented in a previous King County assessment (King County, 1999a). These levels of exposure are likely significant overestimates of swimming exposure levels for the EW, given that they were developed for areas that include a greater number of recreational access points than does the EW (e.g., Elliott Bay), and areas that do not have the EW's high concentration of large ship and tug boat traffic.

For the ERA, sediment is the assumed to be the primary source of chemicals for all exposures at the site. The exposure assessment for each receptor focuses on scenarios that include direct or indirect pathways for sediment-associated chemicals. Examples of direct pathways include ingestion of sediment or direct contact with sediment. Indirect pathways include the ingestion of aquatic biota that have been exposed to contaminated media. Because of the potential flux of chemicals from sediment to surface water, ecological receptors may also be indirectly exposed to sediment-associated chemicals through ingestion of surface water or contact with surface water. The exposure pathways evaluated and whether they were considered to be complete and significant are indicated in Figures B-23 and B-24. The receptors of concern for the ERA included the benthic invertebrate community, crab, three fish species (juvenile Chinook salmon, English sole, and brown rockfish), and four aquatic-dependent wildlife species (pigeon guillemot, osprey, river otter, and harbor seal). The rationale for selecting each receptor of concern, including its ecological and societal importance, site use, and sensitivity, is provided in Table B-3.

To estimate exposure, chemical concentrations in tissues were analyzed in various fish and invertebrate species that have been collected from throughout EW. Most of the tissue data were for English sole, shiner surfperch, brown rockfish, juvenile Chinook salmon, Dungeness and red rock crabs, clams, mussels, shrimp, and small invertebrates that live in the sediment, such as amphipods and marine worms. These species were selected because they were assumed to be representative of species within the EW that could be consumed by people and fish. Their tissues were analyzed for a wide variety of chemicals.

4.4 Models Used As the Basis for Risk, Fate and Transport, or ARAR Compliance

4.4.1 Sediment Transport Evaluation

Sediment dynamics were estimated through multiple sediment transport models, with results published in the STER (Anchor QEA and CHE, 2012) and summarized in Chapter 5 of the FS (Anchor and Windward, 2018). The STER documents the movement of sediment related to scour, deposition, and transport patterns, and was then used to refine the physical CSM and the box model.

The hydrodynamic model utilized in the STER was developed through modification of an existing model used to evaluate hydrodynamics in the LDW (Windward and QEA, 2008a). The model utilizes the three-dimensional environmental fluid dynamics computer code to represent hydrodynamic processes. It is a physics-based model that incorporates important physical processes and algorithms to describe the hydrodynamic processes in the system. The model domain extends from the Duwamish River at the south to a boundary between Puget Sound and Elliott Bay that is located between Alki Point and West Point.

The LDW hydrodynamic model was updated to increase the grid resolution within the EW. Data collected as part of the sediment transport evaluation were used to update the bathymetry within the EW and calibrate the model within the EW (current and salinity data). In particular, there was a need to update bathymetry in the vicinity of the shallow water Sill Reach, the Junction Reach, and under-pier areas. In addition, Slips 27 and 36 were included in the model domain.

The updated hydrodynamic model was used to evaluate hydrodynamics (current velocities, salinity distribution, water surface elevations) within the EW due to tidal forcing and various upstream inflow conditions in the Green River and LDW (annual average, mean wet season, 2-year, 10-year, and 100-year flow events). The updated model was also used to evaluate erosion potential (by determining bottom shear stresses) within the EW for these events.

4.4.2 Particle Transport Model

The initial spatial distribution of sediments deposited within the EW from lateral sources was estimated using the PTM developed with USACE (Anchor QEA and CHE, 2012). The purpose of the PTM modeling effort was to estimate the relative contribution and distribution of solids

loads from lateral sources to overall sedimentation rates in the EW. In addition, the PTM modeling results were used to evaluate recontamination potential due to sediment loads from identified lateral sources. Inputs to the PTM model for upstream flows and lateral sediment loads were constant values based on long-term annual average inputs to allow for extrapolation of shorter duration simulations to annual results. Specific inputs to the model include the following:

- Upstream flow – Average annual flow based on hydrology developed by USGS for the gage at Auburn (hydrology is the same as defined for the LDW).
- Tidal conditions were varied over the 28-day simulation and were taken from the National Oceanographic and Atmospheric Agency (NOAA) tide gage in Elliott Bay from June 1, 2009 to July 31, 2009 as a representative large amplitude tide cycle.
- Stormwater sediment loads were developed for an average rainfall year (based on 1986).

CSO sediment loads were developed as annual averages based on approximately 10 years of flow data. The modeling was completed for a range of sediment mass loadings based on the range of total suspended solids (TSS) values in stormwater and CSOs (to account for uncertainty and variability in that data). The simulations included a base case (based on the mean TSS values) and upper and lower bounding simulations (based on the 75th and 25th percentile TSS values, respectively).

4.4.3 Propwash Scour Analysis and Pressure Field Evaluation

The majority of the EW is subject to vessel operations that impact bed sediment movement. As part of the sediment transport evaluation, a study was conducted to develop estimates of maximum near-bed velocities and associated bed shear stresses due to vessel operations. The model output was then used to estimate scour depths for different portions of the EW, as well as estimates of sediment resuspension due to pressure fields from a moving vessel.

Propwash velocities and scour depths were developed for different propwash operational areas. Each area was designated based on the type of vessel and operations occurring within that area, as well as the bathymetry. The first step in estimating the magnitude and location of bottom scour due to ship propulsion is to simulate the current velocity pattern created by the propulsion source installed on the ship, incorporating the channel depth at separate locations in the waterway. The second step is to apply the maximum near-bed velocity in each location to determine the bed shear stress and sediment size at threshold of motion.

The modeling tool applied to determine near-bed velocities was the two-dimensional model JETWASH (CHE, 2003). The JETWASH model simulates the velocity field created by propulsion systems and accounts for the interaction of the velocity jet with the sediment bed.

The JETWASH model is based on a well-established and empirically verified theory of flow produced by a momentum jet. The JETWASH model has been implemented by EPA Region 8 and USACE for the analysis of sediment stability under impact from propwash of vessels ranging

in size from small recreational boats to large ships (CHE, 2007). JETWASH has also been successfully applied to studies of ships equipped with thrusters. Propwash generated scour depth were then computed using the modified analytical method of de Graauw and Pilarczyk (1980) calibrated with historical bathymetric survey data in the East Waterway and sediment grain size data from Sedflume experiments (LDWG, 2007; Anchor QEA and CHE, 2012).

Fifteen scenarios were developed for analyzing propwash effects based on the list of vessel operations. The scenarios consist of maneuvers for: 1) docking, undocking, and navigating the waterway; 2) using a ship's main power and thrusters; and 3) using various types of tugs. Additional specifics regarding vessel characteristics (e.g., length, depth, and draft) and propulsion were collected from public information obtained from the shipping line, tug companies, and Coast and Harbor Engineering archives.

All simulations assumed a tidal elevation of MLLW. This will result in conservatively high estimates of near-bed velocity and bed shear stress due to propwash because it represents the case where the ship's propulsion system is closest to the bed. Simulations of all vessels, including tugs, in the docking and undocking maneuvers assumed that the source of propwash was stationary. Tugs transiting the waterway were assumed to have a speed of 4 knots, which represents safe operating speeds within the EW based on interviews with tug pilots.

Near-bed currents generated beneath a moving vessel can be an agent for mobilizing sediment on the waterway bed if the velocity is of sufficient magnitude. Hydrodynamic forces generated by the pressure field of a vessel were calculated using the Vessel Hydrodynamics Longwave Unsteady model (Shepsis et al., 2001). This model predicts water level and velocity fluctuations surrounding a moving ship and the resulting velocity beneath the hull. The main factors that determine the magnitude of the pressure wave generated by the moving vessel are the ship's length, beam, draft, shape, and speed at which it moves relative to the water.

4.4.4 Box Model

A box model evaluation was used to predict the EW site-wide SWAC over time (years 0 through 40 following construction) for the four human health risk driver COCs (total PCBs, arsenic, cPAHs, and dioxins/furans) for each remedial alternative based on anticipated solids deposition and vertical mixing in the EW. For FS purposes, SWACs are used to estimate exposure point concentrations to assess risk to human or ecological receptors and for estimating the effectiveness of the alternatives at reducing that risk. Only these four risk drivers were analyzed in this way because their compliance is measured as a site-wide average concentration (RAOs 1, 2, and 4). These results were used to compare the site performance over time of the proposed remedial alternatives.

The calculations of the SWAC for the four human health risk driver COCs include the following factors:

1. Incoming solids inputs to the EW (Table B-8)
2. Remedial technology for each alternative applied to each portion of the remediation area:

a. Surface chemistry concentrations post-remedial action at time 0 in remediated and unremediated areas

b. Dredge residuals volume and chemistry (at time 0)

c. Chemistry associated with deeper sediments subject to mixing

3 Physical mixing assumptions based on the propwash evaluation.

The box model evaluation was conducted using a Microsoft Excel spreadsheet-based analytical model that calculates site-wide and sub-area SWACs within the EW. The SWAC for each human health risk driver COC was calculated beginning at year 0 (immediately following construction) and at 5-year intervals through year 40. The site-wide SWAC for each COC was determined at each 5-year interval (e.g., 0, 5, 10, 15, etc.) through a series of calculations that take into account remedial technology and sediment mixing assumptions, which vary across the EW, and incoming sediment characteristics. A sensitivity and bounding evaluation was also conducted, based on range of values for input variables, to determine the effect of uncertainty in the input information on the SWAC calculations.

The box model evaluation utilized several types of input information to estimate SWAC values over the 40-year post-construction time period, as follows:

- Upstream and lateral solids loading and net sedimentation rates within the EW
- Chemistry assumptions for incoming solids
- Post-construction surface sediment concentrations, including dredge residuals thickness and concentrations
- Sediment mixing and underpier exchange assumptions
- Bioavailability of hydrophobic organic contaminants
- Remedial technologies for the remedial alternatives

For reductions in the bioavailability of PCBs, the box model assumed a 70% reduction based on the low end of the effectiveness range (EPA, 2013) to account for dilution of AC during mixing and exchange of underpier sediment. The effects of the estimate of reduction in bioavailability onsite-wide SWACs were determined through a sensitivity analysis.

4.4.5 Point mixing model

A point mixing model evaluation was conducted to assist with determining achievement of RAO 3 (reduce to protective levels risks to benthic invertebrates from exposure to contaminated sediments), which is evaluated on a point by point basis.

The point mixing model evaluation was conducted on a subset of seven risk-driver COCs for RAO 3. The point mixing model was only applied where MNR is used as a remedial technology (Alternative 1A(12)) because all other surface sediment stations will meet RAO 3 PRGs following construction, either through active remediation or because they are currently below RAO 3 PRGs. The point mixing model predicts surface sediment concentrations for years 0 through 40

post-construction for the 18 existing surface sediment sampling station locations in proposed MNR areas that exceed the RAO 3 PRGs.

The calculations were conducted for each point location using similar methodology as the box model evaluation described earlier; where deposition of incoming solids and vertical mixing assumptions were applied to each point location. Exchange between underpier and open-water areas was not included in these calculations, to provide a conservative estimate of natural recovery in these locations. This assumption tends to bias the predicted sediment concentrations high because the calculations do not account for cleaner sediment from open-water areas accumulating in the underpier locations.

4.4.6 Grid model evaluation

The grid model evaluation was used to identify discrete areas within the EW where recontamination from EW lateral deposition could be a concern post-construction. The spatial distribution of surface concentrations throughout the EW due to deposited solids from upstream and lateral inputs was estimated for years 0 through 40 post-construction. The predicted percentage of EW surface area exceeding RALs at any time over that 40-year time period was used to identify areas where potential recontamination from incoming sediments could occur, inform future source control efforts, and target general areas where post-construction monitoring may be needed. This evaluation, referred to as the grid model evaluation, is different than the box model evaluation because it uses the spatial distribution of EW lateral solids deposition predicted by the PTM as input rather than a cumulative sitewide value. This evaluation was completed from years 0 to 40 post-construction for nine key risk driver COCs: PCBs, cPAHs, dioxins/furans, arsenic, mercury, high molecular weight PAHs (HPAHs), low molecular weight PAHs (LPAHs), BEHP, and 1,4-dichlorobenzene (see FS Section 5.4.2 for more detail on selection of COCs for this analysis).

The evaluation of recontamination potential is challenging in the EW due to the influence of anthropogenic activity, such as propwash, which can resuspend recently deposited finer sediments or mix them into the underlying sediments. The effects of propwash on the spatial distribution of EW lateral solids deposition was not taken into account with the PTM because of the difficulty in accurately quantifying the location, mass, and frequency of solids resuspended by vessel activity. Therefore, the recontamination evaluation focused on identifying areas of concern using RALs as metrics without attempting to quantify surface concentrations in the long term with certainty.

Several assumptions were made to simplify the calculations while still meeting the objective of the evaluation. Two primary assumptions were developed to focus the evaluation on recontamination potential due to incoming solids. The first is that the initial surface concentrations within the EW (at year 0) were assumed to be zero. This focuses the results of the evaluation on recontamination from incoming sediment sources only and removes the influence of underlying sediment concentrations. The second is that vertical mixing depths were assumed to be constant throughout the EW and were set to the assumed bioturbation mixing depth of 10 cm for the EW. This limits the amount of dilution of incoming sediment

sources that could occur due to deeper vertical mixing, which may be sporadic or not occur at any particular location.

4.4.7 Food Web Model for PCB Bioaccumulation

A food web model (FWM) was developed for PCBs to estimate the relationship between total PCB conentrations in tissue and sediment in the EW. Output from the FWM was used to estimate RBTCs for total PCBs in sediment and to assess residual risks from PCBs that may remain following various sediment cleanup alternatives. The FWM was limited to PCBs because credible relationships between sediment and tissue contaminant concentrations for other human health risk-driver contaminants could not be verified in the remedial investigation.

The EW FWM was consistent with the LDW FWM (Windward, 2010b). The EW FWM was then parameterized using literature-derived and site specific data to select point estimates or develop distributions for all model parameters. The model was then calibrated to identify sets of parameter values (from the distributions) that best estimated empirical tissue concentration data collected from the EW.

The LDW FWM was based on Arnot and Gobas (2004); the EW FWM included modifications made to the model in Gobas (2006). The Gobas (2006) AQUAWEB 1.2 model has five compartments: a) phytoplankton/algae, b) zooplankton, c) filter-feeding benthic invertebrates, d) scavenger/predator/detritivore benthic invertebrates, and e) fish. The FWM estimated PCB concentrations for each compartment using equations that represent the biological processes involved in the uptake and loss of hydrophobic organic contaminants. Thus, each compartment (e.g., fish) has its own unique set of equations. The model has three physical media: sediment, water column water, and porewater.

Figure B-25 shows the quantitative relations in the model. Input parameter values were randomly selected from probability distributions, and the model was run to yield an estimate of PCB concentrations in tissues of the modeled species. PCB concentrations in water were represented as a distribution, while PCB sediment concentrations were a point estimate (a single SWAC was used). In order to optimize the model, the predicted PCB concentrations in tissues from each model run were compared to empirically-derived mean tissue PCB concentration measured in each of the modeled species. The parameter sets that had a species predictive accuracy factor (the modeled concentration divided by the measured concentration) of 2 or 3 (for clams) were rejected.

Tissue PCB concentration data collected in the EW were used to compare to model output and calibrate the FWM model. Tissues were collecting during sampling efforts in 1995-1998, 2005, and 2008. The sampling efforts 1995-1998 generally only included one or two target species (1995: English sole; 1996 and 1997: mussels; 1998: Red rock crab and Striped perch). The majority of the tissue samples were collected during the EW RI in 2005 and 2008. PCB data were available for six species of fish, Dungeness and Red rock crab, shrimp, mussels, four species of clams, and geoduck. Empirical PCB concentration data were not available for phytoplankton, zooplankton, and juvenile fish tissues.

The output from the FWM were used to generate sediment RBTCs for the human health seafood ingestion scenarios through the consumption of seafood and for two fish receptors, English sole and Brown rockfish. RBTCs were based on exposure to total PCBs in sediment, water, and contaminated prey. The calculation of RBTCs included the following steps:

1. Estimate total PCB concentrations in surface sediment and overlying water column;
2. Run the model probabilistically using Monte Carlo simulation;
3. Calculate risk estimates using the output generated by each FWM run; and,
4. Identify the sediment RBTC associated with a given risk threshold.

Best-fit sediment RBTCs, as well as upper- and lower-bound RBTCs, were identified. Upper and lower bounds were developed based on the model performance criteria and do not reflect the total range of uncertainty in the sediment RBTCs.

5 Current and Potential Future Site and Resource Uses

5.1 Current Land Uses of the East Waterway

The EW is an active industrial waterway used primarily for container loading and transport. Land use, zoning, and land ownership along the EW are consistent with active industrial uses (Figure B-16). The EW provides a critical connection for cargo and other materials moving between water and land. Most vessel traffic consists of shipping companies that move container vessels and associated tugboats into and out of the EW. The sides of the EW contain hardened shorelines with extensive overwater structures, commercial and industrial facilities, and other development.

Most vessel traffic consists of container vessels and assorted tugboats moving into and out of the EW. Each container ship requires at least one tugboat to maneuver the ship during docking and undocking. Container ships berth at T-18, T-25, and T-30 (Figure B-16). Numerous barges and tugboats are moored at the head of the EW along what is currently Harley Marine Services, which includes Olympic Tug and Barge as a subsidiary. At the northeast end, along T-18, tug and barge traffic utilize the Kinder Morgan petroleum products transfer facility. Additional navigation and berthing occurs in Slips 27 and 36. Slip 27 is used by the Port for temporary moorage of barges (along Pier 28), which are maneuvered by tugboats. USCG vessels frequent Slip 36, which serves Pier 36 (south) and Pier 37 (north). USCG moors numerous vessels in Slip 36, including USCG icebreakers, cutters (longer than 65 feet), and gunboats. Only USCG vessels currently use this slip regularly, but the U.S. Navy occasionally uses this slip.

South of the Spokane Street corridor, recreational, and commercial boats access the Harbor Island Marina (T-102) from the LDW. Along the T-102 shoreline within the EW, the Port leases out moorages on a 750-foot-long dock for commercial use. The Spokane Street corridor itself prohibits any type of boat passage, except at low tide by small, shallow-draft boats (e.g., kayaks and skiffs).

5.1.1 Water Recreation

Water recreation can include activities such as swimming, scuba diving, and pleasure boating. The extent to which the EW is used for swimming or diving is unknown, but likely minimal due to the cold water, limited shoreline access, and use of much of the water body by commercial ships (King County issue paper on human site use in Elliott Bay and the Duwamish River, including the EW and the WW; King County 1999b). The EW is accessible to the general public via boat, but fewer recreational opportunities exist in the EW because of limited public access and a greater concentration of commercial shipping activity.

5.1.2 Tribal Use

The EW is frequently used by tribes as a resource and for cultural purposes. Tribal treaties guarantee members of the Muckleshoot Indian Tribe and Suquamish Tribe the right to harvest

seafood from the EW. Currently, the Muckleshoot Indian Tribe conducts commercial netfishery in EW for salmon. Tribal fishermen can also engage in clamming activities (by means of boat access) in all intertidal areas of the EW (Figure B-8) as well as subtidally for geoducks (currently geoduck clams are not being harvested from EW). The south end of T-25 has been unsafe for clamming due to hazards associated with the presence of remnant pilings, but could potentially be an area for shellfish harvesting in the future. Tribal seafood harvesting practices are currently ongoing and will continue to occur in the future.

5.1.3 Shore Recreation

There are currently only two areas along the EW that have public access from shore: on the southeast bank near the Spokane Street Bridge and the Jack Perry Memorial Park Public Access to the northeast (Figure B-8). In addition, there are intertidal areas that the general public is not allowed (e.g., the outcrop at the mouth of Slip 27 and USCG property at Slip 36) because of security measures.

5.1.4 Commercial Use

The EW supports a large number of water-dependent commercial uses. Almost all of the facilities adjacent to the EW rely on vessel traffic on the waterway. Much of the occupational work on the EW, other than commercial fishing, takes place on piers and large ships, and is associated with daily shipping terminal operations. Most of these workers are on docks or aboard vessels and are well above the water surface (generally 20 ft or more above MLLW). However, occupational work that can occur within EW include scuba diving and individuals who perform maintenance and repair work on docks and other structures along the EW.

5.1.5 Recreational Fishing and Shellfish Use

Individuals other than tribal members are known to collect fish and crab from EW despite existing fish advisories. Individuals fishing from piers and bridges along Spokane Street corridor have been observed (King County, 1999b). The potential clamming area for the general public is small because there are only two places where the public can gain access to intertidal areas of the EW (Figure B-8). It is unknown if clam harvesting by the general public is currently occurring. The WSDOH has closed the Duwamish River and the shoreline of King County to shellfish harvesting due to pollution from bacterial contamination.

5.2 Future Waterway Uses

Future land and waterway uses are anticipated to be consistent with current uses.

5.2.1 Land Uses

Future land use within the EW is not expected to differ greatly from current land use. The use of the EW for commercial and industrial purposes is expected to continue into the foreseeable future, although certain recreational activities that are consistent with these land uses may be more common in the future as habitat improves.

5.2.2 Water Uses

The Muckleshoot and Suquamish Tribes, who currently fish for salmon in the EW, have indicated their desire to harvest resident species if they are not contaminated.

USACE completed a draft Seattle Harbor Navigation Improvement Project (SHNIP) Feasibility Report and Environmental Assessment in August 2016 (USACE, 2016). Several alternatives for deepening and widening the federal navigation channels in the EW were evaluated. The draft recommended plan includes the deepening and widening of the federal navigation channels in the EW. Within the EW, the recommended plan would deepen and widen the entrance channel north of Station 0 and the navigation channel south to Station 4950.

The existing ship and vessel traffic usage is expected to remain unchanged, with the exception of deeper draft Panamax class vessels if the navigational channel is deepened as part of the SHNIP. In general, existing zoning and habitat enhancement planning activities are not expected to conflict with potential active and passive remediation activities on a sitewide basis. However, any potential conflicts will be addressed during remedial design, therefore ongoing coordination with the USACE will be required. Deepening will occur after all EW construction is completed.

6 Summary of Risks

The baseline ecological risk assessment (ERA) and human health risk assessment (HHRA) were completed for the EW in 2012. The dataset for the EW HHRA consisted primarily of tissue, sediment, and surface water chemistry data collected from the EW as part of the EW SRI sampling efforts, along with available historical data collected since 1995. The results of the baseline human health and ecological risk assessments (Windward, 2012; Windward, 2012b) indicate that remedial action is warranted to reduce unacceptable human health and ecological risks posed by COCs in EW sediments. Unacceptable risks were estimated for human health exposure scenarios including through seafood consumption and direct contact exposure pathways, and for ecological risks including for benthic organisms and for other ecological receptors.

6.1 Human Health Risk Assessment

6.1.1 Potentially Exposed Populations and Routes of Exposure

The baseline HHRA estimated risks to people from exposure to contaminants in EW seafood, sediments, and water (Figure B-22). Exposure scenarios were selected for consistency with the LDW HHRA (Windward, 2007) and with input from EPA and various site users, including the Muckleshoot Indian Tribe and the Suquamish Tribe. The following exposure pathways were evaluated:

- Exposure through the consumption of seafood from the EW;
- Direct contact with sediment during commercial netfishing, habitat restoration, and clam harvesting in the EW (dermal contact with and incidental ingestion of sediment); and
- Dermal contact with and incidental ingestion of surface water in the EW during water recreation (e.g., while swimming).

The exposure assumptions for seafood consumption and direct sediment contact are summarized in Table B-9.

6.1.2 Seafood Consumption

The seafood consumption rates used for the EW HHRA were developed by EPA based on data collected from areas of Puget Sound for tribal consumers (EPA, 2007) and from an EPA seafood consumption study for API in the King County area. The seafood consumption rates used in the EW HHRA were the same as those used to evaluate risks in the LDW HHRA (Windward, 2007a; Windward, 2009).

RME estimates used for making remedy decisions included the following seafood consumption rates:

- Tulalip tribal consumption rates for adults and children from EPA's tribal framework document (EPA, 2007), and
- Seafood consumption rates for API adults, modified by EPA based on the results of a survey of API consumers (EPA, 1999) to reflect rates by individuals that harvest seafood only within King County.

The Tulalip Tribe shellfish consumption rates were selected because they were consistent with the LDW risk assessments and because of the limited shellfish habitat in the EW. During consultations, the Suquamish Tribe requested the use of Suquamish shellfish consumption rates for the HHRA; however they also acknowledged that the risk-based threshold concentrations were below background concentrations regardless of whether the Tulalip or Suquamish rates were used. Risk calculations were prepared with Suquamish consumption rates, but only for comparative purposes. This is discussed more fully in Section 13.

Exposure point concentrations for seafood consumption were calculated as the 95% student's-t upper confidence level (95UCL) tissue concentration for each of the consumption categories. Contaminant concentrations in the tissues of a variety of different resident seafood species (English sole, perch, rockfish, crabs, clams, geoduck, and mussels) were used to represent a typical consumer's diet (i.e., a market basket approach was used to evaluate risks associated with seafood consumption). COCs were then determined by estimating cancer and non-cancer effects for the RME scenarios.

Although salmon are a highly preferred and consumed fish from the EW and tissue data were available for salmon, human health risks were not calculated for the consumption of adult salmon. PCBs accumulated in juvenile salmon during the time they spend in the EW constitute only a very small fraction of the PCBs in adult salmon. Most of the PCBs in adult salmon result from foraging activities in Puget Sound or the Pacific Ocean. Based on an analysis by O'Neill et al. (1998), less than 1% of the PCB body burden contained in adult salmon migrating through the LDW could have been obtained from prey items consumed in the EW.

The estimated excess cancer risks for all seafood consumption scenarios is presented in Table B-10. Based on the Tulalip and API RME scenarios, 11 contaminants of potential concern (COPCs) had excess cancer risks greater than 1 in 1,000,000 (1×10^{-6}) or a non-cancer HQ greater than 1 and were therefore selected as COCs for the seafood consumption exposure pathway. The cumulative excess cancer risk for all carcinogenic chemicals ranged from 4×10^{-4} to 1×10^{-3} for the Tulalip and API RME seafood consumption scenarios. The COCs that were the primary contributors to the cumulative excess cancer risk were PCBs, cPAHs, inorganic arsenic, and dioxins/furans.

Table B-11 shows the non-cancer hazard index (HI) (i.e., sum of HQs for a particular endpoint) for each of the seafood consumption scenarios. HI values above 1 (predicting non-cancer effects) were observed for PCBs and dioxins/furans. The highest HI values were observed for the immunological, integumentary, and neurological endpoint.

To provide additional information regarding the total excess cancer risks for the RME seafood consumption scenarios, Table B-12 presents a summary of the excess cancer risks for

COCs and includes the percentages of the total risks attributable to different COCs and seafood consumption categories (i.e., fish, crabs, clams, geoduck, and mussels). The main contributors to the total excess cancer risk for the RME seafood consumption scenarios were total PCBs (55% to 70% of the total risk), arsenic (11% to 14% of the total risk), cPAHs (7% to 27% of the total risk), and dioxins/furans (5% to 7% of the total risk). In addition, the majority of the arsenic and cPAH risks (73% to 90%) are attributable to clams, while the total PCB and dioxin/furan risk is attributable to several different seafood consumption categories and is more variable across scenarios. For total PCBs, the risk is primarily attributable to benthic fish fillet (16% to 41%), rockfish (9% to 59%), perch (3% to 26%), crab edible meat (3% to 10%), and whole body crab (7% to 9%). For dioxins/furans, the risk is primarily attributable to clams (25% to 31%), crab edible meat (8% to 22%), whole body crab (18%), and rockfish (5% to 5%).

6.1.3 Direct Contact with Contaminated Sediments

The direct sediment exposure scenarios evaluated in the EW HHRA (Windward, 2012b) included two netfishing scenarios, a habitat restoration worker scenario, and three clamming scenarios: 1) tribal RME (120 days per year); 2) high-end exposure included at the request of the Suquamish Tribe (183 days per year); and 3) 7 days per year. As in the LDW HHRA (Windward, 2007), exposure frequency and duration assumptions for the evaluation of direct sediment exposure under the commercial netfishing scenario were based on site use information collected from the Muckleshoot Indian Tribe, which conducts commercial netfishing for adult salmon in the Green/Duwamish River, including the EW. No site-specific information was available to estimate exposure for the clamming and habitat restoration scenarios and, thus, exposure parameters were (when possible) consistent with the LDW and/or were based on default EPA values and best professional judgment.

Netfishing can occur throughout the EW (i.e., in intertidal and subtidal areas), while clamming and habitat restoration activities would occur in specific areas of the EW (i.e., in specific intertidal areas), which are shown in Figure B-8. Intertidal sediment areas (i.e., not riprap) identified as potential clamming areas are shown on Figure B-26.

Excess cancer risks for the direct sediment exposure scenarios were lower than those for the seafood consumption scenarios (Table B-13). Excess cancer risks for all direct contact scenarios were less than the upper end of the EPA risk range (1×10^{-4}), with total excess cancer risks equal to 7×10^{-6} for the netfishing RME scenario and 3×10^{-5} for the tribal clamming RME scenario. Cancer risks were highest for arsenic and cPAHs, which together accounted for over 84% of the total excess cancer risk. PCBs and dioxin/furan TEQ were lesser contributors.

No COPCs had non-cancer HQs greater than 1 for any of the direct sediment exposure scenarios. In addition, the total HI for each exposure scenario did not exceed 1. Therefore, non-cancer hazard was not the basis for selection of any direct contact COC.

Contaminants with either an estimated excess cancer risk greater than 1×10^{-6} or a non-cancer HQ greater than 1 for at least one RME scenario were selected as COCs for the direct sediment contact exposure pathways. Based on these criteria, four contaminants were identified as COCs for direct sediment contact exposure (Table B-14): arsenic, cPAHs, total PCBs, and total TEQ (sum of dioxin/furan TEQ and PCB TEQ).

6.1.4 Surface Water Exposure

In addition to the seafood consumption and direct sediment contact scenarios, exposure to surface water in the EW was assessed for a swimming scenario, for which the exposure parameters were based on the adult swimming scenarios presented in the King County Combined Sewer Overflow Water Quality Assessment for the Duwamish River and Elliott Bay (King County, 1999a). No RME level of exposure was defined because parameters used for this scenario likely result in significant overestimates of swimming exposure levels for the EW, given that they were developed for areas that include a greater number of recreational access points than the EW, and swimming in the EW will be limited because of a high concentration of large ship and tug boat traffic and cold water temperatures. None of the COPCs exceeded the 10^{-4} cancer risk or an HQ of 1 for non-cancer risk. Therefore, no COCs were identified based on exposure to surface water (Windward, 2012b).

6.1.5 Sum of Risks for Multiple Exposure Scenarios

Risks for multiple scenarios were summed to represent the possible exposure of a single individual to EW COPCs during different activities. Summed risks (i.e., the sum of risks across pathways) are presented in Table B-15 for the following multiple exposure scenarios:

- Adult tribal RME netfishing, adult tribal RME seafood consumption, and swimming
- Adult tribal central tendency netfishing, adult tribal central tendency seafood consumption, and swimming
- Adult tribal RME clamming, adult tribal RME seafood consumption, and swimming

When estimated excess cancer risks were rounded to one significant figure, the sums for the three scenario groups above were the same as the estimates for the seafood consumption alone. Overall, swimming had the lowest risk estimates. This analysis demonstrates that the contributions of netfishing, clamming, and swimming to estimated risks are relatively small in comparison with the contributions of seafood consumption, and it highlights the significance of the seafood consumption exposure pathway for all users of the EW.

6.1.6 Selection of Risk-Driver Contaminants

Risk drivers were identified from the COC list based on several considerations, including:

1. Risk magnitude relative to acceptable risk thresholds (including a consideration of background concentrations, if applicable);
2. Percent contribution to the total risk estimate;

3. Detection frequency; and,
4. Other data quality or uncertainty considerations.

Table B-16 summarizes the COCs and risk drivers for the seafood consumption and direct sediment exposure scenarios. It should be noted that no RME level of exposure was defined for the swimming scenario, and thus no COCs or risk drivers were identified for that scenario.

A subset of the COCs identified for the seafood consumption RME and direct sediment exposure RME scenarios were identified as risk drivers and are as follows:

- Seafood consumption scenarios – Of the 12 chemicals or chemical groups that were identified as COCs, three were identified as risk drivers (cPAH [TEQ], PCBs, and dioxins/furans [TEQ]).
- Direct sediment exposure scenarios – Of the four chemicals or chemical groups that were identified as COCs, two were identified as risk drivers (arsenic and cPAHs [TEQ]).

COCs not selected as risk drivers will be included in the post-remedial monitoring program.

6.2 Baseline Ecological Risk Assessment

The baseline ERA (Windward, 2012a) estimated risks for ecological receptors in the EW that may be exposed to contaminants in sediment, surface water, porewater, and prey items.

Nine receptors of concern were selected in the baseline ERA to be representative of groups of organisms in the EW with the same exposure pathways and that will be protective or representative of other species that were not explicitly evaluated (Table B-17). These receptors of concern included the benthic invertebrate community; Dungeness crab; English sole, brown rockfish, and juvenile Chinook salmon (collectively discussed as “fish”); and pigeon guillemot, osprey, river otter, and harbor seal (collectively discussed as “wildlife species”).

A conservative risk-based screening process first identified COPCs for the ERA, which included a comparison of maximum contaminant concentrations with established criteria or literature-based toxicity reference values (TRVs; Windward, 2012a). In this process, contaminant concentrations in sediment, surface water, porewater, and aquatic biota were compared to risk-based screening levels. Those contaminants present at concentrations above the screening levels or demonstrating the potential for unacceptable effects were identified as COPCs and underwent further risk analysis in the ERA as follows:

- Benthic community:
    - Comparison of COPC concentrations in sediment with the numerical criteria of the Washington State SMS;
    - Site-specific sediment toxicity tests and comparison with numerical criteria of the Washington State SMS;
    - Comparison of VOC concentrations in porewater to aquatic toxicity data

  - Comparison of PCB, mercury, and TBT concentrations in benthic invertebrate tissues to concentrations associated with adverse effects; and,
  - Comparison of COPC concentrations in surface water to marine water quality criteria (WQC).
- Fish and crab:
  - Comparison of COPC concentrations in fish and crab tissue with tissue residues associated with effects on survival, growth, or reproduction;
  - Comparison of COPC concentrations in surface water to marine WQC;
  - Comparing COPC concentrations in fish diets (based on prey and sediment concentrations, or stomach content concentrations) to dietary concentrations that have been shown to cause adverse effects on survival, growth, or reproduction.
- Wildlife:
  - Comparison of daily doses of COPCs derived from the ingestion of sediment, water, and prey species with doses that have been shown to cause adverse effects on survival, growth, or reproduction.

Risks based on surface water, porewater, tissue, and dietary exposure were estimated by comparing COPC concentrations in the media of concern to WQC or TRVs, including no observed adverse effect levels (NOAELs) and lowest observed adverse effect levels (LOAELs). Risks were estimated by calculating HQs as the ratio of the COPC concentrations in the media of concern to the toxicity value as represented by SMS, WQC, or selected NOAELs and LOAELs.

6.2.1.1 Risks to Benthic Invertebrate Community

Contaminant concentrations in surface sediments were compared to the SQS and the CSL numerical chemical values of the SMS. Concentrations of total dichlorodiphenyltrichloroethane (DDT) in surface sediment were compared with Washington State Dredged Material Management Program (DMMP) screening levels because SMS values were not available for total DDT. A contaminant was selected as a COC if its concentration was found to be above the lower SQS criteria (or above the DMMP guidelines in the case of total DDT) in one or more sediment samples from the EW. Thirty contaminants were identified as COCs for the benthic invertebrate community based on surface sediment data (Table B-18).

SMS criteria were exceeded in approximately 61% (96 acres) of the EW study area (Figure B-27). Contaminant concentrations in surface sediments from the remaining 39% of the EW (61 acres) were below the SMS criteria and were considered unlikely to have adverse effects on the benthic invertebrate community. Of those areas exceeding the SMS criteria, approximately 23% (36 acres) of the EW exceeded the higher CSL criteria, indicating a higher likelihood for minor adverse effects. Approximately 59 acres (38% of the EW) had contaminant concentrations or

biological effects that exceeded the SQS but not the CSL representing a potential for minor adverse effects in these areas.

VOCs in sediment porewater were considered unlikely to pose a risk to the benthic invertebrate community, except for naphthalene, which had a concentration that exceeded toxicity data representing the lowest observed effect concentration at one location. Naphthalene was selected as a COC for the benthic invertebrate community based on porewater exposure.

The potential for adverse effects from exposure to TBT was identified for benthic invertebrates in 2 of the 12 benthic invertebrate tissue sampling areas because the LOAEL TRV for TBT was exceeded in samples collected from those areas. Mercury and PCBs were considered unlikely to pose a risk to the benthic invertebrate community based on concentrations in tissue. TBT was selected as a COC based on concentrations in benthic invertebrate tissue.

6.2.1.2 Crabs, Fish, and Wildlife Species

COCs were identified for crabs, fish, and wildlife species where LOAEL-based HQs were greater than or equal to 1. In addition, COCs were defined for crabs and fish if exposure concentrations in surface water exceeded chronic WQC or TRVs. Cadmium, copper, and zinc were identified as COCs for crabs based on the tissue residues evaluation, indicating the potential for adverse effects. The tissue residue evaluation for fish resulted in the identification of TBT as a COC for brown rockfish and total PCBs as COCs for English sole and brown rockfish.

Cadmium was identified as a COC for juvenile Chinook salmon, English sole, and brown rockfish based on the dietary exposure evaluation. In addition, the potential for adverse effects was identified for English sole from exposure to copper and vanadium in the diet.

No COCs were identified for fish or crabs based on the surface water evaluation, or for wildlife based on the dietary exposure evaluation.

6.2.2 Selection of Risk Driver COCs for Ecological Receptors

A subset of the COCs was identified as risk drivers for ecological receptors based on: 1) the uncertainty in risk estimates based on quantity and quality of exposure and effects data, 2) magnitude of exposure concentrations compared to TRVs, and 3) comparison of concentrations in EW sediment with PSAMP rural Puget Sound background concentrations in sediment in accordance with EPA (1992, 1997a, 1997b, 1998) guidance. The selected risk drivers and the associated rationale for identifying these risk driver COCs is summarized in Tables B-19 and B-20.

A total of 30 contaminants were selected as COCs for benthic invertebrates. Of 30 COCs identified in the screening-level assessment, 29 contaminants were selected as risk drivers for benthic invertebrates because they had concentrations greater than the SQS in at least one sediment sample. SMS is the Washington State law governing sediment remediation in the State of Washington, has promulgated chemical specific threshold values, and is an ARAR for this site. The remaining COC, total DDTs, was not selected as a risk driver because of the low

detection frequency, known analytical uncertainties from PCB interference, and uncertainties in the effects data.

TBT was identified as a risk driver for the benthic invertebrate community for the tissue evaluation because of two LOAEL-based HQs greater than 1 and low uncertainty in the exposure data.

Total PCBs were selected as a risk driver for English sole and brown rockfish because PCBs in tissue residues exceeded the higher LOAEL TRV that was associated with significant effects and uncertainties are low in the exposure assumptions data. Non-risk driver COCs are evaluated to during monitoring to assess the potential for risk reduction following remedial actions.

7 Remedial Action Objectives and Preliminary Remediation Goals

Based on CERCLA and MTCA/SMS requirements, four RAOs were formulated for the cleanup of EW sediments. The RAOs describe what the sediment cleanup actions in the EW should accomplish to address the risks identified in the human health and ecological risk assessments.

The RAOs for the EW are:

- RAO 1: Reduce risks associated with the consumption of contaminated resident EW fish and shellfish by adults and children with the highest potential exposure to protect human health.
- RAO 2: Reduce risks from direct contact (skin contact and incidental ingestion) to contaminated sediments during netfishing and clamming to protect human health.
- RAO 3: Reduce to protective levels risks to benthic invertebrates from exposure to contaminated sediments.
- RAO 4: Reduce to protective levels risks to crabs and fish from exposure to contaminated sediment, surface water, and prey.

PRGs were developed in the FS for each RAO and are described below by RAO. PRGs are intended to protect human health and the environment and to comply with ARARs for specific contaminants (EPA, 1991b).

PRGs were developed based on consideration of the following factors:

- ARARs, including SMS cleanup level development requirements;
- RBTCs based on the human health and ecological risk assessments;
- Background concentrations if protective RBTCs are below background concentrations; and,
- Analytical PQLs if protective RBTCs are below concentrations that can be quantified by chemical analysis and a suitable background concentration is unavailable.

For the EW, PRGs are numerical concentrations or ranges of concentrations in sediment that protect a particular receptor from exposure to a risk driver COC by a specific pathway. The PRGs are expressed as sediment concentrations for the identified risk driver COCs because the alternatives in the FS address cleanup of contaminated sediments. Although ARARs were identified in the FS for surface water, PRGs are not developed for surface water because actions to directly address water quality are not included among the proposed remedy alternatives. The PRGs for the EW are summarized in Table B-21.

7.1 Applicable or Relevant and Appropriate Requirements (ARARs) and the Role of Background

Table B-22 lists and summarizes ARARs identified for the EW. Some ARARs prescribe minimum numerical requirements or standards for specific media such as sediment, surface water, and groundwater. Other ARARs place requirements or limitations on actions that may be undertaken as part of a remedy. ARARs are described further is Section 12.

Washington State has enacted environmental laws and promulgated regulations to implement or co-implement several major federal laws through federally approved programs, such as the Clean Water Act, Clean Air Act, and RCRA. Washington's state cleanup law, MTCA, is an ARAR for the EW, and sediment sites under MTCA are regulated by SMS, which promulgates methods for developing and complying with cleanup levels. The PRGs are developed to comply with SMS.

Promulgated MTCA cleanup standards that are more stringent than CERCLA standards are ARARs under CERCLA. MTCA requires that cleanup levels be set at a cumulative cancer risk level of 1×10^{-5} and a HI of 1, and at an individual contaminant risk of 1×10^{-6} (and HI of 1). MTCA provides that for final cleanup actions, cleanup levels cannot be set at concentrations lower than natural background when risk-based threshold concentrations are below natural background (see WAC 173-340-705(4)-(6) among other sections).

WAC 173-340-200 defines "natural background" as the concentrations of hazardous substances consistently present in an environment that has not been influenced by localized human activities. This definition includes substances such as metals that naturally occur in bedrock, soils, and sediments due solely to geologic processes, and low concentrations of some particularly persistent organic compounds such as PCBs that can be found in surficial soil and sediments throughout much of the state due to global distribution of these hazardous substances.

PRGs were based on natural background concentrations if RBTCs were below (or anticipated to be below) natural background. This applies to total PCBs and dioxins/furans for the human seafood consumption scenario, and arsenic for the direct contact scenarios. Estimates of natural background were developed using the 95% upper confidence limit (95UCL) of the 2008 EPA Puget Sound Oceanographic Survey Vessel (OSV) *Bold* survey dataset (EPA *OSV Bold* survey; EPA, 2008).

CERCLA Section 121(d)(2)(A)(ii) makes nationally recommended water quality criteria generally relevant and appropriate requirements for CERCLA site remedial actions. Consequently, the more stringent of the recommended federal marine WQC and the state marine WQC are ARARs for the site.

7.2 RAO 1

RAO 1 is to reduce risks associated with the consumption of contaminated resident EW fish and shellfish by adults and children with the highest potential exposure to protect human health.

The lifetime excess cancer risks from human consumption of resident EW seafood are estimated to be greater than 1 x 10^{-5} for some individual carcinogens, and greater than 1 x 10^{-4} for carcinogens cumulatively under RME seafood consumption scenarios. In addition, the estimated non-cancer risks exceed an HI of 1. These estimated risks warrant response actions to reduce exposure.

Achieving RAO 1 requires that site-wide average concentrations of COCs in sediment or bioavailability be reduced, which, in conjunction with source control, is expected to reduce COC concentrations in water and fish and shellfish tissue. Exposure of fish and shellfish to COCs in sediment occurs within the biologically active zone, which is estimated to be the upper 10 cm of sediment. Therefore, the top 10 cm of sediment is the point of compliance for this RAO. Deeper, undisturbed sediments contribute negligibly to the risks addressed by this RAO if contaminants in these deeper sediments do not migrate into or are exposed to the biologically active zone. However, shallow subsurface contamination were incorporated into the biologically active zone due to vessel scour in some areas in order to achieve this RAO.

7.2.1 Tissue RBTCs for RME seafood consumption scenarios

Tissue RBTCs associated with the three RME seafood consumption scenarios were calculated for all three risk driver COCs (i.e., total PCBs, cPAHs, and dioxins/furans) for the three excess cancer risk levels, and for total PCBs and dioxin/furan TEQ for a non-cancer HQ of 1 (Table B-23). Tissue RBTCs associated with human seafood consumption scenarios were calculated using the risk equations in the baseline HHRA. To derive the tissue RBTCs, these equations were solved for the concentration in seafood for a given target risk level using scenario-specific parameters (e.g., ingestion rates, body weights). The tissue RBTCs for the adult tribal RME scenario based on Tulalip data were the lowest of all the RME scenarios for a given risk threshold for each risk driver COC.

7.2.2 Sediment RBTCs for RME seafood consumption scenarios

Sediment RBTCs for the human health seafood consumption exposure scenarios represent the sediment concentrations at which tissue concentrations equate to the targeted risk level. Thus, these RBTCs require developing a relationship between concentrations in sediment and tissue, as described below for each risk driver COC.

7.2.2.1 Total PCB sediment RBTCs

A food web model (FWM) calibrated for the EW was used to estimate the relationship between sediment and tissue concentrations for total PCBs, and to calculate sediment RBTCs. The model is described in Section 4.3. A range of RBTCs was calculated for each seafood exposure scenario using best estimate, upper bound, and lower bound parameter sets in the FWM. Sediment RBTCs for PCBs at the 1×10^{-6} and 1×10^{-5} excess cancer risk levels and non-cancer risk of HQ = 1 for the tribal RME (adult and child) scenario could not be calculated because the contribution of total PCBs from water alone was high enough to result in excess cancer risks or non-cancer risk above those risk levels even in the absence of any contribution from sediment. At the 1 ×

10^{-4} excess cancer risk level, sediment RBTCs for total PCBs ranged from 2 to 250 µg/kg dw for the three RME scenarios (Table B-24). These sediment RBTCs for total PCBs are lower than the current SWAC of total PCBs in the EW (approximately 470 µg/kg dw).

7.2.2.2 Dioxin/furan sediment RBTCs

Dioxin/furan sediment RBTCs were developed using site-specific biota-sediment accumulation factors (BSAFs) for four species (English sole, brown rockfish, shiner surfperch, and crab), which were based on empirical data collected from the EW. BSAF values were calculated for a subset of four individual dioxin/furan congeners that were selected because they were the congeners that had the greatest contributions to the dioxin/furan TEQ values in tissues. The main assumptions required for these calculations were the relative ingestion rates for the various items in the market basket diet and the relative tissue contaminant concentrations among the food items. At the 1×10^{-6} target risk level, the sediment RBTCs for the RME scenarios were less than 1 ng TEQ/kg dw (Table B-24). At the 1×10^{-4} target risk level, sediment RBTCs for dioxin/furan TEQ ranged from 18 to 94 ng TEQ/kg dw for the three RME scenarios.

7.2.2.3 cPAH sediment RBTCs

For cPAHs, 73% to 90% of the risk associated with seafood consumption for the RME scenarios is attributable to the consumption of clams. Because of the importance of clam consumption in the cPAH TEQ risk estimate, the clam tissue-to-sediment relationship was evaluated to assess the potential for calculating sediment RBTCs. As discussed in the SRI, the clam tissue-to-sediment relationship for cPAHs in the EW is too uncertain to develop a sediment RBTC based on clam consumption. Long-term clam tissue monitoring following sediment remediation and source control will be needed to determine whether (and to what extent) decreases in cPAH concentrations in sediment result in decreases in cPAH concentrations in clam tissue.

7.2.3 Sediment PRGs for RAO 1

PRGs that address RAO 1 and the basis for the selected values are shown in Table B-25. Numerical PRGs for total PCBs and dioxins/furans are set to natural background because the sediment RBTCs for the RME seafood consumption scenarios are below natural background. Although cPAHs were a risk driver for seafood consumption, a PRG for cPAH was not identified for RAO 1. Excess cancer risks for cPAHs were largely attributable to the consumption of clams. Based on data collected during the SRI, there is not a significant relationship between cPAH concentrations in sediment and concentrations in clam tissue. Meeting the PRGs for the other COCs defined in Tables B-25 and B-26 will lead to reductions in sediment concentrations of cPAHs.

Model results project that no alternative will meet these PRGs, so institutional controls (e.g., seafood consumption advisories, likely enhanced by public outreach and education programs) will be needed to meet the threshold criterion of protectiveness.

Sediment RBTCs for the human health seafood consumption exposure scenarios represent the sediment concentrations at which tissue concentrations equate to the target risk level. These

RBTCs require developing a relationship between concentrations in sediment and tissue, as described below.

7.3 RAO 2

RAO 2 is to reduce risks from direct contact (skin contact and incidental ingestion) to contaminated sediments during netfishing and clamming to protect human health.

Lifetime excess cancer risk from human direct contact during these RME scenarios are estimated to be within EPA's 10^{-4} to 10^{-6} target risk range for the individual risk driver COCs. Some individual excess cancer risks exceed 1×10^{-5}, and total risks from all risk driver COCs exceed 1×10^{-5}, both which are SMS thresholds. Therefore, risks associated with these exposure pathways warrant response actions to reduce exposure.

Achieving RAO 2 requires that average concentrations of COCs be reduced at locations and depths within the sediment where people have the potential to be exposed. For netfishing activities, exposure is over the entire EW and to surface sediment biologically active zone (0 to 10 cm). Direct contact risks in the clamming areas are assumed to result from exposure to the upper 25 cm depth interval, which accounts for potential exposures to clammers who may dig holes deeper than 10 cm. The exposure area for the RME clamming scenario included all intertidal areas where clams could occur because such areas are potentially accessible either from a boat or from shore. Institutional controls, such as harvesting advisories, public outreach, and education may be necessary to further reduce risk, depending on the potential human health risks following remediation.

7.3.1 Netfishing and Tribal Clamming RBTCs

Sediment RBTCs were calculated for two RME direct sediment exposure scenarios evaluated in the HHRA, which consisted of tribal netfishing and tribal clamming. RBTCs were not estimated for non-cancer hazards for direct-contact scenarios because none of the RME scenarios had HQs for an individual chemical greater than 1 or generated endpoint-specific HIs in excess of 1.

7.3.2 PRGs for RAO 2

For RAO 2, PRGs are based on the sediment RBTCs (1×10^{-6} excess cancer risk threshold) or background, whichever is higher. These PRGs are presented in Table B-25. RBTCs were developed for two exposure scenarios: netfishing and tribal clamming direct contact (which includes both dermal contact and incidental ingestion) with sediment. PRGs are applied on a spatially-weighted average basis over a given exposure area (e.g., site-wide for the netfishing PRG and over clamming areas for the tribal clamming PRG). The PRGs for the cPAHs are based on their RBTCs. The arsenic PRG for RAO 2 is based on natural background because the RBTCs at 1×10^{-6} excess cancer risk threshold are below this value.

7.4 RAO 3

RAO 3 is to reduce to protective levels risks to benthic invertebrates from exposure to contaminated sediments.

The 29 contaminants identified in the ERA with concentrations in EW surface sediment exceeding SQS criteria are COCs because they pose a risk to the benthic invertebrate community. These 29 COCs are designated risk drivers for this pathway.

Benthic organisms reside primarily in the biologically active zone (uppermost 10 cm) of intertidal and subtidal sediments of the EW, therefore this is the point of compliance for RAO 3. Deeper sediments in areas subject to disturbance (e.g., from erosion, propeller scour, and earthquakes) that contain COCs at concentrations above the SQS may warrant response actions to maintain compliance in the biologically active zone.

7.4.1 Sediment RBTC for TBT

A sediment RBTC for TBT for the protection of the benthic invertebrate community was calculated using a BSAF developed using benthic invertebrate tissue and co-located sediment TBT and TOC concentrations from the EW. The sediment RBTC for TBT is 7.5 mg/kg OC.

7.4.2 PRG for TBT

For RAO 3, the SMS numerical criteria for the protection of benthic organisms apply on a point-by-point basis (Table B-25). WAC 173-204-570(4) specifies that the site-specific cleanup standards shall be as close as practicable to the sediment cleanup objective (SCO), but in no case shall exceed the minimum cleanup level (the CSL). For this reason, the PRGs for RAO 3 are set to the SQS (same as the benthic SCO). However, where co-located toxicity test data are available, sediment toxicity results override the numerical criteria for RAO 3. A PRG for TBT is also established for RAO 3 based on the sediment RBTC (Table B-23).

7.5 RAO 4

RAO 4 is to reduce to protective levels risks to crabs and fish from exposure to contaminated sediment, surface water and prey.

Total PCBs were identified as a risk driver COC for English sole and brown rockfish because PCBs in fish tissue exceeded the two LOAEL TRVs associated with adverse effects. Three COCs (cadmium, copper, and zinc) were identified for crab but not determined to be risk driver COCs. No adverse effects are expected for birds or mammals because no contaminants of potential concern have concentrations exceeding the relevant threshold concentrations, and thus there are no COCs for these receptors. Thus, achievement of RAO 4 is based on addressing PCB risks to fish.

Fish are indirectly exposed to PCBs in sediment primarily through the consumption of prey. Therefore, reductions in site-wide average concentrations of PCBs in sediment through remedial action should reduce PCB concentrations in fish. The potential for exposure of prey to

COCs occurs primarily within the biologically active zone (upper 10 cm of sediment). Deeper sediments, if left undisturbed, contribute negligibly to the risks addressed by this RAO. Deeper sediments in areas subject to disturbance (e.g., from erosion, propeller scour, and earthquakes) that contain COCs at concentrations above an action level designed to achieve the RAO 4 PRGs may warrant response actions to maintain compliance in the biologically active zone.

Expected improvements to surface water quality will be achieved through remediation of site sediments; no active remediation of surface water is anticipated. Remediation will reduce COC concentrations in the EW sediments; this in turn should also reduce those same COC concentrations in surface water, thereby contributing to a reduction of their concentrations in fish tissue (including prey species). The relationships between sediment, surface water, and tissue concentrations are complex, and will be assessed through long-term monitoring following completion of the remedial actions.

7.5.1 RBTCs for protection of fish

Sediment RBTCs for fish were derived using the calibrated FWM for the EW, based on the tissue TRVs that were evaluated in the ERA (Windward, 2012a). The sediment RBTC values calculated by the FWM ranged from 39 to greater than 470 µg/kg wet weight (ww), depending on the tissue RBTC and species (FS Table 3-9). Sediment RBTCs of greater than 470 µg/kg dw indicate that even under current conditions in the EW, average tissue concentrations are estimated to be less than the tissue RBTC. This is consistent with the fact that average tissue concentrations in both species are less than the tissue TRV of 2,640 µg/kg ww. Only 4 out of the 15 individual rockfish samples and 7 out of 13 English sole whole-body composite tissue samples exceeded the tissue TRV of 2,640 µg/kg ww.

7.5.2 PRGs for RAO 4

For RAO 4, PRGs for total PCBs for the protection of fish are based on RBTCs. The selected PRGs are shown in Table B-26.

8 Description of Alternatives

A total of nine alternatives were developed for evaluation, in addition to the no action alternative. Key variables used for developing remedial alternatives are the remedial technologies and the RALs.

8.1 Remedial Technologies

Representative remedial technologies were evaluated following a screening process that was consistent with EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA, 1988). The screening process is detailed in two screening memos: the *East Waterway Remedial Alternative and Disposal Site Screening Memorandum*; AnchorQEA, 2012) and the screening memorandum prepared for the LDW (AECOM, 2012). The technologies considered included active remedial technologies such as removal, partial removal and capping, ENR-nav (with partial removal as necessary), ENR-sill, and in situ treatment, as well as passive remedial technologies such as MNR, site-wide monitoring, and institutional controls.

The screening process involved the following steps:

- Listing all of the candidate remedial technologies and process options available for evaluation and screening for applicability;
- Summarizing the general site conditions affecting remedial technology selection;
- Developing construction management areas (CMAs) based on site restrictions that affect the selection of applicable remedial technologies;
- Integration of critical site constraints with retained remedial technologies to show where each retained technology is applicable within a particular area; and,
- Determining which technologies are carried forward in the alternatives.

Remedial technologies for the open-water and underpier areas were considered separately due to the distinct engineering and access challenges presented by the underpier areas.

8.1.1 Construction Management Areas (CMAs)

As a functioning industrial waterway, shoreline structures such as pile-supported piers, bridges and riprap slopes exist on nearly all shorelines in the EW. Sediments with COCs above RALs are located under and adjacent to these structures in many areas of the EW, which restricts the technical and economic feasibility of implementing specific technologies and process options. Specific factors that may restrict the implementability include site access (e.g., feasibility of staging from upland facilities, homeland security issues within Pier 36); physical obstructions and structural conditions such as piers, bridge structures, or partially demolished aquatic structures; water depths (i.e., site bathymetric conditions); and navigation and other site use considerations. Based on these factors, the EW was divided into specific CMAs that represent areas with similar structural conditions, or similar aquatic use, habitat, or water depth conditions. These CMAs are shown on Figure B-28 and defined in Table B-27.

The CMAs are grouped into "open-water," which are areas with relatively unrestricted access for remediation, and "limited access areas," which are areas that are difficult to access with typical remediation equipment, and include both the underpier areas and the low bridge areas of the Sill Reach (see Figure B-29). The open-water and limited access area remedial technologies are discussed below. Removal forms the basis of all action alternatives due to sediment elevation constraints for navigation and high forces from propwash in the Deep Main Body Reach and berthing areas of the waterway. Removal and partial removal are performed on between 60% to 70% of the site (and 80% to 99% of the remediation area) for all action alternatives.

Several key considerations that are common to all areas:

- For planning purposes, the FS assumed that suitable land will be available in the vicinity of the EW for staging and support activities. Specific staging areas have not been identified, and only rough assumptions have been made about specific staging area requirements.
- The FS assumed that most dolphins, piles, and in-water structures will remain in place during remediation. Derelict piling and piers may be removed during remediation as determined during remedial design. Piles in removal areas will be extracted before dredging or removed during dredging. Piles in partial dredging and capping areas may be fully removed or partially removed and covered with an engineered cap as determined in design.
- The FS assumes that transloading would occur at a nearby EPA-approved facility, or that a transloading facility would be constructed in the vicinity of the EW. The FS assumed that contaminated sediment would be barged to a nearby existing or newly constructed transloading facility and sent by rail to permitted Subtitle D landfill; no additional transportation is assumed to occur at the landfill facility.
- For mechanical dredging, this FS assumes that dredged sediment will initially be dewatered on the dredge scows with water discharged back to the EW within the dredging area after appropriate on-board processing. It is assumed that the dredge scows will be equipped with appropriate BMPs (e.g., hay bales, weir systems, and filtration) to filter runoff as necessary to maintain compliance with applicable water quality criteria established for the dredging operations.
- For underpier diver-assisted hydraulic dredging, this FS assumes that water management will be performed by constructing a water treatment system on a barge. The water treatment system would consist of a series of tanks and filters to treat dewatered liquid and contaminants from dredged material. Clean water would be discharged back into the waterway.
- The predicted sea level rise in the vicinity of the EW is approximately 4 to 56 inches over the next century, with a mean projection of 24 inches (NRC, 2012). Sea level rise would result in a corresponding shift in the elevations that define intertidal

habitat and regulatory boundaries. Further, the design of engineered shoreline infrastructure (e.g., shoreline caps) may need to address the long-term effects of sea level rise. Sea level may factor into certain remedial design elements in intertidal areas, but will likely impact all alternatives equally.

- The general approach for estimating removal volume was to estimate the thickness of sediment above the appropriate RAL set at every core location to establish an estimated neatline for the dredge prism for each RAL set (Figure B-30). The neatline volume was calculated in CAD by multiplying neatline dredge depth by area for removal areas. Total removal volumes were then estimated by multiplying the neatline volume by a constructability factor of 1.5 (in most areas) to include provisions for stable dredge cut side slopes, allowable overdepth, slumping of sediments between dredge units, and missed inventory (Palermo 2009).
- The neatline volume of contaminated sediment was estimated by interpolating with a triangular irregular network (TIN) based on the contaminated thickness of the appropriate RAL set at the location of each core in CAD. Further refinement of the TIN will be completed during remedial design to develop the dredge prism.
- In the Mound Area, Slip 27 Head and Shoreline, and the Coast Guard Nearshore CMAs (Figure B-28), the dredging depth was assumed to be 5 feet for the FS (plus the constructability factor of 1.5 to account for overdredging, etc.), to accommodate a 5-foot cap while restoring the surface elevations to the existing grade.
- Residuals management cover (RMC) was assumed to be applied as a 9-inch average thickness over all open-water dredging areas plus the interior unremediated areas.
- Backfill to original grade was assumed to be applied to all open-water dredging areas shallower than -10 feet MLLW, and to the Communication Cable Crossing. The backfill volume was assumed to equal the dredging volume in these areas.
- Capping was assumed to be a total of 5 feet thick in all locations, consisting of a 2.5-foot isolation layer, a 1.0-foot filter layer, and a 1.5-foot armor layer. This is a reasonable capping thickness to be assumed site-wide, based on propwash modeling and contaminant transport modeling; however, the cap thickness may be refined during remedial design, based on location–specific conditions.
- ENR in the Sill Reach outside of navigation and berthing areas (ENR-sill) was assumed to be applied as a 9-inch average thickness of sand, similar to RMC.
- ENR inside of navigation and berthing areas (ENR-nav) was assumed to be applied as an 18-inch average thickness of sand.
- In situ treatment was assumed to be applied in underpier areas in a 3-inch thickness (consistent with the Bremerton pilot study), with an appropriate percent of AC (between 2% and 5%) to mix into the bioturbation zone, as determined during

remedial design. A 70% reduction in PCB availability was assumed for AC in the underpier areas.

- The Elliott Bay in-water construction window that formally applies in the EW is July 16 to February 15 (USACE, 2017). However, an in-water construction window of October 1 to February 15 avoids conflicts with tribal netfishing, potential adverse effects to migrating salmon, and for consistency with commonly accepted construction window of upstream waters. The FS conservatively estimates that the total number of construction days for a typical construction season is 100 days/season. It may be feasible that permitting and tribal coordination will allow for a longer construction window (as large as July 16 to February 15; 150 days). A longer construction window would require consultations with the Muckleshoot Indian Tribe and Suquamish Tribe (Section 13).

8.1.1.1 Open-Water Remedial Technologies

The open-water CMAs were combined into four groups (Navigation Channel and Berth Areas, Shallow Main Body, Nearshore, and West Seattle Bridge) based on similar structural, waterway use, habitat, and water depth conditions, which result in a different set of potentially applicable remedial technologies. Based on the retained remedial technologies within these groups of CMAs, three technology options are presented to form the basis of the remedial alternatives. The technology options are ordered from the smallest to the largest removal area (all technology options rely primarily on removal due to the navigation depth requirements in the EW). Table B-28 presents the three open-water technology options (1 through 3) retained in the four open-water CMA groups.

8.1.1.2 Limited Access Area Remedial Technologies

The limited access areas include the underpier CMAs and the two low bridge CMAs in the Sill Reach. These CMAs were divided into two limited access CMA groups based on similar structural, waterway use, habitat, and water depth conditions. Limited access areas present particular challenges for remediation and, as such, have fewer technology options than open-water CMAs. Based on the retained remedial technologies within these CMA groups, four technology options, which are referred to as “limited access area technology options” for simplicity, are presented to form the basis of the remedial alternatives. Note that the non-sequential lettering of these options (e.g., no option D) is due to some options being screened out. Table B-29 presents the four technology options for the two limited access area CMA groups.

8.2 Remedial Action Levels

RALs, the point-based concentrations above which sediment is remediated, were the second key variable in the alternative assembly. Table B-30 present the RALs; alternatives with two different PCB RALs (12 and 7.5 mg/kg OC) were carried forward into Section 8 to provide a range of remediation footprints for the detailed analysis and comparison of alternatives.

RALs were developed in a stepwise manner, with each RAL resulting in additional area requiring remediation. The remediation area was first developed based on the protection of benthic invertebrates (RAO 3) because RALs based on RAO 3 risk drivers (including PCBs and arsenic) generate the majority of the remediation area. These RALs were based on SMS benthic numerical criteria (these are the RBTCs for benthic community) and the TBT RBTC. Next, additional remediation areas were added based on RALs for total PCBs and dioxins/furans, because these RALs add the second largest remediation area. Next, a small remediation area was added based on RALs for cPAHs.

RAO 3: The area requiring remediation includes locations with detected concentrations of the benthic community risk drivers above the SQS (RALs are equal to the RAO 3 PRGs). Toxicity test results were included in the final classifications with passing toxicity results trumping the chemistry results. RALs were developed for a subset of these risk drivers (referred to as indicator SMS chemicals). These indicator SMS chemicals consist of 1,4-dichlorobenzene, acenaphthene, arsenic, butyl benzyl phthalate, fluoranthene, fluorene, mercury, phenanthrene, and total PCBs. RALs were also developed for TBT based on the PRG.

RAO 1: RALs were developed to reduce sitewide SWACs for PCBs and dioxins/furans. For total PCBs, a "hilltopping" evaluation was conducted to select the screening RALs by ranking the measured surface and shallow subsurface sediment PCB concentrations from highest to lowest. The highest values were sequentially replaced with a post-remedy bed sediment replacement value to estimate the site-wide SWAC after each of the values (and associated estimated remediation area) was removed from the dataset. The hill-topping results shown on Figure B-31 informed the selection of the three screening RALs for total PCBs: 12 mg/kg OC (equivalent to 192 µg/kg dw), 7.5 mg/kg OC (equivalent to 120 µg/kg dw), and 5.0 mg/kg OC (equivalent to 80 µg/kg dw). As shown in Figure B-31, each of these screening RALs is below the "knee of the curve," or the point at which further reductions in the RAL does not result in an appreciable reduction in the site-wide SWAC.

A dioxin/furan RAL of 25 ng TEQ/kg dw was selected for consistency with the LDW ROD (EPA, 2014) and to achieve the lowest achievable concentrations in the EW.

RAO-2: Achievement of RAO 2 is assessed on two spatial scales using two direct contact exposure scenarios: 1) site-wide for tribal netfishing; and 2) area-wide within existing and potential future clamming areas based on tribal clamming. Achieving the clamming PRG for RAO 2 requires that average sediment COC concentrations be reduced at locations and depths where people that are clamming have the potential to be exposed to sediment. Direct contact risks in the exposed intertidal areas (e.g., sediment areas not under pier) are assumed to result from exposusre to the upper 25-cm depth interval. Arsenic and cPAHs are the risk driver COCs for direct contact.

For arsenic, the same RAL (57 mg/kg dw applied site-wide) that achieves RAO 3 also achieves RAO 2; it provides overall reductions in sediment concentrations that achieve both the netfishing and clamming PRGs.

For cPAHs, RALs are based on the concentration that achieves the PRGs for site-wide for netfishing (4,800 µg TEQ/kg dw applied to all sediment areas) and area-wide within potential clamming areas (660 µg TEQ/kg dw applied to exposed intertidal potential clamming areas).

RAO-4: For RAO 4, total PCBs is the only risk driver. Achievement of the PRG is assessed on a sitewide basis. Both the total PCB RALs of 7.5 mg/kg OC and 12 mg/kg OC are predicted to achieve RAO 4 immediately after construction, so no additional areas have been added based on this RAO.

8.3 Summary of Alternatives

Ten alternatives were chosen for detailed and comparative analysis, including the No Action alternative and nine Action alternatives. Table B-31 provides a key for the naming of the alternatives and Table B-32 summarizes remedial technologies by alternative and CMA. Note that RALs are the same in all alternatives except for total PCBs. The PCB RAL is noted in the alternative names in parenthesis.

This range in alternatives provides a range in characteristics (areas, volumes, costs, effectiveness, etc.) so that the alternatives can be compared in Section 9. The technology assignment areas, volumes, and costs for each alternative are described in the following sections.

8.3.1 No Action Alternative

This alternative assumes that no remedial actions will occur. The No Action alternative is required as part of the CERCLA FS evaluation process. It is considered a natural recovery alternative, and the only activity for this alternative is site-wide monitoring. "Natural recovery" is distinct from "monitored natural recovery (MNR)" in this context. MNR includes targeted location-specific monitoring, target concentrations, and contingency actions if target concentrations are not achieved. Natural recovery includes site-wide monitoring only, with no target concentrations or contingency actions if target concentrations are not met.

The No Action alternative includes past remedial actions that have been performed in the water such as the NTCRA performed in 2005; however, costs for these actions are not included in the cost estimate for the No Action alternative. The FS baseline dataset represents post-NTCRA conditions (i.e., data from dredged areas has been removed as appropriate).

8.3.2 Alternative 1A(12)

Alternative 1A(12) is based on <u>open-water option 1</u>: removal with capping and ENR-nav where applicable; <u>limited access option A</u>: MNR; and the RAL set including 12 mg/kg oc for PCBs.

The detailed remediation areas and technology assignments are presented in Table B-33 and Figure B-32. Like all the action alternatives, Alternative 1A(12) is removal focused, with removal over 80% of the remediation area (62% of the EW). In comparison with the other action alternatives, Alternative 1A(12) relies the most on natural recovery by using MNR in limited

access areas and ENR in the Deep Main Body and the Sill Reach. Alternative 1A(12) also employs capping where practicable in the Shallow Main Body.

Alternative 1A(12) includes the following combination of remedial technologies:

- Open-water Option 1 (Table B-31):
  - **Navigation Channel and Berth Area:** Removal, ENR-nav, or partial removal and ENR-nav. The Communication Cable Crossing includes removal to the extent practicable and backfill instead of removal to RAL exceedances to protect the structure.
  - **Shallow Main Body Reach**: Removal or partial removal and capping.
  - **Nearshore:** Partial removal and cap.
  - **West Seattle Bridge:** ENR-sill.
- Limited Access Option A (Table B-31):
  - **Underpier areas:** MNR.
  - **Sill Reach – Low Bridges**: ENR-sill in intertidal areas and MNR in subtidal areas.

Table B-33 shows the total remedial areas and the estimated volumes, costs, and construction timeframes for all of the alternatives. Alternative 1A(12) includes 97 acres of removal (including 77 acres of removal, 13 acres of partial removal and capping, 7 acres of partial removal and ENR-nav), 2 acres of ENR-sill, 9 acres of ENR-nav, and 13 acres of MNR in underpier and low bridge areas. The total removal volume is estimated at 810,000 cy and the total placement volume (capping, ENR, RMC layer, and backfill) is 290,000 cy. The alternative will take approximately 9 years to construct (eight seasons of dredging), at a cost of approximately $256 million.

8.3.3 Alternative 1B(12)

Alternative 1B(12) is based on open-water option 1: removal with capping and ENR-nav where applicable; limited access option B: in situ treatment; and the RAL set including 12 mg/kg oc for PCBs. The detailed remediation areas and technology assignments are presented in Table B-32 and Figure B-33. Like Alternative 1A(12), Alternative 1B(12) is removal focused, with removal over 80% of the remediation area (62% of the EW). Alternative 1B(12) is the same as Alternative 1A(12), except that it replaces MNR with in situ treatment as a remedial technology in underpier areas.

Alternative 1B(12) includes the following combination of remedial technologies:

- **Open-water Option 1 (**Table B-31**):** As described for Alternative 1A(12), above.
- Limited Access Option B (Table B-31):
  - **Underpier areas**: In situ treatment.

- Sill Reach – Low Bridges: ENR-sill

Alternative 1B(12) includes 97 acres of removal (77 acres of removal, 13 acres of partial removal and capping, 7 acres of partial removal and ENR-nav), 3 acres of ENR-sill, 9 acres of ENR-nav, and 12 acres of in situ treatment. The total removal volume is estimated at 810,000 cy, and the total placement volume (capping, ENR, RMC layer, and backfill) is 290,000 cy. The alternative has the same construction timeframe (9 years) as Alternative 1A(12), because in situ treatment would occur concurrently with removal operations. Alternative 1B(12) is estimated to cost $264 million.

8.3.4 Alternative 1C+(12)

Alternative 1C+(12) is based on open-water option 1: removal with capping and ENR-nav where applicable; limited access area option C+: removal followed by in situ treatment for areas with PCBs or mercury greater than the CSL and in situ treatment elsewhere when exceeds RALs; and the RAL set including 12 mg/kg oc for PCBs. The detailed remediation areas and technology assignments are presented in Table B-32 and Figure B-34. Alternative 1C+(12) is removal focused, with removal over 82% of the remediation area (63% of the EW). Alternative 1C+(12) is the same as Alternative 1A(12), except that it replaces MNR with in situ treatment and hydraulic dredging followed by in situ treatment as the remedial technologies in underpier areas.

Alternative 1C+(12) includes the following combination of remedial technologies:

- **Open-water Option 1 (**Table B-31**):** As described for Alternative 1A(12), above.
- Limited Access Option C+ (Table B-31):
  - **Underpier areas**: Limited removal using hydraulic dredging followed by in situ treatment was selected for areas with PCBs or mercury concentrations exceeding the CSL. In situ treatment (without being preceded by hydraulic dredging) would be applied in other areas exceeding the RALs.
  - **Sill Reach – Low Bridges**: ENR-sill (same as Alternative 1B(12)).

Alternative 1C+(12) includes 99 acres of removal (77 acres of removal, 13 acres of partial removal and capping, 7 acres of partial removal and ENR-nav, 2 acres of hydraulic dredging followed by in situ treatment), 3 acres of ENR-sill, 9 acres of ENR-nav, and 10 acres of in situ treatment. The total removal volume is estimated at 820,000 cy, and the total placement volume (capping, ENR, RMC layer, and backfill) is 290,000 cy. The alternative has the same construction timeframe (9 years) as Alternative 1B(12), because diver-assisted hydraulic dredging would occur concurrently with open-water removal operations. Alternative 1C+(12) is estimated to cost $277 million.

8.3.5 Alternative 2B(12)

Alternative 2B(12) is based on open-water option 2: removal with capping where applicable; limited access option B: in situ treatment; and the RAL set including 12 mg/kg oc for PCBs. The

detailed remediation areas and technology assignments are presented in Table B-32 and Figure B-35. Alternative 2B(12) is removal focused, with removal over 88% of the remediation area (68% of the EW). Alternative 2B(12) is identical to Alternative 1B(12), except that ENR-nav and partial dredging and ENR-nav are substituted by removal of sediment exceeding RALs. Like Alternative 1B(12), Alternative 2B(12) includes partial dredging and capping where practicable in the Shallow Main Body.

Alternative 2B(12) includes the following combination of remedial technologies:

- Open-water Option 2 (Table B-31):
  - **Navigation Channel and Berth Area**: Removal. The Communication Cable Crossing includes removal to the extent practicable and backfill instead of removal to RAL exceedances to protect the structure.
  - **Shallow Main Body Reach**: Removal or partial removal and capping (same as described for Alternative 1A(12)).
  - **Nearshore**: Partial removal and cap (same as described for Alternative 1A(12)).
  - **West Seattle Bridge**: ENR-sill (same as described for Alternative 1A(12)).
- **Limited Access Option B (**Table B-31**):** As described for Alternative 1B(12), above.

Alternative 2B(12) includes 106 acres of removal (93 acres of removal and 13 acres of partial removal and capping), 12 acres of in situ treatment, and 3 acres of ENR-sill. The total removal volume is estimated at 900,000 cy, and the total placement volume (capping, in situ treatment, ENR, RMC layer, and backfill) is 280,000 cy. The alternative will take approximately 10 years to construct, at a cost of approximately $284 million.

8.3.6 Alternative 2C+(12)

Alternative 2C+(12) is based on open-water option 2: removal with capping where applicable; limited access option C+: removal followed by in situ treatment for areas with PCBs or mercury greater than the CSL and in situ treatment elsewhere; and the RAL set including 12 mg/kg oc for PCBs. The detailed remediation areas and technology assignments are presented in Table B-32 and Figure B-36. Alternative 2C+(12) is removal focused, with removal over 90% of the remediation area (69% of the EW). Alternative 2C+(12) is the same as Alternative 2B(12), except that it includes limited removal using diver-assisted hydraulic dredging (for PCBs or mercury greater than the CSL) followed by in situ treatment as remedial technologies in underpier areas.

Alternative 2C+(12) includes the following combination of remedial technologies:

- **Open-water Option 2 (**Table B-31**):** As described for Alternative 2A(12), above.
- **Limited Access Option C+ (**Table B-31**):** As described for Alternative 1C+(12), above.

Alternative 2C+(12) includes 108 acres of removal (93 acres of removal, 13 acres of partial removal and capping, and 2 acres of hydraulic dredging followed by in situ treatment), 3 acres

of ENR-sill, and 10 acres of in situ treatment. The total removal volume is estimated at 910,000 cy, and the total placement volume (capping, in situ treatment, ENR, RMC layer, and backfill) is 280,000 cy. The alternative has the same construction timeframe (10 years) as Alternative 2B(12), because diver-assisted hydraulic dredging would occur concurrently with open-water removal operations. Alternative 2C+(12) is estimated to cost $297 million..

8.3.7 Alternative 3B(12)

Alternative 3B(12) is based on open-water option 3: maximum removal to the extent practicable in open-water areas; limited access option B: in situ treatment; and the RAL set including 12 mg/kg oc for PCBs. The detailed remediation areas and technology assignments are presented in Table B-32 and Figure B-37. Alternative 3B(12) is removal focused, with removal over 88% of the remediation area (69% of the EW). Alternative 3B(12) is identical to Alternative 2B(12), but uses removal where practicable in the open-water areas (i.e., removal in the Shallow Main Body CMAs and under the West Seattle Bridge).

Alternative 3B(12) includes the following combination of remedial technologies:

- Open-water Option 3 (Table B-31):
    - **Navigation Channel and Berth Area**: Removal. The Communication Cable Crossing includes removal to the extent practicable and backfill instead of removal to RAL exceedances to protect the structure (same as described for Alternative 2B(12)).
    - **Shallow Main Body Reach**: Removal.
    - **Nearshore**: Partial removal and cap (same as described for Alternative 1A(12)).
    - **West Seattle Bridge**: Removal.
- **Limited Access Option B (**Table B-31**):** As described for Alternative 1B(12), above.

Alternative 3B(12) includes 108 acres of removal (101 acres of removal, 7 acres of partial removal and capping), 12 acres of in situ treatment, and 1 acre of ENR-sill. The total removal volume is estimated at 960,000 cy, and the total placement volume (capping, in situ treatment, ENR, RMC layer, and backfill) is 270,000 cy. The alternative will take approximately 10 years to construct, at a cost of approximately $298 million.

8.3.8 Alternative 3C+(12)

Alternative 3C+(12) is based on open-water option 3: maximum removal to the extent practicable in open-water areas; limited access option C+: removal followed by in situ treatment for areas with PCBs or mercury greater than the CSL and in situ treatment elsewhere exceeding RALs; and the RAL set including 12 mg/kg oc for PCBs. The detailed remediation areas and technology assignments are presented in Table B-32 and Figure B-38. Alternative 3C+(12) is removal focused, with removal over 90% of the remediation area (70% of the EW).

Alternative 3C+(12) is the same as 2C+(12) but uses removal where practicable in the open-water areas (i.e., removal in the Shallow Main Body CMAs).

Alternative 3C+(12) includes the following combination of remedial technologies:

- **Open-water Option 3 (**Table B-31**):** As described for Alternative 3B(12), above.
- **Limited Access Option C+ (**Table B-31**):** As described for Alternative 1C+(12), above.

Alternative 3C+(12) includes 110 acres of removal (101 acres of removal, 7 acres of partial removal and capping, 2 acres of hydraulic dredging followed by in situ treatment), 1 acre of ENR-sill, and 10 acres of in situ treatment. The total removal volume is estimated at 960,000 cy, and the total placement volume (capping, in situ treatment, ENR, RMC layer, and backfill) is 270,000 cy. The alternative will take approximately 10 years to construct, at a cost of approximately $310 million.

8.3.9 Alternative 2C+(7.5)

Alternative 2C+(7.5) is based on open-water option 2: removal with capping where applicable; limited access option C+: removal followed by in situ treatment in areas with PCBs or mercury greater than the CSL and in situ treatment elsewhere above RALs; and the RAL set including 7.5 mg/kg oc for PCBs. The detailed remediation areas and technology assignments are presented in Table B-32 and Figure B-39. Alternative 2C+(7.5) is removal focused, with removal over 90% of the remediation area (75% of the EW). Is identical to Alternative 2C+(12), except for a larger remediation area due to a lower RAL for PCBs.

Alternative 2C+(7.5) includes the following combination of remedial technologies:

- **Open-water Option 2 (**Table B-31**):** Same as described for Alternative 2B(12), above, but with a larger remediation area due to the lower RAL.
- **Limited Access Option C+ (**Table B-31**):** Same as described for Alternative 1C+(12), above, but with a larger remediation area due to the lower RAL.

Alternative 2C+(7.5) includes 118 acres of removal (103 acres of dredging, 13 acres of partial removal and capping, 2 acres of hydraulic dredging followed by in situ treatment), 3 acres of ENR-sill, and 11 acres of in situ treatment. The total removal volume is estimated at 1,010,000 cy, and the total placement volume (capping, in situ treatment, ENR, RMC layer, and backfill) is 290,000 cy. The alternative will take approximately 11 years to construct, at a cost of approximately $326 million.

8.3.10 Alternative 3E(7.5)

Alternative 3E(7.5) is based on open-water option 3: maximum removal to extent practicable; limited access option E: removal followed by in situ treatment in all areas exceeding RALs; and the RAL set including 7.5 mg/kg oc for PCBs. The detailed remediation areas and technology assignments are presented in Table B-32 and Figure B-40. Alternative 3E(7.5) can be considered the overall most aggressive removal-focused alternative with maximum removal in the open-

water areas due to a PCB RAL of 7.5 mg/kg OC, combined with hydraulic dredging followed by in situ treatment in underpier areas.

Alternative 3E(7.5) includes the following combination of remedial technologies:

- **Open-water Option 3 (**Table B-31**):** Same as described for Alternative 3C+(12), above, but with a larger remediation area due to the lower RAL.
- Limited Access Option E Table B-31):
    - **Underpier areas**: Removal using hydraulic dredging followed by in situ treatment.
    - **Sill Reach – Low Bridges**: ENR-sill (same as Alternative 1B(12)).

Alternative 3E(7.5) includes 131 acres of removal (111 acres of removal, 7 acres of partial removal and capping and 13 acres of hydraulic dredging followed by in situ treatment) and 1 acre of ENR-sill. The total removal volume is estimated at 1,080,000 cy, and the total placement volume (capping, ENR, RMC layer, and backfill) is 270,000 cy. The alternative will take approximately 13 years to construct, at a cost of approximately $411 million. Additional costs and construction timeframes for this alternative are entirely due to additional underpier footprint for diver-assisted hydraulic dredging.

9 Comparative Analysis of Alternatives

This section compares the alternatives with respect to the nine CERCLA evaluation criteria. Table B-38 (Table 10-1 from the FS) provides a detailed summary of this analysis. Figure B-41 presents an overall summary of the alternatives.

9.1 Overall Protection of Human Health and the Environment

The No Action alternative does not fully provide for protection of human health and the environment because it does not provide adequate monitoring, engineering and institutional controls to ensure that the RAOs are achieved. All of the action alternatives result in significant reduction of COC concentrations (by varying methods and in varying timeframes) but meet the threshold criterion for overall protection of human health and the environment only with the addition of institutional controls. They also provide monitoring and, possibly, corrective actions to ensure that RAOs are achieved to the extent practicable.

As none of the alternatives are capable of lowering PCBs and dioxins/furans in surface sediment to their respective PRGs for RAO 1, all alternatives would require institutional controls to assure protectiveness. These include: seafood consumption advisories, restrictive covenants, monitoring and notification of waterway users, public education and outreach to reduce human exposures to resident seafood, and possibly other community programs. Waterway use restrictions may also be required in areas where subsurface contamination remains above protective levels will reduce the potential for re-exposure.

9.2 Compliance with ARARs

The two key ARARs for evaluating the remedial alternatives are:

- The Washington Model Toxics Control Act (WAC 173-340), which includes by reference the Washington State Sediment Management Standards (WAC 173-204)
- Surface Water Quality Criteria or Standards (WAC-173-201A-240)

For MTCA/SMS standards for protection of human health for seafood consumption (RAO 1), current modeling suggests that the action alternatives are not predicted to achieve all of the natural background PRGs for PCBs or dioxins/furans. This is due to model input parameters that assume ongoing contribution of contaminants from diffuse nonpoint sources upstream of the EW. All of the action alternatives are expected to comply with PRGs for protectiveness of human health for direct contact (RAO 2) immediately following construction. For protection of the benthic community (RAO 3), Alternative 1A(12) is predicted to comply with the PRGs within 39 years, and all other action alternatives immediately following construction. All action alternatives are expected to comply with protection of higher trophic level organisms (RAO 4) PRGs immediately following construction.

All of the action alternatives are expected to comply with state water quality standards and federal surface water quality criteria upon completion of the remedial action, provided that dredging BMPs and careful project planning (e.g. production rates, project sequencing) are

implemented to ensure that dissolved and suspended releases do not result in exceedances of water quality standards. Cleanup of sediments, along with source control actions, are expected to reduce concentrations of COCs in the water column following cleanup actions. However, other factors not related to releases from the site also contribute to COC concentrations in water. Currently, Green River upstream and Elliott Bay downstream water concentrations appear to be above federal recommended human health water quality criteria for total PCBs and arsenic.

Following remediation, if long-term monitoring data indicates that MTCA/SMS or water quality ARARs cannot be met, EPA will determine whether further remedial action could practicably achieve the ARAR. If EPA concludes that an ARAR cannot be practicably achieved, EPA may waive the ARAR on the basis of technical impracticability (TI) in a future decision document.

9.3 Long-term Effectiveness and Permanence

9.3.1 Magnitude of Residual Risk

This criterion assesses the magnitude and type of residual risk that would remain at the site after RAOs are achieved, and the extent and effectiveness of the controls that may be required to manage the risks posed by re-exposure of residual contamination. Residual risks to humans, wildlife, and the benthic community from surface sediment concentrations remaining on-site at the completion of active remediation (and further in time as a result of additional natural recovery) are estimated using output from the box model, as described in Section 4.3 and in Figures B-42 and B-43. The corresponding risk 40-year risk levels are presented in Tables B-34 through B-36.

Residual Risk for RAO 1 for 40 Years after Construction Completion

Risk Scenario		No Action	1A(12)	1B(12) through 3E(7.5)
Total excess cancer risk	Adult Tribal RME	5×10^{-4}	3×10^{-4}	2×10^{-4}
	Child Tribal RME	9×10^{-5}	5×10^{-5}	4×10^{-5}
	Adult API RME	2×10^{-4}	1×10^{-4}	9×10^{-5}
Total PCBs non-cancer HQs	Adult Tribal RME	11	5	4 or 5
	Child Tribal RME	23	12	9 or 10
	Adult API RME	9	5	4

For RAO 1, none of the alternatives are predicted to achieve the natural background-based PRGs for PCBs or dioxins/furans. However, many of the alternatives do achieve similar significant reductions in risk and do result in significant reductions in risk.

For RAO 2, all alternatives are predicted to achieve a total excess cancer risk of less than 1×10^{-5}. For cPAHs, all alternatives are predicted to achieve individual excess cancer risks of less than 1×10^{-6}. For arsenic, all action alternative are predicted to achieve individual excess cancer

risk of 2 x 10^{-6} for netfishing and 7 x 10^{-6} for clamming. The target risk threshold is below natural background, so the PRG was also used for comparison. All action alternatives are predicted to meet the natural-background based PRG immediately following construction, but not in the long term due to incoming Green/Duwamish River concentrations.

For RAO 3, the No Action Alternative is not expected to achieve the benthic PRGs. Alternative 1A(12) is predicted to meet benthic PRGs in 99% of point locations 40 years following construction. Alternatives 1B(12) through 3E(7.5) are predicted to meet benthic PRGs in 100% of point locations after construction completion.

For RAO 4 the No Action alternative is predicted to meet both PRGs within 25 years after construction; the action alternatives are predicted to meet the PRGs immediately following construction. For risk reduction, the No Action alternative does not achieve an HQ less than 1.0 using the lower TRV, but does when using the higher TRV. All action alternatives are predicted to achieve an HQ less than 1.0 for English sole using either TRV, and for brown rockfish using the higher TRV. An HQ ranging from 1.0 to 1.3 for brown rockfish is achieved using the lower TRV.

All of the action alternatives achieve similar risk outcomes, with Alternative 1A(12) having slightly higher risks. Evaluation of residual risks also considered the potential for exposure of subsurface contamination left in place following remediation. All of the action alternatives emphasize removal of contaminated sediments, and thus, have a low potential for subsurface to be exposed. Subsurface contaminated sediment in both open-water and under piers, is removed in these areas:

- Alternatives 1A(12), 1B(12), and 1C+(12) perform removal in 77 to 79 acres
- Alternatives 2B(12) and 2C+(12) perform removal in 94 to 96 acres
- Alternatives 3B(12), 3C+(12), and 2C+(7.5) perform removal in 100 to 106 acres
- Alternative 3E(7.5) performs removal in over124 acres

The risk of exposing contaminated subsurface sediment is relatively low in capped areas because the caps are engineered to remain structurally stable under location-specific conditions and provide a high degree of protectiveness. All action alternatives perform a similar degree of partial dredging and capping, ranging from 7 acres (Alternatives 3B(12), 3C+(12), and 3E(7.5)), to 13 acres (Alternatives 1A(12), 1B(12), 1C+(12), 2B(12), 2C+(12), and 2C+(7.5)).

Areas remediated by in situ treatment, partial removal and ENR-nav/ENR-nav, ENR-sill, or MNR have a higher potential for exposure of contaminated subsurface sediment as a result of disturbance, such as from propwash. These technologies represent a relatively small contribution (less than 20%) to the overall EW remedial footprint for alternatives: 29 to 31 acres for Alternatives 1A(12), 1B(12), and 1C+(12); 11 to 15 acres for Alternatives 2B(12), 2C+(12), 2C+(7.5), 3B(12), and 3C+(12); and 1 acre for Alternative 3E(7.5).

The number of core stations exceeding the CSL remaining following construction was used as a quantitative measure of contamination left behind. The action alternatives remove between 66

and 71 core stations (of a total of 76) that exceed the CSL. In addition, the majority of cores with CSL exceedances remaining after remediation are located under isolation caps for all alternatives. Within the ENR-sill and no action areas, Alternatives 1A(12), 1B(12), 1C+(12); 2B(12), and 2C+(12) leave 3 cores behind; Alternatives 3B(12) and 3C+(12) leave 2 behind; Alternative 2C+(7.5) leaves one core behind; and Alternative 3E(7.5) leaves no cores behind. No cores exceed the CSL in MNR and in situ treatment areas for any of the alternatives.

9.3.2 Adequacy and Reliability of Controls

For this evaluation, adequacy and reliability of controls have five major aspects: controls of dredge residuals, source control, monitoring, maintenance, and institutional controls.

All dredging projects leave behind some level of residual contamination immediately after completion of in-water work. The management of dredge residuals was acknowledged in the development of all of the alternatives with the assumption that dredging would be followed by a thin-layer placement of RMC sand layer. The dredge residuals management approach and decision framework will be further developed during remedial design.

Potential sources to the EW are regulated under existing state and federal programs, as described in Section 4.2. However, ongoing sources will affect the adequacy and reliability of all alternatives equally, so source control does not factor into the comparative analysis of alternatives.

Differences among the alternatives in the adequacy and reliability of long-term post-cleanup monitoring are minor. The scope and duration of monitoring are similar for the action alternatives. However, alternatives with MNR, ENR, and in situ treatment components would require the collection of more project-specific operation and maintenance monitoring data to achieve data quality objectives, and have more potential for contingency actions in the future.

After construction, long-term monitoring is useful in identifying maintenance and repair needs for the remedial action, in order to continue to limit the post-remediation exposure to subsurface contaminated sediment. Alternatives with more removal have a reduced level of effort for maintenance compared to alternatives with more containment, ENR, and MNR. ENR, in situ treatment, and MNR areas are assumed to have a higher maintenance requirement compared to capping. However, because these areas are also small compared to the removal areas, the difference among alternatives with regard to maintenance requirements is small.

Institutional controls are needed for all alternatives because thresholds of excess cancer risk are associated with levels in sediment below natural background for total PCBs, dioxin/furans, and arsenic. In addition, none of the alternatives achieve natural background-based PRGs for total PCBs or dioxins/furans for RAO 1. Thus, remaining risks to the community from consuming resident fish and shellfish would be managed by institutional controls designed to reduce such seafood consumption exposures. While the No Action Alternative includes no provisions for site-wide institutional controls to manage residual risks, the action alternatives would require an ICIAP for the EW. The ICIAP would include several elements, such as a notification,

monitoring, and reporting program for areas of the EW and WDOH seafood consumption advisories, public outreach, and education programs.

9.4 Reduction in Toxicity, Mobility, or Volume through Treatment

This criterion assesses the degree to which site media are treated to permanently and significantly reduce the toxicity, mobility, or volume of site contaminants. Based on EPA guidance, the contaminated sediments within the EW are classified as low-level threat wastes because they are not highly toxic nor highly mobile. All action alternatives, except for Alternative 1A(12), include in situ treatment using AC. AC lowers the mobility of contaminants, reducing the toxicity and bioavailability to biological receptors. For comparison purposes, the reduction of mobility achieved by in situ treatment is assumed to be proportional to the area that undergoes treatment. Alternatives 1B(12), 1C+(12), 2B(12), 2C+(12), 3B(12), 3C+(12), 2C+(7.5), and 3E(7.5) employ in situ treatment in underpier areas above RALs (varying from 12 to 13 acres). The No Action Alternative and Alternative 1A(12) do not treat any contaminated sediment.

9.5 Short-term Effectiveness

This evaluation criterion addresses the effects of the alternatives on human health and the environment during the construction phase of the remedial action and until RAOs are achieved. This criterion includes the protection of workers and the community during construction, environmental impacts that result from construction, and the length of time until RAOs are achieved.

9.5.1 Community and Worker Protection

Short-term impacts to both workers and the community are largely proportional to the length of the construction period (Table B-37). In general, disruptions and inconveniences to the public and commercial community (e.g., increased street and vessel traffic, and potential temporary waterway restrictions) can be expected to increase with the duration of construction.

Local transportation impacts (e.g., traffic, noise, and air pollutant emissions) are assumed to be proportional to the number of truck, train, and barge miles estimated for support of material hauling operations. All of the action alternatives have large impacts from truck, train, and barge miles due to the larger amounts of sediments being removed from the EW. Alternatives 1A(12), 1B(12), and 1C+(12) have the lowest transportation impacts from truck, train, and barge miles to remove 810,000 to 820,000 cy of sediment. Alternatives 2B(12), 2C+(12), 3B(12), and 3C+(12) have moderate transportation impacts due to removing 900,000 to 60,000 cy of sediment, and Alternatives 2C+(7.5) and 3E(7.5) have the largest transportation impacts due to removing 1,010,000 to 1,080,000 cy of sediment.

Activities on the construction site related to the operation of heavy equipment pose the greatest risk of physical accidents. The potential for exposure, injury, or fatality increases in

proportion to the duration of construction activities, volume of material handled, and transportation requirements. Diver assisted hydraulic dredging (used in Alternatives 1C+(12), 2C+(12), 3C+(12), 2C+(7.5), and 3E(7.5)) inherently has more risk for workers than any of the other construction activities. Alternative 3E(7.5) poses the highest risk to worker safety because of the greater number of years estimated for this activity (12 construction years compared to 0 or 2 for other alternatives).

9.5.2 Environmental Impacts

Cleaning up the EW will have short-term environmental impacts that can be grouped into the categories of air pollutant emissions, landfill capacity utilization, ecological impacts, and energy consumption. In general, longer duration alternatives and those with more removal have greater short-term impacts in all of these categories than similarly scaled alternatives that use more containment or ENR and MNR.

Longer construction timeframes increase air pollutant emissions from construction equipment and noise. The primary source of air pollutant emissions is fuel consumption during construction activities. Transloading, transportation, and disposal of contaminated sediments account for the largest portion of the emissions. Rail and barge transport will be used to the maximum extent possible, which will reduce air pollutant emissions as compared to long-haul trucking.

All of the action alternatives greatly rely on dredging, and therefore consume landfill space proportional to the total removal volume. Alternatives that include partial removal and ENR-nav/ENR-nav (i.e., Alternatives 1A(12), 1B(12), and 1C+(12)) consume less landfill space than the other action alternatives (i.e., Alternatives 2B(12), 2C+(12), 3B(12), 3C+(12), 2C+(7.5) and 3E(7.5)).

All alternatives except the No Action Alternative have similarly large remediation footprints, so the areal extent of short-term disturbances to the existing benthic community and other resident aquatic life is comparable.

For energy consumption, Alternative 3E(7.5) has the largest energy consumption because of its large removal volume, while Alternative 1A(12) has the lowest energy consumption because of its higher use of ENR and MNR. The other action alternatives have moderate energy consumption.

9.5.3 Time to Achieve RAOs

Table B-38 presents the predicted times at which the alternatives achieve RAOs, as follows:

- RAO 1: All action alternatives are predicted to achieve the same order of magnitude cancer risk and non-cancer HQ. Alternative 1A(12) is predicted to achieve it in a longer timeframe than the other action alternatives (34 years from the start of construction, compared to 9 to 13 years). All of the action alternatives are predicted to achieve the other risk metrics at the end of construction (9 to 13 years).

- RAO 2: All action alternatives are predicted to achieve the arsenic PRG at the end of construction. Model predictions indicate that arsenic concentrations in the EW could increase following construction, and maintaining the PRG in the long term is uncertain because of incoming sediment concentrations. All action alternatives are predicted to achieve the cPAH PRG or 1×10^{-6} excess cancer risk immediately after construction completion. The No Action Alternative is predicted to achieve 1×10^{-6} risk for cPAHs for clamming in 20 years.
- RAO 3: Alternative 1A(12) is predicted to achieve the RAO 3 PRGs 39 years from the start of construction, while the other action alternatives are predicted to achieve it immediately after construction completion (9 to 13 years). The No Action Alternative is not expected to achieve the RAO 3 PRGs.
- RAO 4: The No Action Alternative is predicted to achieve RAO 4 PRGs at 10 and 25 years for English sole and brown rockfish, respectively, while all action alternatives are predicted to achieve RAO 4 PRGs after construction completion (9 to 13 years).

Overall, Alternatives 1B(12) and 1C+(12) are predicted to achieve RAOs 2 through 4 in 9 years, followed by Alternatives 2B(12), 2C+(12), 3B(12), and 3C+(12) in 10 years; 2C+(7.5) in 11 years; 3E(7.5) in 13 years; and 1A(12) in 9 years for RAOs 2 and 4 and 39 years for RAO 3. All action alternatives are predicted to meet similar risk thresholds for RAO 1 within 9 to 13 years except Alternative 1A(12), which is predicted to take 34 years to achieve similar child tribal risk thresholds.

As described in Section 13, the total number of years of construction could be reduced by about 2 years, consistently for all action alternatives, if a longer construction window is allowed. Therefore, times to achieve RAOs would also be reduced accordingly.

9.6 Implementability

The technical implementability challenges are similar across the action alternatives in open water areas, but are different across these alternatives in underpier areas. For underpier areas, there are few technical challenges for MNR, moderate technical challenges for in situ treatment material placement, and the most technical challenges for diver-assisted hydraulic dredging. MNR, as part of Alternative 1A(12), has few technical challenges, with the lowest potential for difficulties and delays and impacts to EW users. Alternatives 1B(12), 1C+(12), 2B(12), 2C+(12), 3B(12), 3C+(12), 2C+(7.5), and 3E(7.5) have either in situ treatment or both in situ treatment and diver-assisted hydraulic dredging in underpier areas.

Administrative implementability challenges include the need for contingency actions and need to reauthorize the federal navigation channel depth. After construction, the alternatives vary in the potential for contingency actions related to maintaining the remedy in ENR, in situ treatment, and MNR areas. Although all of the alternatives rely primarily on dredging, Alternatives 1A(12), 1B(12), and 1C+(12) have more areas with potential future contingency actions (29 to 31 acres), Alternatives 2B(12), 2C+(12), 3B(12), 3C+(12), and 2C+(7.5) have some

areas with potential future contingency actions (11 to 15 acres), and Alternative 3E(7.5) has 1 acre of area with potential future contingency actions.

The action alternatives vary with respect to the need to reauthorize the federal navigation channel. Alternatives 1A(12), 1B(12), 1C+(12), 2B(12), 2C+(12), and 2B(7.5) include partial dredging and capping in the Shallow Main Body – South CMA, where the cap would be placed at elevations shallower than the current authorized elevation. Reauthorization from -34 to -30 feet MLLW was assumed for the FS to make some remedial actions feasible and appears to be a reasonable assumption based on current and anticipated future site use.

9.7 Cost

This assessment evaluates the construction and non-construction costs of each alternative. The costs are very sensitive to the estimated dredge removal volume. Modest changes in dredge design factors (e.g., dredge footprint, depth of contamination, depth required for navigation clearance, side slope designs, or the amount of diver-assisted hydraulic dredging) can result in significant changes to dredge volumes and costs. Other factors, such as fuel and labor, can also significantly impact costs. Costs for contingency are included as a percentage of the construction costs (30%) to cover unknowns, unforeseen circumstances, and unanticipated conditions reducing the overall risk of cost overruns. Total project costs for the alternatives are expressed in net present value and 2016 dollars, and are assumed to be accurate within the range of -30% to +50%.

Although EPA guidance recommends using a discount rate of 7% for estimating net present value for cleanups conducted by non-federal parties, for EW a discount rate of 0% was used for the following reasons:

- First, three of the potentially responsible parties are public entities and have different capital costs than the private sector. Public entities may not be able to set aside sufficient funds for investment without incurring additional costs of bonding or borrowing and, therefore, would not be able to take advantage of the interest accumulation assumption implied by the net present value calculation.
- Second, the lending environment has changed significantly since the EPA guidance was published in 2000. The current recommendations in the Office of Management and Budget Circular A-94 Appendix C, revised November 2016, indicates that the discount rate ranges from -0.5% for a 3-year investment to 0.7% for a 30-year investment.

Alternative 3E(7.5) has the highest cost at $411 million, followed by Alternatives 3C+(12) and 2C+(7.5) at $310 and $326 million, respectively. Then Alternatives 1C+(12), 2B(12), 2C+(12), and 3B(12) with costs from approximately $277 to $298 million. Alternatives 1A(12) and 1B(12) are cheaper still at $256 and $264 million, respectively. The No Action Alternative has lowest cost, at only $950,000.

9.8 State/Tribal Acceptance & Community Acceptance

Stakeholders were engaged early during the development of the scope of work and through the duration of the project. EPA will consider additional input from the affected communities when developing the Proposed Plan.

Ecology has be actively involved in the application of the State promulgated Sediment Management Standards throughout the process, as well as coordinating cleanup activities in adjacent properties. The State is also the lead agency for source control for upstream sources (Green River and Duwamish River). Three issues specific to the State SMS include sediment recovery zones (SRZ), natural background for arsenic, and the development of regional background concentrations. These issues have been resolved through the development and finalization of the FS.

King County, the City of Seattle, and the Port of Seattle comprise the EWG and represent the PRPs and land owners along the East Waterway. The EWG has prepared the SRI and FS documents. The EWG is also responsible for source control activities for lateral sources adjacent to the EW.

The Tribes have been consulted with throughout the process through the cooperative agreement. There is support for the cleanup project provided it is consistent with continued support of Tribal fisheries. The HHRA used Tribal risk scenarios to ensure that Tribal fisheries are supported in the future. Construction timelines have also included windows for Tribal fisheries. The API community also fishes in the waterway and may object to potential short-term closures during implementation.

Commercial activities associated with shipping and the use of adjacent terminals, docks and piers are the dominant waterway users. There is general support for the project. For commercial waterway users the potential for waterway use restrictions are likely to be the biggest concern, including the potential economic impacts during construction. Residential use of the waterway is limited to Jack Perry Memorial Park and fishing piers. Concerns by the general public are likely to be associated with potential short-term closures of intertidal areas and fishing piers, noise and air-quality impacts during construction and any economic impacts.

10 Principal Threat Waste

The contaminated sediments in the EW are low-level threat wastes, according to the definitions in *A Guide to Principal Threat and Low Level Wastes* (EPA, 1991a). Principal threat wastes are "those source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur." The source materials in the EW are not principal threat wastes for the following reasons:

- EW sediments are not highly mobile:
- Sediments within the EW largely remain within the EW. Sub-surface transport of sediment is minimal, likely dominated by limited scour due to vessel traffic (i.e. propwash) with re-deposition in nearby areas of the EW.
- EW sediments are not highly toxic:
- Maximum concentrations detected for the four human health risk drivers are:
    - 8,400 μg/kg dw for total PCBs
    - 49.7 ng TEQ/kg dw for dioxins/furans
    - 17,000 μg TEQ/kg dw for cPAHs
    - 241 mg/kg dw for arsenic
- Excess cancer risks due to direct contact in the netfishing and clamming RME scenario were low, ranging from 7×10^{-6} to 3×10^{-5}. The greatest risks to human health (1×10^{-3}) are for consumption of contaminated seafood under the adult tribal RME scenario.

Determination of sources as principal or low-level threat wastes is intended to help determine the appropriate types of remedies for the site. Although the sediment in the EW are not designated as principal threat wastes, removal is the primary remedy proposed for the site. However, proposed remedies for the underpier areas include both treatment and containment options, due to the practicability of accessing under-pier areas.

It is important to remember that for PCBs and dioxins/furans, the primary threat comes from bioaccumulation. Once contaminated sediment is disposed of at a landfill, aquatic receptors (e.g., fish and shellfish) cannot come into contact with the material, and it cannot bioaccumulate into fish and shellfish and be consumed by humans and wildlife.

11 Preferred Alternative

EPA Region 10's preferred remedy for the EW is a hybrid of Alternatives 2B(12) and 3B(12). The 2B/3B(12) alternative provides a highly permanent remedy that is consistent with future uses of the open-water areas and provides treatment for areas that are not readily accessible for removal. The 2B/3B(12) hybrid achieves the RAOs (to the extent possible) at the completion of the construction timeframe of 10 years and the estimated cost of $290 million represents an intermediate cost, relative to the other active remedial alternatives (range: $256 million to $411 million).

Key elements of the Preferred Alternative are described below.

1. Main Channel Area: The Preferred Alternative relies primarily on dredging in the main channel area. Dredging removes the greatest mass of contaminants, is highly permanent, provides greater certainty in future remedy performance and is compatible with the current and future use of the waterway. In the limited areas where full dredging is unfeasible, partial dredging and engineered caps is proposed. A 10-cm residual management cover layer will be applied following removal.
2. Sill Reach: For the shallow sill reach at the south end of the site, a 9-inch enhanced natural recovery (ENR) sand/gravel layer is proposed because overwater structures present significant challenges to dredging and this area is not used for navigation.
3. Under-Pier Areas: *In-situ* treatment (most likely with AC) will be used to address under-pier hot spots followed by the application of an ENR layer.

The Preferred Alternative addresses all areas with PCB concentrations greater than 12 mg/kg organic carbon (OC). Figure B-44 provides detailed information on the cleanup footprint and locations where each technology will be applied. Of the 157 acres in the EW, the preferred remedy assignments are as follows:

- **99 acres** for sediment removal from open water areas
- **7 acres of partial removal and cap** where depth of contamination makes full removal impractical
- **3 acres** of ENR placement in the Sill Reach
- **34 acres** of unremediated open water area
- **12 acres** of in-situ treatment in underpier areas
- **2 acres** of unremediated underpier area

The total dredging volume is estimated at 960,000 cubic yards of contaminated sediment would be removed and disposed of in an upland landfill. The total cost of the 2B/3B(12) alternative would be $290 million. The distribution of costs are as follows:

Preconstruction/Planning/Mobilization	10%
Sediment Removal	9%

Sediment Disposal	34%
Material Placement (AC/ENR/capping/RMC)	6%
Contingency and Taxes	35%
Post Construction/Long-term Monitoring	6%

Areas, volumes and costs will be modified in the design phase based on additional sampling and verification of the natural recovery model. Alternative 2B/3B(12) also includes long-term monitoring, and institutional controls to further reduce exposures, including waterway/land use restrictions as needed to protect caps and ENR areas, and fish consumption advisories. EPA will require monitoring and BMPs to manage dredge and other construction-related releases, and will evaluate performance data and make necessary adjustments.

The preferred alternative employs the most reliable remedial technology (removal) for all open water areas and results in lower residual risk than for alternatives employing ENR and capping. With removal, there is also a reduced potential for resuspension due to vessel scour. The remedy is compatible with future uses of the waterway (e.g. channel deepening). Alternatives that rely on ENR or capping are considered less reliable over the long-term and may be inconsistent with maintaining or deepening the navigational channels. The preferred alternative only employs capping outside the navigation channel.

The residual risks for this alternative was among the lowest long-term risks among the active alternatives and similar to that of the "2" and "3" alternatives. Residual risks associated with each of the RAOs are as follows:

RAO 1 would require institutional controls. The residual risks associated with the seafood consumption pathways are as follows:

PCB Cancer Risk 2×10^{-4} (Adult Tribal), 3×10^{-5} (Child Tribal), and 7×10^{-5} (Adult API)

PCB Non-Cancer 5 (Adult Tribal), 10 (Child Tribal), and 4 (Adult API)

PCB Cancer Risk 5×10^{-5} (Adult Tribal), 8×10^{-6} (Child Tribal), and 2×10^{-5} (Adult API)

PCB Non-Cancer 1 (Adult Tribal), 3 (Child Tribal RME), and 1 (Adult API)

RAO 2 PRGs or 1×10^{-6} excess cancer risk threshold for cPAHs are predicted to be achieved by this alternative immediately after construction completion for both site wide and in clamming exposure areas. Alternative 2B/3B(12) is also predicted to achieve 7 mg/kg dw for arsenic by year 10 (immediately after construction completion) for both site-wide and clamming exposure areas, and may achieve 7 mg/kg dw in the long-term.

RAO 3, PRGs are predicted to be achieved, with at least 98% of surface sediment locations below the PRGs immediately after construction completion for total PCBs and for the other key benthic risk driver COCs.

RAO 4 PRGs for total PCBs for both English sole and brown rockfish are predicted to be achieved immediately after construction completion.

The preferred alternative utilizes in-situ remediation in the underpier areas (the "B" alternatives) to reduce toxicity and mobility to a greater extent than MNR (the "A" alternative), and does not rely on diver-assisted dredging (the C+ and E alternatives) that represent short-term risks to workers and structures. It thus provides the best balance of short-term risks due to construction and long-term risk reduction and permanence.

Prior to remedy implementation, supplemental data will be gathered to determine the final areas to be remediated and the remediation technologies to be applied. Treatability studies may be needed to refine the in-situ remedial technologies that could be applied to the underpier areas to evaluate their effectiveness, stability, ancillary effects on benthic communities. Based on findings during remedial design, any adjustment to remediation areas and technologies applied to specific areas will be incorporated into the finalized design

12 Applicable or Relevant and Appropriate Requirements (ARARs)

ARARs identified for the EW are summarized in Table B-22. Two ARARs used to evaluate the alternatives are discussed in this section: 1) federal and state surface water quality standards (WQS) (RCW 90-48 and WAC 173-201A, respectively) and 2) MTCA and the Washington SMS (WAC 173-204), which apply to sediment cleanup sites.

National recommended federal WQC developed to protect ecological receptors and human consumers of fish and shellfish are relevant and appropriate requirements pursuant to CERCLA Section 121(d)(2)(A)(ii) and RCW 70.105D.030(2)(e). However, federal recommended ambient water quality criteria for consumption of organisms and water are not relevant because the EW is not a source of drinking water. More stringent state surface WQS apply where the state has adopted, and EPA has approved, WQS that are more stringent than the federal recommended WQC established under Section 304(a) of the Clean Water Act. Both chronic and acute standards for marine water are used as appropriate.

The SMS are used to establish cleanup levels for sediment under MTCA and contain numerical criteria (SQS and CSL) for the protection of biological resources, including benthic invertebrate organisms. The SMS also contains general methodology for developing numerical standards for the protection of human health and higher trophic level species and the process for complying with and achieving SMS requirements.

For the remaining ARARs listed in Table B-22, it is assumed that all action alternatives will comply through required engineering design, agency review process, and tools within SMS. Further, the remedial design phase will address the various land use and resource protection ARAR requirements (e.g., habitat preservation and mitigation).

12.1 Surface Water Quality Standards

Requirements for compliance with surface water quality ARARs during in-water construction are set in project-specific Section 401 Water Quality Certifications. These certifications generally require water quality monitoring at a compliance boundary located downstream of the construction area. Compliance with the requirements of Water Quality Certifications is expected to be met through the use of operational and structural BMPs. Active remedial measures for the water column are not technically feasible and are therefore not included as part of the alternatives. While significant water quality improvements are anticipated from sediment remediation and source control, currently, upstream Green River and downstream Elliott Bay water concentrations are above federal recommended WQC for some chemicals, and therefore, it is not technically practicable for any alternative to meet all human health recommended federal or state ambient water quality criteria or standards that are based on human consumption of bioaccumulative contaminants (e.g., total PCBs and arsenic). EPA may determine that no additional practicable actions can be implemented under CERCLA to meet ARARs and issue a ROD Amendment or Explanation of Significant Differences (ESD) providing

the basis for a TI or other waiver for specified surface water quality-based ARARs under Section 121(d)(4) of CERCLA.

12.2 Model Toxics Control Act and Sediment Management Standards

Washington State MTCA regulations governing the selection of cleanup standards are ARARs under CERCLA. Sediment sites under MTCA are regulated by the SMS, which provides risk thresholds for specified exposure pathways (e.g., 1×10^{-6} excess cancer risk threshold for individual carcinogens to achieve the SCO), methods for setting the sediment cleanup levels (SCLs) to appropriate levels up to the CSL (e.g., potentially adjusting to regional background levels), and specific target concentrations for individual chemicals for protection of the benthic community. The PRGs for EW were developed to be consistent with the SMS for protection of human health, the benthic community, and higher trophic level species. PRGs developed for RAOs 1 and 2 are consistent with the SMS for protection of human health, PRGs developed for RAO 3 are consistent with the SMS for protection of the benthic community, and PRGs developed for RAO 4 are consistent with the SMS for protection of higher trophic level species. The following paragraphs explain how the alternatives achieve the SMS ARAR for each RAO.

None of the action alternatives are predicted to achieve the natural background PRGs for RAO 1 for PCBs or dioxins/furans, due to model input parameters that assume ongoing contribution from contaminants from diffuse nonpoint sources upstream of the EW. Although the SMS allows for use of a regional background-based cleanup level if it is not technically possible to meet and maintain natural background levels, regional background levels have not yet been established for the geographic area of the EW.

However, CERCLA compliance with MTCA/SMS ARARs may be attained if:

- Post-remedy monitoring demonstrates sediment concentrations are much lower than FS predictions, and PRGs identified in this FS are attained in a reasonable restoration timeframe.
- SCLs are adjusted upward once regional background levels are established for the geographic area of the EW, and are attained in a reasonable restoration timeframe, consistent with SMS requirements.

In either case, the restoration timeframe needed to meet the cleanup levels could be extended beyond 10 years, consistent with the substantive requirements of an SRZ as defined in the SMS (see Section 4.3.1 and Appendix A of the FS). Following remediation and long-term monitoring, if EPA determines that no additional practicable actions can be implemented under CERCLA to meet certain MTCA/SMS ARARs, EPA may issue a ROD Amendment or ESD providing the basis for a TI waiver for specified MTCA/SMS ARARs under Section 121(d)(4) of CERCLA.

All alternatives (except for No Action) are predicted to meet the natural background-based RAO 2 PRG for arsenic of 7 mg/kg dw immediately after construction and depending on incoming sediment concentrations may maintain this value in the long term. However, modeling using

best-estimate model inputs predicts that arsenic concentrations will increase to above 7 mg/kg dw in the long term after construction due to incoming sediment concentrations, meaning that the RAO 2 PRG for arsenic is predicted to be met only temporarily. All action alternatives achieve RAO 2 target risk estimates or PRGs for cPAHs.

The achievement of RAO 3 was estimated for key benthic risk driver COCs (total PCBs, arsenic, mercury, total HPAHs, total LPAHs, BEHP, and 1,4-dichlorobenzene) using a point mixing model. The subset of COCs analyzed served as a surrogate for the 29 SMS contaminants identified as benthic invertebrate community COCs in the ERA. The PRGs (the SQS or benthic SCO, based on SMS numerical criteria) were applied to these COCs on a point-by-point basis. An alternative's ability to achieve RAO 3 was determined when at least 98% of existing surface (where potentially exposed from propwash) sediment sample locations with key benthic risk driver COC concentrations predicted to be below the PRGs. This metric acknowledges that the SMS has some flexibility in defining practicability for compliance with the SQS. In addition, the FS recognized that, given the uncertainty in predictions of future contaminant concentrations based on model- and contaminant-specific assumptions, achievement of 100% compliance with the SQS may not prove to be practicable. Small numbers of SQS point exceedances may represent the potential for isolated minor adverse effects on the benthic community, and those do not necessarily merit further action based on a number of factors (such as sediment toxicity test results), as prescribed in the SMS. Adaptive management measures (e.g., verification monitoring, contingency actions) may become necessary, consistent with the technical feasibility provisions of the SMS, in response to isolated or localized SQS point exceedances. This metric is used for FS area and cost estimating purposes only and will not be used for determining post-cleanup compliance with the SMS.

All alternatives are predicted to achieve the RAO 4 PRGs.

13 Technical and Policy Issues

Technical and policy issues that will require further discussion prior to implementation of the preferred alternative are summarized below:

- **Sediment Recovery Zones -** None of the action alternatives are predicted to achieve the natural background and PQL PRGs for RAO 1 for PCBs or dioxins/furans due to model input parameters that assume ongoing contribution from contaminants from diffuse nonpoint sources upstream of the EW. CERCLA compliance with these MTCA/SMS ARARs may be attained if post-remedy monitoring demonstrates sediment concentrations are much lower than FS predictions and PRGs identified in the FS are attained in a reasonable restoration timeframe. However, if the PRGs can't be met within 10 years, then the restoration timeframe could be extended, consistent with the substantive requirements of am SRZ as defined in the SMS. A SRZ is used to track a cleanup area with a restoration timeframe longer than 10 years. The requirements of a SRZ are (WAC 173-204-590(2)) consistent with the CERCLA requirements for cleanup and source control, and would be substantively met through various components of the CERCLA remedy (e.g., the long-term monitoring and 5-year review framework; and the alternatives analysis, comparison, and selection process).

  However, if, following remediation and long-term monitoring, EPA determines that no additional practicable actions can be implemented under CERCLA to meet this MTCA/SMS ARAR, EPA may issue a ROD Amendment or ESD providing the basis for a TI waiver for specified MTCA/SMS ARARs under Section 121(d)(4) of CERCLA.

- **Regional Background for PCBs –** An additional approach for meeting the natural background based PRGs for PCB risks due to seafood consumption (RAO 1) is through the use of regional background. MTCA/SMS requires cleanup to natural background when possible. Cleanup to regional background is allowed if it is not technically possible to meet and maintain natural background levels. However, regional background levels have not yet been established for the geographic area of the EW and likely won't be until after project construction, if ever.

- **Natural Background for Arsenic –** PRGs for arsenic for RAO2 are based on natural background. Ecology and EPA use different statistical methods for calculating natural background values: EPA uses the 95UCL value and Ecology uses the 90/90 UTL value. For arsenic, the EPA calculated natural background value is 7 mg/kg dw and Ecology's natural background value is 11 mg/kg dw. There is concern over the potential for recontamination from other MTCA sites that clean up to Ecology's background level of 11 mg/kg dw if the EW is cleaned up to 7 mg/kg dw.

- **Coordination with other projects –** Additional coordination with other projects in the area will continue to be necessary

- **The Lower Duwamish Waterway –** Coordination with the LDW site regarding source control and timing of construction will be necessary to reduce risks of recontamination of East Waterway sediments from LDW sources. In addition, consistency of RALs and PRGs needs to be carefully evaluated. The LDW ROD received substantial public comment, and the EW ROD is expected to as well. Any inconsistencies will be noticed.
- **Seattle Harbor Deepening –** Additional coordination with the Seattle Harbor Navigation Improvement Project is necessary to verify that future conditions in the EW will not result in increased risks, especially due to propwash from the larger more powerful vessels planned for.
- **US Coast Guard –** Additional nature and extent data is needed to assess contamination in the Slip 36 area due to elevated cPAHs.
- **Fish Windows and Construction Timeline –** The dredging window in the EW is determined by the USFWS fish window, the approved in-water work window for the protection of ESA listed fish species, and Tribal fishing windows. Due to these timing restrictions dredging season in the EW is quite short, and consequently the project construction time to completion is quite long – 9-13 years.

  Attempts to lengthen the construction season into portions of the fish window or tribal fishing window could significantly reduce the total project construction timeframe, thereby reducing overall risks by reaching protective levels sooner.
- **Underpier Sediments –** Although sediment under piers represents a significantly smaller volume of sediment relative to open-water portions of the EW, some of the highest contaminant concentrations are found there. Because these areas are difficult to access, treating sediment in place with AC is considered the preferred remedy. Removal of underpier sediments using diver-assisted dredging was also considered, diver-assisted dredging within overwater structures and among rip-rap boulders cannot completely remove contaminated sediment underpiers. It therefore did not provide enough risk reduction and long-term effectiveness to outweigh the increased risk to divers and costs. However, diver-assisted dredging will be considered as a contingency if monitoring indicates that in-situ treatment is not protective.
- **Tribal Shellfish Consumption Rates -** For the EW, given the limited quantity of current or potential shellfish habitat (particularly high-quality habitat), the Tulalip Tribes' rate was selected, as approved by EPA (Windward, 2010a), to characterize the RME seafood consumption risks in the EW. Inasmuch as the EW is within the U&A fishing area of the Suquamish Tribe, and the Suquamish Tribe requested that their seafood consumption data be used to characterize risk, the EW HHRA also evaluated risk using Suquamish Tribe consumption rates.

The Suquamish Tribe requested that the tribal RME scenario be represented as a range of exposures based on the Tulalip and Suquamish consumption rates. Rather, the use of the Tulalip rates represents an EPA policy decision. However, the Muckleshoot and Suquamish Tribes recognize that sediment cleanup levels for bioaccumulative risk driver contaminants based on seafood consumption risks will likely be below background, regardless of whether Tulalip or Suquamish consumption rates are used to develop cleanup levels. For this reason, the tribes have not pursued their disagreement with EPA more vigorously regarding the selection of the Tulalip Tribes' rate to characterize RME seafood consumption risks for the EW. The tribes regard the EW seafood consumption rate decision to be site-specific and do not regard it as being precedent-setting.

14 Cost Information

This section provides cost information for the all the alternatives, including the preferred alternative as described in Section 11. The cost estimates include the following:

- Pre-construction planning activities such as baseline monitoring, design, permitting, and site preparation.
- Construction costs for all remedial components (sediment removal, pile removal, in-situ, capping, and RMC placement).
- Long-term monitoring costs for 20 years post-construction, and potential contingency remedial actions.
- Overall project contingency costs.

Cost estimates were based on bids and construction estimates from recent sediment remediation projects, best professional judgement based on costs for similar remedial actions, local marine contractor input. Main assumptions include:

- Mobilization and demobilization at project initiation and annually for each construction year
- Construction of a new transload facility
- Dredged sediment transportation via rail to a RCRA Subtitle D landfill
- Total project contingency of 30% for construction costs to cover uncertainties
- Long-term monitoring for 20 years post-construction
- Contingency remediation is needed in 15% of MNR, ENR, and in situ remediation areas

Table B-38 summarizes the total costs for each of the alternatives. Detailed cost information can be found in (FS, Appendix E, Table 4).

Costs for the preferred alternative are detailed in Figure B-45. The largest portion of the project cost is sediment disposal, totaling 34% of the cost. Contingency for project uncertainties accounts for 18% of the total cost.

For the estimates a discount rate of 0% was used. The recommended rate of 7% for net present value calculations is not appropriate for the EW OU because:

- All three of the PRPs are public entities and have different capital costs than the private sector. Public entities may not be able to set aside sufficient funds for investment without incurring additional costs of bonding or borrowing and, therefore, would not be able to take advantage of the interest accumulation assumption implied by the net present value calculation.

- The lending environment has changed significantly since the EPA guidance was published in 2000. The current recommendations in the Office of Management and Budget Circular A-94 Appendix C, revised November 2016, indicates that the discount rate ranges from -0.5% for a 3-year investment to 0.7% for a 30-year investment.

These costs represent the best estimate total costs for the proposed EW remedial alternatives. The major uncertainties between the cost estimate and the eventual actual cleanup costs include the following:

- Changes in the scope of cleanup due to additional characterization (e.g., changes to dredging volume)
- Changes in the scope of cleanup due to changes in remedial approach or adaptive management (e.g., ENR is considered viable in a larger area)
- Changes in unit costs due to changes in acceptable remediation practices (e.g., changes to dewatering or transloading practices)
- Changes in unit costs due to changes in economic conditions (e.g., cost of fuel, availability of contractors)
- Changes in unit costs due to changes in the rate of construction (e.g., additional delays from working around shipping vessels, or tribal fishing vessels associated with salmon runs. The latter may trigger additional standby costs if work is halted entirely while tribal fishing is conducted within the EW)
- Additional costs that were not considered for this FS, such as economic disruption to the Port of Seattle and fisheries mitigation

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Tables

Table A-1

Summary of Estimated Excess Cancer Risks for the RME Seafood Consumption Scenarios

COC	Adult Tribal RME (Tulalip Data)		Child Tribal RME (Tulalip Data)		Adult API RME	
	Excess Cancer Risk (% of Total[a])	**Percent of Risk by Seafood Consumption Category[b]**	**Excess Cancer Risk (% of Total[a])**	**Percent of Risk by Seafood Consumption Category[b]**	**Excess Cancer Risk (% of Total[a])**	**Percent of Risk by Seafood Consumption Category[b]**
Arsenic (inorganic)	2×10^{-4} (14%)	82% clams; 8.9% crab EM	4×10^{-5} (11%)	82% clams; 8.9% crab EM	8×10^{-5} (14%)	87% clams; 6.0% mussels
cPAHs (TEQ)	1×10^{-4} (7%)	90% clams	1×10^{-4} (27%)	90% clams	5×10^{-5} (9%)	73% clams; 25% mussels
Total PCBs	1×10^{-3} (70%)	41% benthic fillet; 26% perch; 9.5% crab EM; 9.1% rockfish; 8.5% crab WB; 6.1% clams	2×10^{-4} (55%)	41% benthic fillet; 26% perch; 9.5% crab EM; 9.1% rockfish; 8.5% crab WB; 6.1% clams	4×10^{-4} (69%)	59% rockfish; 16% benthic fillet; 7.3% crab WB; 6.7% clams; 5.5% benthic WB
PCBs (TEQ)	7×10^{-4}	30% benthic fillet; 27% perch; 13% crab WB; 12% crab EM; 11% rockfish; 7.7% clams	1×10^{-4}	30% benthic fillet; 27% perch; 13% crab WB; 12% crab EM; 11% rockfish; 7.7% clams	3×10^{-4}	62% rockfish; 11% benthic fillet; 9.7% crab WB; 7.5% clams; 4.8% benthic WB
Dioxin/furan (TEQ)	1×10^{-4} (7%)	25% clams; 22% crab EM; 18% crab WB; 17% perch; 10% benthic fillet	2×10^{-5} (5%)	25% clams; 22% crab EM; 18% crab WB; 17% perch; 10% benthic fillet	4×10^{-5} (7%)	35% rockfish; 31% clams; 18% crab WB; 7.9% crab EM
Other COCs[c]	3×10^{-5} (2%)	nc	4×10^{-6} (1%)	nc	7×10^{-6} (1%)	nc
Total excess cancer risk and main contributors to the total risk[d]	**1×10^{-3}**	**29% – PCBs in benthic fillet 18% – PCBs in perch 10% – arsenic in clams 6.7% – PCBs in crab EM 6.4% – PCBs in rockfish 6.2% – cPAHs in clams 6.0% – PCBs in crab WB 17% – other**	**4×10^{-4}**	**26% – cPAHs in clams 22% – PCBs in benthic fillet 14% – PCBs in perch 8.1% – arsenic in clams 5.2% – PCBs in crab EM 25% – other**	**6×10^{-4}**	**41% – PCBs in rockfish 11% – arsenic in clams 11% – PCBs in benthic fillet 6.7% – cPAHs in clams 5.1% – PCBs in crab WB 25% – other**

Notes:

a. Total excess cancer risk includes the risks associated with all COPCs, including total PCBs but excluding PCB TEQ.
b. Seafood consumption categories contributing greater than 5% of the risk for each COC are listed in this table.
c. Together, all other COCs contributed less than 2% to the total excess cancer risk.
d. Seafood consumption category-COC combinations contributing greater than 5% of the total risk are listed separately. All other combinations are included in the "other" category. Total PCBs is included in the total, and total PCBs TEQ is not included to avoid double-counting risks due to PCBs.

API – Asian and Pacific Islander
cPAH – carcinogenic polycyclic aromatic hydrocarbon
COC – contaminant of concern
COPC – contaminant of potential concern
EM – edible meat
HHRA – human health risk assessment
nc – not calculated
PCB – polychlorinated biphenyl
RME – reasonable maximum exposure
TEQ – toxic equivalent
WB – whole body

Table A-2
Estimated Excess Cancer Risks for the HHRA Direct Sediment Exposure Scenarios

COPC	Estimated Excess Cancer Risk					
	Netfishing		Habitat Restoration Worker	Clamming		
	RME	CT		Tribal RME	Tribal – 183 Days per Year	7 Days per Year
Arsenic	3×10^{-6}	7×10^{-7}	5×10^{-7}	1×10^{-5}	2×10^{-5}	4×10^{-7}
cPAHs (TEQ)	3×10^{-6}	2×10^{-7}	7×10^{-7}	2×10^{-5}	3×10^{-5}	5×10^{-7}
Total PCBs	6×10^{-7}	6×10^{-8}	2×10^{-7}	3×10^{-6}	6×10^{-6}	1×10^{-7}
PCBs (TEQ)	3×10^{-7}	4×10^{-8}	5×10^{-8}	1×10^{-6}	2×10^{-6}	3×10^{-8}
Dioxin/furan (TEQ)	6×10^{-7}	1×10^{-7}	NA	1×10^{-6}	2×10^{-6}	4×10^{-8}
Total TEQ excess cancer risk for dioxins/furans and coplanar PCBs	**9×10^{-7}**	**1×10^{-7}**	**NA**	**2×10^{-6}**	**4×10^{-6}**	**7×10^{-8}**
Total excess cancer risk (excluding PCB TEQ)[a]	**7×10^{-6}**	**1×10^{-6}**	**1×10^{-6}**	**3×10^{-5}**	**6×10^{-5}**	**1×10^{-6}**
Total excess cancer risk (excluding total PCBs)[a]	**7×10^{-6}**	**1×10^{-6}**	**1×10^{-6}**	**3×10^{-5}**	**5×10^{-5}**	**1×10^{-6}**

Notes:
Shaded cells indicate excess cancer risks greater than 1×10^{-6}.
a. Total risk values include the risks associated with all COPCs. However, only those COPCs with excess cancer risks greater than 1×10^{-6} for at least one scenario are listed in this table.

COPC – contaminant of potential concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
CT – central tendency
NA – not applicable (not a COPC)
PCB – polychlorinated biphenyl
RME – reasonable maximum exposure
TEQ – toxic equivalent

Table A-3
COCs and Risk Drivers Identified for ERA Receptors

Receptor	Evaluation Type	COPCs	COCs	Risk Driver
Benthic invertebrate community	sediment	29 chemicals, including metals, PAHs, total PCBs, phthalates, other SVOCs, total DDTs[a]	29 COPCs[b]	28 SMS chemicals[c]
	tissue residue	TBT, total PCBs	TBT	TBT
	surface water	cadmium, mercury, TBT	TBT	none
	porewater	naphthalene	naphthalene	none
Crab	tissue residue	arsenic, cadmium, copper, zinc, total PCBs	cadmium, copper, zinc	none
	surface water	cadmium, mercury, TBT	none	none
Fish	dietary	arsenic, cadmium, chromium, copper, vanadium, benzo(a)pyrene	cadmium, copper, vanadium	none
	tissue residue	beta-endosulfan, total PCBs, TBT	total PCBs, TBT	total PCBs
	surface water	cadmium, mercury, TBT	none	none
Birds	dietary dose	mercury, total PCBs, PCB TEQ	none	none
Mammals	dietary dose	mercury, selenium, total PCBs, PCB TEQ	none	none

[a] The 29 COPCs were arsenic, cadmium, mercury, zinc, acenaphthene, benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, chrysene, dibenzo (a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3,-c,d)pyrene, phenanthrene, pyrene, total benzofluoranthenes, HPAH, LPAH, BEHP, BBP, di-n-butyl phthalate, 1,4-dichlorobenzene, 2-methylnaphthalene, 2,4-dimethylphenol, dibenzofuran, n-nitrosodiphenylamine, phenol, total PCBs, and total DDTs. All COPCs had exceedances of SMS chemical criteria except total DDTs, which was based on exceedances of the DMMP guideline.

[b] Anthracene was inadvertently omitted as a COC in the ERA. One sample had an anthracene concentration above the SQS, with an HQ of 1.03. Anthracene has been included in Section 4 and the FS evaluation as a COC and benthic risk driver based on the SQS exceedance.

[c] All SMS chemicals were identified as risk drivers for benthic invertebrates. Total DDTs were identified as a COC based on the exceedance of DMMP criteria. However, total DDTs were not identified as risk drivers.

BBP – butyl benzyl phthalate
BEHP – bis(2-ethylhexyl) phthalate
COC – contaminant of concern
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
DMMP – Dredge Material Management Program
ERA – ecological risk assessment
FS – feasibility study
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
HQ – hazard quotient
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SMS – Washington State Sediment Management Standards
SQS – sediment quality standards
SVOC – semivolatile organic compound
TBT – tributyltin
TEQ – toxic equivalent

Table A-4: Summary of Preliminary Remediation Goals

Risk Driver	PRG	Purpose	Basis	Spatial Scale
Total PCBs	2 µg/kg dw[a]	Protection of Human Health for Seafood Consumption (RAO 1)	Natural background	Site-wide
	250, 370 µg/kg dw	Protection of Fish (RAO 4)	RBTC established based on brown rockfish (250) and English sole (370)	Site-wide
	12 mg/kg OC (SQS)	Protection of the Benthic Community (RAO 3)	RBTC	Point
Arsenic (mg/kg dw)	7[a]	Protection of Human Health for Direct Contact (RAO 2)	Natural background	Site-wide (netfishing) and clamming areas (clamming)
	57 (SQS)	Protection of the Benthic Community (RAO 3)	RBTC	Point
cPAH (µg TEQ/kg dw)	380	Protection of Human Health for Direct Contact for Netfishing (RAO 2)	RBTC	Site-wide
	150	Protection of Human Health for Direct Contact for Clamming (RAO 2)	RBTC	Clamming Areas
Dioxins/furans (ng TEQ/kg dw)	2[a]	Protection of Human Health for Seafood Consumption (RAO 1)	Natural background	Site-wide
TBT (mg/kg OC)	7.5	Protection of the Benthic Community (RAO 3)	RBTC	Point
Other benthic risk drivers	SQS	Protection of the Benthic Community (RAO 3)	RBTC	Point

Notes:

a. Following SMS (SCUM II),[5] PRGs developed for protection of human health for total PCBs, arsenic, and dioxins/furans would be slightly different than those presented above. Based on the SCUM II methodology, the natural background-based PRGs would be 3.5 µg/kg dw for total PCBs and 11 mg/kg dw for arsenic, and the PRG for dioxins/furans would be 5 ng TEQ/kg dw, based on the PQL.

µg – microgram
dw – dry weight
mg – milligram
kg – kilogram
ng – nanogram
OC – organic carbon
PCBs – polychlorinated biphenyls
PQL – practical quantitation limit
PRG – preliminary remediation goal
RAO – remedial action objective
RBTC – risk-based threshold concentration
SCUM – Sediment Cleanup Users Manual
SQS – sediment quality standard
TBT – tributyltin
TEQ – toxic equivalent

5 Washington State Department of Ecology, 2017. Sediment Cleanup Users Manual II. Guidance for Implementing the Cleanup Provisions of the Sediment Management Standards, Chapter 173-204 WAC. Publication No. 12-09-057. April 2017.

Table A-5. Summary of Selected RALs

Risk Driver	RAL	RAO 1	RAO 2	RAO 3	RAO 4
		Human Health Seafood	Human Health Direct Contact	Benthic Inverts	Ecological - Fish
PCBs (mg/kg OC)	7.5/12 site wide	Substantial risk reduction to 2E-4 based on modeling		Achieves PRG: 12 mg/kg OC	Achieves PRG: 250, 370 µg/kg
Dioxin/Furan (ng TEQ/kg)	25 site wide				
Arsenic (mg/kg)	57 site wide		Achieves PRG: 57 mg/kg	Achieves PRG: 57 mg/kg	
cPAHs (µg TEQ/kg)	4800 site wide		Achieves PRG: 380 µg/kg TEQ		
cPAHs (µg TEQ/kg)	660 clam areas		Achieves PRG: 150 µg/kg TEQ		
TBT (mg/kg OC)	7.5 site wide			Achieves PRG: 7.5 mg/kg OC	
Other benthic risk drivers	SQS			RALs achieve the PRGs for all 29 benthic drivers	

Table A-6. Retained Alternatives and Alternative Key

Action Alternatives	Technologies for Open-water Areas	Technologies for Restricted Access Areas (Underpier and Low Bridges)	PCBs RAL All Areas
No Action			
1A(12)	1. Removal with capping and ENR where applicable	A MNR	(12) 12 mg/kg OC
1B(12)		B In situ treatment	
1C+(12)		C+ Diver-assisted hydraulic dredging followed by in situ treatment for PCBs or mercury > CSL; in situ treatment elsewhere	
2B(12)	2. Removal with capping where applicable	B In situ treatment	
2C+(12)		C+ Diver-assisted hydraulic dredging followed by in situ treatment for PCBs or mercury > CSL; in situ treatment elsewhere	
3B(12)	3. Maximum removal to the extent practicable	B In situ treatment	
3C+(12)		C+ Diver-assisted hydraulic dredging followed by in situ treatment for PCBs or mercury > CSL; in situ treatment elsewhere	
2C+(7.5)	2. Removal with capping where applicable		(7.5) 7.5 mg/kg OC
3E(7.5)	3. Maximum removal to the extent practicable	E Diver-assisted hydraulic dredging followed by in situ treatment	

Notes:

CSL – cleanup screening level
ENR – enhanced natural recovery
mg/kg – milligrams per kilogram
MNR – monitored natural recovery
OC – organic carbon
PCB – polychlorinated biphenyl
RAL – remedial action level

Table A-7. Areas, Volumes and Costs for Alternatives

Alternative	Total Remediated Area (acres)	No Action Area (acres)	Total Area[a] (acres)	Total Removal Volume[b] (cubic yards)	Total Placement Volume (capping, ENR, in situ treatment, RMC; cubic yards)	Total Cost[c]	Construction Timeframe (years)
No Action	0	157	157	0	0	$950,000	0
1A(12)	121	36	157	810,000	290,000	$256,000,000	9
1B(12)	121	36	157	810,000	290,000	$264,000,000	9
1C+(12)	121	36	157	820,000	290,000	$277,000,000	9
2B(12)	121	36	157	900,000	290,000	$284,000,000	10
2C+(12)	121	36	157	910,000	290,000	$297,000,000	10
3B(12)	121	36	157	960,000	290,000	$298,000,000	10
3C+(12)	121	36	157	960,000	290,000	$310,000,000	10
2C+(7.5)	132	25	157	1,010,000	290,000	$326,000,000	11
3E(7.5)	132	25	157	1,080,000	270,000	$411,000,000	13

Notes:

a. Total area does not include locations without sediment (approximately 19 acres of uncovered riprap)

b. Removal volume is based on the assumptions made in Appendix F of the Feasibility Study.

c. Costs are based on assumption in Appendix E of the Feasibility Study

ENR - enhanced natural recovery

RMC - residuals management cover

Table B-1. Maintenance Dredging History in the East Waterway from 2000-2009

Project Name	Date	Details
Stage 1 navigational dredging	December 1999 - February 2000	Dredging to -51 ft MLLW from the north end of the EW to Station 4950
T-30 Berth dredging	January 2002 - February 2002	Dredging to -44 ft MLLW from Station 1400 to 2900
Phase 1 Removal Action dredging	January 2004 - February 2005	Dredging to - 51 ft MLLW from Station 3000 to 4950. Contingency dredging occurred to -52 to -53 ft MLLW over most of the dredge footprint, which was followed by placement of minimum 6 inches of sand cover.
Slip 36 dredging	August 2004 - February 2005	Dredging to -40 ft MLLW
Terminal 46 berth maintenance dredging	January 2008 to February 2009	Dredging to -51 ft MLLW from station -200 to -700
Terminal 30 berth dredging	January 2008 - February 2009	Dredging to -51 ft MLLW from station 1700 to 3500
Terminal 18 berth dredging	January 2005 - November 2006	Dredging in beths 2 through 5 to -51 ft MLLW from station 1500 to 4950
Terminal 18 minor berth maintenance dredging	January - February 2009	Dredging to -51 ft MLLW from station 500 to 4900 with less than 1,000 cubic yards (cy) removed

Table B-2

Net Sedimentation Rates Defined by Vessel Operational Area

Propwash Area	Area (square feet)	Geochronology Cores Located in Area	Net Sedimentation Rate (in cm/yr) Range Based on Cs-137 Data (see Table 3-3 in EW SRI[a])			Net Sedimentation Rate (in cm/yr) Range Based on Pb-210 Data (see Table 3-3 in EW SRI[a])			Net Sedimentation Rate Assigned[b,c] (cm/yr)	Basis
			Via Cs-137 Peak	Low	High	Estimate Based on Best-Fit Line	Low	High		
1A-1	273,332	None	No Data (previously dredged area)			No Data (previously dredged area)			1.6	Average of the Cs-137 data, consistent with adjacent area (Area 5).
1A-2	286,107	None	No Data (previously dredged area)			No Data (previously dredged area)			1.6	Average of the Cs-137 data, consistent with adjacent areas to the south and moderate propeller wash forces in this area compared to Area 1A-3 (which has higher propeller wash forces; Figure 5-2).
1A-3	283,699	GC-08	No Peak			0.28	0.20	0.49	0.5	Average of the Pb-210 data, due to core GC-08 having Pb-210 data but no Cs-137 peak. In addition, the area is adjacent to the area with no recovery (Area 1A-4), but no bathymetric evidence of sediment propeller wash is present in this area (Figure 2-3b).
1A-4	271,317	GC-03	Archived			Archived			0	Net sedimentation rate set to 0 due to both an unrecovered core (GC-04) and predicted high scour rates from propeller wash in this area (Figure 5-2). This is also consistent with bathymetric evidence of propeller wash (Figure 2-3b).
		GC-04	Unrecovered			Unrecovered				
		GC-06	Archived			Archived				
1A-5	224,452	GC-01	Archived			Archived			0.5	Average of the Pb-210 data, due to the area having a recoverable core (which was archived), being adjacent to the area with no recovery (Area 1A-4), and having similar predicted propeller wash forces as Areas 1A-3 and 1A-4. No bathymetric evidence of sediment propeller wash is present in this area (Figure 2-3b).
1A-6	415,855	None	No Data (previously dredged area)			No Data (previously dredged area)			1.6	Average of the Cs-137 data, consistent with adjacent areas. This area is predicted to have propeller wash forces similar to Areas 1A-1, 1A-2, and 4A (Figure 5-2).
1B-1	870,200	GC-07	Archived			Archived			1.6	Average of Cs-137 data. Area 1B-1 had a recoverable core (which was archived) and is part of the navigation channel servicing T-18 Berths 3 and 4 (Areas 1A-1 and 1A-2), T-30 (Area 1A-6), T-25 (Area 4A), and Slip 27 (Area 3), and therefore is assigned the same sedimentation rate as these areas.
1B-2	870,200	GC-05	No Peak			0.67	0.26	0.67	0.5	Average of the Pb-210 data, due to core GC-05 having Pb-210 data but no Cs-137 peak. In addition, the area is part of the navigation channel that services the larger vessels that use T-18 Berths 1 and 2 (Areas 1A-3 through 1A-5), and therefore is assigned the same sedimentation rate as these areas that also have recoverable cores (i.e., Areas 1A-3 and 1A-5).
1C	403,971	None	No Data			No Data			1.6	Average of Cs-137 data, because sedimentation rate is consistent with adjacent areas to the north and south, and Area 1C is not expected to have large propeller wash forces compared to T-18 Berths 1 and 2 and the adjacent navigation channel (Figure 5-2).
2	301,364	GC-02	No Peak			Low Correlation			1.6	Average of Cs-137 data, consistent with Area 3 (another slip) that suggests selection of a higher range net sedimentation rate for this area.
3	215,033	GC-09	No Peak			0.56	0.35	1.4	1.6	Average of Cs-137 data. Cs-137 and Pb-210 data in this area suggest selection of a higher range net sedimentation rate for this area.
		GC-10	1.3	1.2	1.4	0.61	0.3	0.61		
4A	359,473	GC-13	No Peak			0.69	0.34	0.69	1.6	Average of Cs-137 data. Although core GC-13 only had a Pb-210 peak, the area is expected to have a higher sedimentation rate due to proximity to the narrow to wide waterway transition and the data in adjacent Areas 4B and 6-2. Cs-137 data used because nearby core GC-12 includes Cs-137 sedimentation rates but has a lower Pb-210 sedimentation rate than core GC-13, indicating the sediment rates are similar in these two areas (i.e., Areas 4B and 4A).
4B	412,584	GC-12	>1.9	1.8	2.0	0.46	0.27	1.8	1.6	Average of Cs-137 data due to Cs-137 peak.
		GC-16	1.6	1.2	1.4	Low Correlation				

Table B-2

Net Sedimentation Rates Defined by Vessel Operational Area

Propwash Area	Area (square feet)	Geochronology Cores Located in Area	Net Sedimentation Rate (in cm/yr) Range Based on Cs-137 Data (see Table 3-3 in EW SRI[a])			Net Sedimentation Rate (in cm/yr) Range Based on Pb-210 Data (see Table 3-3 in EW SRI[a])			Net Sedimentation Rate Assigned[b,c] (cm/yr)	Basis
			Via Cs-137 Peak	Low	High	Estimate Based on Best-Fit Line	Low	High		
5	356,623	GC-11	>1.7	1.6	1.8	0.47	0.27	1.8	1.6	Average of Cs-137 data due to Cs-137 peak.
		GC-15	1.3	1.1	1.3	Low Correlation				
6	181,099	GC-17	Unrecovered			Unrecovered			0.5	Average of Pb-210 data. Cs-137 data from core GC-18 suggests a higher net sedimentation rate, but core GC-17 was unrecoverable in this area, which suggests a moderate net sedimentation rate.
		GC-18	>1.9	1.8	2.0	Low Correlation				
		GC-20	Low Recovery			Low Recovery				
6-2	66,247	GC-16	1.6	1.5	1.7	0.18	0.09	4.2	1.6	Average of Cs-137 data due to Cs-137 peak.
7	86,233	GC-19A	1.2	1.1	1.3	Low Correlation			1.6	Average of Cs-137 data due to Cs-137 peak.
8	93,598	GC-21	Unrecovered			Unrecovered			0	Net sedimentation rate set to 0 due to two unrecovered cores in area.
		GC-22	Unrecovered			Unrecovered				

Notes:

a. East Waterway (EW) Supplemental Remedial Investigation (SRI) (Windward and Anchor QEA 2014).

b. One of three values were assigned to each of the areas: 0 cm/yr, 0.5 cm/yr, or 1.6 cm/yr, representing no sedimentation, moderate sedimentation based on the average of Pb-210 data, and higher sedimentation based on the average of Cs-137. As discussed in Section 5.1.2, the Cs-137 data are considered more reliable than the Pb-210 and serve as the default in areas without additional data. Shading in the table matches shading in net sedimentation areas shown in Figure 5-1.

c. Site-wide area-weighted net sedimentation rate is 1.2 cm/yr.

cm/yr – centimeters per year Cs-137 – cesium-137 Pb-210 – lead-210 T – Terminal

Table B-3

Receptors of Concern Selected for the EW and Summary of Rationale for Selection

ROC	Ecological Significance	Societal Significance	Site Use	Sensitivity
Benthic invertebrate community	food source for other invertebrates, fish, birds, and mammals; nutrient cycling; sediment oxygenation	valued as food source to other species of high societal value	present year-round; multiple life stages, diverse phyla	range of contaminant sensitivities represented
Cancrid crab	higher-trophic-level benthic invertebrate; food for other invertebrates, fish, birds, and mammals	recreational and commercial value	multiple life stages (gravid females, juveniles)	effects data available for decapods; sensitivity relative to other decapods unknown
Brown rockfish	higher-trophic-level fish; important prey item for fish, birds, and mammals	some commercial (though not in EW) and recreational value	adults and juveniles present year-round; may spawn in the EW	effects data available for other fish species; relative sensitivity of brown rockfish unknown; potential for elevated exposure via bioaccumulation because of trophic position; long-lived
English sole	important prey item for fish, birds and mammals; key benthic invertebrate predator	some commercial and recreational value (though not in EW)	juveniles present year-round; adults present except during spawning migration to Puget Sound	NMFS data suggest they are as sensitive as other flatfish species
Juvenile Chinook salmon	important prey item for fish, birds and mammals; seasonally one of the most abundant juvenile salmonids in the EW	T&E species; returning adults important to tribal, commercial, and sport fisheries	generally present April to July; individuals likely present in EW for a few days to couple of weeks; most estuary-dependent juvenile salmonid	sensitive to a wide range of contaminants
Osprey	high trophic level	highly valued and well-studied bird of prey; protected under the Migratory Bird Treaty Act	nests along the EW and likely forages in the EW	effects data available for other bird species; relative sensitivity of osprey unknown; potential for elevated exposure via bioaccumulation because of trophic position
Pigeon guillemot	high trophic level	valued in general as wildlife species; protected under the Migratory Bird Treaty Act	nests observed along the EW	effects data available for other bird species; relative sensitivity of pigeon guillemot unknown; potential for elevated exposure via bioaccumulation because of trophic position
River otter	high trophic level	highly valued by society	limited data, although anecdotal information indicates year-round presence of a river otter family on Kellogg Island	mink are sensitive to some contaminants, such as PCBs, although the relative sensitivity of river otter is unknown; potential for elevated exposure via bioaccumulation because of trophic position

ROC	Ecological Significance	Societal Significance	Site Use	Sensitivity
Harbor seal	high trophic level	protected under Marine Mammal Protection Act	occasional use based on a survey in the EW	pinnipeds suspected to be sensitive to some contaminants, such as PCBs, although the relative sensitivity of harbor seal is unknown; potential for elevated exposure via bioaccumulation because of trophic position

EW – East Waterway
NMFS – National Marine Fisheries Service
PCB – polychlorinated biphenyl
ROC – receptor of concern
T&E – threatened and endangered

Table B-4

Summary of Potential Sources, Transport Pathways, and Source Control Programs in the East Waterway

	Direct Discharges[a]		Groundwater Discharge[b]	Bank Erosion	Atmospheric Deposition	Spills[c]	Treated-Wood Structures[d]	Surface Water Inputs and Sediment Transport[e]
	Stormwater/Sheetflow	CSOs						
Potential source	Land use activities and atmospheric deposition that deposit contaminants on land surfaces and subsequently are entrained during rainfall events and enter SD systems or sheetflow. Examples include manufacturing, maintenance, and repair activities (industrial and residential), and spills or leaks.	Direct discharge or land use activities and atmospheric deposition that deposit contaminants on land surfaces and subsequently are entrained during rainfall events. Examples include municipal and industrial wastewater and stormwater collected within combined sewer service areas.	Land use activities that result in contamination to soils and groundwater at cleanup or industrial sites.	Land use activities that result in contamination of nearshore bank soils, which may erode due to natural or human activity.	Local, regional, and global air emissions.	Spills of contaminants in upland areas, conveyance areas, or from adjacent or overwater operations.	Treated-wood pilings and structures, which may release contaminants within the EW.	Suspended sediments and associated contaminants from upstream areas (e.g., LDW) and from Elliott Bay.
Pathways	Entrained contaminants in stormwater are conveyed by private and public drainage systems or direct discharge of sheetflow to the EW.	Combined sewer collection and conveyance of stormwater, municipal and industrial wastewater, and associated solids.	Groundwater migration from the EW nearshore areas; potential leakage into damaged SD or sewer lines	Erosion of unstable banks.[f]	Movement of air and entrained particulates and contaminants within EW airshed; direct deposition or transport via stormwater runoff.	Discharge to the EW from adjacent properties or overwater operations. Upland spills impacting groundwater or entrained in conveyance systems (stormwater and CSO).	Release of wood treatment material to surface water or sediment via abrasion/damage or by leaching.	Transport of suspended sediments by river flows, ship prop wash, and tidal currents deposited in the EW sediments.
Point of initial entry to EW	Storm drain outfalls and direct discharge of sheetflow from bridges and terminal aprons	Discharge to the EW at CSO outfalls during CSO discharge events.	Discharge of nearshore groundwater to sediments or to the EW in seeps; discharges of groundwater at stormwater or CSO outfalls.	Unstable bank erosion or failure.	Direct deposition of contaminants onto the EW surface and discharge at outfalls that convey stormwater to the EW.	Direct entry to the EW at the spill location or indirect entry via SD or CSO outfalls	Locations of remaining treated-wood pilings and structures within the EW[e]	Movement of suspended sediments into the EW and potential deposition onto the EW sediments
Examples of ongoing source control program(s)	Local stormwater management programs (e.g., controls on new and redevelopment projects, business, illicit detection elimination programs, O&M programs, and street sweeping), and the NPDES	City of Seattle and King County CSO control programs, compliance, inspection programs, county industrial waste permit programs, and O&M programs.	Site cleanup and associated programs.	Site cleanup and associated programs.	Ecology Air Toxics Program, PSCAA, King County air monitoring, and air emissions reduction programs.	Federal, state, and local spill reporting and response programs; site cleanup and associated programs; and site BMPs.	Permitting (does not allow new installation) and DNR creosote-treated material removal program.[g]	Federal, state, and local source control and cleanup programs.

Note: This table provides a concise summary of each potential source and pathway under evaluation, including the transport pathways by which source-associated materials may be transported to and enter the EW. Different lines of evidence are appropriately used to identify the locations, quantity, and quality of solids and pollutant inputs to the EW as necessary to support the evaluation of potential sediment recontamination in the FS. Sanitary/combined sewer systems may also include EOF structures at pump stations.

[a] No permitted industrial wastewater discharges to the EW were identified during an information review conducted as part of the EISR (Anchor and Windward 2008a). Three outfalls have been identified that had no associated drainage basin delineation and are presumed to be historical (i.e., inactive outfalls). No discharge has been observed from the outfalls and no industrial wastewater permits have been identified.

[b] Groundwater from upland cleanup sites may contribute groundwater to some stormwater or combined sewer conveyances.

[c] Spills to upland properties may contribute contaminants to stormwater or combined sewer systems.

[d] Most creosote-treated pilings and structures have been removed from the EW as discussed in Section 9.4.6.

[e] See Section 3 as well as the EW CSM and data gaps analysis report (Anchor et al. 2008b) and STER (Anchor QEA and Coast & Harbor Engineering 2012 [in prep]).

[f] Most EW shorelines are armored. The current construction of EW shorelines is summarized in Section 9.4.5.

[g] See the DNR *Creosote Removal Program* details at: http://www.dnr.wa.gov/ResearchScience/Topics/AquaticClean-UpRestoration/Pages/aqr_creosote_removal_program.aspx

BMP – best management practice
CSM – conceptual site model
CSO – combined sewer overflow
DNR – Washington State Department of Natural Resources
Ecology – Washington State Department of Ecology
EOF – emergency overflow
EW – East Waterway
FS – feasibility study
LDW – Lower Duwamish Waterway
NPDES – National Pollutant Discharge Elimination System
O&M – operations and maintenance
PSCAA – Puget Sound Clean Air Agency
SD – storm drain
STER – sediment transport evaluation report

Table B-5

Statistical Summaries for Human Health Risk Driver COCs in Surface Sediment

Contaminant	Unit	Detection Frequency	Concentration				SWAC
			Mean	Median	95th Percentile	Maximum	
Surface							
Total PCBs[a]	µg/kg dw	235/248	490	290	1,600	8,400	460
cPAHs[b]	µg TEQ/kg dw	15/15[c]	1,900	230	nc	17,000	680
		241/248	1,600	250	3,500	68,000	
Arsenic[d]	mg/kg dw	170/239	11	6.7	21	250	9.0
Dioxins/ furans[e]	ng TEQ/kg dw	13/13[f]	16	16	nc	31	nc
		19/19[g]	32	38	52	71	
MIS composite samples[h]							
Total PCBs[a]	µg/kg dw	3/3[i]	970	770	nc	1,590	nc
		1/1[j]	nc	nc	nc	370	
cPAHs[b]	µg TEQ/kg dw	3/3[i]	1,000	780	nc	1,900	nc
		1/1[j]	nc	nc	nc	390	
Arsenic[d]	mg/kg dw	3/3[i]	10	9.1	nc	13.3	nc
		1/1[j]	nc	nc	nc	7.7	
Dioxins/ furans[e]	ng TEQ/kg dw	3/3[i]	12.1	13.2	nc	13.8	nc
		1/1[j]	nc	nc	nc	8.52	
Subsurface							
Total PCBs[a]	µg/kg dw	207/290	1,500	275	4,300	17,600	nc
cPAHs[b]	µg TEQ/kg dw	218/269	1,000	250	3,600	23,000	nc
Arsenic[d]	mg/kg dw	250/255	10	9	29	96	nc
Dioxins/ furans[e]	ng TEQ/kg dw	16/16	17.2	2.70	78.0	184	nc

Notes:

a. Total PCBs represent the sum of the detected concentrations of the individual Aroclors. If none of the individual Aroclors were detected in a given sample, the non-detect value represents the highest reporting limit.
b. Total cPAH TEQs were calculated by summing the products of concentrations and compound-specific PEFs for individual cPAH compounds. PEF values (California EPA 2005; Ecology 2001) are based on the individual PAH component's relative toxicity to benzo(a)pyrene. By using the PEFs, the toxicity of the various cPAH compounds can be expressed as a single number, the TEQ. If an individual PAH compound was not detected, the PEF for that compound was multiplied by one-half the RL for that compound.
c. Intertidal composite samples.
d. Summary statistics were calculated assuming one-half the reporting limit for non-detect results.
e. Dioxin/furan TEQs were calculated using TEFs for mammals presented in Van den Berg et al. (2006). The TEF expresses the toxicity of dioxins/furans relative to the most toxic form of dioxin (2,3,7,8-TCDD). By using the TEFs, the toxicity of the various dioxin/furan congeners can be expressed as a single number, the TEQ. Dioxin/furan TEQs were calculated for each sample by summing the product of individual congener concentrations and congener-specific TEFs. If an individual congener was not detected, the TEF for that congener was multiplied by one-half the RL for that congener. In cases where the congener result was K-flagged or EMPC-flagged, the TEF for that congener was multiplied by one-half the reported value for that congener.
f. Subtidal surface composite samples collected in 13 subareas of the waterway.
g. Sediment grab samples selected for dioxin/furan analysis.
h. Intertidal composite samples collected using multi-increment sampling (MIS) technique.
i. Area-wide intertidal MIS composite.
j. Public access intertidal MIS composite.

µg – microgram
cPAH – carcinogenic polycyclic aromatic hydrocarbon
dw – dry weight
EMPC – estimated maximum possible concentration
kg – kilogram
MIS – multi-increment sampling
nc – not calculated
ng – nanogram
PCB – polychlorinated biphenyl
PEF – potency equivalency factor
RL – reporting limit
SWAC – spatially-weighted average concentration
TEF – toxic equivalency factor
TEQ – toxic equivalent

Table B-6

Statistical Summaries for Benthic Risk Driver COCs in Surface Sediment

Chemical	Detection Frequency		Frequency of Detected Concentrations > SQS and ≤ CSL			Maximum Detected SQS EF	Frequency of Detected Concentrations > CSL			Maximum Detected CSL EF
	No. of Samples[a]	%	No. of Samples[b]	%	No. Non-detected with RL > SQS and ≤ CSL		No. of Samples[c]	%	No. Non-detected with RL > CSL	
Metals										
Arsenic	170/239	71	0/239	0.0	0	4.4	3/239	1.3	0	2.7
Cadmium	163/239	68	1/239	0.4	0	1.3	1/239	0.4	0	1.0
Mercury	241/247	98	41/247	17	0	2.6	10/247	4.0	0	1.8
Zinc	239/239	100	4/239	1.7	0	3.2	2/239	0.8	0	1.4
PAHs										
2-Methylnaphthalene	95/248	38	0/248	0.0	0	2.2	3/248	1.2	0	1.3
Acenaphthene	134/248	54	11/248	4.4	0	53.1	13/248	5.2	0	38.0
Anthracene	217/248	88	5/248	2.0	0	19.8	2/248	0.8	0	19.8
Benzo(a)anthracene	234/248	94	7/248	2.8	0	31.5	7/248	2.8	0	25.6
Benzo(a)pyrene	233/248	94	7/248	2.8	0	27.5	8/248	3.2	0	27.5
Total benzofluoranthenes[e]	236/248	95	7/248	2.8	0	21.3	8/248	3.2	0	18.9
Chrysene	238/248	96	9/248	3.6	0	32.1	3/248	1.2	0	16.1
Dibenzofuran	115/248	46	9/248	3.6	0	17.8	6/248	2.4	0	6.3
Fluoranthene	241/248	97	15/248	6.0	0	46.5	7/248	2.8	0	31.6
Fluorene	152/248	61	10/248	4.0	0	21.1	9/248	3.6	0	16.1
Phenanthrene	238/248	96	14/248	5.6	0	37.3	9/248	3.6	0	37.3
Pyrene	243/248	98	2/248	0.8	0	31.9	5/248	2.0	0	25.2

Table B-6 continued

Statistical Summaries for Benthic Risk Driver COCs in Surface Sediment

Chemical	Detection Frequency		Frequency of Detected Concentrations > SQS and ≤ CSL			Maximum Detected SQS EF	Frequency of Detected Concentrations > CSL			Maximum Detected CSL EF
	No. of Samples[a]	%	No. of Samples[b]	%	No. Non-detected with RL > SQS and ≤ CSL		No. of Samples[c]	%	No. Non-detected with RL > CSL	
Total HPAHs[g]	245/248	99	10/248	4.0	0	34.1	7/248	2.8	0	24.1
Total LPAHs[h]	238/248	96	6/248	2.4	0	20.0	9/248	3.6	0	20.0
Phthalates										
BEHP	215/239	90	4/239	1.7	1	40.0	5/239	2.1	1	24.0
Benzylbutyl phthalate	109/239	46	16/239	6.7	6	3.8	0/239	0.0	0	0.3
Di-n-butyl phthalate	33/239	14	0/239	0.0	0	12.0	1/239	0.4	0	1.5
Other SVOCs										
1,4-Dichlorobenzene	153/239	64	21/239	8.8	2	350.0	9/239	3.8	0	120.0
2,4-Dimethylphenol	19/239	8	0/239	0.0	0	3.8	9/239	3.8	39	3.8
n-Nitrosodiphenylamine	2/239	1	0/239	0.0	0	6.4	3/239	1.3	2	4.5
PCBs										
Total PCBs	235/248	95	137/248	55	0	70.0	23/248	9.3	0	13.0
TBTs										
TBT[k]	68/75	91	11/75	15	0	50.0	NA	NA	NA	NA

Notes:

a. Represents the number of detects per total number of samples.

b. Represents the number of detects > SQS and ≤ CSL per total number of samples. If any individual sample had a TOC content > 4% or < 0.5% and the dry-weight concentration was > LAET and ≤ 2LAET, the concentration was considered to be > SQS and ≤ CSL.

c. Represents the number of detects > CSL per the total number of samples. If any individual location had a TOC content > 4% or < 0.5% and the dry-weight concentration was > 2LAET, the concentration was considered to be > CSL.

d. One of these six samples could not be OC-normalized because the TOC was outside of the appropriate range; the exceedance was based on a comparison with the 2LAET.
e. Total benzofluoranthenes were calculated as the sum of benzo(b)fluoranthene and benzo(k)fluoranthene.
f. One of these three samples could not be OC-normalized because the TOC was outside of the appropriate range; the exceedance was based on a comparison with the 2LAET.
g. Total HPAHs were calculated as the sum of benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, total benzofluoranthenes, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, and pyrene.
h. Total LPAHs were calculated as the sum of acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, and phenanthrene.
i. This sample could not be OC-normalized because the TOC was outside of the appropriate range; the exceedance was based on a comparison with the 2LAET.
j. Two of these twenty-three samples could not be OC-normalized because the TOC was outside of the appropriate range; the exceedance was based on a comparison with the 2LAET.
k. TBT does not have SMS criteria; however, the ecological risk assessment (Windward 2012a) calculated a RBTC of 7.5 mg/kg OC for benthic invertebrates. This RBTC value was used as a surrogate for the frequency of detected concentrations above the SQS column.

2LAET – second-lowest-apparent-effect threshold
BEHP – bis(2-ethylhexyl) phthalate
CSL – cleanup screening level
DDT – dichlorodiphenyltrichloroethane
DMMP – Dredged Material Management Program
dw – dry weight
EF – exceedance factor
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LAET – lowest-apparent-effect threshold
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
mg/kg – milligram per kilogram
NA – not applicable
OC – organic carbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RBTC – risk-based threshold concentration
RL – reporting limit
SRI – Supplemental Remedial Investigation
SMS – Washington State Sediment Management Standards
SQS – sediment quality standard
SVOC – semivolatile organic compound
TBT – tributyltin
TOC – total organic carbon

Table B-7
Summary Statistics for Key Contaminants in Tissue

Chemical and Tissue Type	Unit	Detection Frequency[a]	Concentration		
			Minimum	Mean	Maximum
Total PCBs[b]					
Fish					
Brown rockfish, whole body	µg/kg ww	15/15	400 J	2,000	6,200
English sole, whole body	µg/kg ww	13/13	1,460	3,200	7,900 J
Juvenile Chinook salmon, whole body	µg/kg ww	12/12	7.4	59	91.5
Sand sole, whole body	µg/kg ww	5/6	167	540[b]	1,310
Shiner surfperch, whole body	µg/kg ww	11/11	380 JN	1,500	5,400
English sole, fillet	µg/kg ww	20/20	409	1,700	5,700
Striped perch, fillet	µg/kg ww	6/6	104.0	155	203 J
Invertebrates	µg/kg ww				
Crab, soft tissue[c]	µg/kg ww	9/9	180 J	300	860
Crab, edible meat	µg/kg ww	12/12	48 J	130	210 J
Crab, hepatopancreas	µg/kg ww	9/9	310 J	590	1,900
Intertidal Clam, whole body[d]	µg/kg ww	11/11	4.7 JN	56	82

Table B-7 Continued
Summary Statistics for Key Contaminants in Tissue

Chemical and Tissue Type	Unit	Detection Frequency[a]	Concentration		
			Minimum	Mean	Maximum
Mussel, whole body[d]	µg/kg ww	14/17	19 JN	26	44 J
Shrimp, whole body[e]	µg/kg ww	1/1	460 J	na	460 J
Geoduck clam, whole body[c]	µg/kg ww	4/4	25 J	28	34 JN
Geoduck clam, edible meat	µg/kg ww	6/6	14	19	24 JN
Geoduck clam, gutball	µg/kg ww	3/3	51 J	66	78
Benthic invertebrates, whole body	µg/kg ww	13/13	93	210	380
PCB TEQ[f]					
Fish					
Brown rockfish, whole body	ngTEQ/kg ww	6/6	5.05	24.8	59.5
English sole, whole body	ngTEQ/kg ww	3/3	32.4	35.0	37.4
Shiner surfperch, whole body	ngTEQ/kg ww	3/3	11.4	13.1	14.3
English sole, fillet	ngTEQ/kg ww	3/3	10.1	12.9	15.4
Invertebrates					
Crab, whole body[c]	ngTEQ/kg ww	3/3	3.67	4.83	5.61
Crab, edible meat	ngTEQ/kg ww	3/3	1.53	1.63	1.71
Crab, hepatopancreas	ngTEQ/kg ww	3/3	8.06	9.92	11.0
Intertidal Clam, whole body	ngTEQ/kg ww	3/3	0.212	0.406	0.734
Geoduck clam, whole body[c]	ngTEQ/kg ww	1/1	0.228	na	0.228
Geoduck clam, edible meat	ngTEQ/kg ww	3/3	0.0910	0.141	0.192
Geoduck clam, gutball	ngTEQ/kg ww	2/2	0.378	0.461	0.544
Dioxins and Furans[g]					
Fish					
Brown rockfish, whole body	ngTEQ/kg ww	6/6	5.71 J	26.9	61.8 J
English sole, whole body	ngTEQ/kg ww	3/3	34.3 J	36.8	39.0 J
Shiner surfperch, whole body	ngTEQ/kg ww	3/3	12.4 J	14.3	15.6 J
English sole, fillet	ngTEQ/kg ww	3/3	10.8 J	13.6	16.1 J
Invertebrates					
Crab, whole body[c]	ngTEQ/kg ww	3/3	4.84 J	6.03	6.80 J
Crab, edible meat	ngTEQ/kg ww	3/3	1.98 J	2.10	2.18 J
Crab, hepatopancreas	ngTEQ/kg ww	3/3	10.3 J	12.2	13.4 J
Intertidal Clam, whole body	ngTEQ/kg ww	3/3	0.446 J	0.688	1.11 J
Geoduck clam, whole body[c]	ngTEQ/kg ww	1/1	0.433 J	na	0.433 J
Geoduck clam, edible meat	ngTEQ/kg ww	3/3	0.337 J	0.375	0.431 J
Geoduck clam, gutball	ngTEQ/kg ww	2/2	0.681 J	0.881	1.08 J

Table B-7 Continued
Summary Statistics for Key Contaminants in Tissue

Chemical and Tissue Type	Unit	Detection Frequency[a]	Concentration		
			Minimum	Mean	Maximum
cPAHs[g]					
Fish					
Brown rockfish, whole body	µgTEQ/kg ww	0/13	na	12 U[i]	na
English sole, whole body	µgTEQ/kg ww	9/11	0.45 J	11	11
Juvenile Chinook salmon, whole body	µgTEQ/kg ww	0/6	na	56 U[i]	na
Shiner surfperch, whole body	µgTEQ/kg ww	6/8	0.76 J	1.2[i]	2.2
English sole, fillet	µgTEQ/kg ww	3/11	0.32 J	0.29[i]	0.42 J
Invertebrates					
Crab, whole body[c]	µgTEQ/kg ww	7/7	0.71 J	0.96	1.2 J
Crab, edible meat	µgTEQ/kg ww	6/9	0.40 J	0.60[i]	2.4 J
Crab, hepatopancreas	µgTEQ/kg ww	7/7	0.96 J	1.3	2.4 J
Intertidal Clam, whole body	µgTEQ/kg ww	11/11	2.4	16	63
Mussel, whole body	µgTEQ/kg ww	16/17	3.8 J	20[i]	110
Shrimp, whole body[e]	µgTEQ/kg ww	0/1	na	na	na
Geoduck clam, whole body[c]	µgTEQ/kg ww	4/4	2.1 J	3.1	4.1 J
Geoduck clam, edible meat	µgTEQ/kg ww	6/6	0.99 J	1.6	2.8 J
Geoduck clam, gutball	µgTEQ/kg ww	3/3	6.3	8.2	11 J
Benthic invertebrates, whole body	µgTEQ/kg ww	13/13	45	170	420
Inorganic Arsenic					
Fish					
Brown rockfish, whole body	mg/kg ww	13/13	0.004 J	0.0.008	0.023 J
English sole, whole body	mg/kg ww	11/11	0.023 J	0.032	0.059 J
Juvenile Chinook salmon, whole body	mg/kg ww	na	na	na	na
Shiner surfperch, whole body	mg/kg ww	8/8	0.012 J	0.021	0.037 J
English sole, fillet	mg/kg ww	0/11	na	na	na
Invertebrates					
Crab, whole body[c]	mg/kg ww	9/9	0.031 J	0.042	0.057 J
Crab, edible meat	mg/kg ww	9/9	0.020 J	0.032	0.043 J
Crab, hepatopancreas	mg/kg ww	9/9	0.038 J	0.058	0.089 J
Intertidal Clam, whole body[d]	mg/kg ww	12/12	0.074 J	0.166	0.443
Mussel, whole body[d]	mg/kg ww	11/11	0.040 J	0.078	0.133 J
Geoduck clam, whole body[c]	mg/kg ww	4/4	0.027 J	0.036	0.049 J
Geoduck clam, edible meat	mg/kg ww	6/6	0.012 J	0.029	0.063 J

Table B-7 Continued
Summary Statistics for Key Contaminants in Tissue

Chemical and Tissue Type	Unit	Detection Frequency[a]	Concentration		
			Minimum	Mean	Maximum
Geoduck clam, gutball	mg/kg ww	3/3	0.075 J	0.087	0.110 J
Benthic invertebrates, whole body	mg/kg ww	na	na	na	na
TBT					
Fish					
Brown rockfish, whole body	µg/kg ww	13/13	38	160	420
English sole, whole body	µg/kg ww	11/11	17	26	38
Juvenile Chinook salmon, whole body	µg/kg ww	0/5	na	3.6 U	na
Shiner surfperch, whole body	µg/kg ww	8/8	30 J	58	67
English sole, fillet	µg/kg ww	7/14	1.63	5.7[i]	14
Striped perch, fillet	µg/kg ww	6/6	5 J	20	31 J
Invertebrates					
Crab, whole body[c]	µg/kg ww	1/9	13	3.2[i]	13
Crab, edible meat	µg/kg ww	0/12	na	3 U[i]	na
Crab, hepatopancreas	µg/kg ww	1/9	23	6.0[i]	23
Intertidal Clam, whole body[d]	µg/kg ww	10/10	15	47	140
Mussel, whole body[d]	µg/kg ww	16/17	7.5	33[i]	92.8
Geoduck clam, whole body[c]	µg/kg ww	4/4	8.1 J	9.9	12
Geoduck clam, edible meat	µg/kg ww	6/6	5.1 J	7.6	9.8
Geoduck clam, gutball	µg/kg ww	3/3	14	19	29
Benthic invertebrates, whole body	µg/kg ww	12/12	20	110	390

Note: Brown rockfish whole-body samples and geoduck edible meat samples were analyzed as individual samples. All other tissue samples were analyzed as composite samples.

[a] This table includes all tissue data in the SRI dataset

[b] Total PCBs represent the sum of the detected concentrations of the individual Aroclors. If none of the individual Aroclors were detected in a given sample, the non-detect value represents the highest reporting limit.

[c] Whole body concentrations were calculated from edible meat and hepatopancreas results for crab, and from edible meat and gutball results for geoduck. No shells were included in these samples.

[d] Whole body clam and mussel samples include all soft tissues. No shells were included in these samples.

[e] Shrimp sample is one composite of 26 individuals collected from multiple shrimp traps.

[f] PCB TEQs were calculated using TEFs for mammals presented in Van den Berg et al. (2006) (see Appendix D for a list of these TEFs). PCB TEQs were calculated for each sample by summing the TEQs for each PCB congener. PCB individual congener TEQs were calculated as the product of individual congener concentrations and congener-specific TEFs. If an individual congener was not detected, the TEF for that congener was multiplied by one-half the RL for that congener.

[g] Dioxin and furan TEQs were calculated using TEFs for mammals presented in Van den Berg et al. (2006) (see Appendix D for a list of these TEFs). Dioxin and furan TEQs were calculated for each sample by summing the TEQs for each dioxin and furan congener. Dioxin and furan individual congener TEQs for were calculated as the product of individual congener concentrations and congener-specific TEFs. If an individual congener was not detected, the TEF for that congener was multiplied by one-half the RL for that congener.

Table B-8
Incoming Solids Concentrations

Deposited Solids[1]		Upstream			EW Laterals		Total
		LDW Lateral	LDW Bed	Green	EW SDs	EW CSOs	
	% of total[2]	0.24%	0.55%	98.4% - 99.05%	0.16% - 0.66%	0.01% - 0.20%	100%
COC-Time	Scenario	Chemistry Assumptions					Incoming[6,7] Concentration
		LDW Lateral[3]	LDW Bed[3]	Green River[4]	EW SDs[5]	EW CSOs[6]	
PCB-*Current* (µg/kg dw)	Base Case	300	350	42	250	260	45.7
	Low Bounding			5	55	240	8.0
	High Bounding			80	450	630	85.6
PCB-*Future* (µg/kg dw)	Base Case			42	190	260	44.9
	Low Bounding			5	55	240	7.7
	High Bounding			80	450	630	84.5
cPAHs-*Current* (µg TEQ/kg dw)	Base Case	1,400	390	135	1300	680	146
	Low Bounding			40	480	430	47
	High Bounding			270	1900	1500	287
cPAHs-*Future* (µg TEQ/kg dw)	Base Case			135	950	680	142
	Low Bounding			40	480	430	46
	High Bounding			270	1900	1500	283
Arsenic-*Current* (mg/kg dw)	Base Case	13	16	9	10	5	9.05
	Low Bounding			7	9	6	7.07
	High Bounding			10	20	9	10.10
Arsenic-*Future* (mg/kg dw)	Base Case			9	10	5	9.05
	Low Bounding			7	9	6	7.07
	High Bounding			10	20	9	10.09

Table B-8 continued
Incoming Solids Concentrations

Deposited Solids[1]		Upstream			EW Laterals		Total
		LDW Lateral	LDW Bed	Green	EW SDs	EW CSOs	
	% of total[2]	0.24%	0.55%	98.4% - 99.05%	0.16% - 0.66%	0.01% - 0.20%	100%
COC-Time	Scenario	Chemistry Assumptions					Incoming[6,7] Concentration
		LDW Lateral[3]	LDW Bed[3]	Green River[4]	EW SDs[5]	EW CSOs[6]	
Dioxin/Furan-*Current* (ng TEQ/kg dw)	Base Case	20	26	6	27	16	6.3
	Low Bounding			2	12	7.6	2.2
	High Bounding			8	53	37	8.5
Dioxin/Furan-*Future* (ng TEQ/kg dw)	Base Case			6	22	16	6.2
	Low Bounding			2	12	7.6	2.2
	High Bounding			8	45	37	8.3

Notes:
1. Methodology for determining volumes for deposited solids discussed in Sections 5.1.1 through 5.1.3.
2. See Table 5 in Appendix B, Part 1 for EW solids loads for all scenarios (base, low, and high for current and future conditions).
3. Values for LDW Bed and Laterals are taken from the LDW FS (AECOM 2012).
4. Methodology for determining values for the Green River provided in Section 5.3.1 and Appendix B, Part 3.
5. Methodology for determining values for EW CSOs and SDs provided in Appendix B, Part 4.
6. Incoming concentrations are calculated as a weighted average by mass for listed incoming sediment sources.

µg/kg – micrograms per kilogram
COC – contaminant of concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
CSO – combined sewer overflow
dw – dry weight
EW – East Waterway
FS – feasibility study
LDW – Lower Duwamish Waterway
mg/kg – milligrams per kilogram
ng – nanograms
PCB – polychlorinated biphenyl
SD – storm drain
TEQ – toxic equivalent

Table B-9. Summary of Exposure Parameters and Risks Associated with Seafood Consumption Scenarios

Scenario	Ingestion Rate (g/day)[a]	Meals per Month[b]	Exposure Duration (years)	Excess Cancer Risk	Maximum Non-Cancer HI[c]
Adult tribal RME (Tulalip data)	97.5	13.1	70	1×10^{-3}	28
Adult tribal CT (Tulalip data)	15	2.0	30	7×10^{-5}	3
Child tribal RME (Tulalip data)	39.0	13.1	6	4×10^{-4}	59
Child tribal CT (Tulalip data)	6.0	2.0	6	4×10^{-5}	6
Adult tribal (Suquamish data)	597.7	80	70	1×10^{-2}	219
Adult API RME	51.5	6.9	30	6×10^{-4}	25
Adult API CT	5.3	0.7	9	1×10^{-5}	1
Adult one-meal-per-month					
Benthic fish	7.5	1.0	30	2×10^{-4}	13
Clam	7.5	1.0	30	3×10^{-5}	0.5
Crab	7.5	1.0	30	2×10^{-5}	0.9
Pelagic fish, rockfish	7.5	1.0	30	4×10^{-4}	21
Pelagic fish, perch	7.5	1.0	30	1×10^{-4}	8

[a] Ingestion rates do not include consumption of adult salmon because these fish acquire most of their contaminant body burden from outside the EW.

[b] It was assumed that one adult meal was equal to 227g (8 ounces). Child consumption rates were based on 40% of adult rates (EPA 2007b). For the purpose of calculating meals per month for children, this 40% conversion is assumed to represent a smaller meal size (40% of adults, which is equal to 91 g or 3.2 ounces).

[c] The sum of non-cancer HQs across all COPCs is not directly interpretable for risk assessment because some HQs may relate to different toxic effects (i.e., endpoints) that are not additive. Thus, the maximum non-cancer HI for any endpoint is presented here. For all scenarios, this maximum is for either the immunological endpoint, neurological endpoint, or integumentary endpoint, all of which include total PCBs in the sum.

API – Asian and Pacific Islander
COPC – contaminant of potential concern
CT – central tendency
EPA – US Environmental Protection Agency
EW – East Waterway
HI – hazard index (a sum of the HQs for individual contaminants)
HQ – hazard quotient
PCB – polychlorinated biphenyl
RME – reasonable maximum exposure

Table B-9 (cont'd). Summary of Exposure Parameters and Risks Associated with Direct Sediment Exposure Scenarios

Scenario	Exposure Area	Incidental Sediment IR (g/day)	Exposed Skin SA (cm^2)	Exposure Frequency (days/yr)	Exposure Duration (years)	Excess Cancer Risk
Netfishing RME	all subtidal and intertidal	0.050	3,600	119	44	7×10^{-6}
Netfishing CT	all subtidal and intertidal	0.050	3,600	63	29	1×10^{-6}
Habitat restoration worker	intertidal area accessible from the shore or from a boat	0.1	6,040	15	20	1×10^{-6}
Tribal clamming RME	intertidal area accessible from the shore or from a boat	0.1	6,040	120	64	3×10^{-5}
Tribal clamming – 183 days per year	intertidal area accessible from the shore or from a boat	0.1	6,040	183	70	6×10^{-5}
Clamming – 7 days per year	intertidal area accessible from the shore	0.1	6,040	7	30	1×10^{-6}

Note: Non-cancer HQs did not exceed 1 for any COPC and are therefore not shown in this table.

COPC – contaminant of potential concern
CT – central tendency
HQ – hazard quotient
IR – ingestion rate
RME – reasonable maximum exposure
SA – surface area

Table B-10
Estimated Excess Cancer Risks for the HHRA Seafood Consumption Scenarios

COPC[a]	Estimated Excess Cancer Risk											
								Adult One Meal per Month				
	Adult Tribal RME (Tulalip Data)	Adult Tribal CT (Tulalip Data)	Child Tribal RME (Tulalip Data)	Child Tribal CT (Tulalip Data)	Adult Tribal (Suquamish Data)	Adult API RME	Adult API CT	Benthic Fish	Clam	Crab	Pelagic Fish, Rockfish	Pelagic Fish, Perch
Arsenic[b]	2×10^{-4}	1×10^{-5}	4×10^{-5}	4×10^{-6}	2×10^{-3}	8×10^{-5}	2×10^{-6}	3×10^{-7}[c]	1×10^{-5}	2×10^{-6}	7×10^{-7}	2×10^{-6}
cPAHs (TEQ)[d]	1×10^{-4}	4×10^{-6}	1×10^{-4}	9×10^{-6}	1×10^{-3}	5×10^{-5}	9×10^{-7}	1×10^{-7}	9×10^{-6}	4×10^{-7}	9×10^{-8}	5×10^{-7}[c]
1,4-Dichlorobenzene	1×10^{-6}[e]	7×10^{-8}[e]	2×10^{-7}[e]	3×10^{-8}[e]	7×10^{-6}[e]	4×10^{-7}[e]	8×10^{-9}[e]	4×10^{-8}[c]	4×10^{-8}[c]	4×10^{-8}[c]	4×10^{-8}[c]	2×10^{-7}[c]
Pentachlorophenol	2×10^{-6}[e]	4×10^{-8}[e]	4×10^{-7}[e]	2×10^{-8}[e]	2×10^{-5}[e]	3×10^{-7}	4×10^{-9}	1×10^{-8}[c]	4×10^{-8}	1×10^{-8}[c]	1×10^{-8}[c]	3×10^{-8}[c]
Total PCBs	1×10^{-3}	5×10^{-5}	2×10^{-4}	2×10^{-5}	9×10^{-3}	4×10^{-4}	7×10^{-6}	2×10^{-4}	6×10^{-6}	1×10^{-5}	4×10^{-4}	1×10^{-4}
PCBs (TEQ)[f]	7×10^{-4}	4×10^{-5}	1×10^{-4}	2×10^{-5}	6×10^{-3}	3×10^{-4}	8×10^{-6}	1×10^{-4}	5×10^{-6}	1×10^{-5}	3×10^{-4}	9×10^{-5}
Total DDTs	1×10^{-6}	9×10^{-8}	2×10^{-7}	4×10^{-8}	1×10^{-5}	6×10^{-7}	1×10^{-8}	2×10^{-7}	2×10^{-8}	2×10^{-8}[c]	5×10^{-7}	2×10^{-7}
alpha-BHC	4×10^{-6}[e]	2×10^{-7}[e]	7×10^{-7}[e]	1×10^{-7}[e]	2×10^{-5}[e]	9×10^{-7}[e]	3×10^{-8}[e]	1×10^{-7}[c]	1×10^{-7}[c]	1×10^{-7}[c]	2×10^{-7}	1×10^{-7}[c]
beta-BHC	1×10^{-6}[e]	7×10^{-8}[e]	2×10^{-7}[e]	3×10^{-8}[e]	7×10^{-6}[e]	3×10^{-7}[e]	8×10^{-9}[e]	4×10^{-8}[c]	4×10^{-8}[c]	3×10^{-8}[c]	4×10^{-8}[c]	3×10^{-8}[c]
Dieldrin	8×10^{-6}[e]	5×10^{-7}[e]	1×10^{-6}[e]	2×10^{-7}[e]	5×10^{-5}[e]	2×10^{-6}[e]	7×10^{-8}[e]	2×10^{-7}	3×10^{-7}[c]	3×10^{-7}[c]	4×10^{-7}	5×10^{-7}
Total chlordane	2×10^{-6}	9×10^{-8}	3×10^{-7}	4×10^{-8}	1×10^{-5}	7×10^{-7}	1×10^{-8}	4×10^{-8}	8×10^{-8}	2×10^{-8}[c]	1×10^{-7}	5×10^{-8}
Heptachlor	1×10^{-6}[e]	7×10^{-8}[e]	2×10^{-7}[e]	3×10^{-8}[e]	7×10^{-6}[e]	3×10^{-7}[e]	1×10^{-8}[e]	4×10^{-8}[c]	4×10^{-8}[c]	4×10^{-8}[c]	5×10^{-8}[c]	4×10^{-8}[c]
Heptachlor epoxide	2×10^{-6}[e]	2×10^{-7}[e]	4×10^{-7}[e]	7×10^{-8}[e]	1×10^{-5}[e]	7×10^{-7}[e]	2×10^{-8}[e]	9×10^{-8}[c]	9×10^{-8}[c]	9×10^{-8}[c]	1×10^{-7}	9×10^{-8}[c]
Mirex	4×10^{-6}[e]	3×10^{-7}[e]	8×10^{-7}[e]	1×10^{-7}[e]	3×10^{-5}[e]	1×10^{-6}[e]	4×10^{-8}[e]	2×10^{-7}[c]	2×10^{-7}[c]	2×10^{-7}[c]	4×10^{-7}	2×10^{-7}[c]
Dioxin/furan (TEQ)[f]	1×10^{-4}	6×10^{-6}	2×10^{-5}	3×10^{-6}	7×10^{-4}	4×10^{-5}	1×10^{-6}	5×10^{-6}	3×10^{-6}	3×10^{-6}	2×10^{-5}	9×10^{-6}
Total TEQ (dioxins/furans and coplanar PCBs)	8×10^{-4}	5×10^{-5}	1×10^{-4}	2×10^{-5}	7×10^{-3}	3×10^{-4}	9×10^{-6}	1×10^{-4}	8×10^{-6}	1×10^{-5}	3×10^{-4}	1×10^{-4}
Total excess cancer risk (excluding PCB TEQ)[g]	**1×10^{-3}**	**7×10^{-5}**	**4×10^{-4}**	**4×10^{-5}**	**1×10^{-2}**	**6×10^{-4}**	**1×10^{-5}**	**2×10^{-4}**	**3×10^{-5}**	**2×10^{-5}**	**4×10^{-4}**	**1×10^{-4}**
Total excess cancer risk (excluding total PCBs)[h]	**1×10^{-3}**	**6×10^{-5}**	**3×10^{-4}**	**4×10^{-5}**	**1×10^{-2}**	**5×10^{-4}**	**1×10^{-5}**	**1×10^{-4}**	**3×10^{-5}**	**2×10^{-5}**	**3×10^{-4}**	**1×10^{-4}**

Notes:

Shaded cells indicate excess cancer risks greater than 1×10^{-6}.

a. Only those COPCs with an excess cancer risk greater than 1×10^{-6} for one or more scenarios are included in this table.
b. Arsenic exposure point concentrations and risk estimates are based on inorganic arsenic.
c. There were no detected values of this COPC for this seafood category. Risk estimate was based on one-half the maximum RL.
d. The higher contribution of cPAHs to overall children's cancer risks is because cPAHs have a mutagenic mode of action and pose greater risks to children than adults. EPA risk assessment procedures account for the greater cancer risks mutagens pose to children.
e. Greater than 50% of the risk associated with this COPC was derived from seafood categories with no detected values.
f. No mussel data were available for this COPC. When the CDI and risk values were calculated, the portion of seafood consumption that had been assigned to mussels was divided proportionally among the remaining consumption categories.
g. Total risk values include the risks associated with all COPCs. Total PCBs is included in the total, and total PCBs TEQ is not included to avoid double-counting risks due to PCBs.
h. Total risk values include the risks associated with all COPCs. Total PCBs TEQ is included in the total, and total PCBs not included to avoid double-counting risks due to PCBs.

API – Asian and Pacific Islander
BHC – benzene hexachloride
CDI – chronic daily intake
COPC – contaminant of potential concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
CT – central tendency
DDT – dichlorodiphenyltrichloroethane
EPA – U.S. Environmental Protection Agency
FS – Feasibility Study
HHRA – human health risk assessment
PCB – polychlorinated biphenyl
RL – reporting limit
RME – reasonable maximum exposure
TEQ – toxic equivalent

Table B-11

Estimated Non-cancer Hazards for the HHRA Seafood Consumption Scenarios

COPC[a]	Estimated Non-Cancer Hazard											
								Adult One Meal per Month				
	Adult Tribal RME (Tulalip Data)	Adult Tribal CT (Tulalip Data)	Child Tribal RME (Tulalip Data)	Child Tribal CT (Tulalip Data)	Adult Tribal (Suquamish Data)	Adult API RME	Adult API CT	Benthic Fish	Clam	Crab	Pelagic Fish, Rockfish	Pelagic Fish, Perch
Arsenic[b]	0.4	0.05	0.9	0.1	4	0.4	0.03	0.002	0.08	0.01	0.004	0.009
Cadmium	0.7	0.08	2	0.2	2	0.4	0.03	0.01	0.01	0.09	0.004	0.004
Cobalt	0.6	0.07	1	0.2	4	0.5	0.04	0.01	0.07	0.05	0.02	0.02
Mercury	0.6	0.07	1	0.2	3	0.4	0.04	0.05	0.02	0.09	0.2	0.04
TBT as ion	0.3	0.03	0.7	0.07	4	0.4	0.03	0.007	0.05	0.003	0.2	0.04
Total PCBs[c]	27	3	58	6	214	24	1	13	0.4	0.8	21	8
Total PCBs[d]	8	0.8	17	2	61	7	0.4	4	0.1	0.2	6	2
PCB TEQ[e]	7	0.9	14	2	58	7	0.6	2	0.1	0.3	6	2
Dioxin/furan TEQ[e]	1	0.1	2	0.3	7	0.9	0.07	0.1	0.06	0.07	0.4	0.2
Total TEQ[e]	**8**	**1**	**16**	**2**	**65**	**8**	**0.7**	**2**	**0.2**	**0.4**	**6**	**2**
HIs by Endpoint:												
Hematological endpoint[f]	**0.3**	**0.05**	**0.8**	**0.1**	**2**	**0.2**	**0.02**	**0.01**	**0.02**	**0.04**	**0.03**	**0.02**
Immunological endpoint[g]	**27**	**3**	**59**	**6**	**218**	**24**	**1**	**13**	**0.5**	**0.8**	**21**	**8**
Kidney endpoint[h]	**0.8**	**0.1**	**2**	**0.2**	**3**	**0.5**	**0.04**	**0.02**	**0.02**	**0.1**	**0.01**	**0.01**
Liver endpoint[i]	**0.06**	**0.008**	**0.1**	**0.02**	**0.3**	**0.04**	**0.003**	**0.007**	**0.006**	**0.004**	**0.01**	**0.008**
Neurological endpoint[j]	**28**	**3**	**59**	**6**	**218**	**25**	**1**	**13**	**0.4**	**0.9**	**21**	**8**
Endocrine endpoint[k]	**0.6**	**0.08**	**1**	**0.2**	**4**	**0.5**	**0.04**	**0.01**	**0.08**	**0.05**	**0.02**	**0.02**
Integumentary endpoint[l]	**28**	**3**	**59**	**6**	**219**	**25**	**1**	**13**	**0.5**	**0.8**	**21**	**8**
Digestive system endpoint[m]	**0.5**	**0.06**	**1**	**0.1**	**2**	**0.3**	**0.03**	**0.005**	**0.04**	**0.04**	**0.02**	**0.02**
Developmental endpoint[n]	**10**	**1**	**16**	**2**	**65**	**8**	**0.7**	**4**	**0.2**	**0.5**	**7**	**2**

Notes:

Shaded cells indicate non-cancer HQs greater than 1.

a. Only those COPCs with HQs greater than 1 for one or more scenario are included in this table.
b. Arsenic exposure point concentrations and risk estimates are based on inorganic arsenic.
c. HQ used for the calculation of the immunological, integumentary, and neurological endpoint HIs (Table B.4-1 of the HHRA, Windward 2012b).
d. HQ used for the calculation of the developmental endpoint HI (Table B.4-1 of the HHRA; Windward 2012b).
e. HQs for PCB and dioxin/furan TEQs were not presented in the EW HHRA because no RfD was available to calculate these values. The recently released RfD for 2,3,7,8-TCDD has since been used to calculate the HQs presented in this table. Additional information regarding these new HQs are presented in Attachment 7 to the HHRA (Appendix B of the SRI; Windward and Anchor QEA 2014).
f. Hematological endpoint includes the following chemicals: antimony, selenium, and zinc.
g. Immunological endpoint includes the following chemicals: dibutyltin, total PCBs, and TBT.
h. Kidney endpoint includes the following chemicals: cadmium, molybdenum, and pentachlorophenol.
i. Liver endpoint includes the following chemicals: 1,4-dichlorobenzene, alpha-BHC, total chlordane, total DDTs, dieldrin, heptachlor, heptachlor epoxide, mirex, and pentachlorophenol.
j. Neurological endpoint includes the following chemicals: mercury, total PCBs, and selenium. Neurological effects associated with exposure to lead are discussed in the HHRA, Section B.5.4 (Windward 2012b).
k. Endocrine endpoint includes the following chemicals: antimony and cobalt.
l. Integumentary endpoint includes the following chemicals: arsenic, total PCBs, selenium, and vanadium.
m. Digestive system endpoint includes the following chemicals: chromium and copper.
n. Developmental endpoint includes the following chemicals: mercury, PCBs (the higher of either the total PCB HQ based on the developmental RfD or the PCB TEQ HQ), and dioxin/furan TEQ.

API – Asian and Pacific Islander
BHC – benzene hexachloride
COPC – contaminant of potential concern
CT – central tendency
DDT – dichlorodiphenyltrichloroethane
HHRA – human health risk assessment
HI – hazard index
HQ – hazard quotient
PCB – polychlorinated biphenyl
RfD – reference dose
RME – reasonable maximum exposure
SRI – Supplemental Remedial Investigation
TBT – tributyltin
TEQ – toxic equivalent

Table B-12

Summary of Estimated Excess Cancer Risks for the RME Seafood Consumption Scenarios

COC	Adult Tribal RME (Tulalip Data)		Child Tribal RME (Tulalip Data)		Adult API RME	
	Excess Cancer Risk (% of Total[a])	Percent of Risk by Seafood Consumption Category[b]	Excess Cancer Risk (% of Total[a])	Percent of Risk by Seafood Consumption Category[b]	Excess Cancer Risk (% of Total[a])	Percent of Risk by Seafood Consumption Category[b]
Arsenic (inorganic)	2×10^{-4} (14%)	82% clams; 8.9% crab EM	4×10^{-5} (11%)	82% clams; 8.9% crab EM	8×10^{-5} (14%)	87% clams; 6.0% mussels
cPAHs (TEQ)	1×10^{-4} (7%)	90% clams	1×10^{-4} (27%)	90% clams	5×10^{-5} (9%)	73% clams; 25% mussels
Total PCBs	1×10^{-3} (70%)	41% benthic fillet; 26% perch; 9.5% crab EM; 9.1% rockfish; 8.5% crab WB; 6.1% clams	2×10^{-4} (55%)	41% benthic fillet; 26% perch; 9.5% crab EM; 9.1% rockfish; 8.5% crab WB; 6.1% clams	4×10^{-4} (69%)	59% rockfish; 16% benthic fillet; 7.3% crab WB; 6.7% clams; 5.5% benthic WB
PCBs (TEQ)	7×10^{-4}	30% benthic fillet; 27% perch; 13% crab WB; 12% crab EM; 11% rockfish; 7.7% clams	1×10^{-4}	30% benthic fillet; 27% perch; 13% crab WB; 12% crab EM; 11% rockfish; 7.7% clams	3×10^{-4}	62% rockfish; 11% benthic fillet; 9.7% crab WB; 7.5% clams; 4.8% benthic WB
Dioxin/furan (TEQ)	1×10^{-4} (7%)	25% clams; 22% crab EM; 18% crab WB; 17% perch; 10% benthic fillet	2×10^{-5} (5%)	25% clams; 22% crab EM; 18% crab WB; 17% perch; 10% benthic fillet	4×10^{-5} (7%)	35% rockfish; 31% clams; 18% crab WB; 7.9% crab EM
Other COCs[c]	3×10^{-5} (2%)	nc	4×10^{-6} (1%)	nc	7×10^{-6} (1%)	nc
Total excess cancer risk and main contributors to the total risk[d]	**1×10^{-3}**	**29% – PCBs in benthic fillet 18% – PCBs in perch 10% – arsenic in clams 6.7% – PCBs in crab EM 6.4% – PCBs in rockfish 6.2% – cPAHs in clams 6.0% – PCBs in crab WB 17% – other**	**4×10^{-4}**	**26% – cPAHs in clams 22% – PCBs in benthic fillet 14% – PCBs in perch 8.1% – arsenic in clams 5.2% – PCBs in crab EM 25% – other**	**6×10^{-4}**	**41% – PCBs in rockfish 11% – arsenic in clams 11% – PCBs in benthic fillet 6.7% – cPAHs in clams 5.1% – PCBs in crab WB 25% – other**

Notes:

a. Total excess cancer risk includes the risks associated with all COPCs, including total PCBs but excluding PCB TEQ.
b. Seafood consumption categories contributing greater than 5% of the risk for each COC are listed in this table.
c. Together, all other COCs contributed less than 2% to the total excess cancer risk.
d. Seafood consumption category-COC combinations contributing greater than 5% of the total risk are listed separately. All other combinations are included in the "other" category. Total PCBs is included in the total, and total PCBs TEQ is not included to avoid double-counting risks due to PCBs.

API – Asian and Pacific Islander
cPAH – carcinogenic polycyclic aromatic hydrocarbon
COC – contaminant of concern
COPC – contaminant of potential concern
EM – edible meat
HHRA – human health risk assessment
nc – not calculated
PCB – polychlorinated biphenyl
RME – reasonable maximum exposure
TEQ – toxic equivalent
WB – whole body

Table B-13

Estimated Excess Cancer Risks for the HHRA Direct Sediment Exposure Scenarios

COPC	Estimated Excess Cancer Risk					
	Netfishing		Habitat Restoration Worker	Clamming		
	RME	CT		Tribal RME	Tribal – 183 Days per Year	7 Days per Year
Arsenic	3×10^{-6}	7×10^{-7}	5×10^{-7}	1×10^{-5}	2×10^{-5}	4×10^{-7}
cPAHs (TEQ)	3×10^{-6}	2×10^{-7}	7×10^{-7}	2×10^{-5}	3×10^{-5}	5×10^{-7}
Total PCBs	6×10^{-7}	6×10^{-8}	2×10^{-7}	3×10^{-6}	6×10^{-6}	1×10^{-7}
PCBs (TEQ)	3×10^{-7}	4×10^{-8}	5×10^{-8}	1×10^{-6}	2×10^{-6}	3×10^{-8}
Dioxin/furan (TEQ)	6×10^{-7}	1×10^{-7}	NA	1×10^{-6}	2×10^{-6}	4×10^{-8}
Total TEQ excess cancer risk for dioxins/furans and coplanar PCBs	**9×10^{-7}**	**1×10^{-7}**	**NA**	**2×10^{-6}**	**4×10^{-6}**	**7×10^{-8}**
Total excess cancer risk (excluding PCB TEQ)[a]	**7×10^{-6}**	**1×10^{-6}**	**1×10^{-6}**	**3×10^{-5}**	**6×10^{-5}**	**1×10^{-6}**
Total excess cancer risk (excluding total PCBs)[a]	**7×10^{-6}**	**1×10^{-6}**	**1×10^{-6}**	**3×10^{-5}**	**5×10^{-5}**	**1×10^{-6}**

Notes:

Shaded cells indicate excess cancer risks greater than 1×10^{-6}.

a. Total risk values include the risks associated with all COPCs. However, only those COPCs with excess cancer risks greater than 1×10^{-6} for at least one scenario are listed in this table.

COPC – contaminant of potential concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
CT – central tendency
NA – not applicable (not a COPC)
PCB – polychlorinated biphenyl
RME – reasonable maximum exposure
TEQ – toxic equivalent

Table B-14
Summary of COCs for the HHRA

COCs Identified for One or More RME Scenarios	Seafood Consumption Scenarios			Direct Sediment Exposure Scenarios	
	Adult Tribal RME (Tulalip Data)	Child Tribal RME (Tulalip Data)	Adult API RME	Netfishing RME	Tribal Clamming RME
Arsenic	X	X	X	X	X
Cadmium		X			
cPAH (TEQ)	X	X	X	X	X
Pentachlorophenol	X				
Total PCBs	X	X	X		X
PCB (TEQ)	X	X	X		
alpha-BHC	X				
Dieldrin	X		X		
Total chlordane	X				
Heptachlor epoxide	X				
Mirex	X				
Dioxins/furans (TEQ)	X	X	X		
Total TEQ[a]					X

Notes:

a. Total TEQ is equal to the sum of PCB TEQ and dioxin/furan TEQ. When excess cancer risks for either PCB TEQ or dioxin/furan TEQ were not independently greater than 1×10^{-6}, the sum of these two chemicals (total TEQ) was identified as a COC if it was greater than this threshold.

API – Asian and Pacific Islander
BHC – benzene hexachloride
COC – contaminant of concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RME – reasonable maximum exposure
TEQ – toxic equivalent

Table B-15
Excess Cancer Risk Estimates Across Scenarios

Activity	Excess Cancer Risk[a]
Adult Tulalip RME Combination Scenario	
Netfishing RME	7×10^{-6}
Swimming (medium level of exposure)	2×10^{-6}
Adult tribal RME seafood consumption based on Tulalip data	1×10^{-3}
Total	$\mathbf{1 \times 10^{-3}}$
Adult Tulalip CT Combination Scenario	
Netfishing CT	1×10^{-6}
Swimming (low level of exposure)	2×10^{-8}
Adult tribal CT seafood consumption based on Tulalip data	7×10^{-5}
Total	$\mathbf{7 \times 10^{-5}}$
Activity	**Excess Cancer Risk[a]**
Adult RME Clamming Combination Scenario	
Tribal clamming RME (120 days per year)	3×10^{-5}
Swimming (medium level of exposure)	2×10^{-6}
Adult tribal RME seafood consumption based on Tulalip data	1×10^{-3}
Total	$\mathbf{1 \times 10^{-3}}$

Notes:

a. For the seafood consumption and sediment exposure scenarios, total excess cancer risk estimates that excluded PCB TEQ were used because these were equal to or higher than total excess cancer risk estimates that excluded total PCBs. For swimming, the total excess cancer risk estimates that excluded total PCBs were used because they were higher than the total that excluded PCB TEQ.

CT – central tendency
PCB – polychlorinated biphenyl
RME – reasonable maximum exposure
TEQ – toxic equivalent

Table B-16. Summary of COCs and Risk Drivers Based on RME Scenarios

Scenario Type	COCs	Risk Drivers
Seafood consumption RME scenarios	arsenic, cadmium, cPAH TEQ, pentachlorophenol, total PCBs, PCB TEQ,[a] alpha-BHC, dieldrin, total chlordane, heptachlor epoxide, mirex, and dioxin/furan TEQ[a]	cPAH TEQ, PCBs,[a, b] and dioxin/furan TEQ[a]
Direct sediment exposure RME scenarios	arsenic, cPAH TEQ, total PCBs, and total TEQ[c]	arsenic and cPAH TEQ

[a] Chemical lists for COCs and risk drivers do not include total TEQ (i.e., the sum of PCB TEQ and dioxin/furan TEQ) because the two components of the sum qualified individually as COCs or risk drivers.

[b] Consideration of PCBs as a risk driver is intended to account for both total PCBs and PCB TEQ. It should be noted that risks for total PCBs were higher than those for PCB TEQ for all scenarios.

[c] For the direct sediment exposure clamming scenario, total TEQ is listed because neither PCB TEQ nor dioxin/furan TEQ independently qualified as a COC, yet the total TEQ did qualify as a COC. \

BHC –benzene hexachloride

COC – chemical of concern

cPAH – carcinogenic polycyclic aromatic hydrocarbon

PCB – polychlorinated biphenyl

RME – reasonable maximum exposure

TEQ – toxic equivalent

Table B-17

Receptors of Concern Selected for the EW and Summary of Rationale for Selection

ROC	Ecological Significance	Societal Significance	Site Use	Sensitivity
Benthic invertebrate community	food source for other invertebrates, fish, birds, and mammals; nutrient cycling; sediment oxygenation	valued as food source to other species of high societal value	present year-round; multiple life stages, diverse phyla	range of contaminant sensitivities represented
Cancrid crab	higher-trophic-level benthic invertebrate; food for other invertebrates, fish, birds, and mammals	recreational and commercial value	multiple life stages (gravid females, juveniles)	effects data available for decapods; sensitivity relative to other decapods unknown
Brown rockfish	higher-trophic-level fish; important prey item for fish, birds, and mammals	some commercial (though not in EW) and recreational value	adults and juveniles present year-round; may spawn in the EW	effects data available for other fish species; relative sensitivity of brown rockfish unknown; potential for elevated exposure via bioaccumulation because of trophic position; long-lived
English sole	important prey item for fish, birds and mammals; key benthic invertebrate predator	some commercial and recreational value (though not in EW)	juveniles present year-round; adults present except during spawning migration to Puget Sound	NMFS data suggest they are as sensitive as other flatfish species
Juvenile Chinook salmon	important prey item for fish, birds and mammals; seasonally one of the most abundant juvenile salmonids in the EW	T&E species; returning adults important to tribal, commercial, and sport fisheries	generally present April to July; individuals likely present in EW for a few days to couple of weeks; most estuary-dependent juvenile salmonid	sensitive to a wide range of contaminants
Osprey	high trophic level	highly valued and well-studied bird of prey; protected under the Migratory Bird Treaty Act	nests along the EW and likely forages in the EW	effects data available for other bird species; relative sensitivity of osprey unknown; potential for elevated exposure via bioaccumulation because of trophic position
Pigeon guillemot	high trophic level	valued in general as wildlife species; protected under the Migratory Bird Treaty Act	nests observed along the EW	effects data available for other bird species; relative sensitivity of pigeon guillemot unknown; potential for elevated exposure via bioaccumulation because of trophic position
River otter	high trophic level	highly valued by society	limited data, although anecdotal information indicates year-round presence of a river otter family on Kellogg Island	mink are sensitive to some contaminants, such as PCBs, although the relative sensitivity of river otter is unknown; potential for elevated exposure via bioaccumulation because of trophic position

ROC	Ecological Significance	Societal Significance	Site Use	Sensitivity
Harbor seal	high trophic level	protected under Marine Mammal Protection Act	occasional use based on a survey in the EW	pinnipeds suspected to be sensitive to some contaminants, such as PCBs, although the relative sensitivity of harbor seal is unknown; potential for elevated exposure via bioaccumulation because of trophic position

EW – East Waterway
NMFS – National Marine Fisheries Service
PCB – polychlorinated biphenyl
ROC – receptor of concern
T&E – threatened and endangered

Table B-18
Summary of COCs and Selection of Risk Driver COCs for Benthic Invertebrates Based on Surface Sediment Exposure

COC	SMS Criteria			No. of Detected Concentrations in Surface Sediments		Risk Driver?
	Unit	SQS	CSL	> SQS, ≤ CSL	> CSL	
Metals						
Arsenic	mg/kg dw	57	93	0	3	Yes
Cadmium		5.1	6.7	1	1	Yes
Mercury		0.41	0.59	41	10	Yes
Zinc		410	960	4	2	Yes
PAHs						
2-Methylnaphthalene	mg/kg OC	38	64	0	3	Yes
Acenaphthene		16	57	11	13	Yes
Anthracene		220	1,200	5	2	Yes
Benzo(a)anthracene		110	270	7	7	Yes
Benzo(a)pyrene		99	210	7	8	Yes
Benzo(g,h,i)perylene		31	78	7	8	Yes
Total benzofluoranthenes		230	450	9	3	Yes
Chrysene		110	460	9	6	Yes
Dibenzo(a,h) anthracene		12	33	15	7	Yes
Dibenzofuran		15	58	10	9	Yes
Fluoranthene		160	1,200	14	9	Yes
Fluorene		23	79	2	5	Yes
Indeno(1,2,3-cd) pyrene		34	88	10	7	Yes
Phenanthrene		100	480	6	9	Yes
Pyrene		1,000	1,400	0	3	Yes
Total HPAH		960	5,300	11	13	Yes
Total LPAH		370	780	5	2	Yes
Phthalates						
Bis(2-ethylhexyl) phthalate	mg/kg OC	47	78	4	5	Yes
Butyl benzyl phthalate		4.9	64	16	0	Yes
Di-n-butyl phthalate		220	1,700	0	1	Yes
Other SVOCs						
1,4-Dichlorobenzene	mg/kg OC	3.1	9	21	9	Yes
2,4-Dimethylphenol	µg/kg dw	29	29	0	9	Yes

Table B-18 continued

Summary of COCs and Selection of Risk Driver COCs for Benthic Invertebrates Based on Surface Sediment Exposure

COC	SMS Criteria			No. of Detected Concentrations in Surface Sediments		Risk Driver?
	Unit	SQS	CSL	> SQS, ≤ CSL	> CSL	
n-Nitrosodiphenylamine	mg/kg OC	11	11	0	3	Yes
Phenol	µg/kg dw	420	1,200	5	0	Yes
PCBs						
Total PCBs	mg/kg OC	12	65	137	23	Yes
Pesticides						
Total DDTs	µg/kg dw	6.9[a]	69[a]	2	0	No

Notes:

This table is derived from Table A.6-1 of the ERA (Windward 2012a), updated with 8 surface sediment samples from Slip 36 (see Section 2.10).

a. No SQS or CSL values are available for total DDTs. Thus, the comparison is with the DMMP SL and ML.

µg/kg – micrograms per kilogram
COC – contaminant of concern
CSL – cleanup screening level
DDT – dichlorodiphenyltrichloroethane
DMMP – Dredged Material Management Program
dw – dry weight
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
mg/kg – milligrams per kilogram
ML – maximum level
OC – organic carbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RI – remedial investigation
SL – screening level
SMS – Washington State Sediment Management Standards
SQS – sediment quality standard
SVOC – semivolatile organic compound

Table B-19

Summary of COCs and Selection of Risk Drivers for Ecological Receptors[a]

Receptor of Concern – Type of Evaluation	COC[b]	LOAEL-based HQ	Risk Driver?	Rationale for Selection or Exclusion as Risk Driver
Benthic invertebrate community – tissue	TBT	3.3	Yes	LOAEL-based HQs greater than 1.0 in two areas of the EW; low uncertainty in exposure data
Benthic invertebrate community – surface water	TBT	1.4	No	High uncertainty in surface water dataset; only one detected value; low LOAEL-based HQ
Benthic invertebrate community – porewater	Naphthalene	6	No	High uncertainty in effects data; only one porewater sample had a concentration exceeding the low-effect HQ; naphthalene did not exceed the SMS in any sediment samples
Crab – tissue	Cadmium	1.4	No	Three COCs identified for crab were not selected as risk drivers because site sediment concentrations were similar to PSAMP rural Puget Sound concentrations (cadmium and copper) and because of uncertainties in the effects data for all three COCs, including the lack of toxicity data for crabs
	Copper	1.1	No	
	Zinc	1.5	No	
English sole – tissue	Total PCBs	1.6 – 7.9[c]	Yes	HQ based on higher LOAEL TRV, which was associated with significant effects, was >1.0; low uncertainty in exposure data
Brown rockfish and English sole – tissue	Total PCBs	2.3 – 12[c]	Yes	
	TBT	1.4	No	High uncertainty in toxicity dataset; exposure concentration representing the population of rockfish did not exceed LOAEL; low LOAEL-based HQ
Juvenile Chinook salmon – diet	Cadmium	1.0	No	Three dietary COCs for fish were not selected as risk drivers because the site sediment concentrations were similar to PSAMP rural Puget Sound concentrations and because of uncertainties in exposure or effects data
English sole – diet	Cadmium	2.4	No	
	Copper	1.1	No	
	Vanadium	1.9	No	
Brown rockfish – diet	Cadmium	2.5	No	

Notes:

a. No COCs were identified for birds and mammals. Benthic risk drivers are presented separately in the text below.

b. A contaminant was identified as a COC if the LOAEL-based HQ was greater than or equal to 1.0; however, for juvenile Chinook salmon, NOAEL-based HQs were used because it is a listed species.

c. HQs were calculated from a range of effects concentrations because of uncertainty in the TRVs.

COC – contaminant of concern
HQ – hazard quotient
LOAEL – lowest-observed-adverse-effect level
NOAEL – no-observed-adverse-effect level
PCB – polychlorinated biphenyl
PSAMP – Puget Sound Ambient Monitoring Program
RI – remedial investigation
TBT – tributyltin

Table B-20. COCs and Risk Drivers Identified for ERA Receptors

Receptor	Evaluation Type	COPCs	COCs	Risk Driver
Benthic Invertebrate Community	sediment	29 chemicals, including metals, PAHs, total PCBs, phthalates, other SVOCs and total DDTs	29 COPCs[a]	28 SMS chemicals
	tissue residue	TBT, total PCBs	TBT	TBT
	surface water	cadmium, mercury, TBT	TBT	none
	porewater	naphthalene	naphthalene	none
Crab	tissue residue	arsenic, cadmium, copper, zinc, and total PCBs	cadmium, copper, zinc	none
	surface water	cadmium, mercury, TBT	none	none
Fish	dietary	arsenic, cadmium, chromium, copper, vanadium, benzo(a)pyrene	cadmium, copper, vanadium	none
	tissue residue	beta-endosulfan, total PCBs, mercury, TBT	total PCBs, TBT	total PCBs
	surface water	cadmium, mercury, TBT	none	none
Birds	dietary dose	mercury, total PCBs, PCB TEQ, total TEQ	none	none
Mammals	dietary dose	mercury, selenium, total PCBs, PCB TEQ, total TEQ	none	none

[a] Arsenic, cadmium, mercury, zinc, acenaphthene, benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, chrysene, dibenzo (a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3,-c,d)pyrene, phenanthrene, pyrene, total benzofluoranthenes, HPAH, LPAH, bis(2-ethylhexyl) phthalate, butyl benzyl phthalate, di-n-butyl phthalate, 1,4-dichlorobenzene, 2-methylnaphthalene, 2,4-dimethylphenol, dibenzofuran, n- nitrosodiphenylamine, phenol, and total PCBs and total DDTs. All COCs had exceedances of SMS chemical criteria except total DDTs, which was based on exceedances of DMMP guideline

COC – chemical of concern
COPC – chemical of potential concern
DDT – dichlorodiphenyltrichloroethane
DMMP – Dredge Material Management Program
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SMS – Washington State Sediment Management Standards
SVOC – semivolatile organic compound
TBT – tributyltin
TEQ – toxic equivalent

Table B-21: Summary of Preliminary Remediation Goals

Risk Driver	PRG	Purpose	Basis	Spatial Scale
Total PCBs	2 µg/kg dw[a]	Protection of Human Health for Seafood Consumption (RAO 1)	Natural background	Site-wide
	250, 370 µg/kg dw	Protection of Fish (RAO 4)	RBTC established based on brown rockfish (250) and English sole (370)	Site-wide
	12 mg/kg OC (SQS)	Protection of the Benthic Community (RAO 3)	RBTC	Point
Arsenic (mg/kg dw)	7[a]	Protection of Human Health for Direct Contact (RAO 2)	Natural background	Site-wide (netfishing) and clamming areas (clamming)
	57 (SQS)	Protection of the Benthic Community (RAO 3)	RBTC	Point
cPAH (µg TEQ/kg dw)	380	Protection of Human Health for Direct Contact for Netfishing (RAO 2)	RBTC	Site-wide
	150	Protection of Human Health for Direct Contact for Clamming (RAO 2)	RBTC	Clamming Areas
Dioxins/furans (ng TEQ/kg dw)	2[a]	Protection of Human Health for Seafood Consumption (RAO 1)	Natural background	Site-wide
TBT (mg/kg OC)	7.5	Protection of the Benthic Community (RAO 3)	RBTC	Point
Other benthic risk drivers	SQS	Protection of the Benthic Community (RAO 3)	RBTC	Point

Notes:

a. Following SMS (SCUM II),[5] PRGs developed for protection of human health for total PCBs, arsenic, and dioxins/furans would be slightly different than those presented above. Based on the SCUM II methodology, the natural background-based PRGs would be 3.5 µg/kg dw for total PCBs and 11 mg/kg dw for arsenic, and the PRG for dioxins/furans would be 5 ng TEQ/kg dw, based on the PQL.

µg – microgram
dw – dry weight
mg – milligram
kg – kilogram
ng – nanogram
OC – organic carbon
PCBs – polychlorinated biphenyls
PQL – practical quantitation limit
PRG – preliminary remediation goal
RAO – remedial action objective
RBTC – risk-based threshold concentration
SCUM – Sediment Cleanup Users Manual
SQS – sediment quality standard
TBT – tributyltin
TEQ – toxic equivalent

5 Washington State Department of Ecology, 2017. Sediment Cleanup Users Manual II. Guidance for Implementing the Cleanup Provisions of the Sediment Management Standards, Chapter 173-204 WAC. Publication No. 12-09-057. April 2017.

Table B-22
ARARs for the East Waterway[a]

Topic	Threshold	Regulatory Citation		Comment
		Federal	State	
Soil, Groundwater, Surface Water and Air Quality	Cleanup standards for multiple media	–	Model Toxics Control Act (MTCA) (Chap. 70.105D RCW; WAC 173-340)	MTCA established excess cancer risk standards, among other important standards.
Sediment Quality	Sediment cleanup standards	–	Sediment Management Standards (SMS) (WAC 173-204)	The SMS are promulgated rules under MTCA for excess human health cancer risk standards, non-cancer risk standards for human health and higher trophic level species, and numerical criteria for the protection of benthic community.
Fish Tissue Quality	Concentrations of contaminants in fish tissues	–	–	The Washington State Department of Health assesses the need for fish consumption advisories.
Surface Water Quality	Surface water quality standards	National Recommended Ambient Water Quality Criteria established under Section 304(a) of the Clean Water Act (33 USC 1251 et seq), water.epa.gov/scitech/swguidance/standards/criteria/index.cfm	Surface Water Quality Standards (RCW 90.48; WAC 173-201A) State Aquatic Life Criteria (National Toxics Rule 40 CFR 131.36(b)(1) as applied to Washington per 40 CFR 131.36(d)(14) State Human Health Criteria)	National Recommended Federal Water Quality Criteria established under Section 304(a) of the Clean Water Act are relevant and appropriate. More stringent State surface water quality standards apply where the State has adopted, and EPA has approved, Water Quality Standards. Both chronic and acute standards are used.
Land Disposal of Waste	Disposal of materials containing polychlorinated biphenyls	Toxic Substances Control Act (TSCA) (15 USC 2605; 40 CFR Part 761)	–	None found to date that exceed TSCA levels
	Hazardous waste	Resource Conservation and Recovery Act (RCRA) Land Disposal Restrictions (42 USC 6901-92k)	Dangerous Waste Regulations Land Disposal Restrictions (RCW 70.105; WAC 173-303, -140, -141)	None found to date that exceed RCRA levels
Waste Treatment Storage and Disposal	Disposal limitations	RCRA (42 USC 6901-6992k; 40 CFR 260-279)	Dangerous Waste Regulations (RCW 70.105; WAC 173-303)	–
Noise	Maximum noise levels	–	Noise Control Act of 1974 (RCW 70.107; WAC 173-60)	–
Groundwater	Groundwater quality	Safe Drinking Water Act Maximum Contaminant Levels and non-zero Maximum Contaminant Level Goals (40 CFR 141)	RCW 43.20A.165 and WAC 173-290-310	For on-site potable water, if any.
Dredge/Fill and Other In-water Construction Work	Discharge of dredged/fill material into navigable waters or wetlands	Clean Water Act (Sections 401, 404; 33 USC 1341, 1344; 40 CFR 121.2, 230, 231; 33 CFR 320, 322-3, 328-30); Rivers and Harbors Act (33 USC 401 et seq)	Hydraulic Code Rules (RCW 75.65; WAC 220-110)	For in-water dredging, filling, or other construction.
	Open-water disposal of dredged sediments	Marine Protection, Research and Sanctuaries Act (33 USC 1401-1445; 40 CFR 227)	Dredged Material Management Program (RCW 79.105.500; WAC 332-30-166 (3))	–
Solid Waste Disposal	Requirements for solid waste handling, management, and disposal	Solid Waste Disposal Act (42 USC 6901-92k; 40 CFR 257, -258)	Solid Waste Handling Standards (RCW 70.95; WAC 173-350)	–
Discharge to Surface Water	Point source standards for new discharges to surface water	National Pollutant Discharge Elimination System (40 CFR 122, 125)	Discharge Permit Program (RCW 90.48; WAC 173-216, -222)	–
Shoreline	Construction and development	–	Shoreline Management Act (RCW 90.58; WAC 173-16)	For construction within 200 feet of the shoreline.
Floodplain Protection	Avoid adverse impacts, minimize potential harm	Executive Order 11988, Protection of flood plains (40 CFR 6, Appendix A); Federal Emergency Management Agency National Flood Insurance Program Regulations (44 CFR 60.3(d)(3))	Growth Management Act critical areas	For in-water construction activities, including any dredge or fill operations. Includes local ordinances: KCC Title 9 and SMC 25.09.

Table B-22 continued

ARARs for the East Waterway[a]

Topic	Threshold	Regulatory Citation		Comment
		Federal	State	
Critical (or Sensitive) Area	Evaluate and mitigate impacts	–	Growth Management Act (RCW 36.70A)	–
Habitat for Fish, Plants, or Birds	Evaluate and mitigate habitat impacts	Clean Water Act (Sect. 404(b)(1)); U.S. Fish and Wildlife Mitigation Policy (81 Fed. Reg. 83440, Nov. 21, 2016); U.S. Fish and Wildlife Coord. Act (16 USC 661 et seq); Migratory Bird Treaty Act (16 USC 703-712)	–	–
Pretreatment Standards	National pretreatment standards	–	40 CFR Part 403; Metro District Wastewater Discharge Ordinance (KCC) to be considered (as a local requirement)	–
Native American Graves and Sacred Sites	Evaluate and mitigate impacts to cultural resources	Native American Graves Protection and Repatriation Act (25 USC 3001 et seq.; 43 CFR Part 10) and American Indian Religious Freedom Act (42 USC 1996 et seq.)	–	–
Critical Habitat for Endangered Species	Conserve endangered or threatened species, consult with species listing agencies	Endangered Species Act of 1973 (16 USC 1531 et seq; 50 CFR 200, -402); Magnuson-Stevens Fishery Conservation and Management Act (16 USC 1801-1884)	Endangered, threatened, and sensitive wildlife species classification (WAC 232-12-297)	Consult and obtain Biological Opinions.
Historic Sites or Structures	Requirement to avoid, minimize, or mitigate impacts to historic sites or structures	National Historic Preservation Act (16 USC 470f; 36 CFR Parts 60, 63, and 800)	–	Considered if implementation of the selected remedy involves removal of historic sites or structures.

Notes:

a. The East Waterway is being remediated under CERCLA and will comply with CERCLA requirements and guidance. ARARs are requirements other than CERCLA.

ARAR – Applicable or relevant and appropriate requirement
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
CFR – Code of Federal Regulations
EPA – U.S. Environmental Protection Agency
KCC – King County Code
RCW – Revised Code of Washington
SMC – Seattle Municipal Code
USC – United States Code
WAC – Washington Administrative Code

Table B-23
Ingestion-weighted Tissue RBTCs for the Human Health RME Seafood Consumption Scenarios

Risk Driver	Target Risk	Ingestion-weighted Tissue RBTC[a]			
		Excess Cancer Risk			Non-Cancer Hazard
		1×10^{-6}	1×10^{-5}	1×10^{-4}	HQ = 1
cPAHs[b] (µg TEQ/kg ww)	Adult Tribal RME (Tulalip Data)	0.11	1.1	11	NA
	Child Tribal RME (Tulalip Data)	0.12[c]	1.2[c]	12[c]	NA
	Adult API RME	0.39	3.9	39	NA
Dioxin/furan[d] (ng TEQ/kg ww)	Adult Tribal RME (Tulalip Data)	0.0056	0.056	0.56	NA[e]
	Child Tribal RME (Tulalip Data)	0.030	0.30	3.0	8.2
	Adult API RME	0.019	0.19	1.9	NA[e]
Total PCBs (µg/kg ww)	Adult Tribal RME (Tulalip Data)	0.42	4.2	42	17
	Child Tribal RME (Tulalip Data)	2.3	23	230	7.8
	Adult API RME	1.4	14	140	24

Notes:

a. Tissue RBTCs associated with human seafood consumption scenarios were calculated in the SRI (Windward and Anchor QEA 2014) using rearrangements of the risk equations in the baseline HHRA (Windward 2012b).
b. cPAHs are presented as benzo(a)pyrene TEQs.
c. Because of the potential for increased susceptibility of children to carcinogens with mutagenic activity, as described in EPA guidance (2005), the risk estimate for children for cPAHs is based on dose adjustments across the 0-to-6-year age range of children (see Section B.5.1 of the HHRA for more information).
d. Dioxins/furans are presented as 2,3,7,8-TCDD mammalian TEQs.
e. An RBTC for dioxin/furan TEQ was only calculated for the child tribal RME scenario based on Tulalip data because it was the only RME scenario with an HQ > 1 for dioxin/furan TEQ.

µg – micrograms
API – Asian and Pacific Islanders
cPAH – carcinogenic polycyclic aromatic hydrocarbon
dw – dry weight
EPA – U.S. Environmental Protection Agency
HHRA – human health risk assessment
HQ – hazard quotient
kg – kilograms
mg – milligrams
NA – not applicable
ng – nanograms
PCB – polychlorinated biphenyl
RBTC – risk-based threshold concentration
RME – reasonable maximum exposure
SRI – Supplemental Remedial Investigation
TCDD – tetrachlorodibenzo-*p*-dioxin
TEQ – toxic equivalent
ww – wet weight

Table B-24
Summary of Sediment RBTCs for Human Health Risk Driver COCs

Scenario	Risk Driver	Unit	RBTCs at Various Risk Levels			
			1×10^{-6}	1×10^{-5}	1×10^{-4}	HQ of 1
Sediment RBTCs for Direct Contact Scenarios						
Netfishing RME	arsenic	mg/kg dw	3.7	37	370	nc[a]
	cPAHs	µg TEQ/kg dw	380	3,800	38,000	nc[a]
Tribal clamming RME	arsenic	mg/kg dw	1.3	13	130	nc[a]
	cPAHs	µg TEQ/kg dw	150	1,500	15,000	nc[a]
Sediment RBTCs for Human Seafood Consumption Scenarios						
Adult Tribal RME (Tulalip data)	total PCBs[b]	µg/kg dw	< 1[c]	< 1[c]	2	< 1[c]
	dioxins/ furan TEQ	ng TEQ/kg dw	0.18	1.8	18	nc
Child Tribal RME (Tulalip data)	total PCBs[b]	µg/kg dw	< 1[c]	< 1[c]	250	< 1[c]
	dioxins/ furan TEQ	ng TEQ/kg dw	0.94	9.4	94	nc
Adult API RME	total PCBs[b]	µg/kg dw	< 1[c]	< 1[c]	100	< 1[c]
	dioxins/ furan TEQ	ng TEQ/kg dw	0.48	4.8	48	nc

[a] Sediment RBTCs for direct-contact scenarios were estimated only for excess cancer risks. Sediment RBTCs were not estimated for non-cancer hazards for direct-contact scenarios because none of the RME scenarios had HQs for an individual chemical > 1 or generated endpoint-specific HIs in > 1 (Appendix B, Section B.5.6).

[b] Total PCB RBTCs were generated using the FWM, as discussed in Appendix C.

[c] For RBTCs presented as < 1 µg/kg dw, a sediment RBTC could not be calculated; even if the total PCB concentration in sediment was set equal to 0 µg/kg dw, FWM-estimated total PCB concentrations in tissue would be greater than the tissue RBTC for the applicable risk level because of the contribution of PCBs from water alone to the tissue levels.

API – Asian and Pacific Islander
cPAH – carcinogenic polycyclic aromatic hydrocarbon
CSL – cleanup screening level
dw – dry weight
FWM – food web model
HI – hazard index
HQ – hazard quotient
nc – not calculated
PCB – polychlorinated biphenyl
RBTC – risk-based threshold concentration
RME – reasonable maximum exposure
TEQ – toxic equivalent

Table B-25

Preliminary Remediation Goals for Total PCBs, Arsenic, cPAHs, and Dioxins/Furans in Sediment for Human Health and Ecological Risk Driver COCs

Analyte	Practical Quantitation Limits			Natural Background[c]		Risk-based Threshold Concentration[a]				Preliminary Remediation Goals		Spatial Scale for PRG Application[f]
	Ecology PQL[b]	SRI QAPP RLs	Range of RLs from Undetected Values	Ecology's Method 90/90 UTL	EPA's Method UCL95	RAO 1: Human Seafood Consumption	RAO 2: Human Direct Contact	RAO 3: Benthic Organisms[d]	RAO 4: Ecological[e]	Value	Basis	
Total PCBs (µg/kg dw)	Not calculated	4[g]	3.9 – 35[h]	3.5[i]	2[i]	2 – 250[j]	NA	NA	39 – 458[k] 100 – >470[k]	2, 3.5(RAO 1)[l] 250, 370 (RAO 4)[m]	Natural Background (RAO 1); RBTC (RAO 4)	Site-wide
						NA	NA	12/65[n]	NA	12 (mg/kg OC) (RAO 3)	RBTC	Point
Arsenic (mg/kg dw)	0.3	0.5	5 – 20	11	7	NA	3.7	NA	NA	7, (RAO 2)	Natural Background	Site-wide
						NA	1.3	NA	NA	7, (RAO 2)	Natural Background	Clamming Areas
						NA	NA	57/93[n]	NA	57 (RAO 3)	RBTC	Point
cPAH (µg TEQ/kg dw)	9	5.9 – 9.5	20 – 48[o]	21	9	NA	380	NA[p]	NA	380 (RAO 2)	RBTC	Site-wide
						NA	150	NA[p]	NA	150[q] (RAO 2)	RBTC	Clamming Areas
Dioxins/furans (ng TEQ/kg dw)	5	0.5[r]	NA	4	2	0.18 – 0.94[s]	NA	NA	NA	2, 5 (RAO 1)[l]	Natural Background/ PQL	Site-wide

Notes:

a. RBTCs developed in the Final SRI (Windward and Anchor QEA 2014).
b. From Table 11-1 of the SCUM II (Ecology 2017). The 2017 version of SCUM II only includes a PCB TEQ PQL value.
c. EPA calculated natural background based on the UCL95 using the OSV *Bold* Survey (DMMP 2009) dataset, as presented in the LDW ROD (EPA 2014). (See Table 4-2.)

d. Sediment RBTCs are also included as the SQS and CSL for the remaining 29 risk driver COCs and TBT for the benthic invertebrate community (see Table 4-4).
e. RAO 4 includes RBTCs (based on two LOAEL TRVs; see Section 3.3.1) for protection of English sole and brown rockfish for PCBs.
f. The spatial scale of site-wide exposure is RAO-specific (e.g., seafood consumption for RAO 1 and netfishing for RAO 2 is site-wide, while tribal clamming for RAO 2 is intertidal clamming areas).
g. PCB RLs (as Aroclors) reported; RLs for individual PCB congeners are much lower (0.5 to 1 ng/kg dw).
h. Range of RLs for undetected values were queried from the SRI database and represent RLs for undetected total PCBs. For samples in which none of the individual Aroclors are detected, the total PCB concentration value is represented as the highest RL of an individual Aroclor, and assigned a U-qualifier, indicating no detected concentrations. Individual undetected Aroclors were not reported because they are not included in the calculation of total PCBs when other Aroclors are detected in the sample.
i. Total PCB value based on the sum of detected PCB congeners.
j. The RBTC is less than 1 µg/kg dw at excess cancer risk levels of 10^{-5} and 10^{-6} and for a Hazard Quotient equal to 1; the RBTC range of 2 to 250 µg/kg dw for the three RME seafood consumption scenarios is at the 10^{-4} excess cancer risk level.
k. Values represent the RBTCs for brown rockfish (39 – 458 µg/kg dw) and English sole (100 – >470 µg/kg dw). The value >470 µg/kg dw indicates that even under current conditions in the EW OU (based on an existing sediment SWAC of 470 µg/kg dw), average tissue concentrations are estimated to be less than the upper bound tissue RBTC.
l. Appendix A describes the justification for adjusting the sediment cleanup level upward from the SCO as required in SMS based on whether the cleanup level is technically possible to achieve and maintain and the net adverse environmental impact of meeting the cleanup level.
m. As described in Appendix A, the sediment PRG is based on the mean of the RBTC values for each fish receptor. Two PRGs have been established based on brown rockfish (250 µg/kg dw) and English sole (370 µg/kg dw).
n. Total PCB concentration units are mg/kg OC and the two values are SQS/CSL. Arsenic concentration units are mg/kg dw and the two values are SQS/CSL.
o. RLs are based on non-detect samples for individual cPAH compounds with units of µg/kg dw. If none of the individual cPAH compounds were detected, then half the RL was multiplied by the PEF for each compound to calculate the cPAH TEQ RL value.
p. Low- and high-molecular weight PAHs are addressed by the SMS. Criteria are set for both groupings and for individual PAH compounds (see Table 4-4).

Table B-26

Preliminary Remediation Goals for Sediment for Benthic Risk Driver COCs

Contaminant	Practical Quantitation Limit (mg/kg dw)			Risk-Based Threshold Concentrations (RAO 3): Sediment Management Standards (mg/kg dw[a] or mg/kg OC[b]) and TBT[c]		Preliminary Remediation Goal[d]			Detection Frequency		Frequency of Detected concentrations above SQS	
	EPA Method	SRI QAPP RLs	Range of RLs from Undetected Values	Sediment Quality Standard (SQS)	Cleanup Screening Level (CSL)	Value	Basis	Spatial Scale of PRG Application	No. of Samples[e]	%	No. of Samples[f]	%
Metals												
Arsenic	EPA 6010B	0.5	6-20[g]	57[a]	93[a]	57[a]	SQS	Point	162/231	70	2/231	0.9
Cadmium	EPA 6010B	0.2	0.2-1.0	5.1[a]	6.7[a]	5.1[a]	SQS		155/231	67	2/231	0.9
Mercury	**EPA 7471A**	**0.05**	**0.04-0.07**	**0.41[a]**	**0.59[a]**	**0.41[a]**	SQS		**233/239**	**98**	**46/239**	**19**
Zinc	EPA 6010B	4.0	NA	410[a]	960[a]	410[a]	SQS		231/231	100	5/231	2.2
PAHs												
2-Methylnaphthalene	EPA 8270D	0.02	0.019 -0.190	38[b]	64[b]	38[b]	SQS	Point	87/240	36	1/240	0.4
Anthracene	EPA 8270D	0.02	**0.019-0.062**	**220[b]**	**1,200[b]**	**220[b]**	SQS		**209/240**	**87**	1/240	0.4
Acenaphthene	EPA 8270D	0.02	**0.019-0.12**	**16[b]**	**57[b]**	**16[b]**	SQS		**126/240**	**53**	**16/240**	**6.7**
Benzo(a)anthracene	EPA 8270D	0.02	0.020-0.061	110[b]	270[b]	110[b]	SQS		226/240	94	7/240	2.9
Benzo(a)pyrene	EPA 8270D	0.02	0.019-0.061	99[b]	210[b]	99[b]	SQS		225/240	94	7/240	2.9
Benzo(g,h,i)perylene	EPA 8270D	0.02	0.019-0.061	31[b]	78[b]	31[b]	SQS		212/240	88	4/240	1.7
Total benzofluoranthenes[h]	EPA 8270D	0.02	0.019-0.061	230[b]	450[b]	230[b]	SQS		228/240	95	7/240	2.9
Chrysene	EPA 8270D	0.02	0.019-0.061	110[b]	360[b]	110[b]	SQS		230/240	96	8/240	3.3
Dibenzo(a,h)anthracene	EPA 8270D-SIM	0.0063	0.019-0.12	12[b]	33[b]	12[b]	SQS		156/240	65	4/240	1.7
Dibenzofuran	EPA 8270D	0.02	0.019-0.190	15[b]	5[b]	15[b]	SQS		107/240	45	8/240	3.3
Fluoranthene	EPA 8270D	0.02	**0.02-0.061**	**160[b]**	**1,200[b]**	**160[b]**	SQS		**233/240**	**97**	**14/240**	**5.8**
Fluorene	EPA 8270D	0.02	**0.019-0.120**	**23[b]**	**79[b]**	**23[b]**	SQS		**144/240**	**60**	**12/240**	**5.0**
Indeno(1,2,3-cd)pyrene	EPA 8270D	0.02	0.019-0.062	34[b]	88[b]	34[b]	SQS		210/240	88	6/240	2.5
Phenanthrene	EPA 8270D	0.02	**0.019-0.061**	**100[b]**	**480[b]**	**100[b]**	SQS		**230/240**	**96**	**15/240**	**6.3**
Pyrene	EPA 8270D	0.02	0.020-0.061	1,000[b]	1,400[b]	1,000[b]	SQS		235/240	98	1/240	0.4
Total HPAHs[i]	EPA 8270D	0.02	0.020	960[b]	5,300[b]	960[b]	SQS		237/240	99	9/240	3.8
Total LPAHs[j]	EPA 8270D	0.02	0.019-0.061	370[b]	780[b]	370[b]	SQS		230/240	96	8/240	3.3
Phthalates												
BEHP	EPA 8270D	0.02	0.020-1.40	47[b]	78[b]	47[b]	SQS	Point	207/231	90	9/231	3.9
BBP	EPA 8270D-SIM	0.0067	0.014-0.190[g]	4.9[b]	64[b]	4.9[b]	SQS		101/231	44	9/231	3.9
Di-n-butyl phthalate	EPA 8270D	0.02	0.019-0.190	220[b]	1,700[b]	220[b]	SQS		32/231	14	1/231	0.4

Table B-26 continued

Preliminary Remediation Goals for Sediment for Benthic Risk Driver COCs

Contaminant	Practical Quantitation Limit (mg/kg dw)			Risk-Based Threshold Concentrations (RAO 3): Sediment Management Standards (mg/kg dw[a] or mg/kg OC[b]) and TBT[c]		Preliminary Remediation Goal[d]			Detection Frequency		Frequency of Detected concentrations above SQS	
	EPA Method	SRI QAPP RLs	Range of RLs from Undetected Values	Sediment Quality Standard (SQS)	Cleanup Screening Level (CSL)	Value	Basis	Spatial Scale of PRG Application	No. of Samples[e]	%	No. of Samples[f]	%
Other SVOCs												
1,4-Dichlorobenzene	EPA 8270D-SIM	0.0067	**0.0009-0.020**	**3.1[b]**	**9.0[b]**	**3.1[b]**	SQS	Point	**146/231**	**63**	**29/231**	**13**
2,4-Dimethylphenol	EPA 8270D-SIM	0.0067	0.019-0.500[g]	0.029[b]	0.029[b]	0.029[b]	SQS		14/231	6.1	1/231	0.4
n-Nitrosodiphenylamine	EPA 8270D-SIM	0.0067	0.0059-0.190	11[b]	11[b]	11[b]	SQS		2/231	0.90	1/231	0.4
Phenol	EPA 8270D-SIM	0.0067	0.019-0.190[g]	0.42[a]	1.2[a]	0.42[a]	SQS		94/231	41	5/231	2.2
PCBs												
Total PCBs	EPA 8082	**0.5**	0.51-3.4	**12[b]**	**65[b]**	**12[b]**	SQS	Point	**227/240**	**95**	**157/240**	**66**
Tributyltin												
Tributyltin	Krone 1989	**0.004**	**0.0034-0.0037**	**7.5[b,c]**		**7.5[b]**	RBTC	Point	**60/67**	**90**	**10/67**	**0.2**

Bold – indicates the contaminant for which 5% or more of the surface sediment samples had detected concentrations above the SQS.

a. Units are mg/kg dw for these contaminants.
b. Units are mg/kg OC for these contaminants
c. An organic carbon normalized sediment RBTC was calculated in the EW SRI (Windward and Anchor QEA 2014). The frequency of detected concentrations above the RBTC is shown.
d. PRGs are considered on the basis of a point concentration or toxicity test pass.
e. Represents the number of detects per total number of samples.
f. Represents the number of detects > SQS per total number of samples. If any individual sample had a TOC content > 4% or < 0.5% and the dry-weight concentration was > LAET, the concentration was considered to be > SQS.
g. RLs elevated above the QAPP RLs due to analytical dilution and matrix interferences.
h. Total benzofluoranthenes were calculated as the sum of benzo(b)fluoranthene and benzo(k)fluoranthene.
i. Total HPAHs were calculated as the sum of benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, total benzofluoranthenes, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, and pyrene.
j. Total LPAHs were calculated as the sum of acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, and phenanthrene.

BBP – butyl benzyl phthalate
BEHP – bis(2-ethylhexyl) phthalate
CSL – cleanup screening level
dw – dry weight
EPA – U.S. Environmental Protection Agency
EW – East Waterway
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
LAET – lowest-apparent-effect threshold
mg/kg – milligrams per kilogram
NA – not applicable
OC – organic carbon-normalized
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PRG – preliminary remediation goal
QAPP – quality assurance project plan
RAO – remedial action objective
RBTC – risk-based threshold concentration
RL – reporting limit
SQS – sediment quality standard
SRI – Supplemental Remedial Investigation
SVOC – semivolatile organic compound
TBT – tributylin
TOC – total organic carbon

q. cPAH PRGs are undefined for the human health seafood consumption pathway (RAO 1). Seafood consumption excess cancer risks for cPAHs were largely attributable to the consumption of clams. There is no consistent relationship, based on site data, relating cPAH concentrations in sediment to concentrations in clam tissue (see Section 8 of SRI; Windward and Anchor QEA 2014). Section 8 of the FS discusses the potential need for future investigations of the sediment/tissue relationship for cPAHs.
r. Dioxins/furans RLs are based on the reporting limits for the individual compounds with units of ng/kg dw.
s. RBTC of 0.18 and 0.94 calculated for adult tribal and child tribal RME scenarios at risk level of 10^{-6} excess cancer risk threshold, respectively.

90/90 UTL – 90% upper tolerance limit on the 90th percentile
µg/kg – micrograms per kilogram
COC – contaminant of concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
CSL – cleanup screening level
dw – dry weight
Ecology – Washington State Department of Ecology
EPA – U.S. Environmental Protection Agency
FS – feasibility study
LOEAL – lowest-observed-adverse-effect level
mg/kg – milligrams per kilogram
NA – not applicable
ng/kg – nanograms per kilogram
OC – organic carbon-normalized
PCB – polychlorinated biphenyl
PEF – potency equivalency factor
PQL – practical quantitation limit
PRG – preliminary remediation goal
QAPP – quality assurance project plan
RAO – remedial action objective
RBTC – risk-based threshold concentration
RL – reporting limit
RME – reasonable maximum exposure
SCO – sediment cleanup objective
SMS – Washington State Sediment Management Standards
SQS – sediment quality standard
SRI – Supplemental Remedial Investigation
SWAC – spatially-weighted average concentration
TBT – tributyltin
TEQ – toxic equivalent
TRV – toxicity reference value
UCL95 –- 95% upper confidence limit on the mean

Table B-27

Construction Management Areas in the East Waterway

Construction Management Area	Description	Structural Restrictions	Use, Habitat, and Water Depth Considerations
Junction Reach	Located south of the Spokane Street corridor and north of the junction with the LDW. Both west and east sides of the EW in this area contain riprap slopes, with floats for small vessels along the west side of the waterway.	Piles and small vessel floats are present in the waterway, but present minimal structural restrictions in this area. It is assumed that dredging adjacent to the piles should be minimized, and dredging at the base of slopes should consider overall slope stability. Existing riprap slopes may limit the ability to conduct remediation immediately adjacent to the riprap slopes without slope improvements.	A shallow bench along the eastern shoreline at T-104 was constructed of fine-grained substrate and provides valuable shallow water habitat for juvenile migratory fish, and intertidal areas provide clam habitat. Small draft recreational and commercial boats move in and out of the Harbor Island Marina (T-102) from the LDW. Tribal netfishing may occur within this area.
Sill Reach	Located under the bridges in the Spokane Street corridor. Four bridge structures pass through this area, including the Spokane Street Bridge and Service Road Bridge between T-102 and T-104, West Seattle Bridge, and BNSF Railway (Railroad Bridge). Elevations in this area range from -4 to -11 feet MLLW.	The West Seattle bridge columns located in the water on each side of the EW are supported by a pile-supported footing or pile cap (approximately 26 feet by 32 feet each) with top of footing at approximately -7 feet MLLW. There are similar-sized pile caps for columns upland on each side of EW. Additional areas adjacent to these columns may have seen some soil improvements that provide additional structural stability to the column and should be considered if significant soil were to be removed. The existing bridge structures limit access for equipment and may restrict removal and/or containment remedial actions underneath the bridges, or immediately adjacent to the bridge structures. The bridge structures are considered critical infrastructure to transportation needs.	Clam habitat is present in intertidal areas. Habitat restoration is proposed for the west side of the EW under the West Seattle Bridge, which would provide off-channel mudflat and marsh habitat, along with riparian vegetation. The project would also involve removal of debris and creosote structures from the shoreline areas. The restoration is subject to Natural Resource Damage Trustee approval, EPA coordination, and obtaining permitting from federal, state, and City agencies. No timeline is established for construction.
Shallow Main Body – South	Located north of the Sill Reach before the EW widens to its full 750 feet width. This area is used to moor tugs and barges along the western side, where a concrete bulkhead is present. There is also a wooden wharf pile-supported structure in-line and to the south of the concrete bulkhead. Details on the date and type of original construction of these structures are unknown. This CMA is within the portion of the federal navigation channel authorized to -34 feet MLLW.	Design and construction details of the concrete bulkhead and timber wharf structure on the west side of the EW are unknown. The condition of the concrete structure is relatively poor, however, based on visual observation. Dredging adjacent to the bulkhead may cause structural impacts.	Numerous barges and tugboats are moored along the west side of the CMA. This CMA also contains a mound of rock placed in the southeast portion of this area specifically for habitat restoration purposes. The mound provides shallow water habitat just north of the Spokane Street pedestrian bridge. Tribal netfishing occurs within this area. Shoreline slope stabilization has recently been proposed along the northwest corner of this CMA (independent of CERCLA).
Former Pier 24 Piling Field	A timber bulkhead and timber piles are present along the southern shoreline of Pier 24. The top of the existing bulkhead is lower than high tides. Removal is planned for these piles, a small pier, and in-water debris, which occupy approximately 2.1 acres of aquatic and shoreline area for fish and wildlife habitat improvements. No timetable for this work is currently established based on the need to coordinate with CERCLA actions. This work may be completed in conjunction with the CERCLA action or may be conducted for habitat restoration purposes ahead of the CERCLA action.	Removal or cutting of piles would be required prior to implementation of remedial alternatives in this area. Structural condition of the existing bulkhead wall is severely deteriorated. As such, removal of the piles and/or any dredging in this area will require strengthening of this wall or removal of the wall plus associated upland grading to contour in-water and upland slope to final desired grades.	This area is potentially slated for Port habitat restoration.
Shallow Main Body – North	Located north of where the EW widens to its full 750 feet and south of the navigation area maintained at -51 feet MLLW. This area extends approximately from Station 4950 to Station 6200 and is included in the portion of the federal navigation channel authorized to -34 feet MLLW.	No structural restrictions.	The water depths in this area reach a maximum depth of -45 feet MLLW (except for the berthing area at T-25, which was designed for -50 feet MLLW). Some limited vessel navigation occurs in this area, including container ships to T-25 at high tide. Tribal netfishing occurs within this area.

Table B-27 continued

Construction Management Areas in the East Waterway

Construction Management Area	Description	Structural Restrictions	Use, Habitat, and Water Depth Considerations
Underpier Areas	Underpier areas apply to T-18, T-25, Slip 27, T-30, Pier 36/37, and T-46 and extend from approximately 125 feet shoreward of the Pier Head Line.	Due to very limited access to underpier areas, only from the water, it is considered extremely difficult to remove sediments from the underpier slopes. Specialized dredging equipment may be capable of removing some of the underpier sediment, but not 100% of sediment. Any underpier removal work would likely need to be conducted using diver assisted methods, and the risks for injury and death during construction will need to be weighed against long-term risk of leaving contaminated sediment in underpier areas. Capping or placement of certain ENR materials within the underpier areas may be infeasible due to equipment access and placement issues. Also, the underpier slopes are typically too steep to place a stable cap over them, and a potential drawdown effect on piling from placing material on the slopes may cause structural damage.	Underpier areas provide habitat for rockfish and epibenthic food for salmon. However, in situ treatment in underpier areas is not restricted based on habitat.
Berth Areas (T-18, T-25, T-30)	Berth areas extend along T-18, T-25, and T-30 and are approximately 150 feet wide. Berth areas at T-18 and T-25 extend from the pier head line into the federal navigation channel.	Berth areas within the EW are actively used by a variety of vessels, the largest of which are container ships. Required berthing elevations typically match the federal navigation channel's authorized elevation of -51 feet MLLW. Removal in front of these terminals may need to limit dredging depths and may include setback areas from the structures to avoid adversely impacting the existing pile-supported wharves. At T-18, a sheetpile wall was installed to provide slope stability to allow dredging along the toe of slope between approximate Stations 4950 and 1900 (terminating at Communication Cable Crossing at bent 213). The capacity of the existing sheetpile wall limits any significant additional material removal at the toe of slope; the sheetpile was designed for a dredge elevation of -51 feet MLLW. The keyways at the base of riprap slopes at T-25 and T-30 are at approximately -50 feet MLLW. For T-18 south of Station 4950, no sheetpile wall exists; T-25 has not had any significant structural berth deepening performed since initial construction in the 1970s. As such, it is unlikely that the structure can accommodate dredging below the initial design dredge elevation. Recent improvements at T-30 (accomplished by the Port in 2007) were completed to allow for dredging in the berth area to -50 feet MLLW.	Along T-18, berthing area elevations are -51 feet MLLW from Station 0 to 4950. Berth 6 (south of Station 4950) depths at T-18 are approximately -35 to -40 feet MLLW. Along T-25, berthing area elevations are -50 feet MLLW. Along T-30, berthing area elevations are -50 feet MLLW. Tribal netfishing occurs within these areas.
Slip 27 Channel/ Pier 28	Slip 27 is located on the east side of the EW, between T-25 and T-30. It is 850 feet long and 240 feet wide. Pier 28 is the concrete structure located on the north side of Slip 27.	A 34-foot-wide truck bridge is present in the eastern portion of Slip 27 connecting T-25 and T-30. This bridge is located to the west of a structural bulkhead wall. The wall and bridge will likely limit the maximum depth of dredging in this area. Pier 28 is a concrete deck and concrete pile structure that is considered at or near the end of its useful life. Structural observations of this facility in 2001 indicate that the pier is deteriorated.	Miscellaneous vessels berth in Slip 27. Pier 28, at the northern portion of the slip, is currently used to berth various vessels and barges. The Slip 27 and Pier 28 areas provide shallow water habitat for juvenile migratory fish, and intertidal areas provide clam habitat. Tribal netfishing occurs within this area.
Slip 36/ T-46 Offshore	Slip 36 is located on the east side of the EW, between Pier 36 and Pier 37. It is approximately 1,200 feet long and 300 feet wide.	Recent construction work on Pier 36 and within Slip 36 included dredging the berth areas to -40 feet MLLW. Further sediment removal may be limited without structural impacts. Recent dredge work at Terminal 46 determined that a non-structural maintenance dredge was possible to allow a berth depth of -51 feet MLLW. Further deepening of the berth area along the west face of the Pier 46 apron would likely require associated structural improvements.	USCG vessels frequent Slip 36, which serves Pier 36 (south) and Pier 37 (north). The western half was dredged to -40 feet MLLW in 2005. USCG berths numerous vessels in Slip 36, and has homeland security access restrictions.

Table B-27 continued

Construction Management Areas in the East Waterway

Construction Management Area	Description	Structural Restrictions	Use, Habitat, and Water Depth Considerations
Mound Area/ Slip 27 Shoreline	This area is located on the east side of the EW just south of the mouth of Slip 27 and along the southern and eastern shoreline of Slip 27. It is open slope, typically with a riprap face.	Possible that structural walls could be necessary to accomplish significant removal of material along this slope without impacting the slope and/or yard area above.	The upland areas along the southern part of Slip 27 have been replanted as part of habitat restoration. The restoration extends from the top of bank (18.5 feet MLLW) down to 12 feet MLLW. The shallow water and intertidal areas also provide habitat for clams and juvenile salmon. Tribal netfishing occurs within this area.
T-25 Nearshore	This area is located on the east side of the EW, between the T-25 Pier and the Mound Area. It is open slope, typically with a riprap face.	Possible that structural walls could be necessary to accomplish significant removal of material along this slope without impacting the slope and/or yard area above.	The shallow water and intertidal areas also provide habitat for clams and juvenile salmon. Tribal netfishing occurs within this area.
T-30/Coast Guard Nearshore	This area is located on the east side of the EW, between Slip 27 and Slip 36.	This area includes several deteriorated structures including remnant piers and both sheetpile and rock bulkhead walls. The specific structural condition of all structures is unknown but appears to be severely deteriorated, suggesting that additional dredging and slope modifications would be problematic without associated structural improvements. This FS assumes that the derelict structures may be removed to facilitate remediation as needed.	Jack Perry Park is a 1.1-acre park located north of T-30 and south of the USCG facility. It provides 120 feet of intertidal area and shoreline access for public recreational activities. Smaller vessels, such as tugboats, barges, and Tribal fishing vessels navigate in this nearshore area. Future development along the shoreline of T-30 is possible, which could result in water depth requirements of -50 feet MLLW (the same as the current T-30 berth area water depth requirements). Shoreline areas provide shallow water habitat for juvenile migratory fish, and intertidal areas provide clam habitat. Tribal netfishing occurs within this area.
Communication Cable Crossing	A communications cable crosses the EW between T-18 and the northern portion of T-30 (Figure 7-1). This cable was originally buried between -61 and -66 feet MLLW in 1972 in an armored trench. The location shown on Figure 7-1 changed following repair due to a vessel anchor incident at T-18. During the T-18 North Apron Upgrade in 2006, the existing crossing at the T-18 face of bullrail was located between bents 213 and 214 (Station 1850). On the T-30 side, the approximate crossing location is indicated by a visible marker on the shore (Station 1550).	For the purposes of this FS, it is assumed that the depth of sediment removal may be limited in this area by the presence of the cable crossing.	Water depths in the footprint of the cable crossing range from -53 feet MLLW to -59 feet MLLW in the federal channel and berth areas. Vessel use is similar to the navigation channel, T-18, and T-30. Tribal netfishing occurs within this area.
Deep Main Body – North	The Deep Main Body – North is 450 feet wide and extends from Station 0 to between Stations 2970 and 3590, depending on location (boundary varies from east to west as shown on Figure 7-2). The channel is authorized to -51 feet MLLW, and maintained to -51 feet MLLW.	No structural restrictions.	The authorized channel elevation of -51 feet MLLW is required to support movement of large container ships throughout the EW. Most vessel traffic consists of shipping companies moving container ships and assorted tugboats into and out of the EW. Each container ship requires at least one tugboat to maneuver the ship during docking and undocking. Container ships call at T-18, T-25, and T-30. Other vessels, such as tugboats, barges, and USCG vessels, regularly use the navigation channel. Also note the Communication Cable Crossing described earlier in this table. Tribal netfishing occurs within this area.

Table B-27 continued

Construction Management Areas in the East Waterway

Construction Management Area	Description	Structural Restrictions	Use, Habitat, and Water Depth Considerations
Deep Main Body – South	The Deep Main Body – South is 450 feet wide and extends from Station 4950 to between Stations 2970 and 3590, depending on location (boundary varies from east to west as shown on Figure 7-2). It is within the federal navigation channel and is authorized to -34 feet MLLW but is maintained to -51 feet MLLW.	No structural restrictions.	Maintenance of this portion of the authorized channel to -51 feet MLLW is required to support movement of large container vessels into berthing areas at T-18 and T-25. Most vessel traffic consists of shipping companies moving container ships and assorted tugboats into and out of the EW. Each container ship requires at least one tugboat to maneuver the ship during docking and undocking. Container ships call at T-18 and T-25. Other vessels, such as tugboats, barges, and USCG vessels, regularly use this area. Tribal netfishing occurs within this area.

Notes:
BNSF – BNSF Railway
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
CMA – Construction Management Area
ENR – enhanced natural recovery
EPA – U.S. Environmental Protection Agency
EW – East Waterway
FS – Feasibility Study
LDW – Lower Duwamish Waterway
MLLW – mean lower low water
Port – Port of Seattle
USCG – U.S. Coast Guard
T – Terminal

Table B-28
Open-water Technology Options

Open-water Technology Option	Navigation Channel and Berth Areas (110 acres)	Shallow Main Body (22 acres)[a]	Nearshore (8 acres)[a]	West Seattle Bridge (2 acres)[a]
	CMAs: - *Federal Navigation Channel – South* - *Federal Navigation Channel – North* - *Deep Draft Berth Areas (T-18, T-30, T-25)* - *Slip 27 Channel* - *Slip 36/T-46 Offshore* - *T-25 Nearshore* - *T-30 Nearshore* - *Junction Reach* - *Communication Cable Crossing*	*CMAs:* - *Shallow Main Body – North and South* - *Former Pier 24 Piling Field*	*CMAs:* - *Mound Area/Slip 27 Shoreline* - *Coast Guard Nearshore*	*CMA:* - *Sill Reach – West Seattle Bridge*
1	• Removal • Partial Removal with ENR-nav • ENR-nav	• Removal • Partial Removal and Cap	• Partial Removal and Cap	• ENR-sill
2	• Removal	• Removal • Partial Removal and Cap	• Partial Removal and Cap	• ENR-sill
3	• Removal	• Removal	• Partial Removal and Cap	• Removal

Notes:
1. Open-water CMAs are shown in Figure 8-1.
2. Remedial technology assignment areas for these options are shown in the appropriate alternative figures (see Figures 8-2 through 8-9).

a. The area for the CMAs represents the total area of the CMAs in that group.
CMA – construction management area
ENR – enhanced natural recovery
T – terminal

Table B-29
Limited Access Area Technology Options

Limited Access Area Technology Option	Underpier (15 acres)[a]	Sill Reach – Low Bridges (2 acres)[a]
	CMA: - *Underpier areas*	*CMAs:* - *Spokane Street Bridge* - *Railroad Bridge*
A	• MNR	• MNR (subtidal) • ENR-sill (intertidal)
B	• In situ treatment	• ENR-sill
C+	• Diver-assisted hydraulic dredging ***followed by in situ treatment*** for PCBs or Hg > CSL[b] • In situ treatment elsewhere	• ENR-sill
E	• Diver-assisted hydraulic dredging followed by in situ treatment	• ENR-sill

Notes:
1. Limited access area CMAs are shown in Figure 8-1.
2. Remedial technology assignment areas for these options are shown in the appropriate alternative figures (see Figures 8-2 through 8-9).

a. The area for the CMAs represents the total area of the CMAs.
b. The underpier dredging-specific action level for the C+ alternatives was developed for PCBs and Hg because they are the primary contributors of risks to human health and the benthic community (see Section 7.8.2).

CMA – construction management areas
CSL – cleanup screening level
ENR – enhanced natural recovery
Hg – mercury
MNR – monitored natural recovery
PCB – polychlorinated biphenyl

Table B-30. Summary of Selected RALs

Risk Driver	RAL	RAO 1	RAO 2	RAO 3	RAO 4
		Human Health Seafood	Human Health Direct Contact	Benthic Inverts	Ecological - Fish
PCBs (mg/kg OC)	7.5/12 site wide	Substantial risk reduction to 2E-4 based on modeling		Achieves PRG: 12 mg/kg OC	Achieves PRG: 250, 370 µg/kg
Dioxin/Furan (ng TEQ/kg)	25 site wide				
Arsenic (mg/kg)	57 site wide		Achieves PRG: 57 mg/kg	Achieves PRG: 57 mg/kg	
cPAHs (µg TEQ/kg)	4800 site wide		Achieves PRG: 380 µg/kg TEQ		
cPAHs (µg TEQ/kg)	660 clam areas		Achieves PRG: 150 µg/kg TEQ		
TBT (mg/kg OC)	7.5 site wide			Achieves PRG: 7.5 mg/kg OC	
Other benthic risk drivers	SQS			RALs achieve the PRGs for all 29 benthic drivers	

Table B-31
Retained Alternatives and Alternative Key

Retained Alternatives	Alternatives Key (General Description)		
	Open-water	**Restricted Access (underpier and low bridges)**	**PCBs RAL**
No Action 1A(12) 1B(12) 1C+(12) 2B(12) 2C+(12) 3B(12) 3C+(12) 2C+(7.5) 3E(7.5)	1 – Removal with capping and ENR where applicable 2 – Removal with capping where applicable 3 – Maximum removal to the extent practicable	A – MNR B – In situ treatment C+ – Diver assisted hydraulic dredging followed by in situ treatment for PCBs or Hg > CSL; In situ treatment elsewhere E – Diver-assisted hydraulic dredging followed by in situ treatment	(12) – 12 mg/kg OC (7.5) – 7.5 mg/kg OC

Notes:
CSL – cleanup screening level
ENR – enhanced natural recovery
Hg – mercury
mg/kg – milligrams per kilogram
MNR – monitored natural recovery
OC – organic carbon
PCB – polychlorinated biphenyl

Table B-32

Remedial Technology Summary for Alternatives by CMA

Alternative	Open-water CMA Groups				Limited Access CMA Groups	
	Deep Main Body and Berth Areas (110 acres)	**Shallow Main Body (22 acres)**	**Nearshore (8 acres)**	**Sill Reach – West Seattle Bridge (2 acres)**	**Underpier (15 acres)**	**Sill Reach – Low Bridges (2 acres)**
	CMAs: - *Federal Navigation Channel – South* - *Federal Navigation Channel – North* - *Deep Draft Berth Areas (T 18, T-30, T-25)* - *Slip 27 Channel* - *Slip 36/T-46 Offshore* - *T-25 Nearshore* - *T-30 Nearshore* - *Junction Reach* - *Communication Cable Crossing*	*CMAs:* - *Shallow Main Body – North and South* - *Former Pier 24 Piling Field*	*CMAs:* - *Mound Area/Slip 27 Shoreline* - *Coast Guard Nearshore*	*CMA:* - *Sill Reach – West Seattle Bridge*	*CMA:* - *Underpier Areas*	*CMAs:* - *Sill Reach – Spokane Street Bridge* - *Sill Reach – Railroad Bridge*
No Action	No Action	No Action	No Action	No Action	No Action	No Action
1A(12)	Removal / Partial Removal and ENR-nav / ENR-nav	Removal / Partial Removal and Cap	Partial Removal and Cap	ENR-sill	MNR	ENR-sill/MNR
1B(12)	Removal / Partial Removal and ENR-nav / ENR-nav	Removal / Partial Removal and Cap	Partial Removal and Cap	ENR-sill	In situ Treatment	ENR-sill
1C+(12)	Removal / Partial Removal and ENR-nav / ENR-nav	Removal / Partial Removal and Cap	Partial Removal and Cap	ENR-sill	Hydraulic dredging ***followed by in situ treatment*** for PCBs or Hg > CSL / In situ treatment elsewhere	ENR-sill
2B(12)	Removal	Removal / Partial Removal and Cap	Partial Removal and Cap	ENR-sill	In situ Treatment	ENR-sill
2C+(12)	Removal	Removal / Partial Removal and Cap	Partial Removal and Cap	ENR-sill	Hydraulic dredging ***followed by in situ treatment*** for PCBs or Hg > CSL / In situ treatment elsewhere	ENR-sill
3B(12)	Removal	Removal	Partial Removal and Cap	Removal	In situ Treatment	ENR-sill
3C+(12)	Removal	Removal	Partial Removal and Cap	Removal	Hydraulic dredging ***followed by in situ treatment*** for PCBs or Hg > CSL / In situ treatment elsewhere	ENR-sill
2C+(7.5)	Removal	Removal	Partial Removal and Cap	Removal	Hydraulic dredging ***followed by in situ treatment*** for PCBs or Hg > CSL / In situ treatment elsewhere	ENR-sill
3E(7.5)	Removal	Removal	Partial Removal and Cap	Removal	Hydraulic dredging followed by in situ treatment	ENR-sill

Notes:
1. Acres for each CMA represent the entire CMA footprint with sediment including areas below RALs that are identified as not requiring remediation. Areas are rounded to the closest acre.
2. See Figure 7-1 for a map of CMA areas.

CMA – Construction Management Area
ENR – enhanced natural recovery
MNR – monitored natural recovery
RAL – remedial action level
T – Terminal

Table B-33

Areas, Volumes, and Costs for Alternatives

Alternative	Area (acres)																	Volume (cubic yards)		Total Cost[d]	Construction Timeframe (years)
	Open-water and Under Low Bridges										Underpier										
	Removal	Removal to the Extent Practicable and Backfill (Communication Cable Crossing Area)	Removal and Backfill to Existing Contours	Partial Removal and Capping	Partial Removal and ENR-nav	ENR-nav	ENR-sill	MNR	Interior Unremediated Area[a]	Exterior Unremediated Area	Hydraulic Dredging Followed by in situ Treatment	In situ Treatment	MNR	Underpier Unremediated	Total Remediated Area	No Action Area	Total Area[b]	Total Removal Volume[c]	Total Placement Volume (capping, ENR, in situ treatment, RMC)		
No Action	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**157**	**157**	0	0	$950,000	0
1A(12)	73	3	1	13	7	9	2	1	19	15	0	0	12	2	**121**	36	**157**	810,000	290,000	$256,000,000	9
1B(12)	73	3	1	13	7	9	3	0	19	15	0	12	0	2	**121**	36	**157**	810,000	290,000	$264,000,000	9
1C+(12)	73	3	1	13	7	9	3	0	19	15	2	10	0	2	**121**	36	**157**	820,000	290,000	$277,000,000	9
2B(12)	88	5	1	13	0	0	3	0	19	15	0	12	0	2	**121**	36	**157**	900,000	280,000	$284,000,000	10
2C+(12)	88	5	1	13	0	0	3	0	19	15	2	10	0	2	**121**	36	**157**	910,000	280,000	$297,000,000	10
3B(12)	92	5	3	7	0	0	1	0	19	15	0	12	0	2	**121**	36	**157**	960,000	270,000	$298,000,000	10
3C+(12)	92	5	3	7	0	0	1	0	19	15	2	10	0	2	**121**	36	**157**	960,000	270,000	$310,000,000	10
2C+(7.5)	98	5	1	13	0	0	3	0	15	8	2	11	0	2	**132**	25	**157**	1,010,000	290,000	$326,000,000	11
3E(7.5)	102	5	4	7	0	0	1	0	15	8	13	0	0	2	**132**	25	**157**	1,080,000	270,000	$411,000,000	13

Notes:

a. Interior unremediated areas are sediment areas with no RAL exceedances, but which are surrounded by areas to be remediated. For FS purposes, an RMC layer is assumed to be placed in these areas (see Appendix F for more details).

b. Area does not include locations without sediment (i.e., 19 acres of uncovered riprap) in the Underpier, T-25 Nearshore, and T-30 Nearshore Construction Management Areas.

c. Removal volume is based on the assumptions in Appendix F and include the neatline dredging volume multiplied by a design factor of 1.5, except for underpier areas (which is based on the neatline volume without a design factor because sediment is underlain by riprap).

d. Costs are based on assumptions in Appendix E.

All values are rounded for presentation. Apparent discrepancies in totals are only due to rounding.

ENR-nav – enhanced natural recovery applied in the navigation channel and deep-draft berthing areas

ENR-sill – enhanced natural recovery used in the Sill Reach

FS – Feasibility Study

MNR – monitored natural recovery

RAL – remedial action level

RMC – residuals management cover

Table B-34a

Estimated Individual Excess Cancer Risks for RME Seafood Consumption Scenarios Based on Predicted Long-term Site-wide Total PCB and Dioxin/Furan SWACs

Total PCBs

Alternative	Construction Time (years)	Adult Tribal RME Baseline Risk = 1 x 10^{-3}									Child Tribal RME Baseline Risk = 2 x 10^{-4}									Adult API RME Baseline Risk = 4 x 10^{-4}								
		Time After Construction (years)									Time After Construction (years)									Time After Construction (years)								
		0	5	10	15	20	25	30	35	40	0	5	10	15	20	25	30	35	40	0	5	10	15	20	25	30	35	40
No Action	-	1E-03	8E-04	7E-04	6E-04	6E-04	5E-04	5E-04	4E-04	4E-04	2E-04	2E-04	1E-04	1E-04	1E-04	9E-05	9E-05	8E-05	8E-05	4E-04	3E-04	3E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04
1A(12)	9	2E-04	3E-04	3E-04	3E-04	3E-04	2E-04	2E-04	2E-04	2E-04	4E-05	6E-05	6E-05	6E-05	6E-05	4E-05	4E-05	4E-05	4E-05	8E-05	1E-04	1E-04	1E-04	1E-04	9E-05	9E-05	8E-05	8E-05
1B(12)	9	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	3E-05	4E-05	4E-05	4E-05	4E-05	4E-05	3E-05	3E-05	3E-05	6E-05	8E-05	8E-05	8E-05	8E-05	7E-05	7E-05	7E-05	7E-05
1C+(12)	9	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	3E-05	4E-05	4E-05	4E-05	4E-05	3E-05	3E-05	3E-05	3E-05	6E-05	8E-05	8E-05	7E-05	7E-05	7E-05	7E-05	7E-05	7E-05
2B(12)	10	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	3E-05	4E-05	4E-05	4E-05	4E-05	4E-05	3E-05	3E-05	3E-05	6E-05	8E-05	8E-05	8E-05	8E-05	7E-05	7E-05	7E-05	7E-05
2C+(12)	10	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	3E-05	4E-05	4E-05	4E-05	4E-05	3E-05	3E-05	3E-05	3E-05	6E-05	8E-05	8E-05	7E-05	7E-05	7E-05	7E-05	7E-05	7E-05
3B(12)	10	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	3E-05	4E-05	4E-05	4E-05	4E-05	4E-05	3E-05	3E-05	3E-05	6E-05	8E-05	8E-05	8E-05	8E-05	7E-05	7E-05	7E-05	7E-05
3C+(12)	10	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	3E-05	4E-05	4E-05	4E-05	4E-05	3E-05	3E-05	3E-05	3E-05	6E-05	8E-05	8E-05	7E-05	7E-05	7E-05	7E-05	7E-05	7E-05
2C+(7.5)	11	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	3E-05	4E-05	4E-05	4E-05	3E-05	3E-05	3E-05	3E-05	3E-05	6E-05	7E-05	7E-05	7E-05	7E-05	7E-05	7E-05	7E-05	7E-05
3E(7.5)	13	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	3E-05	3E-05	3E-05	3E-05	3E-05	3E-05	3E-05	3E-05	3E-05	6E-05	7E-05	7E-05	7E-05	7E-05	7E-05	7E-05	7E-05	7E-05

Dioxins/Furans

Alternative	Construction Time (years)	Adult Tribal RME Baseline Risk = 1 x 10^{-4}									Child Tribal RME Baseline Risk = 2 x 10^{-5}									Adult API RME Baseline Risk = 4 x 10^{-5}								
		Time After Construction (years)									Time After Construction (years)									Time After Construction (years)								
		0	5	10	15	20	25	30	35	40	0	5	10	15	20	25	30	35	40	0	5	10	15	20	25	30	35	40
No Action	-	1E-04	9E-05	8E-05	8E-05	7E-05	7E-05	7E-05	7E-05	7E-05	2E-05	2E-05	2E-05	1E-05	1E-05	1E-05	1E-05	1E-05	1E-05	4E-05	4E-05	4E-05	4E-05	3E-05	3E-05	3E-05	3E-05	3E-05
1A(12)	9	3E-05	5E-05	6E-05	6E-05	5E-05	5E-05	5E-05	5E-05	5E-05	6E-06	1E-05	1E-05	1E-05	1E-05	1E-05	1E-05	9E-06	9E-06	1E-05	2E-05	3E-05	3E-05	2E-05	2E-05	2E-05	2E-05	2E-05
1B(12)	9	2E-05	4E-05	4E-05	5E-05	5E-05	5E-05	5E-05	5E-05	5E-05	4E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	1E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05
1C+(12)	9	2E-05	4E-05	4E-05	5E-05	5E-05	5E-05	5E-05	5E-05	5E-05	4E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	9E-06	1E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05
2B(12)	10	2E-05	4E-05	4E-05	4E-05	5E-05	5E-05	5E-05	5E-05	5E-05	4E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	1E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05
2C+(12)	10	2E-05	4E-05	4E-05	5E-05	5E-05	5E-05	5E-05	5E-05	5E-05	4E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	1E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05
3B(12)	10	2E-05	4E-05	4E-05	4E-05	5E-05	5E-05	5E-05	5E-05	5E-05	5E-06	7E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	1E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05
3C+(12)	10	2E-05	4E-05	4E-05	4E-05	5E-05	5E-05	5E-05	5E-05	5E-05	5E-06	7E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	1E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05
2C+(7.5)	11	2E-05	4E-05	4E-05	4E-05	4E-05	4E-05	5E-05	5E-05	5E-05	4E-06	7E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	1E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05
3E(7.5)	13	2E-05	4E-05	4E-05	4E-05	5E-05	5E-05	5E-05	5E-05	5E-05	4E-06	7E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	1E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05	2E-05

Notes:

1. Baseline human health seafood consumption risks are based on tissue data collected from the EW, as reported in the HHRA (Windward 2012b). HHRA baseline risk estimates are used as year 0 risk estimates for the No Action Alternative.
2. Total PCB excess cancer risks were estimated using tissue concentrations predicted by the FWM (Anchor QEA and Windward 2014) with alternative-specific total PCB SWACs in surface sediment (Table 9-1) and assumed surface water dissolved total PCB concentrations of 0.6 ng/L (except 0.9 ng/L for the No Action Alternative [at years 20 to 40] and for Alternative 1A(12) [years 5 to 20], and 1.2 ng/L for the No Action Alternative [at years 0 to 20]).
3. Dioxin/furan excess cancer risks were estimated using tissue concentrations predicted by BSAFs (Anchor QEA and Windward 2014) with alternative-specific total PCB SWACs in surface sediment (Table 9-1).
4. No mussel or geoduck data could be predicted for total PCBs or dioxins/furans, nor clam data for dioxins/furans. The portion of the diets assigned to these diet items were distributed proportionally to the remaining dietary items.
5. Significant figures are displayed in accordance with the conventions established in the HHRA.
6. Year 0 post-construction risks are estimated considering the likely widespread placement of clean sand (residuals management cover). The increase in risks from year 0 post-construction to year 5 is due to the influences of upstream sediment, lateral loads, vertical mixing of sediment within the waterway, and exchange of sediment between underpier and open-water areas.

10^{-3}
10^{-4}
10^{-5}
10^{-6}

Colored cells indicate estimated excess cancer risk rounded to the nearest order of magnitude.

API – Asian and Pacific Islanders; BSAF – biota-sediment accumulation factor; EW – East Waterway; FWM – food web model; HHRA – human health risk assessment; ng/L – nanogram per liter; PCB – polychlorinated biphenyl; RME – reasonable maximum exposure; SWAC – spatially-weighted average concentration

Table B-34b

Estimated Total Excess Cancer Risks for RME Seafood Consumption Scenarios Based on Predicted Long-term Site-wide Total PCB and Dioxin/Furan SWACs

Alternative	Construction Time (years)	Adult Tribal RME Baseline Risk = 1 x 10^{-3}									Child Tribal RME Baseline Risk = 2 x 10^{-4}									Adult API RME Baseline Risk = 4 x 10^{-4}								
		Time After Construction (years)									Time After Construction (years)									Time After Construction (years)								
		0	5	10	15	20	25	30	35	40	0	5	10	15	20	25	30	35	40	0	5	10	15	20	25	30	35	40
No Action	-	1E-03	9E-04	8E-04	7E-04	7E-04	6E-04	5E-04	5E-04	5E-04	2E-04	2E-04	1E-04	1E-04	1E-04	1E-04	1E-04	9E-05	9E-05	4E-04	3E-04	3E-04	3E-04	2E-04	2E-04	2E-04	2E-04	2E-04
1A(12)	9	2E-04	4E-04	4E-04	4E-04	4E-04	3E-04	3E-04	3E-04	3E-04	5E-05	7E-05	7E-05	7E-05	7E-05	5E-05	5E-05	5E-05	5E-05	1E-04	2E-04	2E-04	1E-04	1E-04	1E-04	1E-04	1E-04	1E-04
1B(12)	9	2E-04	2E-04	3E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	3E-05	5E-05	5E-05	5E-05	4E-05	4E-05	4E-05	4E-05	4E-05	7E-05	1E-04	1E-04	1E-04	1E-04	1E-04	9E-05	9E-05	9E-05
1C+(12)	9	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	3E-05	4E-05	4E-05	4E-05	4E-05	4E-05	4E-05	4E-05	4E-05	7E-05	9E-05	1E-04	9E-05	9E-05	9E-05	9E-05	9E-05	9E-05
2B(12)	10	2E-04	3E-04	3E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	3E-05	5E-05	5E-05	5E-05	4E-05	4E-05	4E-05	4E-05	4E-05	7E-05	1E-04	1E-04	1E-04	1E-04	9E-05	9E-05	9E-05	9E-05
2C+(12)	10	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	3E-05	4E-05	4E-05	4E-05	4E-05	4E-05	4E-05	4E-05	4E-05	7E-05	9E-05	1E-04	9E-05	9E-05	9E-05	9E-05	9E-05	9E-05
3B(12)	10	2E-04	2E-04	3E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	3E-05	5E-05	5E-05	5E-05	4E-05	4E-05	4E-05	4E-05	4E-05	7E-05	1E-04	1E-04	1E-04	1E-04	9E-05	9E-05	9E-05	9E-05
3C+(12)	10	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	3E-05	4E-05	4E-05	4E-05	4E-05	4E-05	4E-05	4E-05	4E-05	7E-05	9E-05	1E-04	9E-05	9E-05	9E-05	9E-05	9E-05	9E-05
2C+(7.5)	11	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	3E-05	4E-05	4E-05	4E-05	4E-05	4E-05	4E-05	4E-05	4E-05	7E-05	9E-05	9E-05	9E-05	9E-05	9E-05	9E-05	9E-05	9E-05
3E(7.5)	13	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	3E-05	4E-05	4E-05	4E-05	4E-05	4E-05	4E-05	4E-05	4E-05	7E-05	9E-05	9E-05	9E-05	9E-05	9E-05	9E-05	9E-05	9E-05

Notes:

1. Baseline human health seafood consumption risks based on tissue data collected from the EW, as reported in the HHRA (Windward 2012b). HHRA baseline risk estimates are used as year 0 risk estimates for the No Action Alternative.
2. Total excess cancer risks include only the risk drivers for the seafood consumption exposure scenario (total PCBs, dioxins/furans). See Table 9-5a for estimated individual excess cancer risks.
3. Significant figures are displayed in accordance with the conventions established in the HHRA.

10^{-3}
10^{-4}
10^{-5}

Colored cells indicate estimated excess cancer risk rounded to the nearest order of magnitude.

API – Asian and Pacific Islanders; EW – East Waterway; HHRA – human health risk assessment; PCB – polychlorinated biphenyl; RME – reasonable maximum exposure; SWAC – spatially-weighted average concentration

Table B-34c

Estimated Non-cancer Hazard Quotients for RME Seafood Consumption Scenarios Based on Predicted Long-term Site-wide Total PCB and Dioxin/Furan SWACs

Total PCBs (based on the immunological, integumentary, or neurological endpoints)

Alternative	Construction Time (years)	Adult Tribal RME Baseline HQ = 27									Child Tribal RME Baseline HQ = 58									Adult API RME Baseline HQ = 24								
		Time After Construction (years)									Time After Construction (years)									Time After Construction (years)								
		0	5	10	15	20	25	30	35	40	0	5	10	15	20	25	30	35	40	0	5	10	15	20	25	30	35	40
No Action	-	27	21	18	16	15	13	12	11	11	58	45	38	34	31	27	25	24	23	24	18	15	14	13	11	10	10	9
1A(12)	9	5	9	9	8	8	6	6	6	5	12	19	18	17	16	13	12	12	12	5	8	7	7	7	5	5	5	5
1B(12)	9	4	5	5	5	5	5	5	5	5	9	11	11	11	11	10	10	10	10	4	5	5	4	4	4	4	4	4
1C+(12)	9	4	5	5	5	5	5	5	5	5	9	11	11	10	10	10	10	10	10	4	4	4	4	4	4	4	4	4
2B(12)	10	4	5	5	5	5	5	5	5	5	9	11	11	11	11	10	10	10	10	4	5	5	4	4	4	4	4	4
2C+(12)	10	4	5	5	5	5	5	5	5	5	9	11	11	10	10	10	10	10	10	4	4	4	4	4	4	4	4	4
3B(12)	10	4	5	5	5	5	5	5	5	5	9	11	11	11	11	10	10	10	10	4	5	5	4	4	4	4	4	4
3C+(12)	10	4	5	5	5	5	5	5	5	5	9	11	11	10	10	10	10	10	10	4	4	4	4	4	4	4	4	4
2C+(7.5)	11	4	5	5	5	5	5	5	5	5	8	10	10	10	10	10	10	10	10	4	4	4	4	4	4	4	4	4
3E(7.5)	13	4	5	5	5	4	4	4	4	4	9	10	10	10	10	10	10	9	9	4	4	4	4	4	4	4	4	4

Total PCBs (based on the developmental endpoint)

Alternative	Construction Time (years)	Adult Tribal RME Baseline HQ = 8									Child Tribal RME Baseline HQ = 17									Adult API RME Baseline HQ = 7								
		Time After Construction (years)									Time After Construction (years)									Time After Construction (years)								
		0	5	10	15	20	25	30	35	40	0	5	10	15	20	25	30	35	40	0	5	10	15	20	25	30	35	40
No Action	-	8	6	5	5	4	4	3	3	3	17	13	11	10	9	8	7	7	7	7	5	4	4	4	3	3	3	3
1A(12)	9	2	2	2	2	2	2	2	2	2	3	5	5	5	5	4	4	3	3	≤1	2	2	2	2	2	≤1	≤1	≤1
1B(12)	9	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	2	3	3	3	3	3	3	3	3	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
1C+(12)	9	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	2	3	3	3	3	3	3	3	3	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
2B(12)	10	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	2	3	3	3	3	3	3	3	3	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
2C+(12)	10	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	2	3	3	3	3	3	3	3	3	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
3B(12)	10	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	3	3	3	3	3	3	3	3	3	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
3C+(12)	10	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	3	3	3	3	3	3	3	3	3	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
2C+(7.5)	11	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	2	3	3	3	3	3	3	3	3	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
3E(7.5)	13	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	2	3	3	3	3	3	3	3	3	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1

Dioxins/Furans (based on the developmental endpoint)

Alternative	Construction Time (years)	Adult Tribal RME Baseline HQ = 1									Child Tribal RME Baseline HQ = 2									Adult API RME Baseline HQ = 0.9								
		Time After Construction (years)									Time After Construction (years)									Time After Construction (years)								
		0	5	10	15	20	25	30	35	40	0	5	10	15	20	25	30	35	40	0	5	10	15	20	25	30	35	40
No Action	-	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	2	2	2	2	2	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
1A(12)	9	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
1B(12)	9	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
1C+(12)	9	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
2B(12)	10	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
2C+(12)	10	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
3B(12)	10	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
3C+(12)	10	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
2C+(7.5)	11	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1
3E(7.5)	13	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1	≤1

Notes:

1. Baseline human health seafood consumption hazard quotients based on tissue data collected from the EW, as reported in the HHRA (Windward 2012b). HHRA baseline risk estimates are used as year 0 risk estimates for the No Action Alternative.
2. Total PCB non-cancer hazard quotients were estimated using tissue concentrations predicted by the FWM (Anchor and Windward 2014) with alternative-specific total PCB SWACs in surface sediment (Table 9-1) and assumed surface water dissolved total PCBs concentrations of 0.6 ng/L(except 0.9 ng/L for the No Action Alternative [at years 20 to 40] and for Alternative 1A(12) [years 5 to 20], and 1.2 ng/L for the No Action Alternative [at years 0 to 20]).
3. Dioxin/furan non-cancer hazard quotients were estimated using tissue concentrations predicted by biota-sediment accumulation factors (Anchor QEA and Windward 2014) with alternative-specific total PCB SWACs in surface sediment (Table 9-1).
4. No mussel or geoduck data could be predicted for total PCBs or dioxins/furans, nor clam data for dioxins/furans. The portion of the diets assigned to these diet items were distributed proportionally to the remaining dietary items.
5. All tabulated values are hazard quotients. HQs are rounded following the conventions established in the HHRA (Windward 2012b).

HQ >1	Colored cells indicate estimated non-cancer hazard quotient.
HQ ≤1	

API – Asian and Pacific Islanders; EW – East Waterway; FWM – food web model; HHRA – human health risk assessment; HQ – hazard quotient; ng/L – nanogram per liter; PCB – polychlorinated biphenyl; RME – reasonable maximum exposure; SWAC – spatially-weighted average concentration

Table B-34d

Estimated Non-cancer Developmental Hazard Index for RME Seafood Consumption Scenarios Based on Predicted Long-term Site-wide Total PCB and Dioxin/Furan SWACs

Total PCBs and Dioxins/Furans (based on the developmental endpoint)

Alternative	Construction Time (years)	Adult Tribal RME Baseline HI = 9									Child Tribal RME Baseline HI = 19									Adult API RME Baseline HI = 8								
		Time After Construction (years)									Time After Construction (years)									Time After Construction (years)								
		0	5	10	15	20	25	30	35	40	0	5	10	15	20	25	30	35	40	0	5	10	15	20	25	30	35	40
No Action	-	9	7	6	5	5	4	4	4	4	19	15	12	11	10	9	9	8	8	8	6	5	5	4	4	4	3	3
1A(12)	9	2	3	3	3	3	2	2	2	2	4	6	6	6	6	5	5	4	4	2	3	3	3	2	2	2	2	2
1B(12)	9	≤1	2	2	2	2	2	2	2	2	3	4	4	4	4	4	4	4	4	≤1	2	2	2	2	2	2	2	2
1C+(12)	9	≤1	2	2	2	2	2	2	2	2	3	4	4	4	4	4	4	4	4	≤1	2	2	2	2	2	2	2	2
2B(12)	10	≤1	2	2	2	2	2	2	2	2	3	4	4	4	4	4	4	4	4	≤1	2	2	2	2	2	2	2	2
2C+(12)	10	≤1	2	2	2	2	2	2	2	2	3	4	4	4	4	4	4	4	4	≤1	2	2	2	2	2	2	2	2
3B(12)	10	≤1	2	2	2	2	2	2	2	2	3	4	4	4	4	4	4	4	4	≤1	2	2	2	2	2	2	2	2
3C+(12)	10	≤1	2	2	2	2	2	2	2	2	3	4	4	4	4	4	4	4	4	≤1	2	2	2	2	2	2	2	2
2C+(7.5)	11	≤1	2	2	2	2	2	2	2	2	3	4	4	4	4	4	4	4	4	≤1	2	2	2	2	2	2	2	2
3E(7.5)	13	≤1	2	2	2	2	2	2	2	2	3	4	4	4	4	4	4	4	4	≤1	2	2	2	2	2	2	2	2

Notes:

1. Baseline human health seafood consumption hazard index based on tissue data collected from the EW, as reported in the HHRA (Windward 2012b). HHRA baseline risk estimates are used as year 0 risk estimates for the No Action Alternative.
2. The developmental hazard index is equal to the sum of total PCBs and dioxins/furans based on the developmental endpoint. See Table 9-5c for estimated individual non-cancer hazard quotients.
3. All tabulated values are hazard indices. HIs are rounded following the conventions established in the HHRA (Windward 2012b).

HI >1	Colored cells indicate estimated non-cancer hazard index.
HI ≤1	

API – Asian and Pacific Islanders; EW – East Waterway; HI – hazard index; HHRA – human health risk assessment; PCB – polychlorinated biphenyl; RME – reasonable maximum exposure; SWAC – spatially-weighted average concentration

Table B-35a

Estimated Individual Excess Cancer Risks for Direct Contact Based on Predicted Long-term Site-wide and Clamming Arsenic and cPAH SWACs

Arsenic

Alternative	Construction Time (years)	Site-wide Netfishing Baseline Risk = 3 x 10^{-6}									Tribal Clamming Baseline Risk = 1 x 10^{-5}								
		Time After Construction (years)									Time After Construction (years)								
		0	5	10	15	20	25	30	35	40	0	5	10	15	20	25	30	35	40
No Action	-	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	1E-05	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06
1A(12)	9	1E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	6E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06
1B(12)	9	1E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	6E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06
1C+(12)	9	1E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	6E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06
2B(12)	10	1E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	6E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06
2C+(12)	10	1E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	6E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06
3B(12)	10	1E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	6E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06
3C+(12)	10	1E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	6E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06
2C+(7.5)	11	1E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	6E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06
3E(7.5)	13	1E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	6E-06	6E-06	7E-06	7E-06	7E-06	7E-06	7E-06	7E-06

cPAHs

Alternative	Construction Time (years)	Site-wide Netfishing Baseline Risk = 3 x 10^{-6}									Tribal Clamming Baseline Risk = 2 x 10^{-5}								
		Time After Construction (years)									Time After Construction (years)								
		0	5	10	15	20	25	30	35	40	0	5	10	15	20	25	30	35	40
No Action	-	3E-06	9E-07	8E-07	7E-07	7E-07	7E-07	6E-07	6E-07	6E-07	2E-05	4E-06	2E-06	2E-06	1E-06	1E-06	1E-06	1E-06	1E-06
1A(12)	9	2E-07	5E-07	5E-07	5E-07	5E-07	4E-07	4E-07	4E-07	4E-07	1E-07	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06
1B(12)	9	1E-07	3E-07	4E-07	4E-07	4E-07	4E-07	4E-07	4E-07	4E-07	1E-07	9E-07	1E-06	1E-06	1E-06	1E-06	9E-07	9E-07	9E-07
1C+(12)	9	1E-07	3E-07	3E-07	3E-07	3E-07	3E-07	4E-07	4E-07	4E-07	1E-07	9E-07	1E-06	1E-06	1E-06	9E-07	9E-07	9E-07	9E-07
2B(12)	10	1E-07	3E-07	4E-07	4E-07	4E-07	4E-07	4E-07	4E-07	4E-07	1E-07	9E-07	1E-06	1E-06	1E-06	1E-06	9E-07	9E-07	9E-07
2C+(12)	10	1E-07	3E-07	3E-07	3E-07	3E-07	3E-07	4E-07	4E-07	4E-07	1E-07	9E-07	1E-06	1E-06	1E-06	9E-07	9E-07	9E-07	9E-07
3B(12)	10	2E-07	3E-07	4E-07	4E-07	4E-07	4E-07	4E-07	4E-07	4E-07	2E-07	9E-07	1E-06	1E-06	1E-06	1E-06	9E-07	9E-07	9E-07
3C+(12)	10	2E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	4E-07	4E-07	2E-07	8E-07	9E-07	9E-07	9E-07	9E-07	9E-07	9E-07	9E-07
2C+(7.5)	11	1E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	1E-07	8E-07	9E-07	9E-07	9E-07	9E-07	9E-07	9E-07	9E-07
3E(7.5)	13	1E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	3E-07	2E-07	8E-07	9E-07	9E-07	9E-07	9E-07	9E-07	9E-07	9E-07

Notes:

1. Baseline direct contact risks based on data collected from the EW, as reported in the HHRA (Windward 2012b). HHRA baseline risk estimates are used as year 0 risk estimates for the No Action Alternative.
2. Arsenic risk estimates are based on SWACs for netfishing and tribal clamming areas for each alternative (Table 9-1).
3. cPAH risk estimates are based on SWACs for netfishing and tribal clamming areas for each alternative (Table 9-1).
4. Significant figures are displayed in accordance with the conventions established in the HHRA (Windward 2012b).
5. Year 0 post-construction risks are estimated considering the likely widespread placement of clean sand (residuals management cover). The increase in risks from year 0 post-construction to year 5 is due to the influences of upstream sediment, lateral loads, vertical mixing of sediment within the waterway, and exchange of sediment between underpier and open-water areas.
6. While cPAH PRG in clamming areas may not be achieved for the No Action Alternative (years 0 to 40) and Alternative 1A(12) (years 5 to 40) (see Table 9-2), the risk threshold of 1 x 10^{-6} is achieved at year 20 (No Action Alternative) and year 0 post-construction (Alternative 1A(12)) (see table above).

> 1 x 10^{-6}
≤ 1 x 10^{-6}

cPAH – carcinogenic polycyclic aromatic hydrocarbon; EW – East Waterway; HHRA – human health risk assessment; SWAC – spatially-weighted average concentration

Table B-35b
Estimated Total Excess Cancer Risks for Direct Contact Based on Predicted Long-term Site-wide and Clamming Arsenic and cPAH SWACs

Alternative	Construction Time (years)	Site-wide Netfishing Baseline Risk = 6 x 10^{-6}									Tribal Clamming Baseline Risk = 3 x 10^{-5}								
		Time After Construction (years)									Time After Construction (years)								
		0	5	10	15	20	25	30	35	40	0	5	10	15	20	25	30	35	40
No Action	-	6E-06	4E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-05	1E-05	9E-06	9E-06	8E-06	8E-06	8E-06	8E-06	8E-06
1A(12)	9	1E-06	2E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	3E-06	2E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06
1B(12)	9	1E-06	2E-06	2E-06	2E-06	3E-06	3E-06	3E-06	3E-06	3E-06	2E-06	7E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06
1C+(12)	9	1E-06	2E-06	2E-06	2E-06	2E-06	2E-06	3E-06	3E-06	3E-06	2E-06	7E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06
2B(12)	10	1E-06	2E-06	2E-06	2E-06	3E-06	3E-06	3E-06	3E-06	3E-06	2E-06	7E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06
2C+(12)	10	1E-06	2E-06	2E-06	2E-06	2E-06	2E-06	3E-06	3E-06	3E-06	2E-06	7E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06
3B(12)	10	1E-06	2E-06	2E-06	2E-06	2E-06	3E-06	3E-06	3E-06	3E-06	3E-06	7E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06
3C+(12)	10	1E-06	2E-06	2E-06	2E-06	2E-06	2E-06	3E-06	3E-06	3E-06	3E-06	7E-06	7E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06
2C+(7.5)	11	1E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	3E-06	3E-06	2E-06	7E-06	7E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06
3E(7.5)	13	1E-06	2E-06	2E-06	2E-06	2E-06	2E-06	2E-06	3E-06	3E-06	3E-06	7E-06	7E-06	8E-06	8E-06	8E-06	8E-06	8E-06	8E-06

Notes:

1. Baseline direct contact risks based on data collected from the EW, as reported in the HHRA (Windward 2012b). HHRA baseline risk estimates are used as year 0 risk estimates for the No Action Alternative.

2. Site-wide and clamming total excess cancer risks are equal to the sum of risks for arsenic and cPAHs (the risk drivers for the direct sediment exposure scenarios). See Table 9-6a for estimated individual excess cancer risks.

3. Significant figures are displayed in accordance with the conventions established in the HHRA (Windward 2012b).

> 1 x 10^{-5}
≤ 1 x 10^{-5}

cPAH – carcinogenic polycyclic aromatic hydrocarbon; EW – East Waterway; HHRA – human health risk assessment; SWAC – spatially-weighted average concentration

Table B-36
Estimated Hazard Quotients for Fish Based on Long-term Site-wide Total PCB SWACs

Using LOAEL TRV of 520 µg/kg ww

Alternative	Construction Time (years)	English Sole Baseline HQ = 7.9									Brown Rockfish Baseline HQ = 0.77 to 12								
		Time After Construction (years)									Time After Construction (years)								
		0	5	10	15	20	25	30	35	40	0	5	10	15	20	25	30	35	40
No Action	-	7.9	3.4	2.8	2.5	2.3	2.0	1.8	1.7	1.6	12	4.7	4.0	3.6	3.4	2.9	2.7	2.6	2.5
1A(12)	9	≤ 1.0	1.3	1.2	1.2	1.1	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	1.3	2.1	2.0	2.0	1.9	1.5	1.4	1.4	1.3
1B(12)	9	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.1
1C+(12)	9	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	1.2	1.2	1.2	1.2	1.2	1.1	1.1	1.1
2B(12)	10	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.1
2C+(12)	10	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	1.2	1.2	1.2	1.2	1.2	1.1	1.1	1.1
3B(12)	10	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.1
3C+(12)	10	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	1.2	1.2	1.2	1.2	1.2	1.1	1.1	1.1
2C+(7.5)	11	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.1
3E(7.5)	13	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1

Using LOAEL TRV of 2,640 µg/kg ww

Alternative	Construction Time (years)	English Sole Baseline HQ = 1.6									Brown Rockfish Baseline HQ = 0.15 to 2.3								
		Time After Construction (years)									Time After Construction (years)								
		0	5	10	15	20	25	30	35	40	0	5	10	15	20	25	30	35	40
No Action	-	1.6	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	2.3	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0
1A(12)	9	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0
1B(12)	9	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0
1C+(12)	9	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0
2B(12)	10	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0
2C+(12)	10	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0
3B(12)	10	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0
3C+(12)	10	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0
2C+(7.5)	11	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0
3E(7.5)	13	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0

Notes:

1. Total PCB hazard quotients were estimated using tissue concentrations predicted by the FWM (Anchor QEA and Windward 2014) with alternative-specific total PCB SWACs in surface sediment (Table 9-1) and assumed surface water dissolved total PCBs concentrations of 0.6 ng/L (except 0.9 ng/L for the No Action Alternative [at years 20 to 40] and for Alternative 1A(12) [years 5 to 20], and 1.2 ng/L for the No Action Alternative [at years 0 to 20]).
2. Baseline ecological risks for fish are based on whole-body tissue data collected from the EW, as reported in the ERA (Windward 2012a). ERA baseline risk estimates are used as year 0 risk estimates for the No Action Alternative.
3. The use of two LOAEL TRVs was done because of the considerable uncertainty in the study from which the TRVs were derived, as is discussed in both the effects section (Section A.4.2.1.3) and uncertainty section (Section A.6.2.2.2) of the ERA (Windward 2012a). The use of the lower of these TRVs (520 µg/kg ww) likely overestimates risks to these receptors.
4. All tabulated values are hazard quotients. HQs are rounded following the conventions established in the ERA (Windward 2012a).

HQ >1.0	Colored cells indicate estimated hazard quotient.
HQ ≤1.0	

µg/kg – microgram per kilogram; ERA – ecological risk assessment; EW - East Waterway; FWM – food web model; HQ – hazard quotient; LOAEL – lowest-observed-adverse-effect level; ng/L – nanogram per liter; PCB – polychlorinated biphenyl; SWAC – spatially-weighted average concentration; TRV – toxicity reference value; ww – wet weight

Table B-37
Estimated Construction Durations

Construction Description	Unit Assumption	Notes	Unit	Alternative																
				No Action	1A(12)	1B(12)	1C+(12)	2A(12)	2B(12)	2C(12)	2C+(12)	3B(12)	3C+(12)	3D(12)	2C+(7.5)	3C+(7.5)	3E(7.5)	2C+(5.0)	3D(5.0)	3E(5.0)
Dredging																				
Open-water Dredging	1,100 cy/day	Based on dredge production calculations	cy	0	813,120	813,120	813,120	902,212	902,212	902,212	902,212	938,455	938,455	938,455	1,007,892	1,016,453	1,016,453	1,077,140	1,086,121	1,086,121
			days	0	739	739	739	820	820	820	820	853	853	853	916	924	924	979	987	987
Limited Access Dredging (Under West Seattle Bridge)	270 cy/day	Based on dredge production calculations	cy	0	0	0	0	0	0	0	0	16,651	16,651	16,651	0	19,365	19,365	0	19,737	19,737
			days	0	0	0	0	0	0	0	0	62	62	62	0	72	72	0	73	73
Hydraulic Dredging (Underpier)	40 cy/day	Vendor quote and best professional judgment	cy	0	0	0	7,016	0	0	7,016	7,016	0	7,016	43,940	7,016	7,016	46,216	7,016	48,816	48,816
			days	0	0	0	175	0	0	175	175	0	175	1,098	175	175	1,155	175	1,220	1,220
Total Dredging Time		**Assumed concurrent operations**	**days**	**0**	**739**	**739**	**739**	**820**	**820**	**820**	**820**	**853**	**853**	**1,098**	**916**	**924**	**1,155**	**979**	**1,220**	**1,220**
Placement - Capping, Backfill, ENR, and In situ Treatment																				
Placement - Sand or Gravel	940 cy/day	Based on recent Puget Sound project experience	cy	0	166,191	166,796	166,730	137,278	137,883	137,821	137,821	129,695	129,372	128,282	134,884	127,571	125,986	127,790	119,003	119,003
			days	0	177	177	177	146	147	147	147	138	138	136	143	136	134	136	127	127
Placement - Armor	560 cy/day	Based on recent Puget Sound project experience	cy	0	30,931	30,931	30,931	30,931	30,931	30,931	30,931	17,654	17,654	17,654	31,062	17,786	17,786	31,062	17,786	17,786
			days	0	55	55	55	55	55	55	55	32	32	32	55	32	32	55	32	32
Placement - Underpier or Under Low Bridge	60 cy/day	Underpier in situ or ENR under low bridges; based on recent pilot study	cy	0	811	5,678	5,678	1,421	6,288	5,506	6,288	6,288	6,288	1,421	6,675	6,675	6,675	6,963	1,562	6,963
			days	0	14	95	95	24	105	92	105	105	105	24	111	111	111	116	26	116
Total Placement Time		**Assumed concurrent operations in open-water and underpier**	**days**	**0**	**232**	**233**	**233**	**201**	**202**	**202**	**202**	**169**	**169**	**168**	**199**	**167**	**166**	**191**	**158**	**158**
Placement - Dredge Residuals Management Cover																				
Placement - Sand	940 cy/day	Based on recent Puget Sound project experience	cy	0	88,580	88,580	88,580	106,341	106,341	106,341	106,341	111,735	111,735	111,735	118,258	123,607	123,592	127,233	132,566	132,566
			days	0	94	94	94	113	113	113	113	119	119	119	126	131	131	135	141	141
Total Construction Time (Best Estimate)																				
Total construction time assuming some concurrent dredging and placement operations	**100 days/ season**	**Total of dredging and residuals management operations during the anticipated construction window (October 1 through February 15)**	**days**	**0**	**833**	**833**	**833**	**933**	**933**	**933**	**933**	**972**	**972**	**1,217**	**1,042**	**1,056**	**1,287**	**1,115**	**1,361**	**1,361**
			seasons	**0**	**8.3**	**8.3**	**8.3**	**9.3**	**9.3**	**9.3**	**9.3**	**9.7**	**9.7**	**12.2**	**10.4**	**10.6**	**12.9**	**11.1**	**13.6**	**13.6**
Total Construction Time (With Extended Construction Season)																				
Total construction time assuming some concurrent dredging and placement operations	**150 days/ season**	**Assume production during an extended construction window (July 16 to September 30) with 50% production during that time due to tribal fishing.**	**days**	**0**	**833**	**833**	**833**	**933**	**933**	**933**	**933**	**972**	**972**	**1,217**	**1,042**	**1,056**	**1,287**	**1,115**	**1,361**	**1,361**
			seasons	**0**	**6.7**	**6.7**	**6.7**	**7.5**	**7.5**	**7.5**	**7.5**	**7.8**	**7.8**	**9.7**	**8.3**	**8.4**	**10.3**	**8.9**	**10.9**	**10.9**

Notes:
1. See Table 3 for construction rate assumption.
cy - cubic yards
ENR - enhanced natural recovery

Table B-38
Comparative Evaluation and Ranking of Alternatives[a]

Evaluation Criteria				Alternative									
				No Action	1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B(12)	3C+(12)	2C+(7.5)	3E(7.5)
Threshold Criteria													
Overall Protection of Human Health and the Environment													
Long-term Effectiveness and Permanence	Magnitude and Type of Residual Risk	RAO 1 – Human Health (Seafood Consumption) [b, c]	Total PCBs and Dioxins/Furans	No Action is predicted to achieve total excess cancer risk of 5×10^{-4} (Adult Tribal RME), 9×10^{-5} (Child Tribal RME), and 2×10^{-4} (Adult APl RME), and total PCB HQs of 11 (Adult Tribal RME), 23 (Child Tribal RME) and 9 (Adult APl RME).	The action alternatives are predicted to achieve total excess cancer risks of 2 to 3×10^{-4} (Adult Tribal RME), 4 to 5×10^{-5} (Child Tribal RME), and 1×10^{-4} to 9×10^{-5} (Adult API RME). The alternatives are also predicted to achieve total PCBs non-cancer risks (based on immunological, integumentary, or neurological endpoints only, which are the highest of the non-cancer risks) of HQ = 4 to 5 (Adult Tribal RME), HQ = 9 to 12 (Child Tribal RME), and HQ = 4 to 5 (Adult APl RME).								
		RAO 2 – Human Health (Direct Contact)	cPAHs and Arsenic	All alternatives are predicted to achieve a total excess cancer risk of less than 1×10^{-5}. For cPAHs, all alternatives are predicted to achieve individual excess cancer risks of less than 1×10^{-6}. For arsenic, all action alternatives achieve individual excess cancer risk of 2×10^{-6} for netfishing and 7×10^{-6} for clamming. Because the target risk threshold for arsenic is below natural background, the PRG is also used as a comparison: all action alternatives are predicted to meet the natural-background-based PRG following construction, but increase above the PRG in the long term due to incoming Green River concentrations. The No Action Alternative is not predicted to meet the arsenic PRG.									
		RAO 3 – Ecological Health (Benthic Organisms)	29 COCs [d]	Not expected to achieve.	Alternative 1A(12) is predicted to meet benthic PRGs in 99% of point locations 40 years following construction.	Alternatives 1B(12) through 3E(7.5) are predicted to meet benthic PRGs in 100% of point locations after construction completion.							
		RAO 4 – Ecological Health (Fish)	Total PCBs	HQ > 1.0 using the lower LOAEL TRV; HQ ≤ 1.0 using the higher LOAEL TRV.	All action alternatives are predicted to achieve HQ ≤ 1.0 for English sole and HQs ≤ 1.0 for brown rockfish for the higher TRV and 1.1 to 1.3 for the lower TRV (assumptions regarding water concentrations result in HQs slightly above 1.0) at year 40 following construction.								
	Controls	Engineering Controls		No controls assumed.	Relies primarily on removal (77 acres). Some reliance on partial removal and capping (13 acres), ENR-nav/partial removal and ENR-nav (16 acres), ENR-sill (2 acres), and MNR (13 acres underpier and low bridges).	Same as Alternative 1A(12) but with in situ treatment in underpier areas (12 acres) and ENR-sill under low bridges (1 acre), instead of MNR.	Same as Alternative 1B(12) but with diver-assisted hydraulic dredging prior to in situ treatment in some underpier areas (2 acres).	More reliance on removal than Alternatives 1A(12), 1B(12), and 1C+(12) (94 acres). Some reliance on partial removal and capping (13 acres), ENR-sill (3 acres), and in situ treatment (12 acres) in underpier areas.	Same as Alternative 2B(12) but with diver-assisted hydraulic dredging prior to in situ treatment in some underpier areas (2 acres).	More reliance on removal than Alternatives 1A(12) through 2C+(12) (100 acres). Some reliance on partial removal and capping (7 acres), ENR-sill (1 acre), and in situ treatment in underpier areas (12 acres).	Same as Alternative 3B(12) but with diver-assisted hydraulic dredging prior to in situ treatment in some underpier areas (2 acres).	More reliance on removal due to a lower RAL of 7.5 mg/kg OC (104 acres). Some reliance on partial removal and capping (13 acres), ENR-sill (3 acres), and in situ treatment (11 acres) and diver-assisted hydraulic dredging followed by in situ treatment (2 acres) in underpier areas.	Most reliance on removal (111 acres). Some reliance on partial removal and capping (7 acres), ENR-sill (1 acre), and diver-assisted hydraulic dredging followed by in situ treatment in underpier areas (13 acres).
		Institutional Controls			Institutional controls, including a notification, monitoring, and reporting program for areas of the EW and seafood consumption advisories and public outreach and education programs will be implemented to reduce seafood consumption exposures. Long-term monitoring, maintenance, and institutional controls are required for these alternatives.								
Short-term Effectiveness				No short-term impact because no actions assumed.	Short-term impacts increase with the length of construction (which vary from 9 to 13 years for the alternatives) and the amount of removal (810,000 to 1,080,000 cy) among the action alternatives. Alternatives 1B(12) through 3E(7.5) achieve RAOs immediately after construction completion, but will occur in a later calendar year for alternatives requiring a longer construction timeframe. Alternative 1A(12) meets all RAOs 39 years from the start of construction. PRGs for RAO 1 are not predicted to be achieved by any alternative. The time to achieve RAO 1 is uncertain, but all active alternatives will reach similar risk levels, except Alternative 1A(12), which may have greater uncertainty associated with MNR. See details on Short-term Effectiveness under Balancing Criteria.								

Table B-38 continued
Comparative Evaluation and Ranking of Alternatives[a]

Evaluation Criteria		Alternative									
		No Action	**1A(12)**	**1B(12)**	**1C+(12)**	**2B(12)**	**2C+(12)**	**3B(12)**	**3C+(12)**	**2C+(7.5)**	**3E(7.5)**
Summary of Overall Protection of Human Health and the Environment		*Does not provide adequate overall protection to human health and the environment.*	*The action alternatives achieve overall protection of human health and the environment by relying primarily on removal of contaminated sediment from the EW. The action alternatives vary primarily in the remedial approach used to remediate sediment in underpier areas. All underpier technologies require engineering controls, including diver-assisted hydraulic dredging, which cannot completely remove sediment due to riprap, debris, and structural supports. All alternatives require institutional controls to fully achieve protectiveness. Longer construction periods and greater removal volumes result in proportionately greater short-term impacts.*								
Compliance of ARARs											
MTCA/SMS	Human Health – Seafood Consumption (RAO 1)	Not expected to comply.	The action alternatives are not likely to meet all natural background-based PRGs. If EPA determines that no additional practicable actions can be implemented under CERCLA to meet certain MTCA/SMS ARARs, EPA may adjust the cleanup level upward to the CSL, which could be attained in a reasonable restoration timeframe, consistent with the substantive requirements of SMS (see Sections 4.3.1 and 9.1.1.2), or waive the ARAR on the basis of technical impracticability in a future decision document (ROD Amendment or ESD).								
	Human Health – Direct Contact (RAO 2)	Predicted to comply within 20 years by achieving the SMS background level for arsenic and 1 x 10^{-6} excess cancer risk threshold for cPAHs.	All action alternatives are expected to comply immediately following construction by achieving the SMS background level for arsenic and 1 x 10^{-6} excess cancer risk threshold for cPAHs site wide and in clamming exposure areas.								
	Ecological Health – Benthic Organisms (RAO 3)	Not expected to comply.	Alternative 1A(12) is predicted to achieve RAO 3 PRGs 39 years from the start of construction.	Alternatives 1B(12) through 3E(7.5) are predicted to achieve RAO 3 PRGs immediately following construction.							
	Ecological Health - Higher Trophic Level Species (RAO 4)	Predicted to comply within 10 years (English sole) to 25 years (brown rockfish).	All action alternatives are predicted to comply by achieving the RAO 4 PRGs immediately following construction.								
Surface Water Quality Standards		No active remedial measures are technically feasible or anticipated expressly for the water column, although significant water quality improvements are anticipated from sediment remediation and additional source control measures. It is not anticipated that any alternative can comply with all federal or state ambient water quality criteria or standards, particularly those based on human consumption of bioaccumulative contaminants that magnify through the food chain (e.g., total PCBs and arsenic). If long-term monitoring data and trends indicate that water quality ARARs cannot be met, EPA may determine whether further remedial action could practicably achieve the ARAR. If EPA concludes that an ARAR cannot be practicably achieved, EPA may waive the ARAR on the basis of technical impracticability in a future decision document (ROD Amendment or ESD).								
Achieve Threshold Criteria?		**No**	**Yes; however, one or more ARAR waivers may be required.**								

Table B-38 continued

Comparative Evaluation and Ranking of Alternatives[a]

Evaluation Criteria			Alternative									
			No Action	**1A(12)**	**1B(12)**	**1C+(12)**	**2B(12)**	**2C+(12)**	**3B(12)**	**3C+(12)**	**2C+(7.5)**	**3E(7.5)**
Balancing Criteria												
Long-term Effectiveness and Permanence												
Magnitude of Residual Risk	Long-term Risk Outcomes		Does not achieve all.	See the risk outcomes for Magnitude and Type of Residual Risk above. The action alternatives achieve similar risk outcomes, with Alternative 1A(12) slightly higher for some risks.								
	Areas (acres; of 157 acres in the EW)[e]	Removal (open-water)	NA	77	77	77	94	94	100	100	104	111
		Partial removal/cap	NA	13	13	13	13	13	7	7	13	7
		Partial removal and ENR-nav, and ENR-nav	NA	16	16	16	NA	NA	NA	NA	NA	NA
		ENR-sill	NA	2	3	3	3	3	1	1	3	1
		MNR	NA	13	NA	NA	NA	NA	NA	NA	NA	NA
		In situ treatment	NA	NA	12	10	12	10	12	10	11	NA
		Diver-assisted hydraulic dredging followed by in situ treatment (underpier areas)	NA	NA	NA	2	NA	2	NA	2	2	13
		No action (area with concentrations < RALs for the action alternatives)	157	36	36	36	36	36	36	36	25	25
	Post-construction number of core stations remaining > CSL (of 76 cores in the EW)[f]	Partial dredging and capping	76	8	8	8	8	8	5	5	8	5
		Partial removal and ENR-nav, and ENR-nav		0	0	0	Not used	Not used	Not used	Not used	Not used	Not used
		ENR-sill		1	1	1	1	1	0	0	1	0
		MNR		0	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used
		In situ treatment		Not used	0	0	0	0	0	0	0	Not used
		No action		2	2	2	2	2	2	2	2	2
	Summary of residual risks (modeled long-term risks and remaining subsurface contaminated sediment)		Highest long-term risks; most contaminated sediment remaining on site.	Slightly higher long-term risks than all active alternatives, moderate contaminated sediment remaining on site.	Lowest long-term risks among the active alternatives, moderate contaminated sediment remaining on site.	Lowest long-term risks among the active alternatives, moderate contaminated sediment remaining on site.	Lowest long-term risks among the active alternatives, low contaminated sediment remaining on site.	Lowest long-term risks among the active alternatives, low contaminated sediment remaining on site.	Lowest long-term risks among the active alternatives, low contaminated sediment remaining on site.	Lowest long-term risks among the active alternatives, low contaminated sediment remaining on site.	Lowest long-term risks among the active alternatives, low contaminated sediment remaining on site.	Lowest long-term risks among the active alternatives, low contaminated sediment remaining on site.
Adequacy and Reliability of Controls	Area requiring monitoring and maintenance (acres)	Moderate level of effort (partial dredging and capping)	No controls assumed.	13	13	13	13	13	7	7	13	7
		Higher level of effort (partial removal and ENR-nav, ENR-nav, ENR-sill, MNR, in situ treatment)		31	31	29	15	13	13	11	14	1
	Institutional Controls			The action alternatives require an Institutional Control Implementation and Assurance Plan with: 1) seafood consumption advisories, public outreach, and education programs; 2) review of in-water construction permit applications, waterway uses, and notification of users; and 3) designation of RNAs and other forms of notification and controls for areas with residual contamination to ensure performance of the remedy.								
Long-term Effectiveness and Permanence Ranking Guide			*The alternatives are ranked relative to other alternatives, with five stars representing the most effective in the long term and most permanent, and one star representing the least effective in the long term and least permanent. The ranking considers the metrics above, summarized as the following two that are considered equally: 1) the magnitude and type of residual risk remaining in the long term, including the risk outcomes and the area with remaining subsurface contamination; and 2) adequacy and reliability of engineering controls, considering the area requiring monitoring and maintenance.*									

Table B-38 continued
Comparative Evaluation and Ranking of Alternatives[a]

Evaluation Criteria	Alternative									
	No Action	**1A(12)**	**1B(12)**	**1C+(12)**	**2B(12)**	**2C+(12)**	**3B(12)**	**3C+(12)**	**2C+(7.5)**	**3E(7.5)**
Summary of Long-term Effectiveness and Permanence	*Least effective and permanent compared to the other alternatives.*	*1A(12) achieves similar risk as all action alternatives* *In open water areas, 1A(12) relies primarily on removal and also includes partial removal and capping, partial removal and ENR, and ENR.* *Underpier, 1A(12) relies on MNR.* *, 1A(12) has less reliable underpier controls and open-water controls, compared to the other alternatives.*	*1A(12) achieves similar risk as all action alternatives* *In open water areas, 1B(12) is the same as 1A(12).* *Underpier, 1B(12) relies on in situ treatment.* *1B(12) has more reliable underpier controls than 1A(12) and slightly less reliable open-water controls than 2B(12) through 3E(7.5)*	*1A(12) achieves similar risk as all action alternatives* *In open water areas, 1C+(12) is the same as 1A(12).* *Underpier, 1C+(12) relies on limited removal plus in situ treatment* *1C+(12), has similarly reliable underpier controls as 1B(12), and slightly less reliable open-water controls than 2B(12) through 3E(7.5).*	*1A(12) achieves similar risk as all action alternatives* *In open water areas, 2B(12) is similar to 1A(12) but with no partial removal and ENR-nav or ENR-nav(more removal).* *Underpier, 2B(12) relies on in situ treatment.* *By relying almost exclusively on removal and capping, 2B(12) is considered highly permanent.*	*1A(12) achieves similar risk as all action alternatives* *In open water areas, 2C+(12) is the same as 2B(12).* *Underpier, 2C+(12) relies on limited removal plus in situ treatment* *By relying almost exclusively on removal and capping, 2C+(12) is considered highly permanent.*	*1A(12) achieves similar risk as all action alternatives* *In open-water areas, 3B(12) is similar to 2B(12) but with capping (more removal)* *Underpier, 2B(12) relies on in situ treatment.* *. By relying almost exclusively on removal and capping, 3B(12) is considered highly permanent.*	*1A(12) achieves similar risk as all action alternatives* *In open water areas, 3C+(12) is the same as 3B(12).* *Underpier, 3C+(12) relies on limited removal plus in situ treatment* *By relying almost exclusively on removal and capping, 3C+(12) is considered highly permanent.*	*1A(12) achieves similar risk as all action alternatives* *In open water areas, 2C+(7.5) is the same as 2B(12) but with a slightly smaller no action area (more removal).* *Underpier, 2C+(7.5) relies on limited removal plus in situ treatment* *2C+(7.5) is considered similarly permanent to 2C+(12) because the lower RAL remediates areas of low contaminant concentrations.*	*1A(12) achieves similar risk as all action alternatives* *In open water areas, 3E(7.5)+(7.5) is the same as 3B(12) but with a slightly smaller no action area (more removal).* *Underpier, 3E(7.5) relies on removal plus in situ treatment* *3E(7.5) is considered similarly permanent to 2C+(7.5) because diver-assisted hydraulic dredging cannot remove all contaminated sediment on underpier structured slopes.*
Ranking[a] for long-term effectiveness and permanence	★	★★★	★★★★	★★★★	★★★★★	★★★★★	★★★★★	★★★★★	★★★★★	★★★★★

Table B-38 continued
Comparative Evaluation and Ranking of Alternatives[a]

Evaluation Criteria	Alternative									
	No Action	**1A(12)**	**1B(12)**	**1C+(12)**	**2B(12)**	**2C+(12)**	**3B(12)**	**3C+(12)**	**2C+(7.5)**	**3E(7.5)**
Reduction of Toxicity, Mobility, or Volume Through Treatment										
In situ treatment area (acres)	NA	NA	12	12	12	12	12	12	13	13
Summary of Reduction of Toxicity, Mobility, or Volume Through Treatment	*No treatment.*	*No treatment.*	*In situ treatment in underpier areas.*	*In situ treatment in underpier areas.*	*In situ treatment in underpier areas.*	*In situ treatment in underpier areas.*	*In situ treatment in underpier areas.*	*In situ treatment in underpier areas.*	*In situ treatment in underpier areas.*	*In situ treatment in underpier areas.*
Reduction of Toxicity, Mobility, or Volume Through Treatment Ranking Guide	*The alternatives are ranked relative to the total remediation area in the waterway, with five stars representing the use of extensive in situ treatment among the alternatives, and one star representing no use of in situ treatment. Although none of the alternatives employ in situ treatment extensively in the waterway, the highest-ranked alternative is given five stars.*									
Ranking[a] for reduction of toxicity, mobility, or volume through treatment	★	★	★★★★★	★★★★★	★★★★★	★★★★★	★★★★★	★★★★★	★★★★★	★★★★★

Table B-38 continued
Comparative Evaluation and Ranking of Alternatives[a]

Evaluation Criteria				Alternative									
				No Action	1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B(12)	3C+(12)	2C+(7.5)	3E(7.5)
Short-term Effectiveness													
Protection of Human Health and the Environment During Construction	Period of effects to human health and the environment (construction timeframe; years) [g]			NA	9	9	9	10	10	10	10	11	13
	Transportation impacts (train/truck/barge; 1,000 miles)			NA	72 / 126 / 13	76 / 126 / 13	77 / 126 / 13	84 / 122 / 13	85 / 122 / 13	89 / 115 / 13	89 / 114 / 13	94 / 126 / 14	100 / 118 / 14
	Diver-assisted dredging (hazardous work duration; diver years)			NA	NA	NA	2	NA	2	NA	2	2	12
	Habitat area shallower than -10 feet MLLW impacted by dredging or capping in open-water areas (acres)			NA	4.1	4.1	4.1	4.1	4.1	5.8	5.8	4.7	6.6
	Depleted natural resources (material placement volume; cy)			NA	290,000	290,000	290,000	280,000	280,000	270,000	270,000	290,000	270,000
	Total removal volume / Consumed landfill capacity (cy) [h]			NA	810,000 / 970,000	810,000 / 970,000	820,000 / 980,000	900,000 / 1,080,000	910,000 / 1,090,000	960,000 / 1,150,000	960,000 / 1,150,000	1,010,000 / 1,210,000	1,080,000 / 1,300,000
	Air quality impacts (CO_2 / PM_{10} emissions; metric tons)			NA	16,000 / 5.4	16,000 / 5.6	16,000 / 5.9	17,000 / 6.1	18,000 / 6.3	18,000 /6.4	18,000 / 6.6	19,000 / 7.0	23,000 / 8.3
	Energy consumption (MJ)			NA	1.1×10^8	1.2×10^8	1.2×10^8	1.2×10^8	1.2×10^8	1.3×10^8	1.3×10^8	1.3×10^8	1.4×10^8
	Carbon footprint (acre-years)[i]			NA	3,800	3,800	3,800	4,000	4,300	4,300	4,300	4,500	5,400
Time to Achieve RAOs (Years from the Start of Construction)[j]	RAO 1 [k]	Total PCBs	10^{-4} Cancer Risk for Adult Tribal RME	35	9	9	9	10	10	10	10	11	13
			10^{-5} Cancer Risk for Child Tribal RME	Does not achieve.	34	9	9	10	10	10	10	11	13
			10^{-4} Cancer Risk for Adult API RME	0 (achieves at baseline conditions or start of construction)									
			10^{-5} Cancer Risk for Adult API RME	Does not achieve.	Not predicted to achieve.								
			Natural background PRG	Does not achieve.	Not predicted to achieve.								
		Dioxins/ Furans	10^{-4} Cancer Risk for Adult Tribal RME	0 (achieves at baseline conditions or start of construction)									
			10^{-5} Cancer Risk for Child Tribal RME	0 (achieves at baseline conditions or start of construction)									
			10^{-4} Cancer Risk for Adult API RME	0 (achieves at baseline conditions or start of construction)									
			10^{-5} Cancer Risk for Adult API RME	0 (achieves at baseline conditions or start of construction)									
			Natural background-based PRGs	Does not achieve.	Not predicted to achieve.								
	RAO 2[l]	Arsenic	Netfishing (site-wide)	Does not achieve.	9	9	9	10	10	10	10	11	13
			Clamming Areas	Does not achieve.	9	9	9	10	10	10	10	11	13
		cPAHs	Netfishing (site-wide)	5	9	9	9	10	10	10	10	11	13
			Clamming Areas	20	9	9	9	10	10	10	10	11	13
	RAO 3	29 COCs [d]		Not expected to achieve all PRGs.	39 [m]	9	9	10	10	10	10	11	13
	RAO 4	Total PCBs	English Sole	10	9	9	9	10	10	10	10	11	13
			Brown Rockfish	25	9	9	9	10	10	10	10	11	13

Table B-38 continued
Comparative Evaluation and Ranking of Alternatives[a]

Evaluation Criteria	Alternative									
	No Action	**1A(12)**	**1B(12)**	**1C+(12)**	**2B(12)**	**2C+(12)**	**3B(12)**	**3C+(12)**	**2C+(7.5)**	**3E(7.5)**
Short-term Effectiveness Ranking Guide	*The alternatives are ranked relative to each other, with five stars representing the most effective in the short term, and one star representing the least effective in the short term. The ranking considers the metrics above, summarized as the following three categories, which are considered in equal proportion: 1) community and worker protection during construction, which includes the duration of hazardous work (diver-assisted dredging); 2) environmental impacts from construction, including as a result of dredge releases, transportation, consumed landfill capacity, air emissions, energy consumption, and carbon footprint during implementation; and 3) the time to achieve RAOs (as a measure of the residual risk that is present on site until the RAOs are met).*									
Summary of Short-term Effectiveness	*No construction impacts.*	*Lowest construction impacts of the action alternatives.*	*1B(12) has low construction impacts.*	*1C+(12) is similar to 1B(12) but with additional construction impacts and risks associated with diver-assisted hydraulic dredging alternatives.*	*2B(12) has relatively low construction impacts (1 year longer than 1B(12)).*	*2C+(12) is similar to 2B(12) but with additional construction impacts and risks associated with diver-assisted hydraulic dredging alternatives.*	*3B(12) has moderate impacts.*	*3C+(12) is similar to 3B(12) but with additional construction impacts and risks associated with diver-assisted hydraulic dredging alternatives.*	*2C+(7.5) is similar to 2C+(12) but with additional construction impacts due to a longer construction duration.*	*3E(7.5) has the largest construction impacts from the most removal and risks associated with extensive diver-assisted hydraulic dredging.*
	Not predicted to achieve RAOs.	*The longest time to achieve RAOs of the action alternatives.*	*The shortest time to achieve RAOs compared to the other action alternatives.*	*Shortest time to achieve RAOs compared to the other action alternatives.*	*Slightly longer time (1 year longer) to achieve RAOs compared to 1B(12) and 1C+(12).*	*Slightly longer time to achieve RAOs (1 year longer) compared to 1B(12) and 1C+(12).*	*Slightly greater time to achieve RAOs compared to 1B(12) and scores slightly lower.*	*Slightly longer time to achieve RAOs (1 year longer) compared to 1B(12) and 1C+(12).*	*Longer time to achieve RAOs (2 years longer) compared to 1B(12) and 1C+(12).*	*Longest time to achieve RAOs behind 1A(12) and the No Action Alternative.*
Ranking [a] for short-term effectiveness	★	★★	★★★★★	★★★★	★★★★	★★★	★★★★	★★★	★★	★

Table B-38 continued
Comparative Evaluation and Ranking of Alternatives[a]

Evaluation Criteria	Alternative									
	No Action	**1A(12)**	**1B(12)**	**1C+(12)**	**2B(12)**	**2C+(12)**	**3B(12)**	**3C+(12)**	**2C+(7.5)**	**3E(7.5)**
Implementability										
Technical Implementability	No construction (beyond source control implemented under different programs).	Shortest construction period. Lowest potential for difficulties and delays and impacts to EW tenants and users. No technical challenges associated with implementing MNR in underpier areas for Alternative 1A(12).	Shortest construction period. Low potential for difficulties and delays and impacts to EW tenants and users. Few technical challenges associated with implementing ENR for Alternative 1B(12).Technical challenges associated with the use of in situ treatment employed in underpier areas.	Shortest construction period. Low potential for difficulties and delays and impacts to EW tenants and users. Significant technical challenges and safety concerns associated with diver-assisted hydraulic dredging. Few technical challenges associated with implementing ENR for 1C+(12). Technical challenges associated with in situ treatment employed in underpier areas.	Moderate construction period and moderate potential for difficulties and delays and impacts to EW tenants and users. Technical challenges associated with in situ treatment in underpier areas.	Moderate construction period and moderate potential for difficulties and delays. Significant technical challenges and safety concerns associated with diver-assisted hydraulic dredging. Technical challenges associated with in situ treatment employed in underpier areas.	Moderate construction period and moderate potential for difficulties and delays. Technical challenges associated with the use of in situ treatment employed in underpier areas.	Moderate construction period and moderate potential for difficulties and delays. Significant technical challenges and safety concerns associated with diver-assisted hydraulic dredging. Technical challenges associated with in situ treatment employed in underpier areas.	Moderate construction period and moderate potential for difficulties and delays. Significant technical challenges and safety concerns associated with diver-assisted hydraulic dredging. Technical challenges associated with in situ treatment employed in underpier areas.	Longest construction period. Highest potential for difficulties and delays and impact to EW tenants and users. Significant technical challenges and safety concerns associated with multiple years of diver-assisted hydraulic dredging. Technical challenges associated with in situ treatment employed in underpier areas.
Administrative Implementability	No contingency actions (beyond source control implemented under different programs).	Lower overall scope. Largest potential for contingency actions in 31 acres of partial removal and ENR-nav, ENR-nav, ENR-sill, and MNR. Reauthorization of a small part of the federal navigation channel (Shallow Main Body – South) will be required.	Low overall scope. Similar potential for contingency actions as 1A(12) in 31 acres of partial removal and ENR-nav, ENR-nav, ENR-sill, and in situ treatment. Reauthorization of a small part of the federal navigation channel (Shallow Main Body – South) will be required.	Low overall scope. Similar potential for contingency actions as 1A(12) in 29 acres of partial removal and ENR-nav, ENR-nav, ENR-sill, and in situ treatment. Reauthorization of a small part of the federal navigation channel (Shallow Main Body – South) will be required.	Moderate overall scope. Potential contingency actions in 3 acres of ENR-sill, and 12 acres of in situ treatment. Reauthorization of a small part of the federal navigation channel (Shallow Main Body – South) will be required.	Moderate overall scope. Potential contingency actions in 3 acres of ENR-sill and 10 acres of in situ treatment. Reauthorization of a small part of the federal navigation channel (Shallow Main Body – South) will be required.	Moderate overall scope. Potential contingency actions in 1 acre of ENR-sill and 12 acres of in situ treatment.	Moderate overall scope. Potential contingency actions in 1 acre of ENR-sill and 10 acres of in situ treatment.	Moderate to high overall scope. Potential contingency actions in 3 acres of ENR-sill and 11 acres of in situ treatment.	Largest overall scope of cleanup. Least potential for contingency actions in 1 acre of ENR-sill.
Implementability Ranking Guide	*The alternatives are ranked relative to each other, with five stars representing the most implementable, and one star representing the least implementable. The ranking considers the following primary metrics considered equally: 1) technical implementability, with the key differentiating factor being the approach to remediating the technically challenging sediments under the piers; and 2) administrative implementability, with the key differentiating factor being the overall complexity of the cleanup, which accounts for annual challenges of permitting, fisheries coordination, Port tenant and shipping vessel coordination, and staging. Contingency actions are also included in the ranking for implementability; however, this is considered a secondary metric which is weighted less in the overall ranking because contingency actions are potential conditions only.*									
Summary of Implementability	*Most implementable of the alternatives.*	*Most implementable of the action alternatives.*	*Less implementable compared to 1A(12) due to challenges with in situ treatment in underpier sediment.*	*Less implementable compared to 1B(12) due to challenges with diver-assisted hydraulic dredging in addition to also implementing in situ treatment.*	*Similar implementability as 1B(12) due to similar technology challenges in open-water and underpier areas.*	*Similar implementability as 1C+(12) due to similar technology challenges in open-water and underpier areas.*	*Similar implementability as 1B(12) due to similar technology challenges in open-water and underpier areas.*	*Similar implementability as 1C+(12) due to similar technology challenges in open-water and underpier areas.*	*Similar implementability as 1C+(12) due to similar technology challenges in open-water and underpier areas.*	*Least implementable of the alternatives due to extensive diver-assisted hydraulic dredging and large scope of open-water remediation.*
Ranking[a] for implementability	★★★★★	★★★★	★★★	★★	★★★	★★	★★★	★★	★★	★

Table B-38 continued
Comparative Evaluation and Ranking of Alternatives[a]

Evaluation Criteria	Alternative									
	No Action	1A(12)	1B(12)	1C+(12)	2B(12)	2C+(12)	3B(12)	3C+(12)	2C+(7.5)	3E(7.5)
Costs										
Costs Ranking Guide	*The No Action Alternative is ranked five stars as the least expensive. The action alternatives are ranked relative to each other, with four stars representing the least expensive, and one star representing the most expensive. The action alternatives are grouped based on ranges of costs, using intervals of $30 million each (i.e., $240 to $270 million, $270 to $300 million, $300 to $330 million, and more than $330 million).*									
Total Costs ($)	950,000	256,000,000	264,000,000	277,000,000	284,000,000	297,000,000	298,000,000	310,000,000	326,000,000	411,000,000
Ranking [a] for costs	★★★★★	★★★★	★★★★	★★★	★★★	★★★	★★★	★★	★★	★

Notes:

a. The alternatives are ranked from one star to five stars relative to the other alternatives, and also considering the metrics used to evaluate the criterion, with more stars indicating a more favorable ranking. See Sections 10.2.1.3, 10.2.2, 10.2.3.4, 10.2.4.1, and 10.2.5 for guidance on interpretation of rankings.
b. Risk estimates are based on the use of the total PCB and dioxin/furan SWACs in the FWM and BSAF, respectively. Risks due to cPAHs, which are based on clam consumption, are not included because cPAHs in clam tissue were not calculated due to the poor relationship between sediment and tissue values in the SRI dataset.
c. See Tables 9-5a and 9-5b for other RME risk scenarios.
d. For FS purposes, achievement of RAO 3 is based on at least 98% of predicted surface sediment locations achieving PRGs for all 29 benthic COCs. Compliance with SMS benthic criteria will be determined based on SMS requirements. Predictive modeling was not conducted for the No Action Alternative for compliance of RAO 3; therefore, the percentage of surface sediment locations below PRGs are presented for existing conditions (see Table 9-3).e. In the context of long-term effectiveness and permanence, different technologies have different magnitude of residual risk because they leave different amounts of contamination on site and use different engineering controls.
f. The total number of core stations is 146; 1 in the underpier areas and 145 in open-water areas. All 76 cores with one or more CSL exceedances are in open-water areas. The number of core stations post-construction remaining exceeding the SQS (but below CSL) are presented in Table 9-10.
g. Construction timeframe rounded up to the nearest year, assuming some concurrent removal and material placement (see Table 8-6 for details). As described in Section 8.1.1.8, the Elliott Bay in-water construction window that formally applies in the EW is July 16 to February 15. However, based on recent project experience, the typically permitted in-water construction window is October 1 to February 15 (i.e., 100 days/season). It may be feasible that permitting and tribal coordination will allow for a longer construction window (as large as July 16 to February 15); thus, the upper end of the number of work days in a construction season could increase to around 150 days/season, reducing the total number of years of construction by about 2 years for all action alternatives. However, the total number of construction days and associated construction impacts would remain unchanged.
h. The landfill capacity consumed is proportional to the volume of dredged material removed and disposed of in the landfill (assuming a 20% bulking factor).
i. One acre-year represents the amount of CO_2 sequestered by 1 acre of Douglas fir forest for 1 year. Carbon footprint in units of acre-years is appropriate to compare the alternatives differences in CO_2 releases over the entire project.
j. Some RAO metrics are achieved immediately after construction. If a longer construction window is allowed (see footnote above), the number of years of construction and corresponding time to achieve the RAOs would decrease by about 2 years for all action alternatives (see Section 9.1.2.3).
k. The orders of magnitude risk values presented for time to achieve RAOs were selected to most differentiate the alternatives. Alternative compliance is based on attaining the PRGs or target risk thresholds. Times to achieve RAOs could be reduced if a longer construction window is allowed, as the total number of years of construction could decrease by 2 years for all action alternatives (see Section 9.1.2.3).
l. Achievement of RAO 2 is based on meeting PRG (arsenic) or cancer risk threshold of 1×10^{-6} (cPAHs; see Table 9-6a). All action alternatives are predicted to meet the arsenic RAO 2 PRG of 7 mg/kg dw following construction, but increase above the PRG in the long term due to the Green River input concentrations (Section 9.15.1.2). All alternatives, including the No Action Alternative, may meet the PRG in the long term, depending on actual site conditions. All alternatives also achieve the Ecology SCUM II natural background-based PRG for arsenic of 11 mg/kg dw (based on Method 90/90 UTL; Ecology 2017).
m. Time to achieve RAO 3 PRG based on total PCBs; all other benthic risk driver COCs achieve PRGs immediately after construction completion.

Abbreviations:

API – Asian Pacific Islander
ARAR – applicable or relevant and appropriate requirements
BSAF – Biota-Sediment Accumulation Factors
CO_2 – carbon dioxide
COC – contaminant of concern
cPAH – carcinogenic polycyclic aromatic hydrocarbon
cy – cubic yards
CSL – cleanup screening level
dw – dry weight
ENR-nav – enhanced natural recovery used in the navigation channel or berthing areas
ENR-sill – enhanced natural recovery used in the sill reach
EPA – U.S. Environmental Protection Agency
EW – East Waterway
FS – Feasibility Study
FWM – Food Web Model
HQ – hazard quotient
LOAEL – lowest observed adverse effect level
mg/kg – milligrams per kilogram
MLLW – mean lower low water
MNR – monitored natural recovery
MJ – megajoule
MTCA – Model Toxics Control Act
NA – not applicable
OC – organic carbon
PCB – polychlorinated biphenyl
PM_{10} – particulate matter less than 10 microns in diameter
PQL – practical quantitation limit
PRG – preliminary remediation goal
RAL – remedial action level
RAO – remedial action objective
RME – reasonable maximum exposure
RNA – restricted navigation areas
SCUM – Sediment Cleanup Users Manual
SMS – Washington State Sediment Management Standards
SQS – sediment quality standard
SRI – Supplemental Remedial Investigation
SWAC – spatially-weighted average concentration
TRV – toxicity reference value

Figures

East Waterway Study Area
Dock/Pier/Bridge

Figure A-1
Location of the East Waterway Study Area
Supplemental Remedial Investigation
East Waterway Study Area

Prepared by cralph, 12/13/2013; W:\Projects\00-08-08 East Waterway\EW RI-FS\Data\GIS\SRI\Executive Summary\Map ES-1 3755 General Location and Vicinity Map.mxd

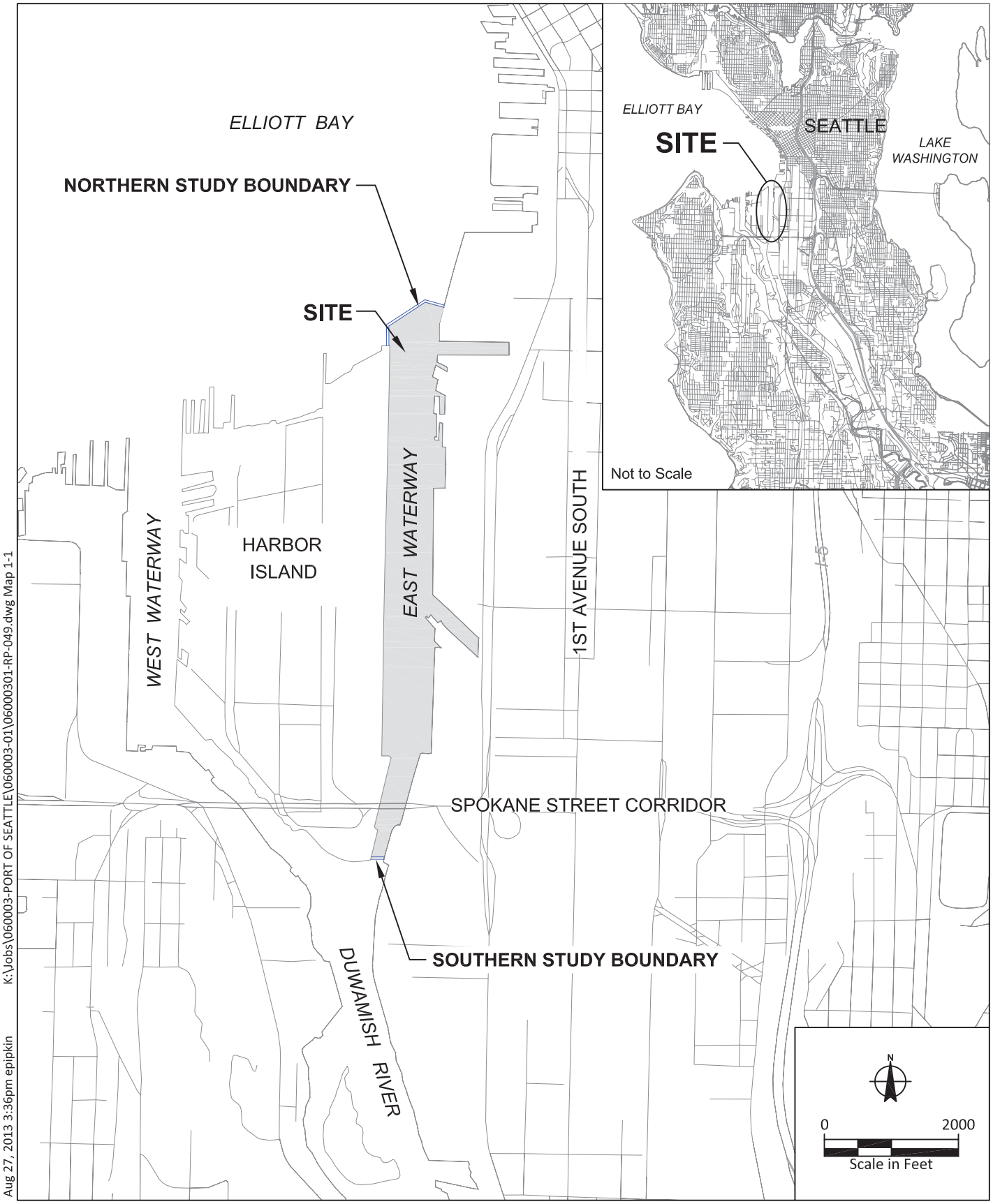


Figure A-2

Vicinity Map and Study Area Boundaries
Supplemental Remedial Investigation
East Waterway Study Area

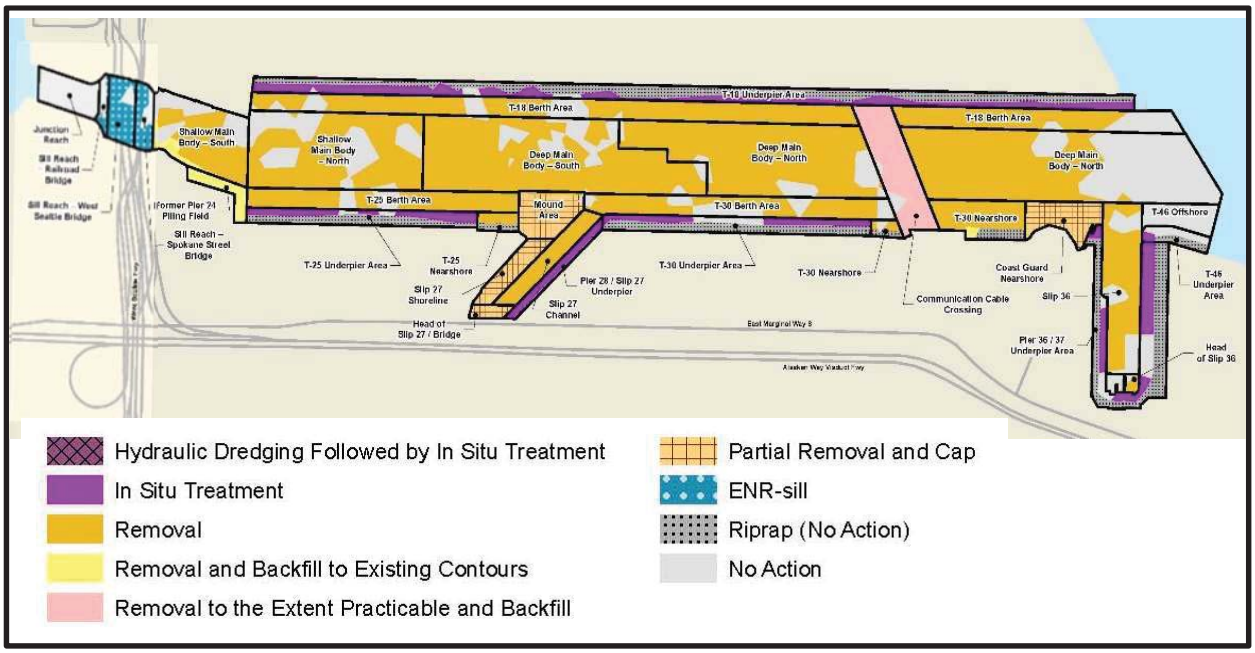
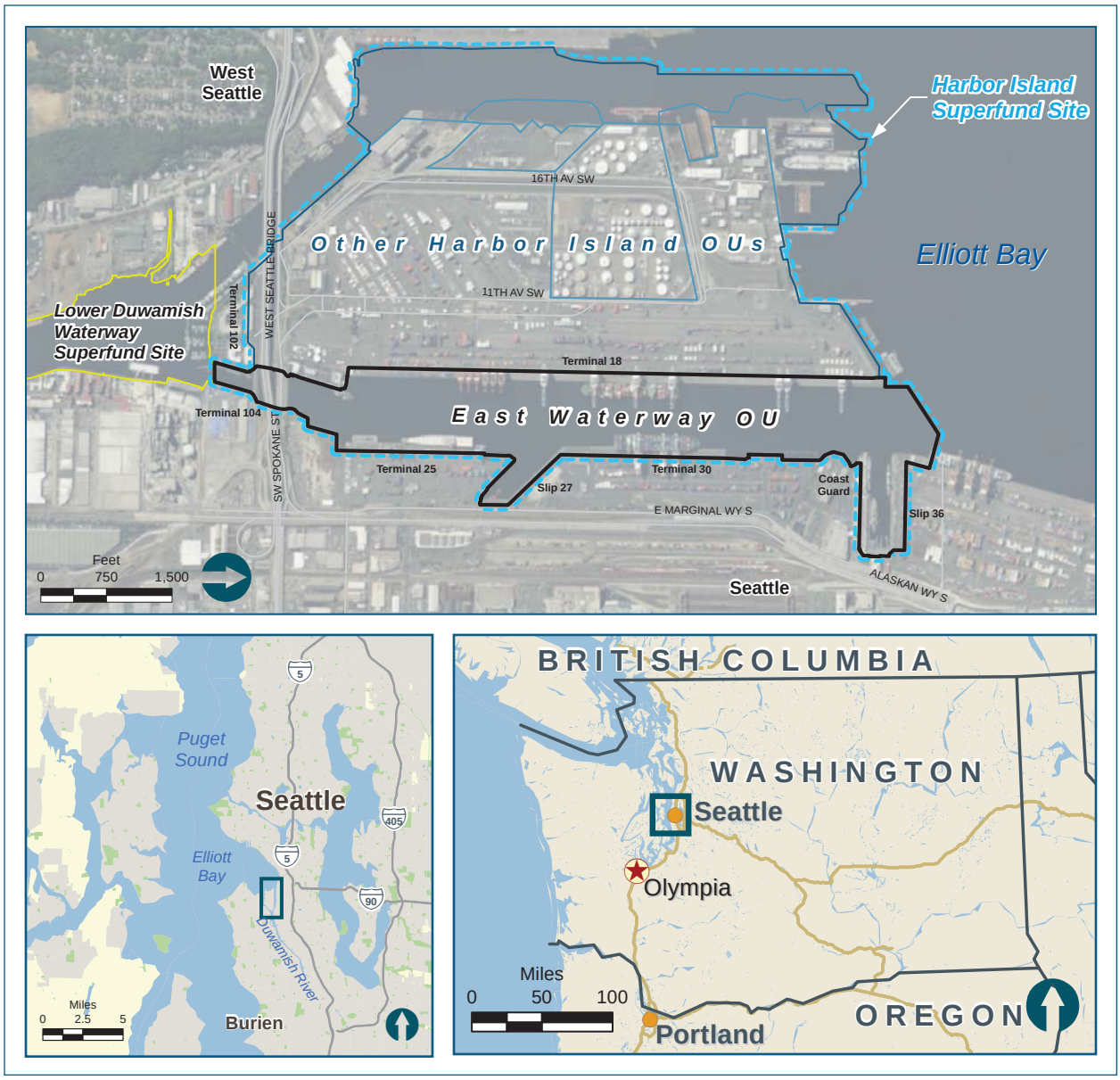


Figure A-3. Alternative 2B/3B(12)

Figure B-1: East Waterway Study Area



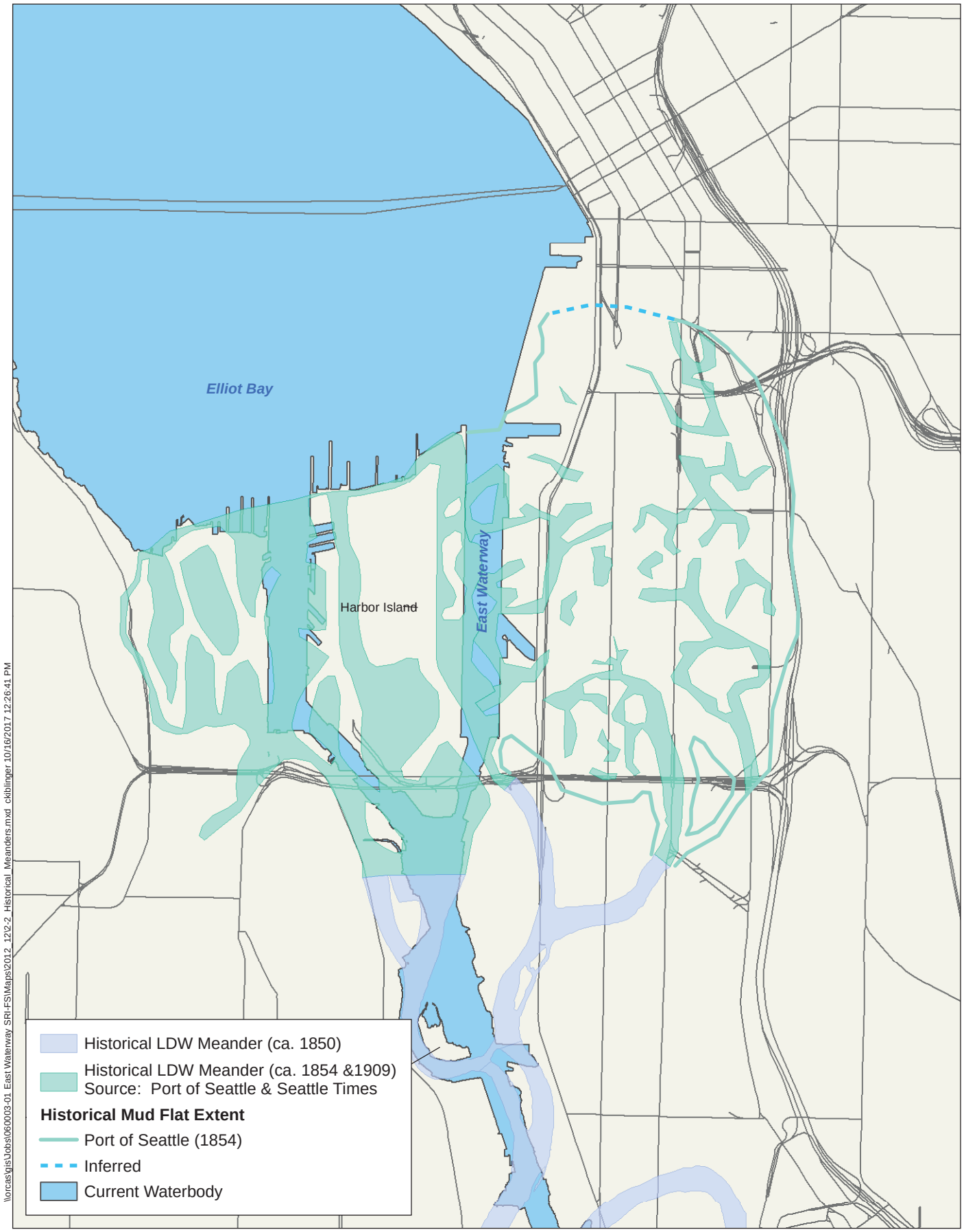


Figure B-2
Duwamish River Historical Meanders

N

0 2,000 4,000

Scale in Feet

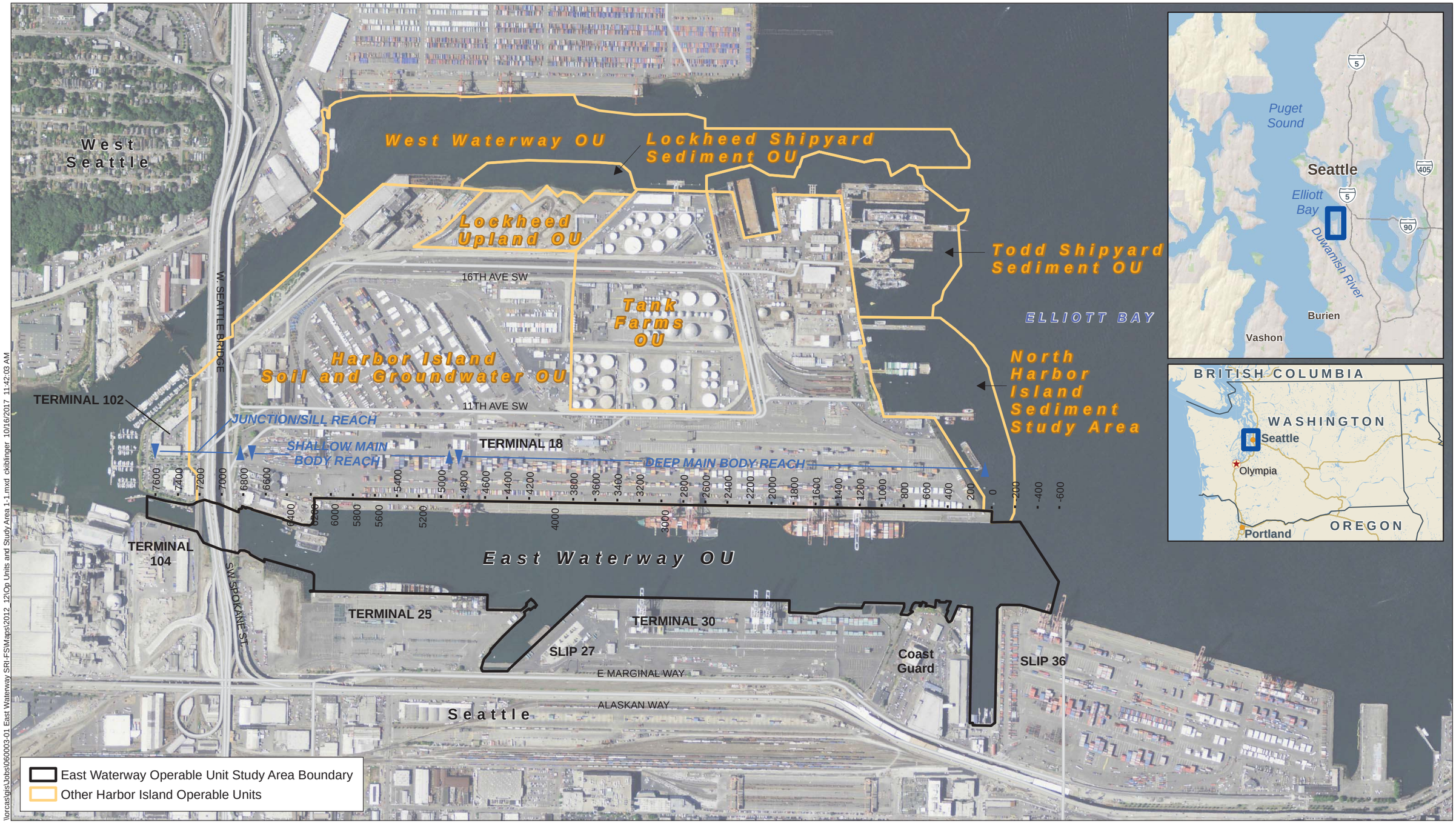


Figure B-3
Location of the East Waterway Study Area

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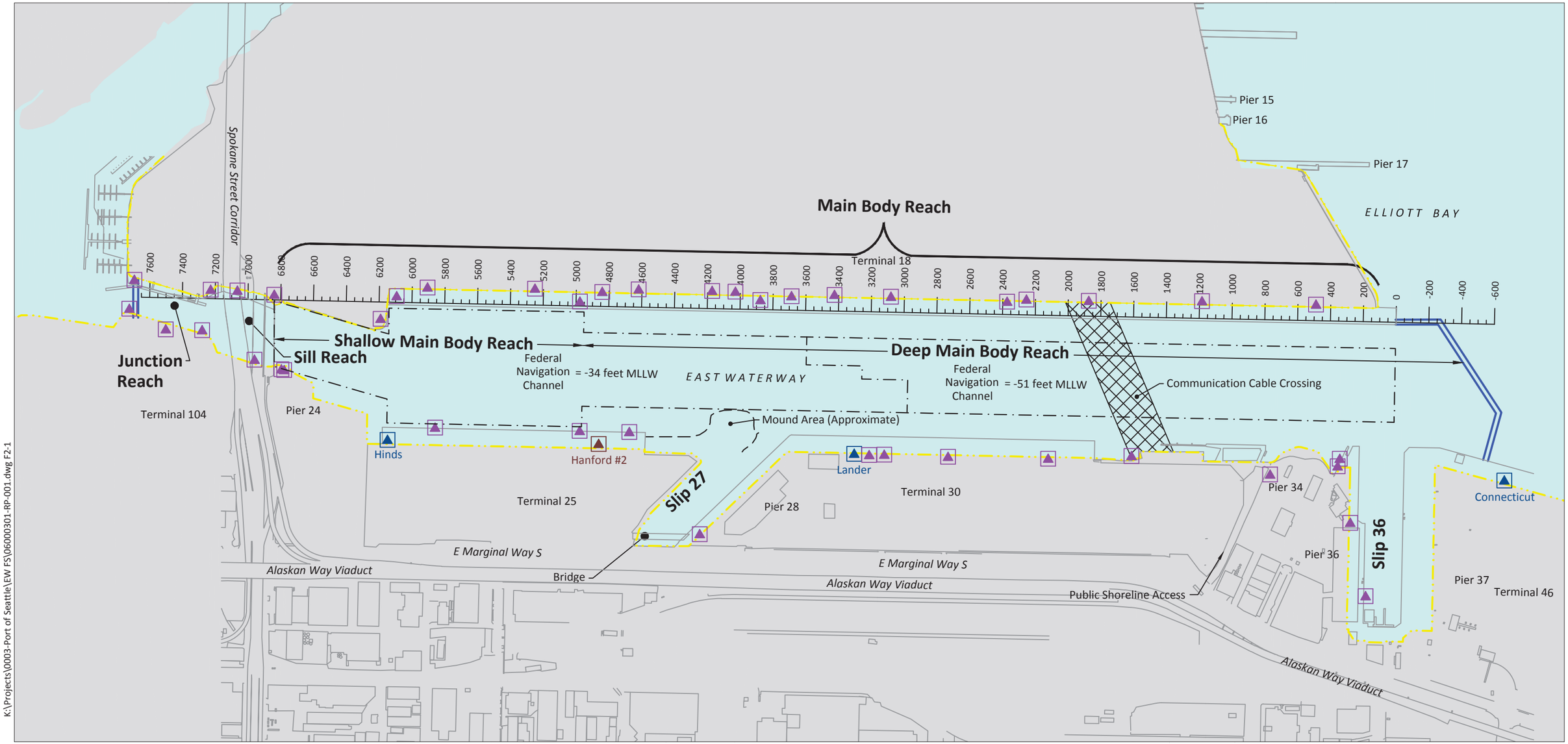

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Jan 08, 2016 12:31pm chewett

NOTE:
1. Previously established station locations for the East Waterway are shown along the western shoreline for reference.

LEGEND:

- East Waterway Study Boundary
- MHHW Line
- Federal Navigation Channel
- CSO
- Storm Drain
- CSO/Storm Drain

0 600
Scale in Feet

Figure 2

Figure B-4
Major East Waterway Features

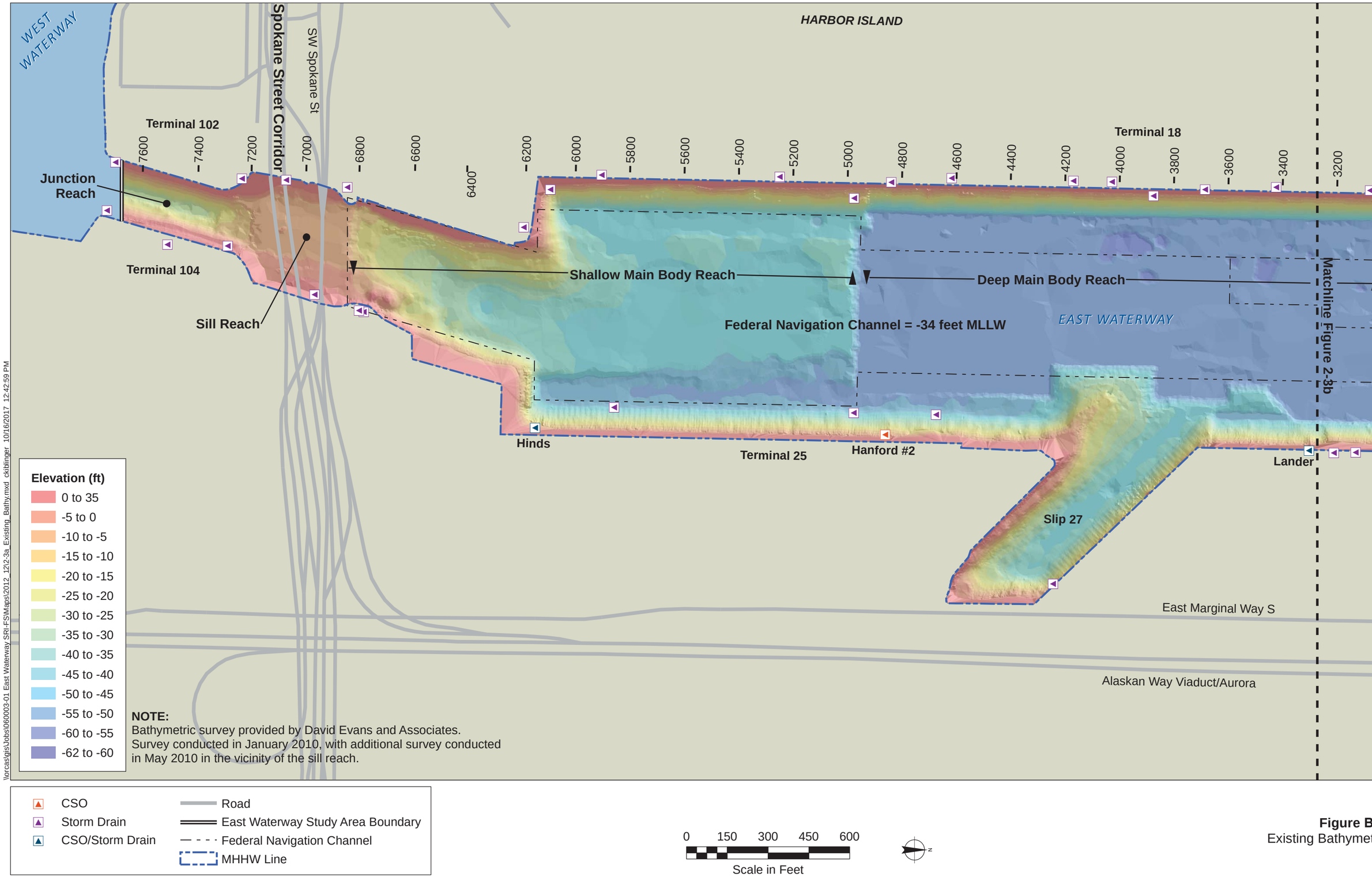
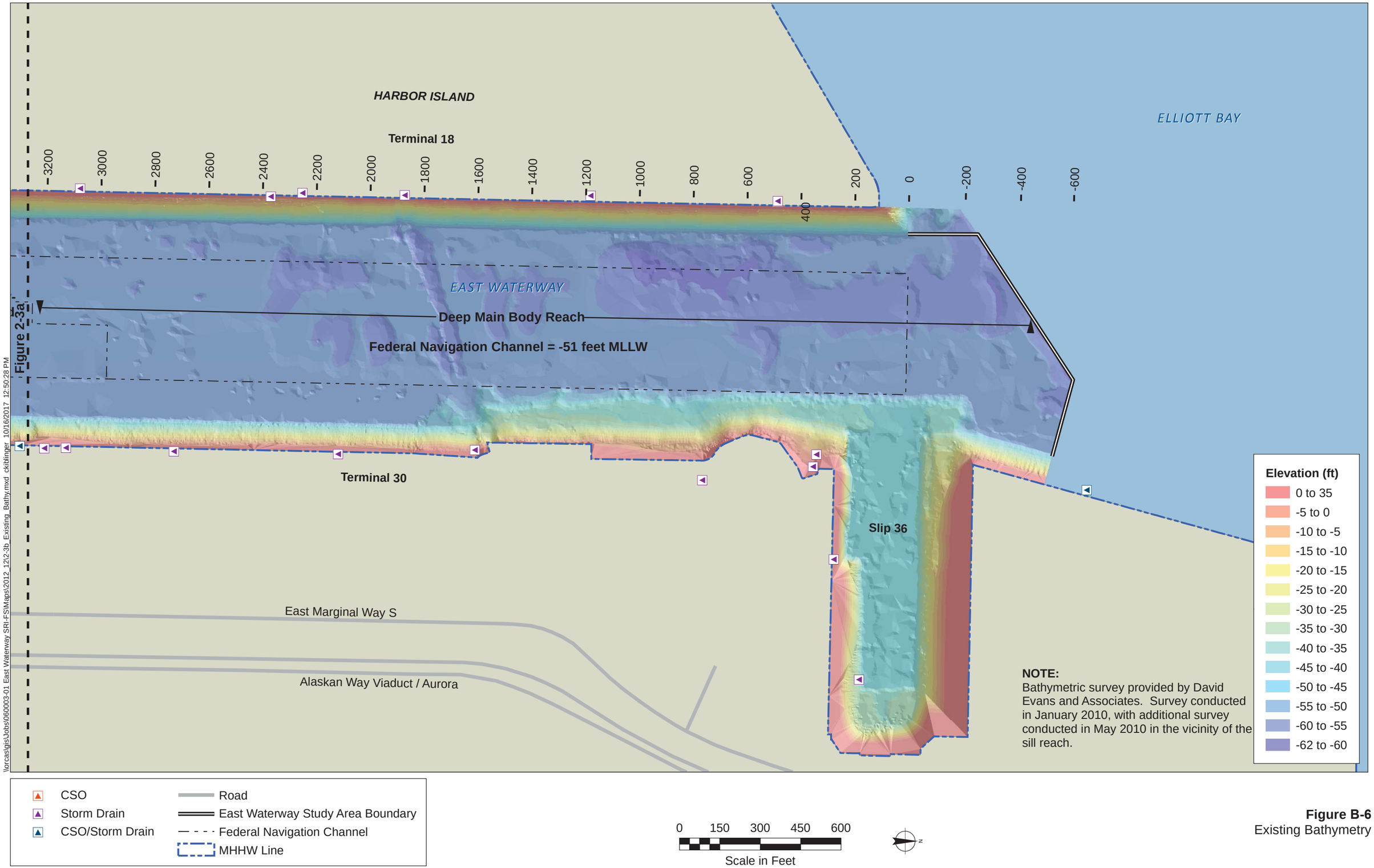


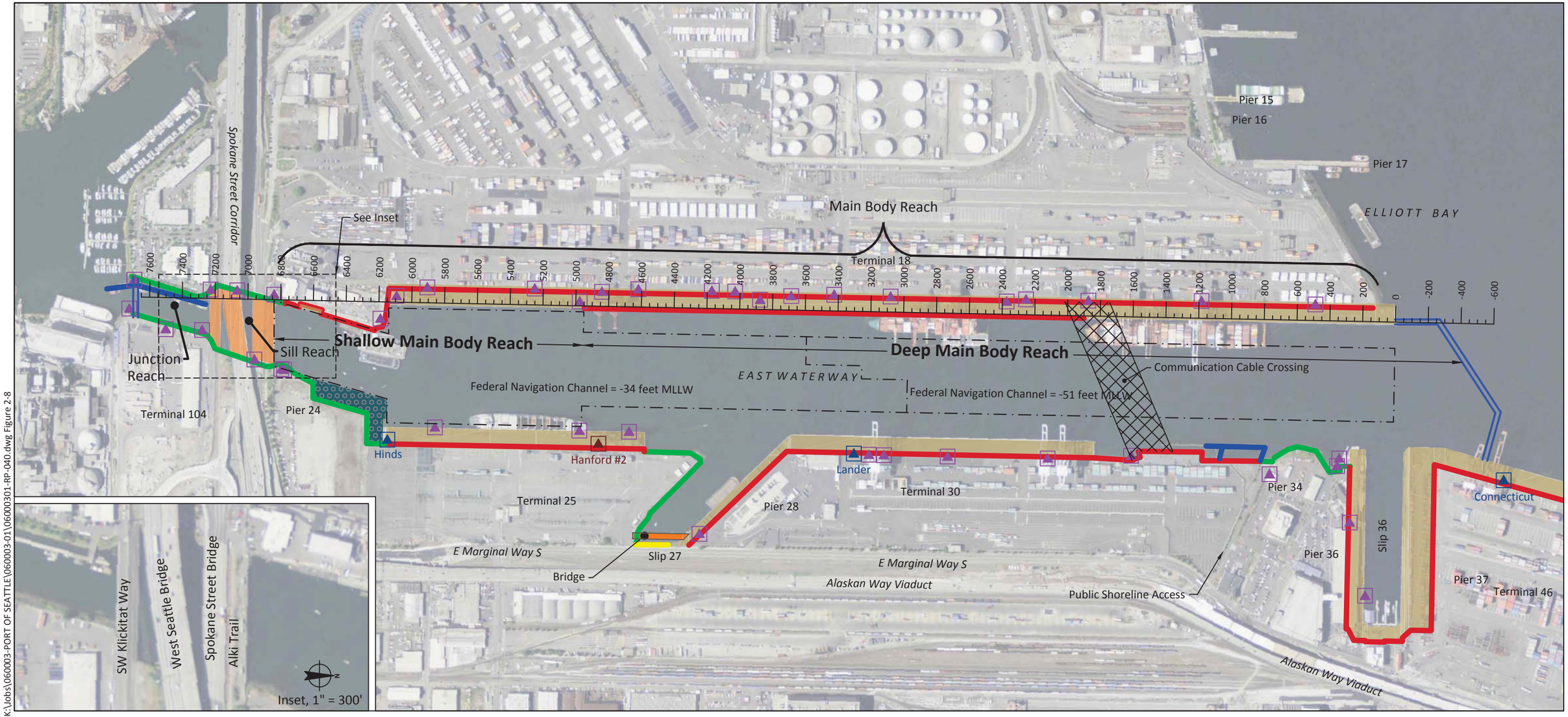
Figure B-5
Existing Bathymetry

\\orcas\gis\Jobs\060003-01 East Waterway SRI-FS\Maps\2012_12\2-3a_Existing_Bathy.mxd ckiblinger 10/16/2017 12:42:59 PM



\\orcas\gis\Jobs\060003-01 East Waterway SRI-FS\Maps\2012_12\2-3b_Existing_Bathy.mxd ckiblinger 10/16/2017 12:50:28 PM

Figure B-6
Existing Bathymetry



K:\Jobs\060003-PORT OF SEATTLE\060003-01\06000301-RP-040.dwg Figure 2-8

Jan 08, 2016 12:27pm chewett

NOTES:

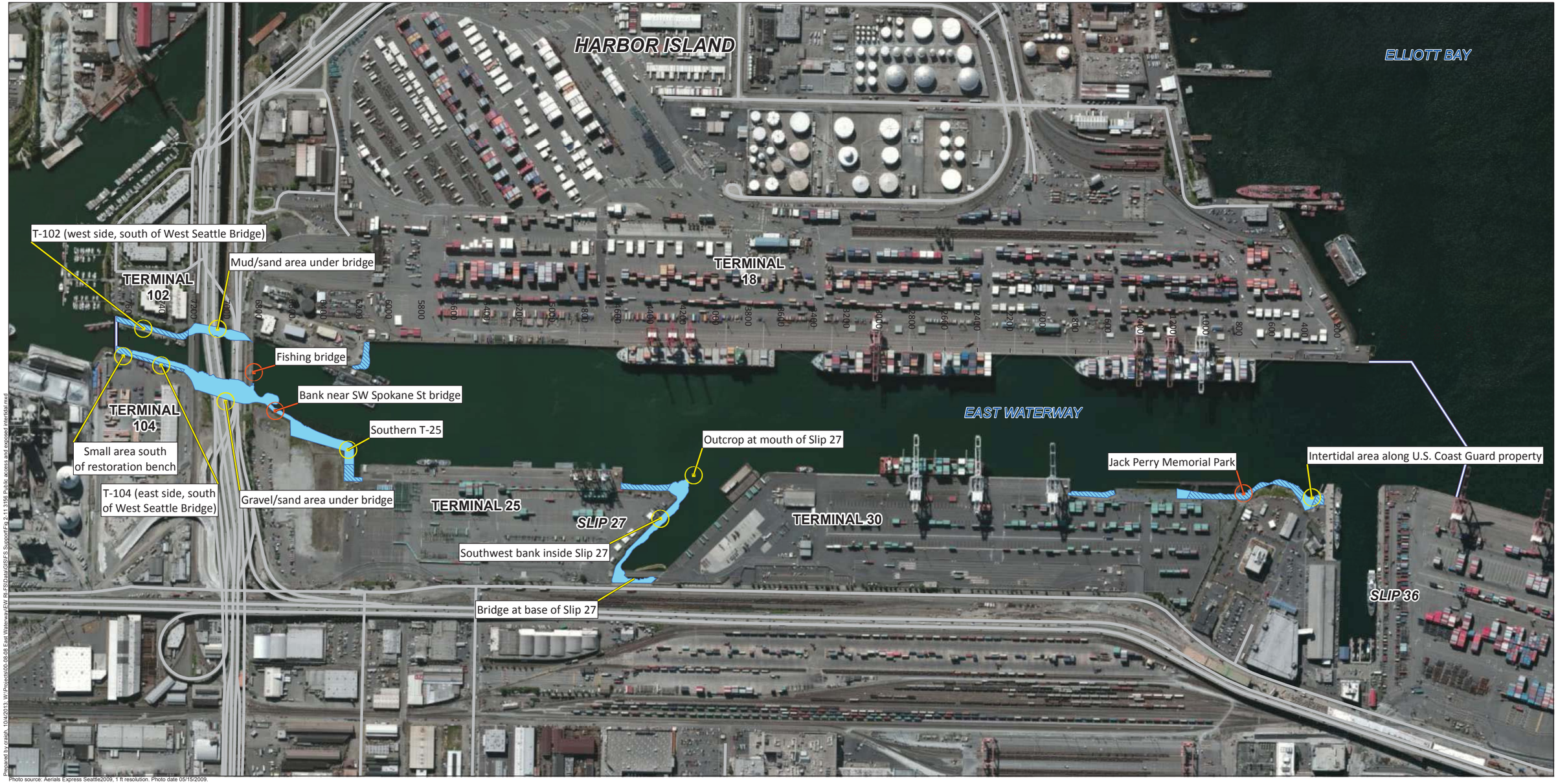
1. Previously established station locations for the East Waterway are shown along the western shoreline for reference.
2. Values along Westside of East Waterway are station reference values.
3. Aerial photo, NAIP 2011.

LEGEND:

- East Waterway Study Boundary
- Federal Navigation Channel
- Piling Field
- Sheetpile Wall
- Exposed Riprap
- Overwater Pier Above Riprap
- Concrete or Timber Bulkhead
- Bridge
- Timber Dock
- CSO
- Storm Drain
- CSO/Storm Drain Location

0 600
Scale in Feet

Figure B-7
Shoreline Conditions and Structures



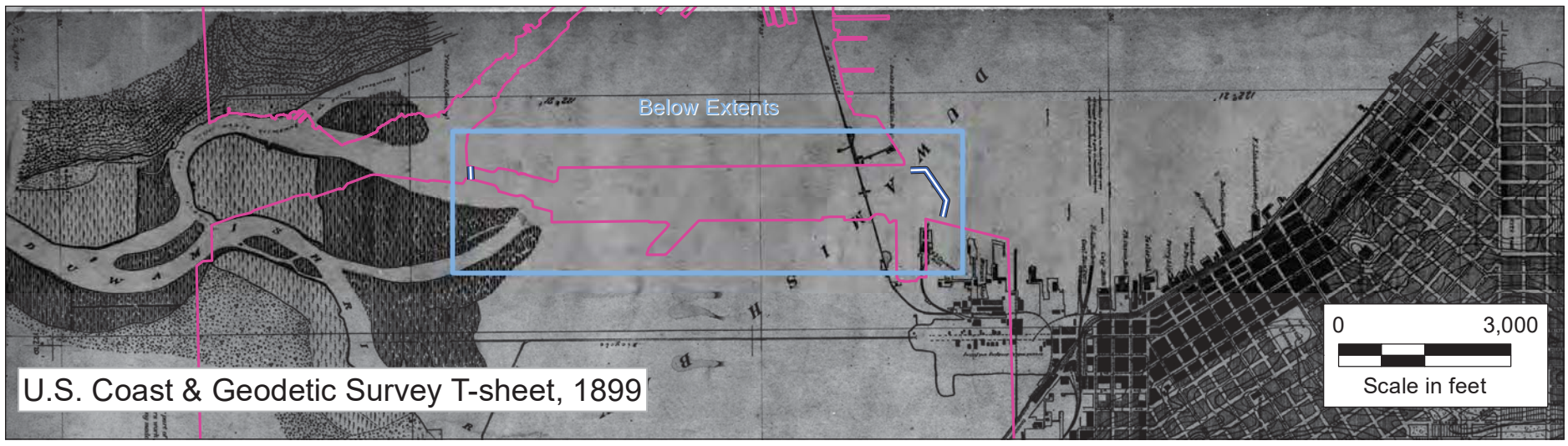
Prepared by zraigh, 10/4/2013; W:\Projects\00-08-08 East Waterway\EW RI-FS\Data\GIS\FS Support\Fig 2-11 3156 Public access and exposed intertidal.mxd

Photo source: Aerials Express Seattle2009, 1 ft resolution. Photo date 05/15/2009.

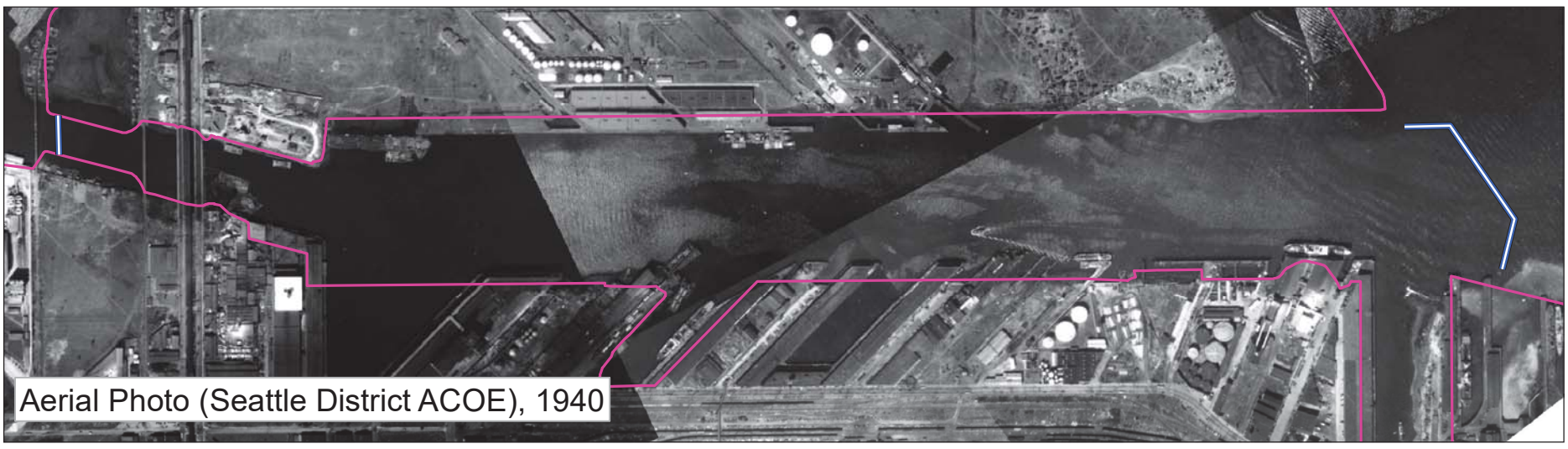
0 600
Scale in feet

- Public Access Location
- Exposed Intertidal Location
- Exposed Intertidal Area
- Fully Armored Exposed Intertidal Area
- East Waterway Study Area

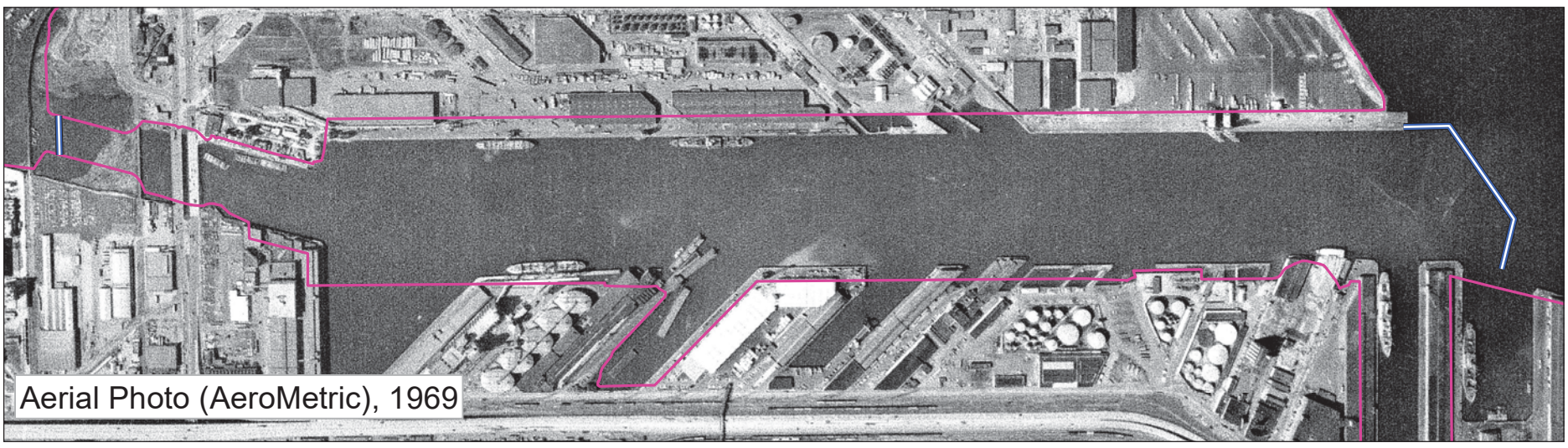
Figure B-8
Public Access Locations and Exposed Intertidal Areas Within the East Waterway



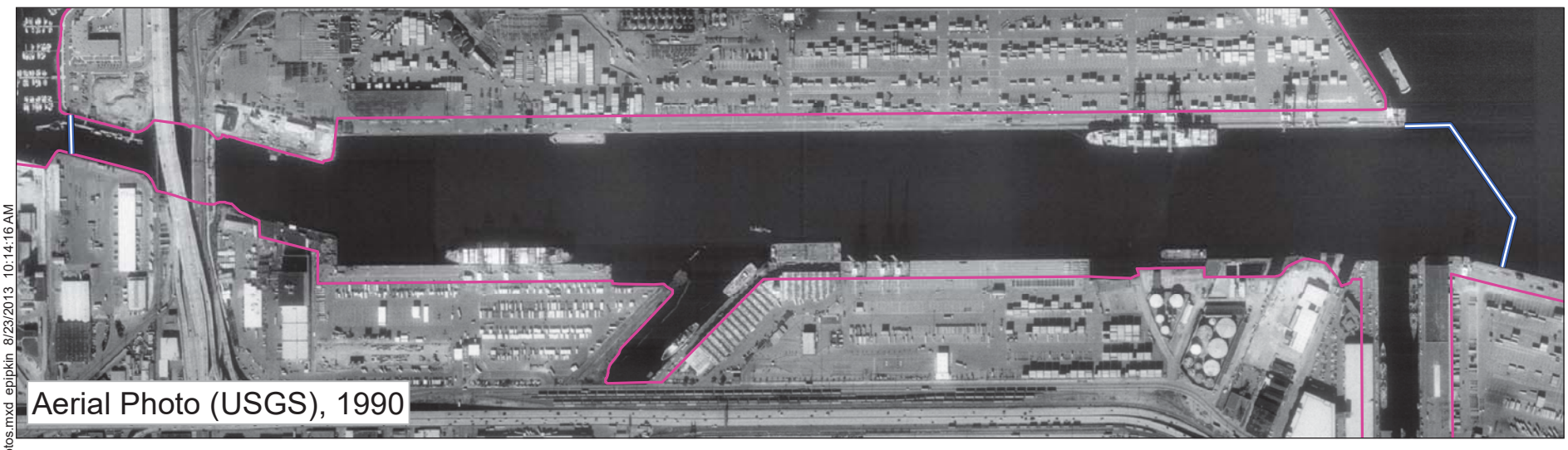
A



B



C



D

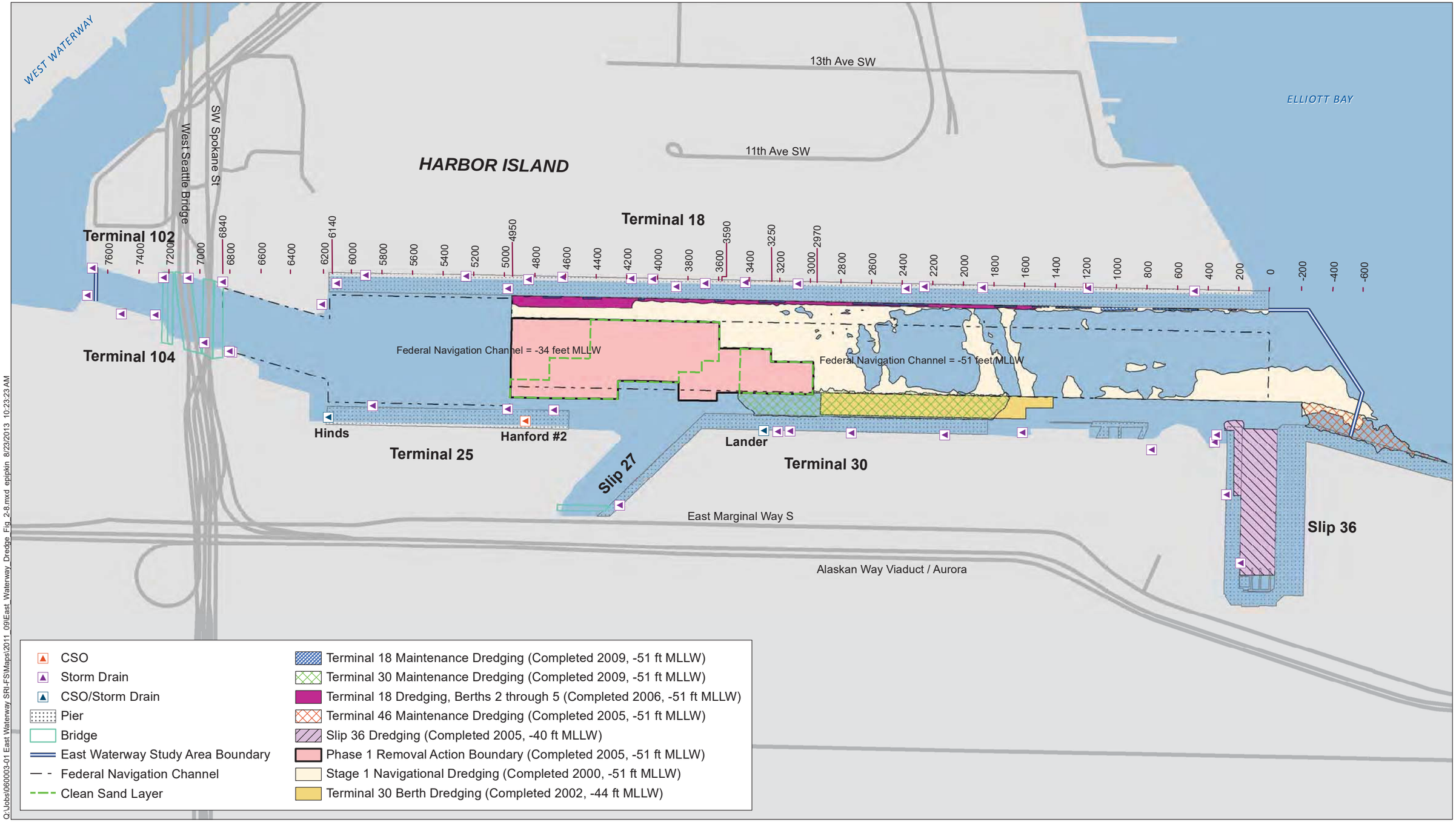
E

East Waterway Study Area Boundary
Present Day EW Region (MHHW)

0 1,000
Scale in feet

Map B-9
Historical Site Development

Q:\Jobs\060003-01 East Waterway SRI-FS\Maps\2011_12\Historic Maps and Photos.mxd epipkin 8/23/2013 10:14:16 AM



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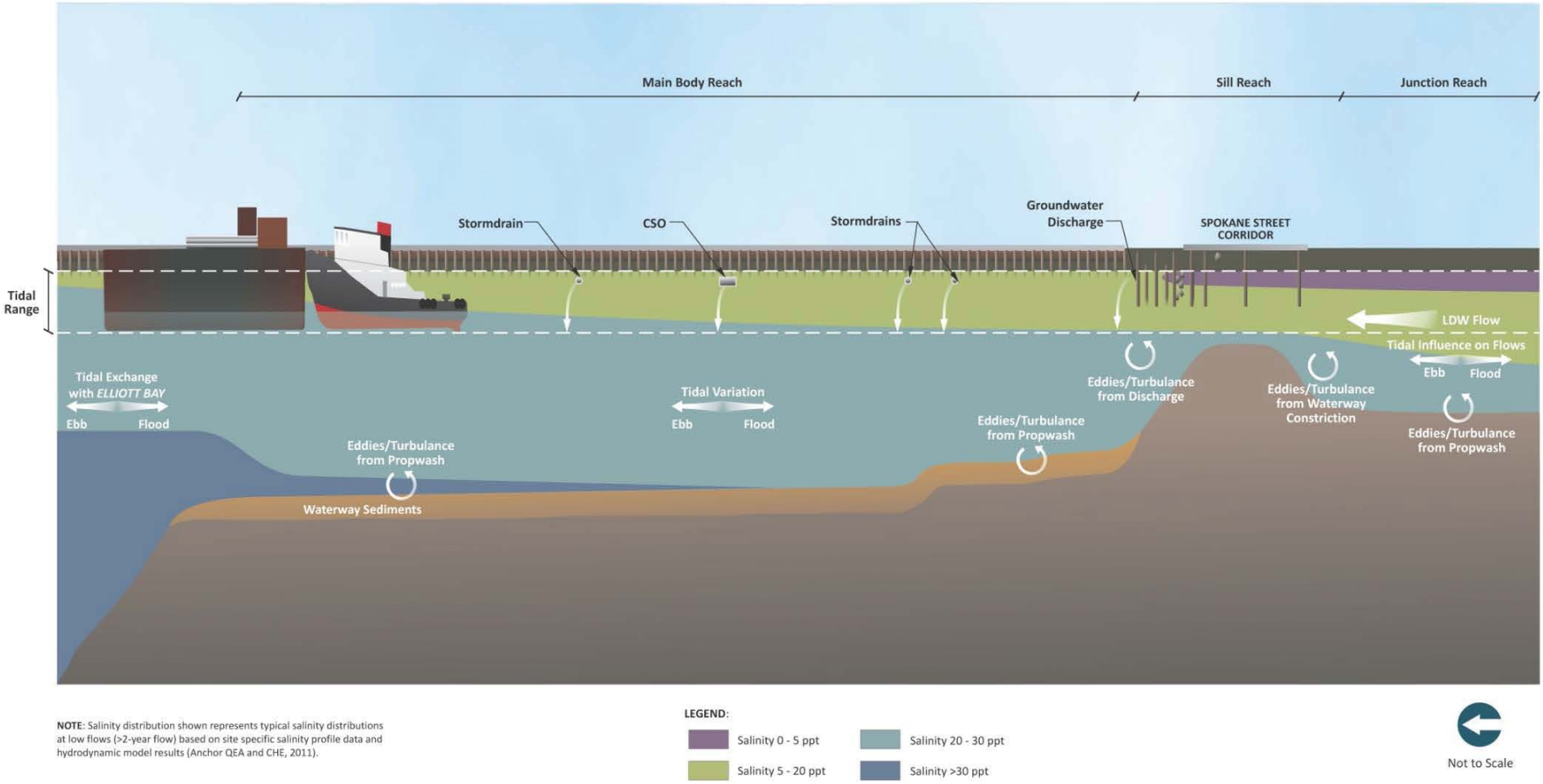
NOTES:
1. Previously established station locations for the East Waterway are shown along the western shoreline for reference.
2. Dredge activities listed indicate events since 2000.

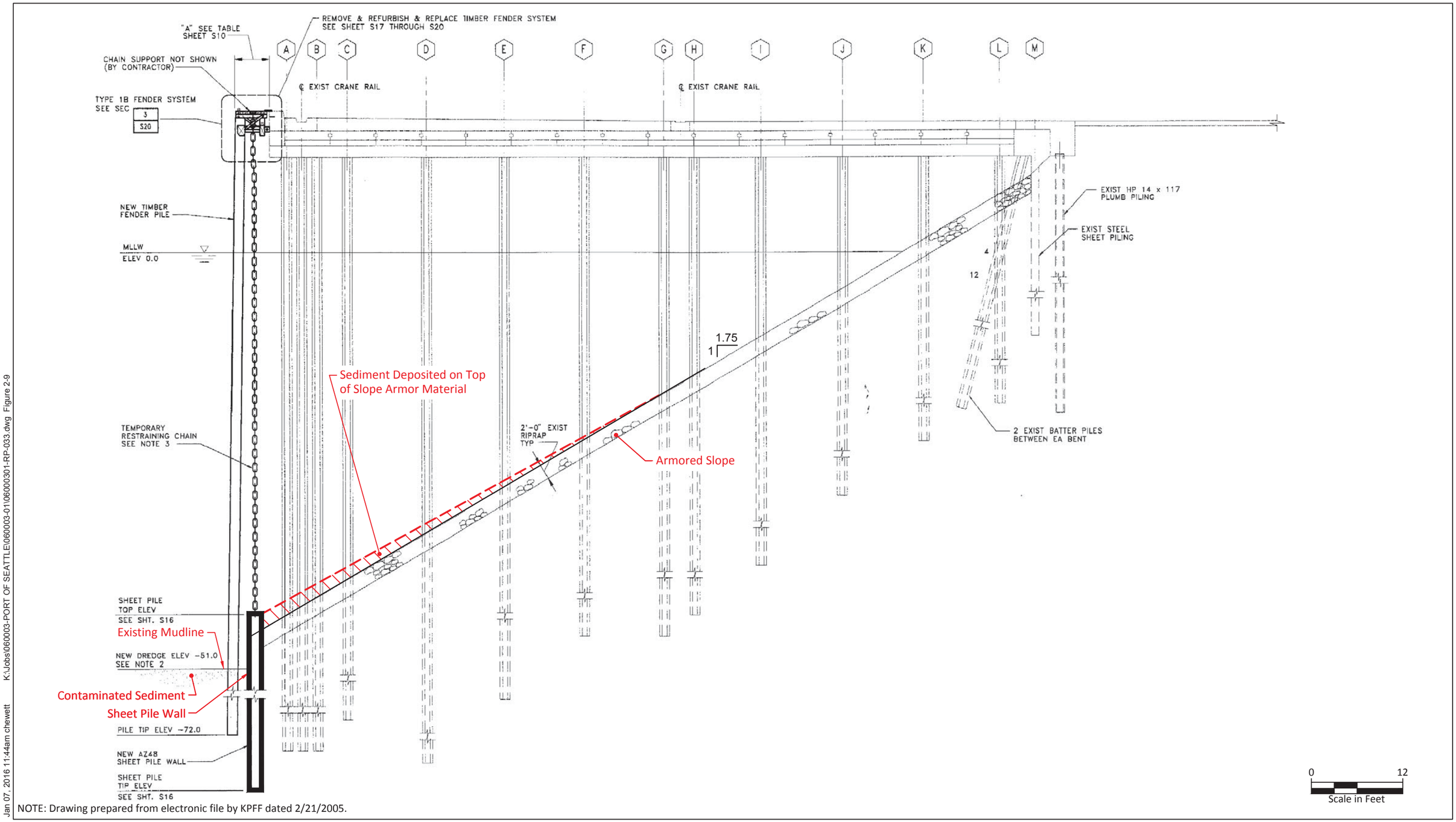
0 300 600 900 1,200
Scale in Feet

Map B-10
Recent Dredge History



NOTE: Salinity distribution shown represents typical salinity distributions at low flows (>2-year flow) based on site specific salinity profile data and hydrodynamic model results (Anchor QEA and CHE, 2011).

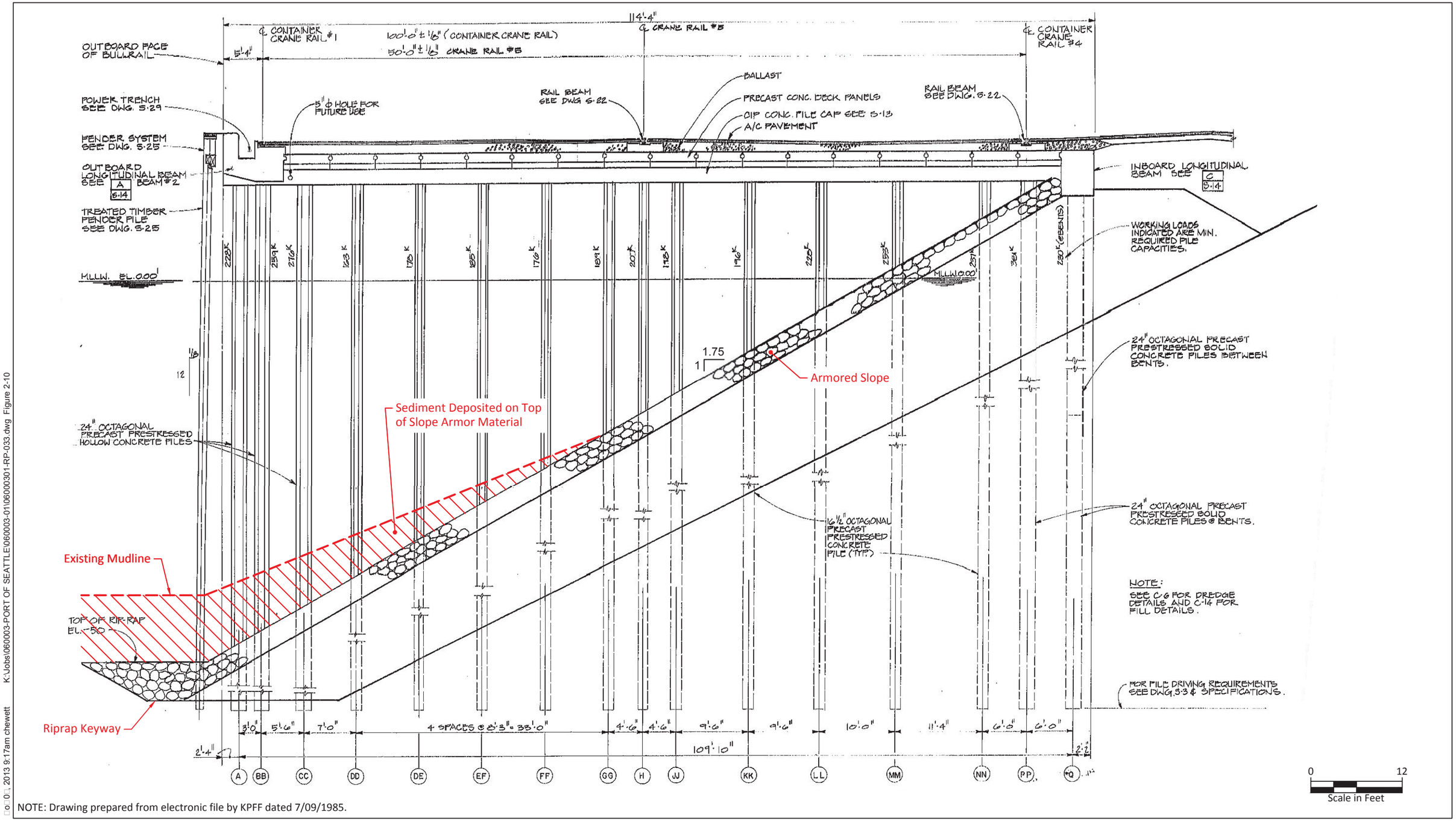
Figure B-11
Summary of Hydrodynamics in East Waterway, Flow Events Equal to or Less than a 2-Year Flow



NOTE: Drawing prepared from electronic file by KPFF dated 2/21/2005.

Jan 07, 2016 11:44am chewett K:\Jobs\060003-PORT OF SEATTLE\060003-01\06000301-RP-033.dwg Figure 2-9

Figure B-12
Typical Cross Section of Terminal 18 Sheetpile Toe Wall



NOTE: Drawing prepared from electronic file by KPFF dated 7/09/1985.

K:\Jobs\060003-PORT OF SEATTLE\060003-01\06000301-RP-033.dwg Figure 2-10

o: 0:, 2013 9:17am chewett

Figure B-13
Typical Cross Section of Terminal 25 and 30

ANCHOR QEA

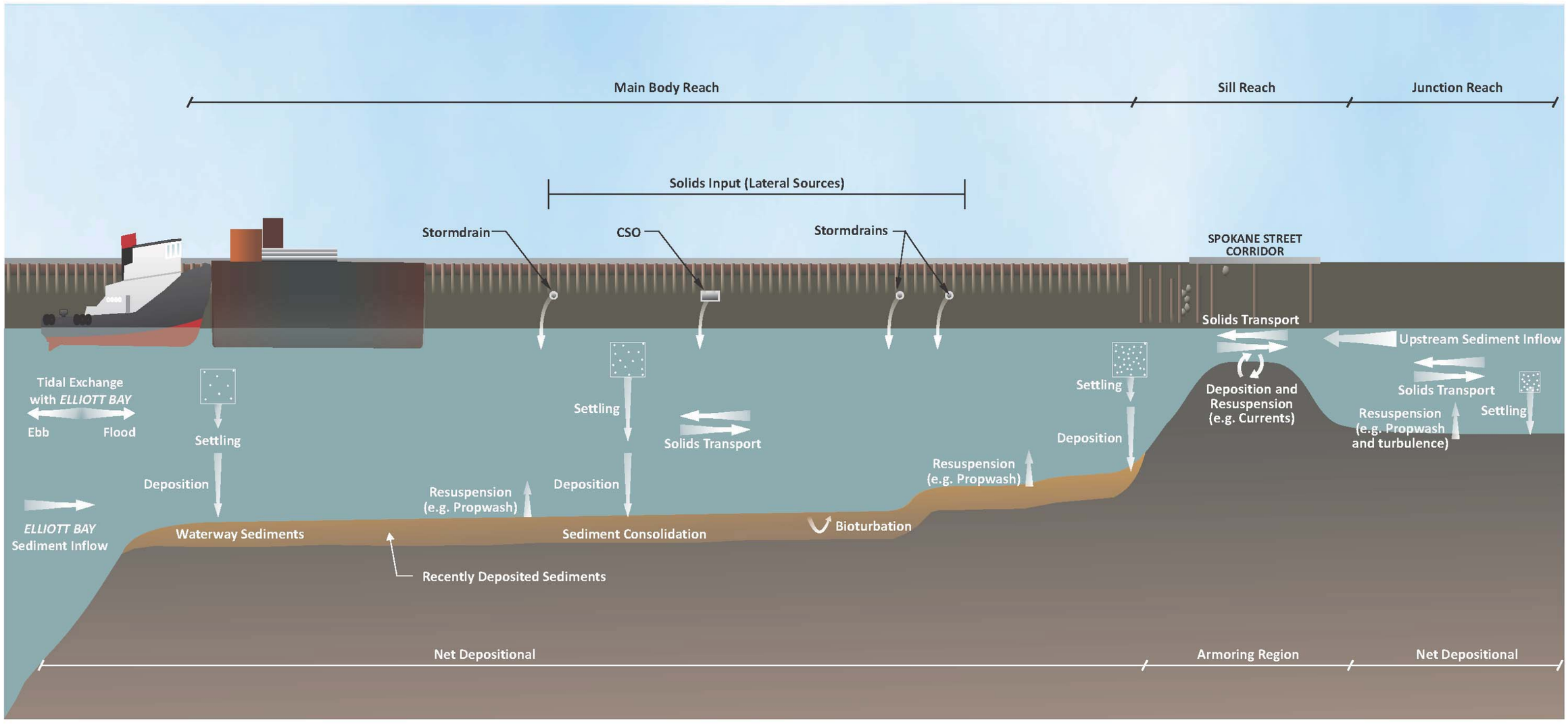
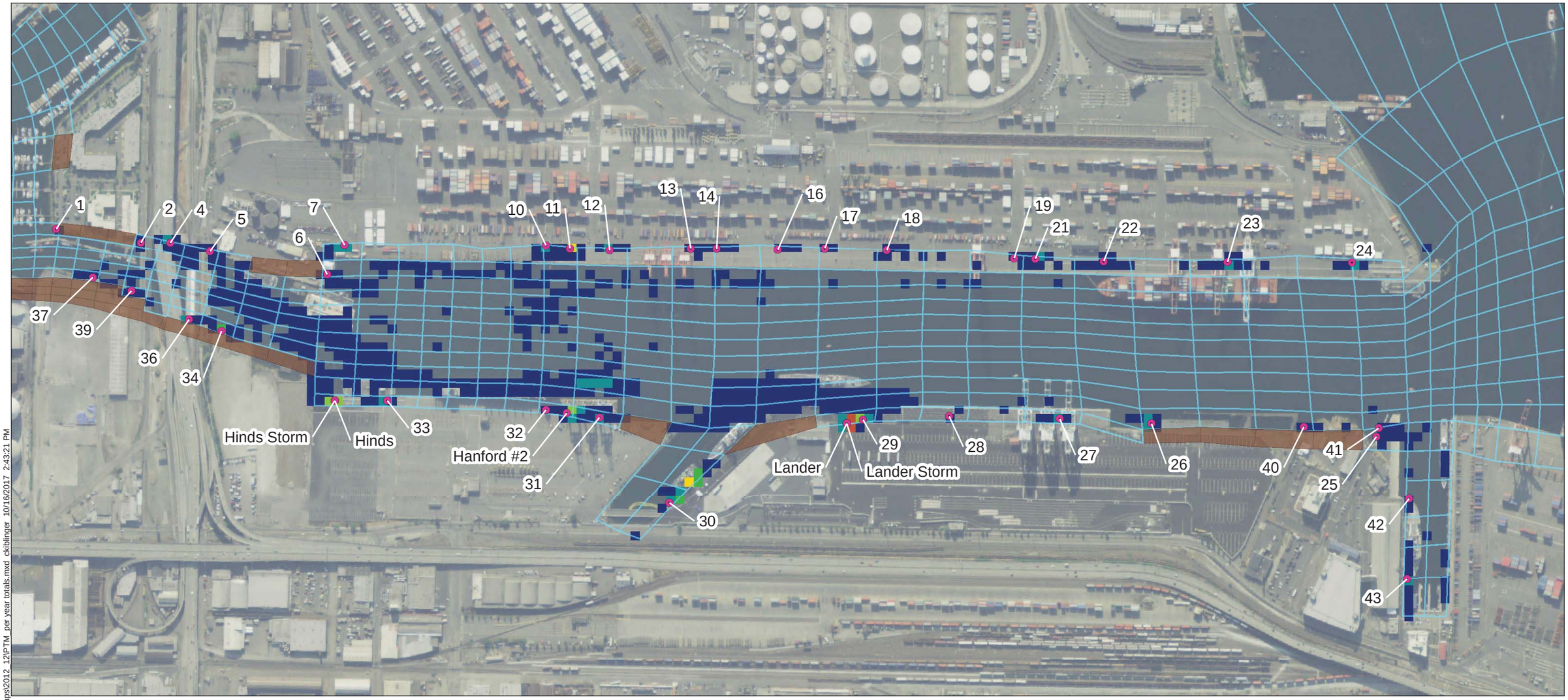


Figure B -14
Conceptual Summary of Sediment Transport in East Waterway

\\fujianchor\Projects\Port of Seattle\060003-01 East WW SRL_FS\FS\Section 1-4\figures\Round 3 Figures\Figure 2-12 source files\Figure 2-12.docx



PTM Outfall Locations

EFDC Hydrodynamic Model Grid

Land

Water

Deposition, cm/year

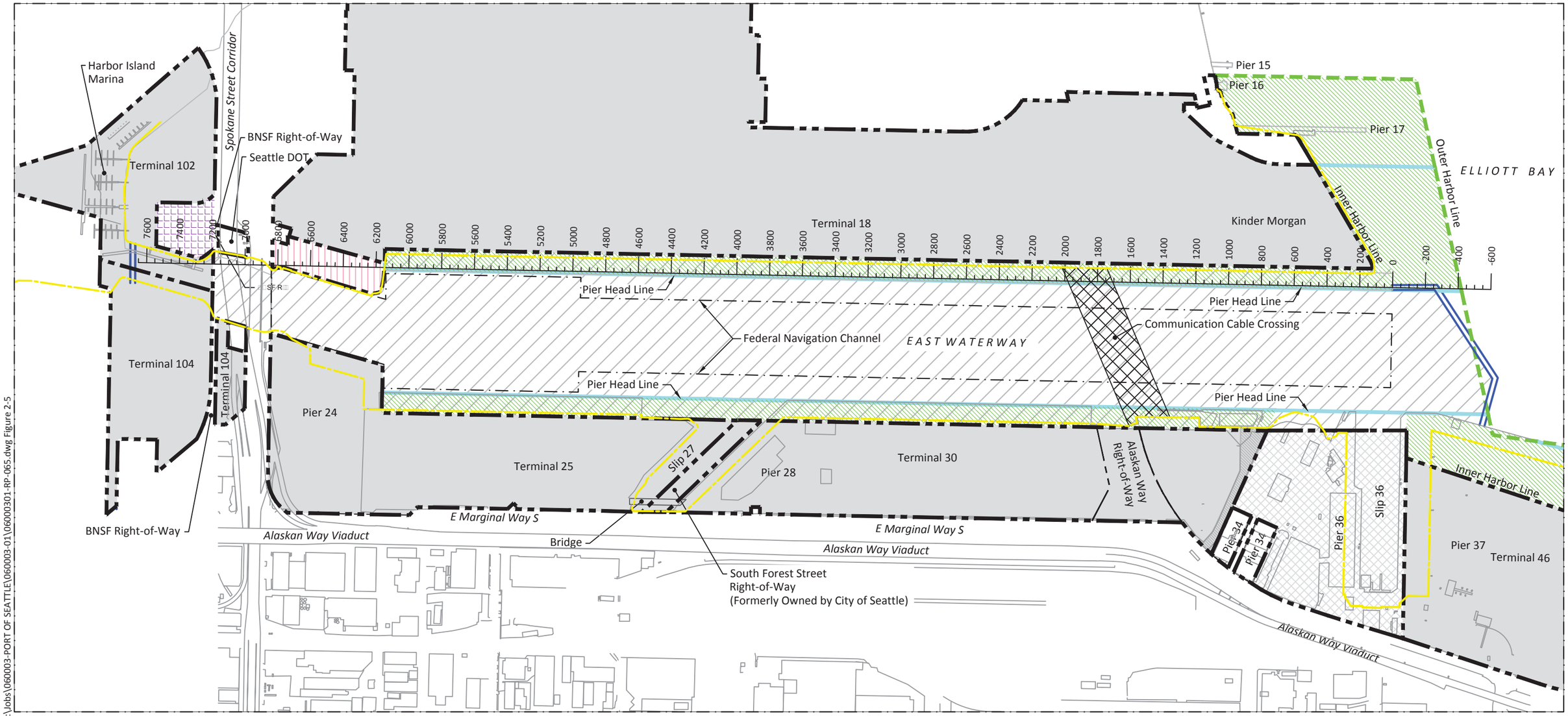
0 - 0.1
0.11 - 0.25
0.26 - 0.5
0.51 - 0.75
0.76 - 1
1.01 - 2
2.01 - 2.47

Feet
0 250 500 750 1,000

NOTES:
1. Deposition data (points) output from PTM model simulation has been represented by a 50 ft x 50 ft resolution raster map of mass accumulation per square foot (lb/sq foot)
2. Mass accumulation represents deposition over one year (extrapolated from a 28 day simulation time).
4. Lander, Hanford, and Hines are CSOs.
5. Outfall numbers (names) correspond to drainage basins.
6. Deposition pattern shown does not account for re-suspension of particles due to prop wash.

\\bellingham2\gisJobs\060003-01 East WW SRI_FS\Maps\2012_12\PTM_per year totals.mxd ckiblinger 10/16/2017 2:43:21 PM

Figure B-15
Predicted Annual Deposition (cm/yr) due to Lateral Loads, Base Case Current Conditions



NOTES:

1. Previously established station locations for the East Waterway are shown along the western shoreline for reference.
2. Olympic Tug and Barge operates as a subsidiary to Harley Marine Services.

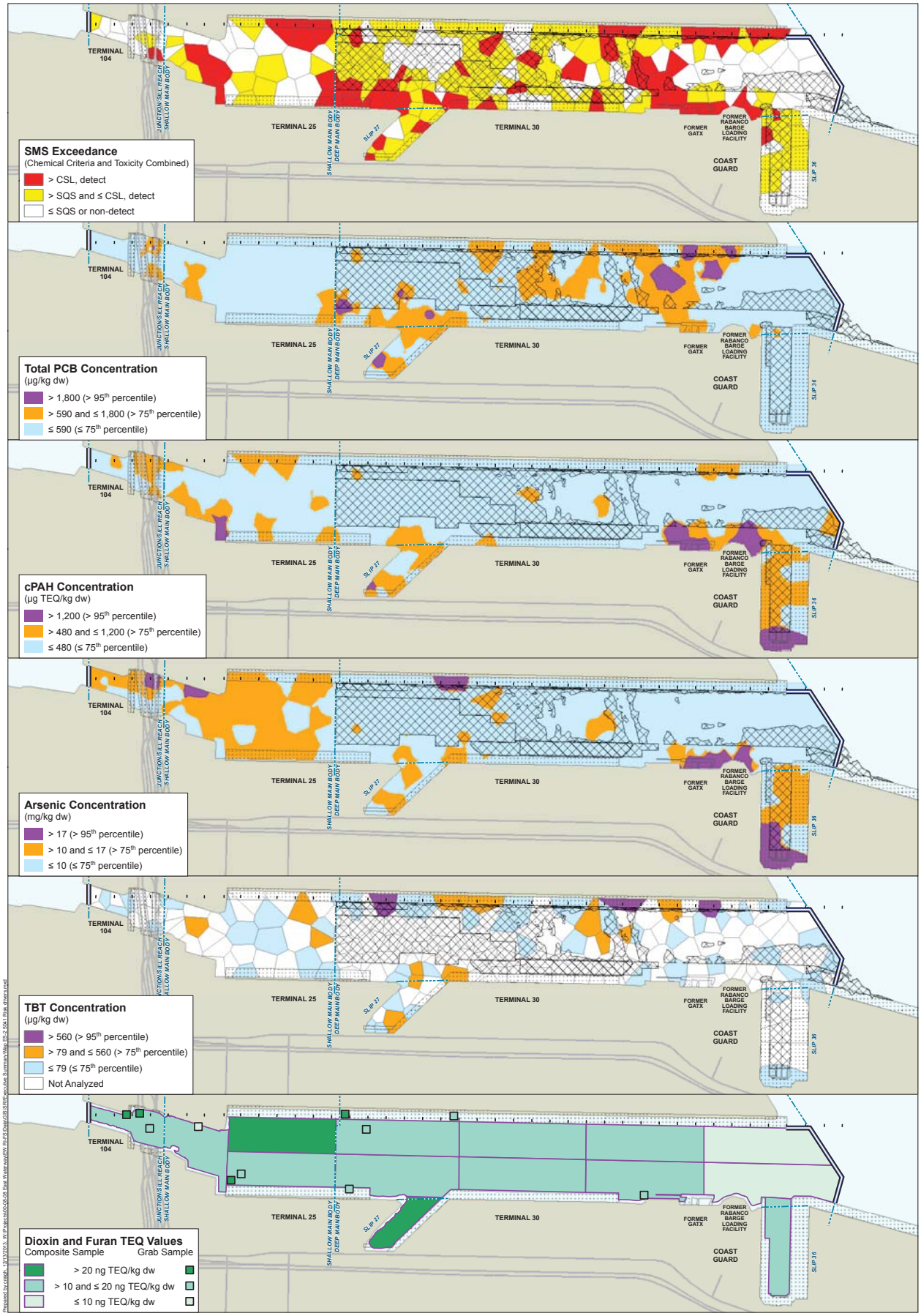
LEGEND:

- Property Line
- East Waterway Study Boundary
- MHHW Line
- Pier Head Line
- Outer Harbor Line
- Federal Navigation Channel
- Port of Seattle
- Harbor Real Estate
- Duwamish Properties, operated by Harley Marine Services
- US Coast Guard
- State-owned Land Managed by the Port of Seattle Under Current Port Management Agreement (PMA) with DNR
- State-owned Land Within East Waterway
- Communication Cable Crossing
- Park/Public Space

0 600
Scale in Feet

Figure B-16
Upland and Aquatic Ownership

K:\Jobs\060003-PORT OF SEATTLE\060003-01\06000301-RP-065.dwg Figure 2-5
Apr 16, 2013 8:21am chewett

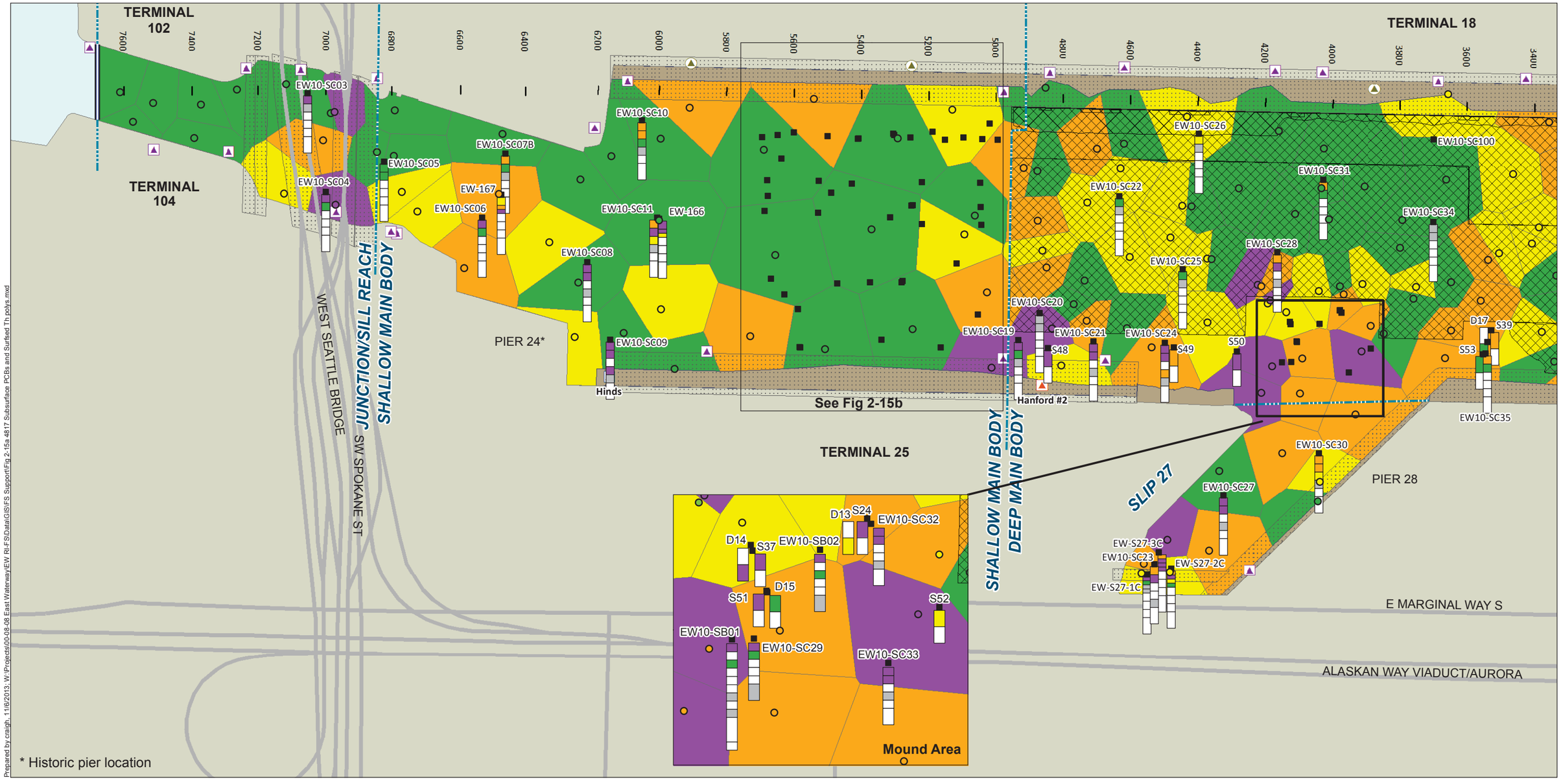


Area Dredged in the Last 11 Years
Dock/Pier/Bridge
Road
East Waterway Study Area Boundary

0 600
Scale in feet

Figure B-17

Surface Sediment Patterns of Select Contaminants



* Historic pier location

Prepared by craigh, 11/6/2013; W:\Projects\00-08-08 East Waterway\EW RI-FS\Data\GIS\FS Support\Fig 2-15a 4817 Subsurface PCBs and Surfsed Th polys.mxd

Subsurface Core Depth Charts

- Subsurface Core Location

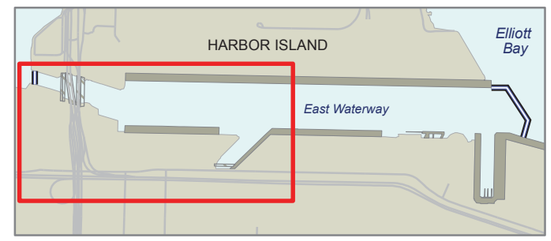
Total PCBs in Subsurface and Surface Sediment (µg/kg dw)

- > 1,000
- > 400 and ≤ 1,000
- > 192 and ≤ 400
- ≤ 192 (RAL)
- Non-detect
- Not Analyzed for This Interval

0 - 2 ft: 0 - 1 ft, 1 - 2 ft
2 - 4 ft: 2 - 3 ft, 3 - 4 ft
4 - 6 ft
6 - 8 ft
8 - 10 ft
> 10 ft

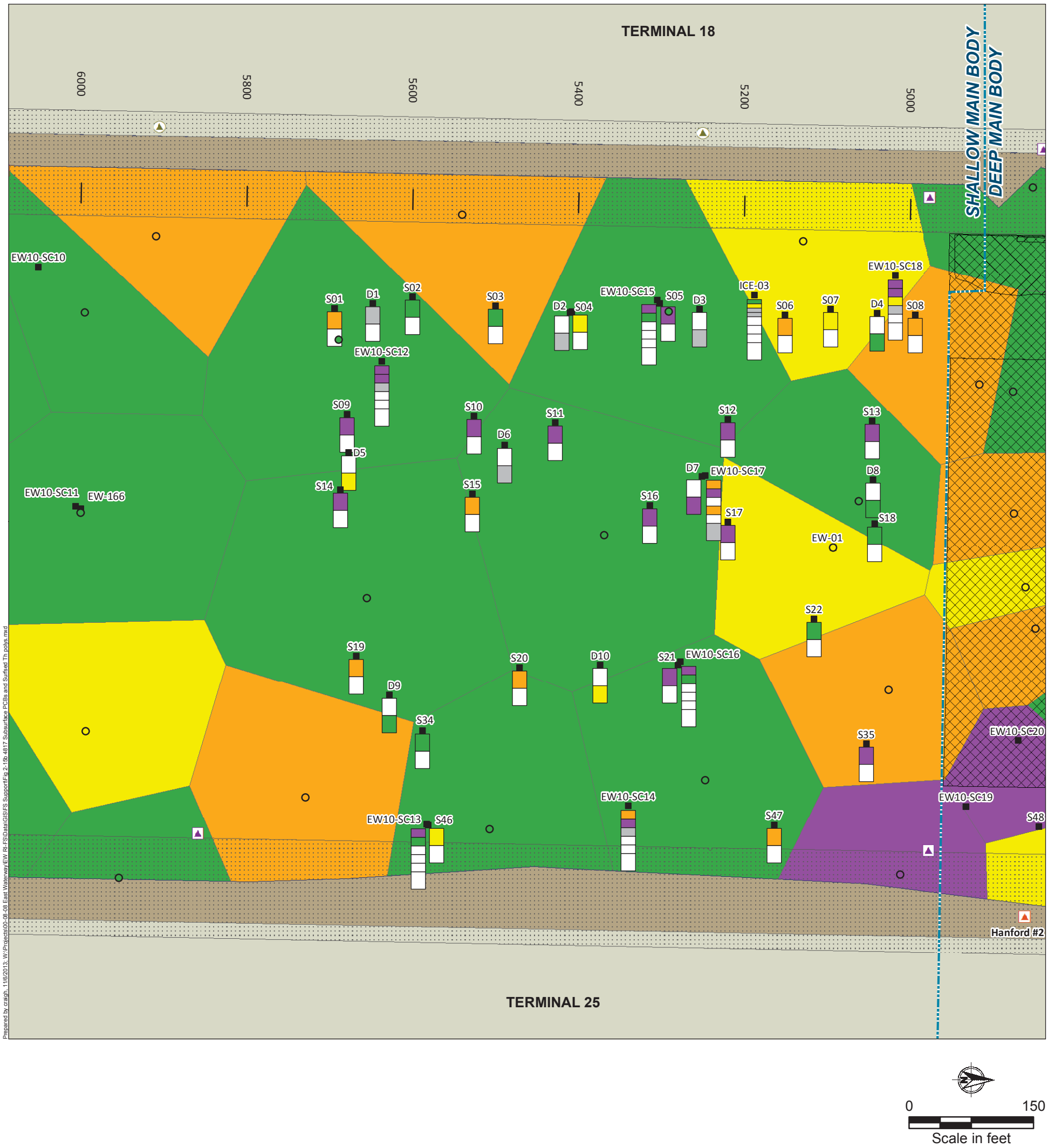
0 - 4 ft
> 4 ft

- Surface Sediment Sampling Location
- CSO
- Storm Drain
- CSO/Storm Drain
- Unknown Outfall
- Area Dredged Since 2000
- Dock/Pier/Bridge
- Riprap without Sediment
- Road
- East Waterway Study Area Boundary



0 600
Scale in feet

Figure B-18a
Surface and Subsurface Sediment Total PCB Concentration



Subsurface Core Depth Charts

- Subsurface Core Location

Total PCBs in Subsurface and Surface Sediment (µg/kg dw)

- > 1,000
- > 400 and ≤ 1,000
- > 192 and ≤ 400
- ≤ 192 (RAL)
- Non-detect
- Not Analyzed for This Interval

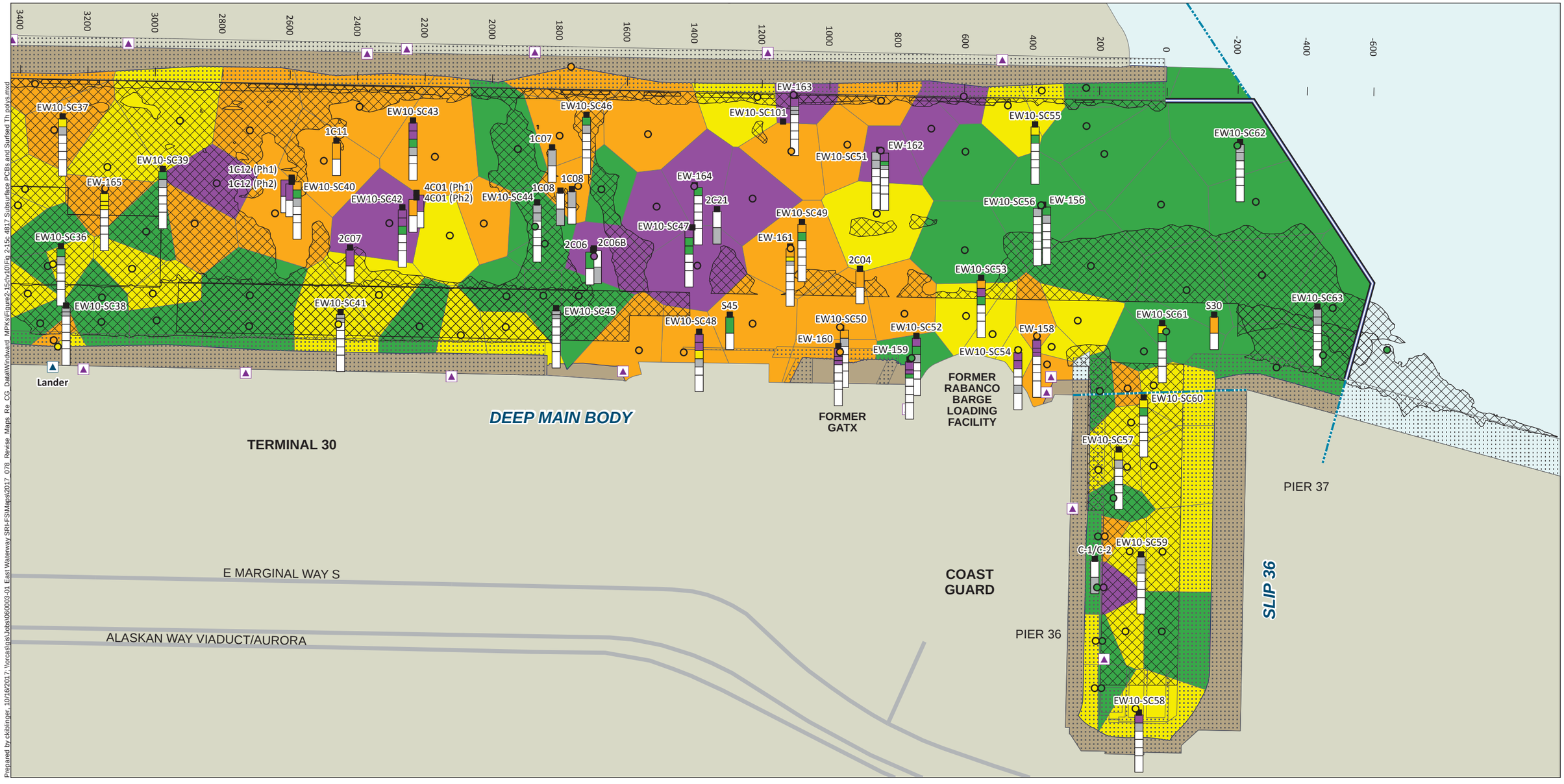
0 - 2 ft: 0 - 1 ft, 1 - 2 ft
2 - 4 ft: 2 - 3 ft, 3 - 4 ft
4 - 6 ft
6 - 8 ft
8 - 10 ft
> 10 ft

0 - 4 ft
> 4 ft

- Surface Sediment Sampling Location
- Area Dredged Since 200
- Dock/Pier/Bridge
- Riprap without Sediment
- CSO
- CSO/Storm Drain
- Storm Drain
- Unknown
- East Waterway Study Area Boundary

Figure B-18b
Surface and Subsurface Sediment

Total PCB Concentrations



Prepared by ckiblinger, 10/16/2017; \\orcas\gis\Jobs\060003-01 East Waterway SRI-FS\Maps\2017_078_Revise_Maps_Re_CG_Data\Windward_MPKs\Figure2-15c\v10\Fig 2-15c 4817 Subsurface PCBs and Surfsed Th polys.mxd

Subsurface Core Depth Charts

- Subsurface Core Location

Total PCBs in Subsurface and Surface Sediment (µg/kg dw)

- > 1,000
- > 400 and ≤ 1,000
- > 192 and ≤ 400
- ≤ 192 (RAL)
- Non-detect
- Not Analyzed for This Interval

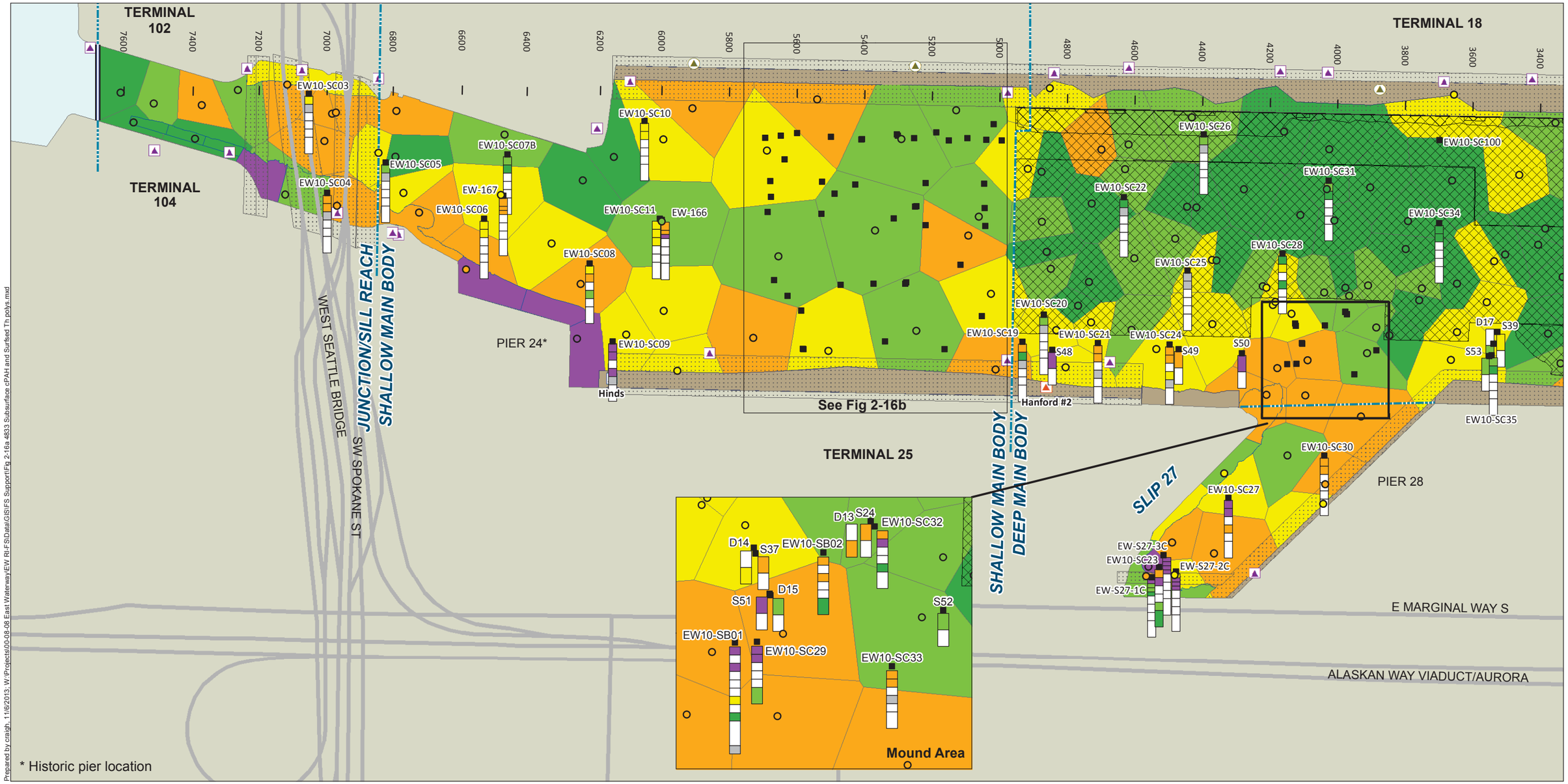
0 - 2 ft: 0 - 1 ft, 1 - 2 ft
2 - 4 ft: 2 - 3 ft, 3 - 4 ft
4 - 6 ft
6 - 8 ft
8 - 10 ft
> 10 ft

0 - 4 ft
> 4 ft

- CSO
- Storm Drain
- CSO/Storm Drain
- Unknown Outfall
- Area Dredged Since 2000
- Dock/Pier/Bridge
- Riprap without Sediment
- Road
- East Waterway Study Area Boundary

0 600
Scale in feet

Figure B-18c
Surface and Subsurface Sediment Total PCB Concentrations



Prepared by craigh, 11/6/2013; W:\Projects\00-08-08 East Waterway\EW RI-FS\Data\GIS\FS Support\Fig 2-16a 4833 Subsurface cPAH and Surfsed Th polys.mxd

Subsurface Core Depth Charts

- Subsurface Core Location

cPAH in Subsurface and Surface Sediment (µg TEQ/kg dw)[a]

- > 1,200 (> 95th percentile)
- > 480 and ≤ 1,200 (≤ 95th percentile)
- > 220 and ≤ 480 (≤ 75th percentile)
- > 95 and ≤ 220 (≤ 50th percentile)
- ≤ 95 (≤ 25th percentile)
- Non-detect
- Not Analyzed for This Interval

0 - 2 ft; 2 - 4 ft; 4 - 6 ft; 6 - 8 ft; 8 - 10 ft; > 10 ft

0 - 1 ft; 1 - 2 ft; 2 - 3 ft; 3 - 4 ft

0 - 4 ft; > 4 ft

- Surface Sediment Sampling Location
- CSO
- Storm Drain
- CSO/Storm Drain
- Unknown Outfall
- Area Dredged Since 2000
- Dock/Pier/Bridge
- Riprap without Sediment
- Road
- East Waterway Study Area Boundary

[a] Gray border = surface sediment Thiessen polygon extrapolation; blue border = MIS composite sample extrapolation.
The percentiles are all numeric percentiles of the surface sediment dataset.

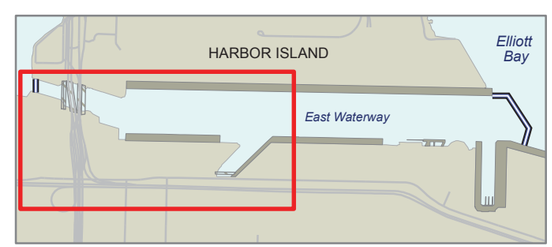
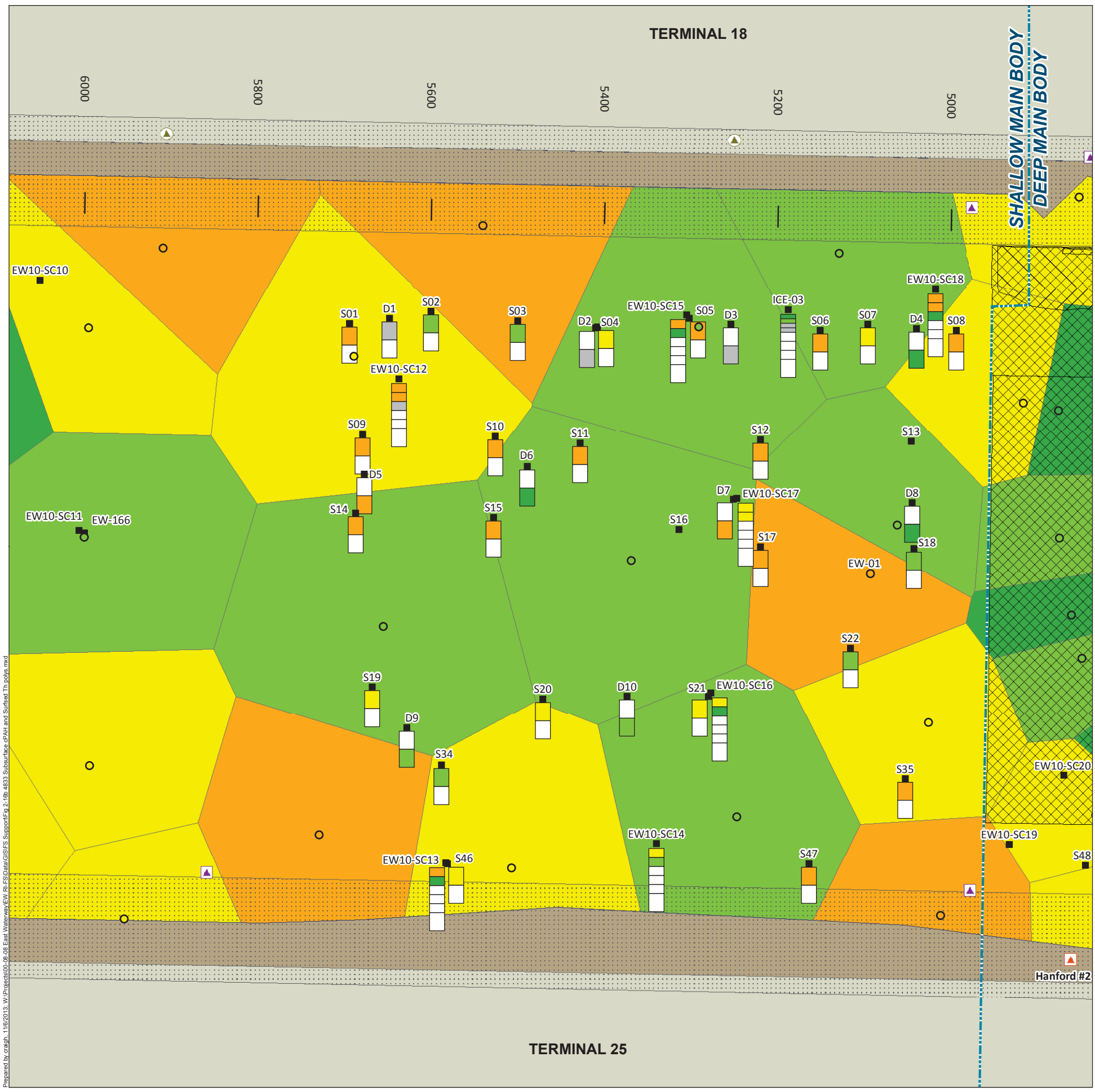


Figure B-19a
Surface and Subsurface Sediment cPAH Concentrations



Prepared by craigh, 11/6/2013, W:\Projects\00-08-08 East Waterway\EW RI-FS\Data\GIS\FS Support\Fig 2-16b 4833 Subsurface cPAH and Surfsed Th polys.mxd

Subsurface Core Depth Charts

- Subsurface Core Location

cPAH in Subsurface and Surface Sediment (µg TEQ/kg dw)

- > 1,200 (> 95th percentile)
- > 480 and ≤ 1,200 (≤ 95th percentile)
- > 220 and ≤ 480 (≤ 75th percentile)
- > 95 and ≤ 220 (≤ 50th percentile)
- ≤ 95 (≤ 25th percentile)
- Non-detect
- Not Analyzed for This Interval

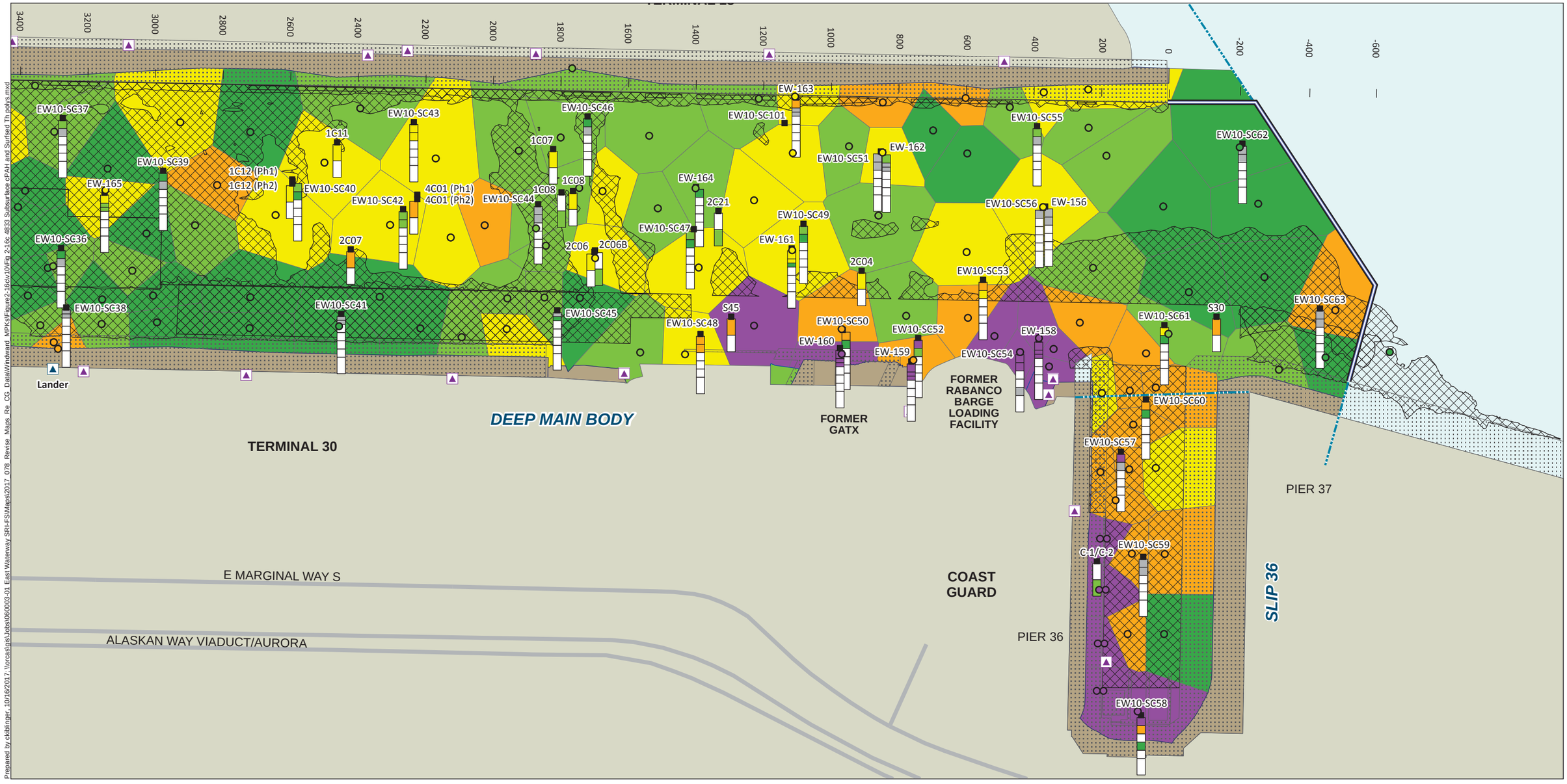
0 - 2 ft: 0 - 1 ft, 1 - 2 ft
2 - 4 ft: 2 - 3 ft, 3 - 4 ft
4 - 6 ft
6 - 8 ft
8 - 10 ft
> 10 ft

0 - 4 ft
> 4 ft

The percentiles are all numeric percentiles of the surface sediment dataset.

- Surface Sediment Sampling Location
- Area Dredged Since 2000
- Dock/Pier/Bridge
- Riprap without Sediment
- CSO
- CSO/Storm Drain
- Storm Drain
- Unknown
- East Waterway Study Area Boundary

Figure B-19b
Surface and Subsurface Sediment



Prepared by ckitblinger, 10/16/2017: \\orcas\gis\Jobs\060003-01 East Waterway SRI-FS\Maps\2017_078_Revise_Maps_Re_CG_Data\Windward_MPKs\Figure2-16dv10\Fig 2-16c 4833 Subsurface cPAH and Surfsed Th polys.mxd

Subsurface Core Depth Charts

- Subsurface Core Location

cPAH in Subsurface and Surface Sediment (µg TEQ/kg dw)[a]

- > 1,200 (> 95th percentile)
- > 480 and ≤ 1,200 (≤ 95th percentile)
- > 220 and ≤ 480 (≤ 75th percentile)
- > 95 and ≤ 220 (≤ 50th percentile)
- ≤ 95 (≤ 25th percentile)
- Non-detect
- Not Analyzed for This Interval

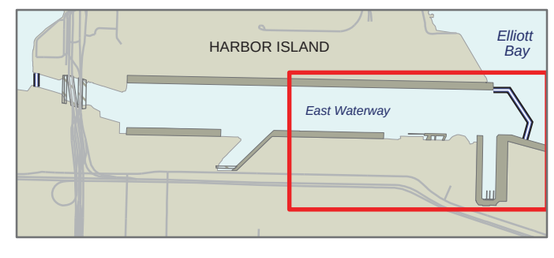
0 - 2 ft; 2 - 4 ft; 4 - 6 ft; 6 - 8 ft; 8 - 10 ft; > 10 ft

0 - 1 ft; 1 - 2 ft; 2 - 3 ft; 3 - 4 ft

0 - 4 ft; > 4 ft

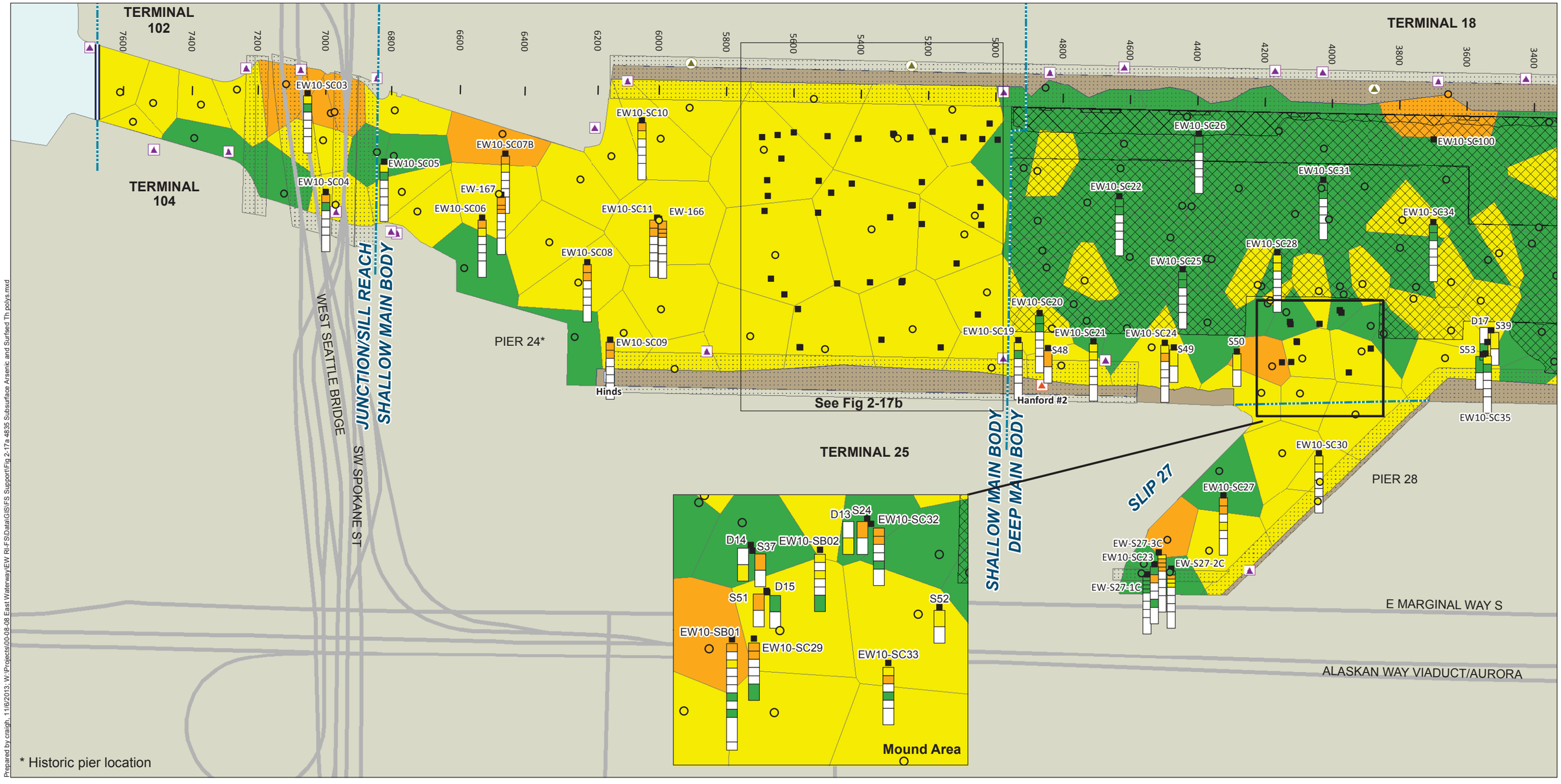
- Surface Sediment Sampling Location
- CSO
- Storm Drain
- CSO/Storm Drain
- Unknown Outfall
- Area Dredged Since 2000
- Dock/Pier/Bridge
- Riprap without Sediment
- Road
- East Waterway Study Area Boundary

[a] Gray border = surface sediment Thiessen polygon extrapolation; blue border = MIS composite sample extrapolation.



0 600
Scale in feet

Figure B-19c
Surface and Subsurface Sediment cPAH Concentrations



Prepared by craigh, 11/6/2013; W:\Projects\00-08-08 East Waterway\EW RI-FS\Data\GIS\FS Support\Fig 2-17a 4835 Subsurface Arsenic and Surfsed Th polys.mxd

Subsurface Core Depth Charts

- Subsurface Core Location

Arsenic in Subsurface and Surface Sediment (mg/kg dw)

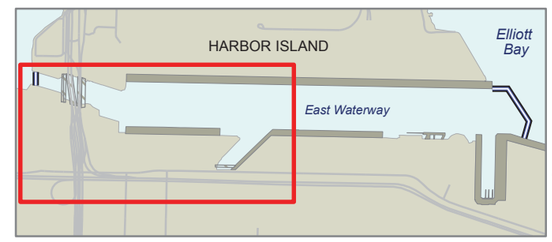
- > 57 (> SQS)
- > 15 and ≤ 57 (≤ SQS)
- > 7.0 and ≤ 15
- ≤ 7.0
- Non-detect
- Not Analyzed for This Interval

0 - 2 ft; 2 - 4 ft; 4 - 6 ft; 6 - 8 ft; 8 - 10 ft; > 10 ft

0 - 1 ft; 1 - 2 ft; 2 - 3 ft; 3 - 4 ft

0 - 4 ft; > 4 ft

- Surface Sediment Sampling Location
- CSO
- Storm Drain
- CSO/Storm Drain
- Unknown Outfall
- Area Dredged Since 2000
- Dock/Pier/Bridge
- Riprap without Sediment
- Road
- East Waterway Study Area Boundary

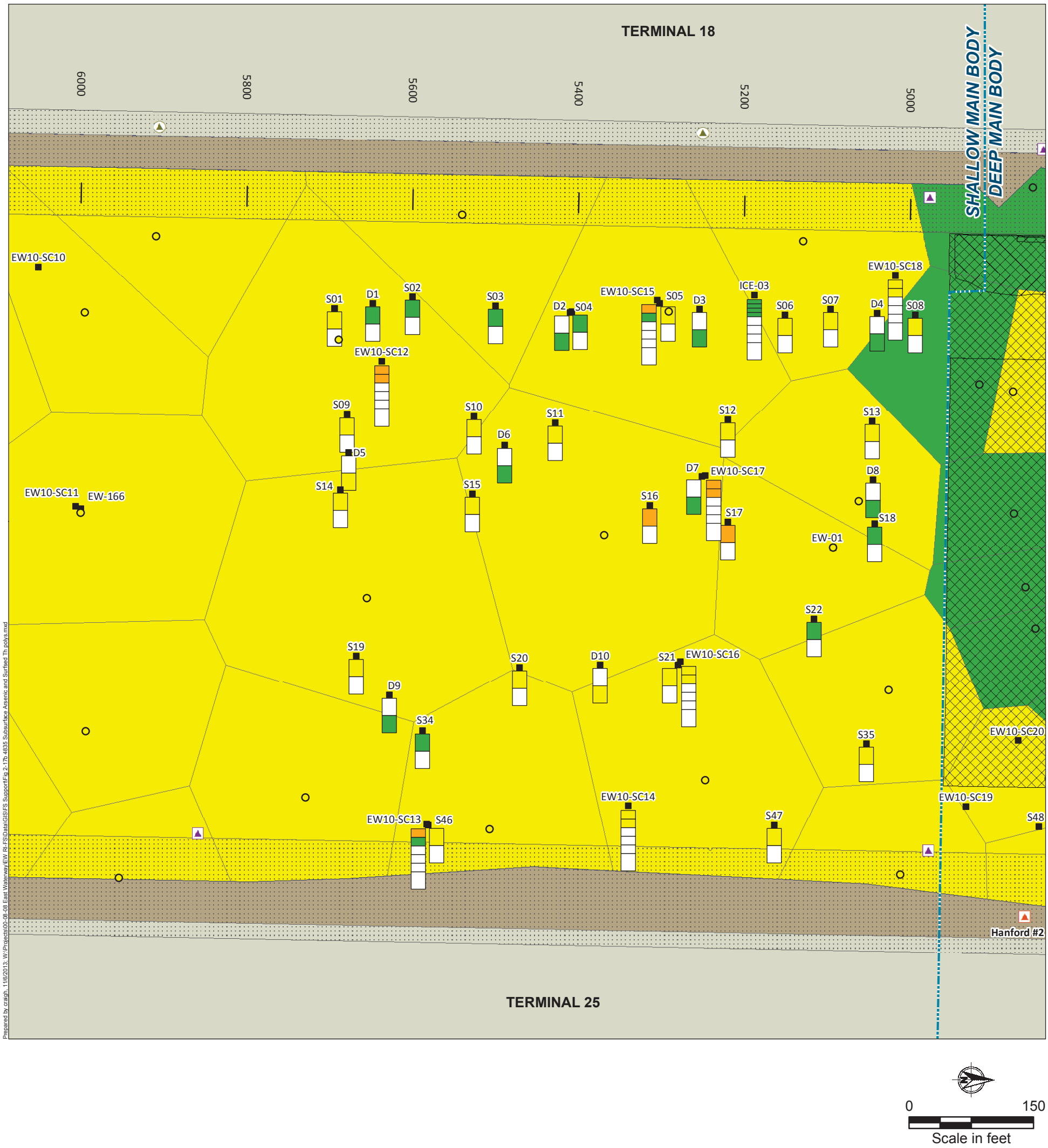


0 600

Scale in feet

Figure B-20a

Surface and Subsurface Sediment Arsenic Concentrations



Prepared by craigh, 11/6/2013; W:\Projects\00-08-08 East Waterway\EW RI-FS\Data\GIS\FS Support\Fig 2-17b 4835 Subsurface Arsenic and Surfeed Th polys.mxd

Subsurface Core Depth Charts

■ Subsurface Core Location

Arsenic in Subsurface and Surface Sediment (mg/kg dw)

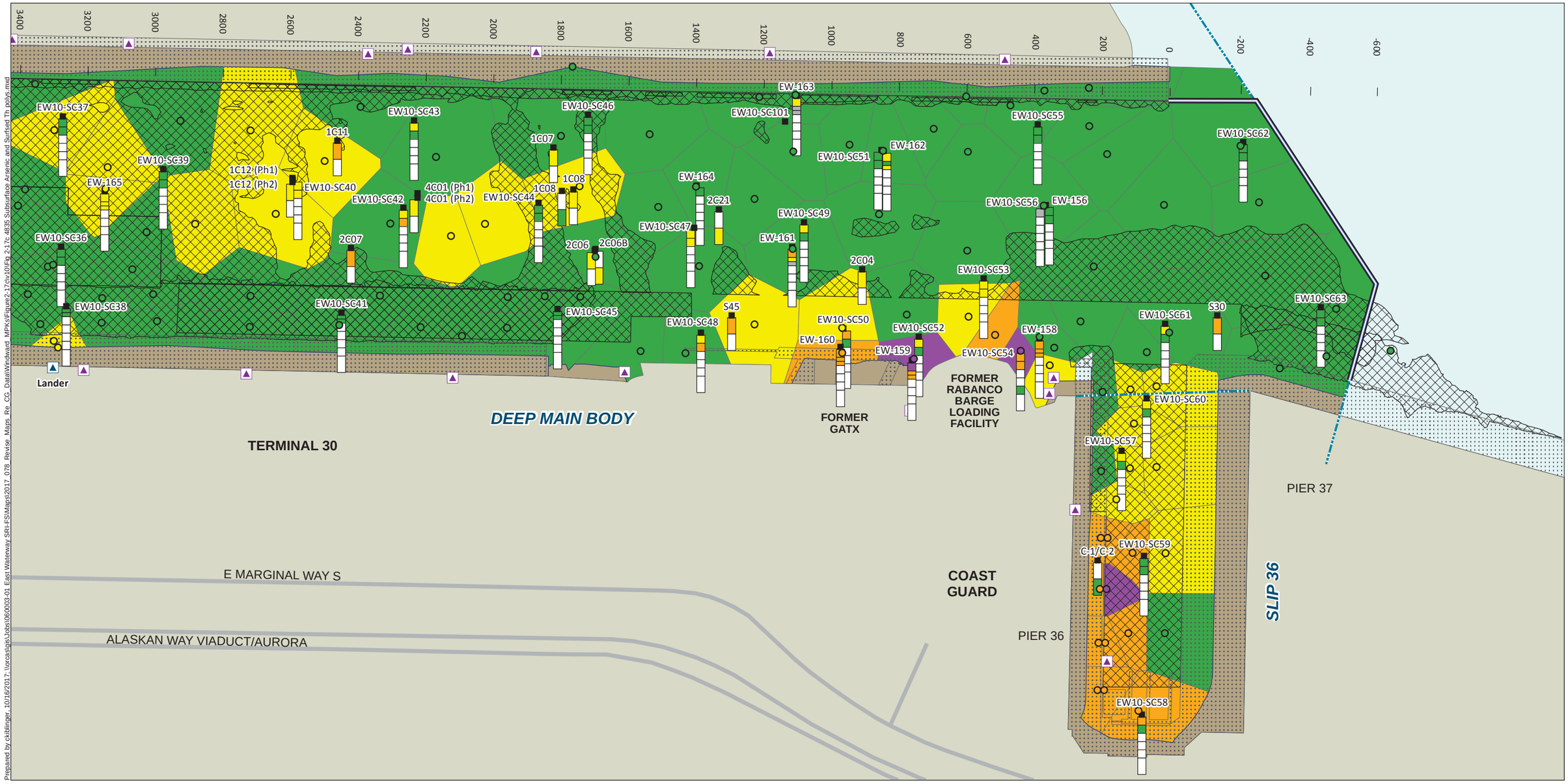
- > 57 (> SQS)
- > 15 and ≤ 57 (≤ SQS)
- > 7.0 and ≤ 15
- ≤ 7.0
- Non-detect
- Not Analyzed for This Interval

0 - 2 ft: 0 - 1 ft, 1 - 2 ft
2 - 4 ft: 2 - 3 ft, 3 - 4 ft
4 - 6 ft
6 - 8 ft
8 - 10 ft
> 10 ft

0 - 4 ft
> 4 ft

- ○ Surface Sediment Sampling Location
- Area Dredged Since 2000
- Dock/Pier/Bridge
- Riprap without Sediment
- CSO
- CSO/Storm Drain
- Storm Drain
- Unknown
- East Waterway Study Area Boundary

Figure B-20b
Surface and Subsurface Sediment



Prepared by ckiblinger, 10/16/2017; \\orcas\gis\Jobs\060003-01 East Waterway SRI-FS\Maps\2017_078_Revise_Maps_Re_CG_Data\Windward_MPKs\Figure2-17\v10\Fig 2-17c 4835 Subsurface Arsenic and Surfsed Th polys.mxd

Subsurface Core Depth Charts

■ Subsurface Core Location

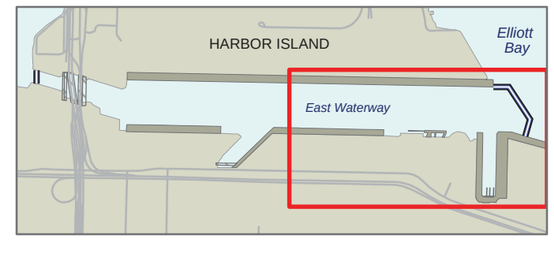
Arsenic in Subsurface and Surface Sediment (mg/kg dw)

- > 57 (> SQS)
- > 15 and ≤ 57 (≤ SQS)
- > 7.0 and ≤ 15
- ≤ 7.0
- Non-detect
- Not Analyzed for This Interval

0 - 2 ft: 0 - 1 ft, 1 - 2 ft
2 - 4 ft: 2 - 3 ft, 3 - 4 ft
4 - 6 ft
6 - 8 ft
8 - 10 ft
> 10 ft

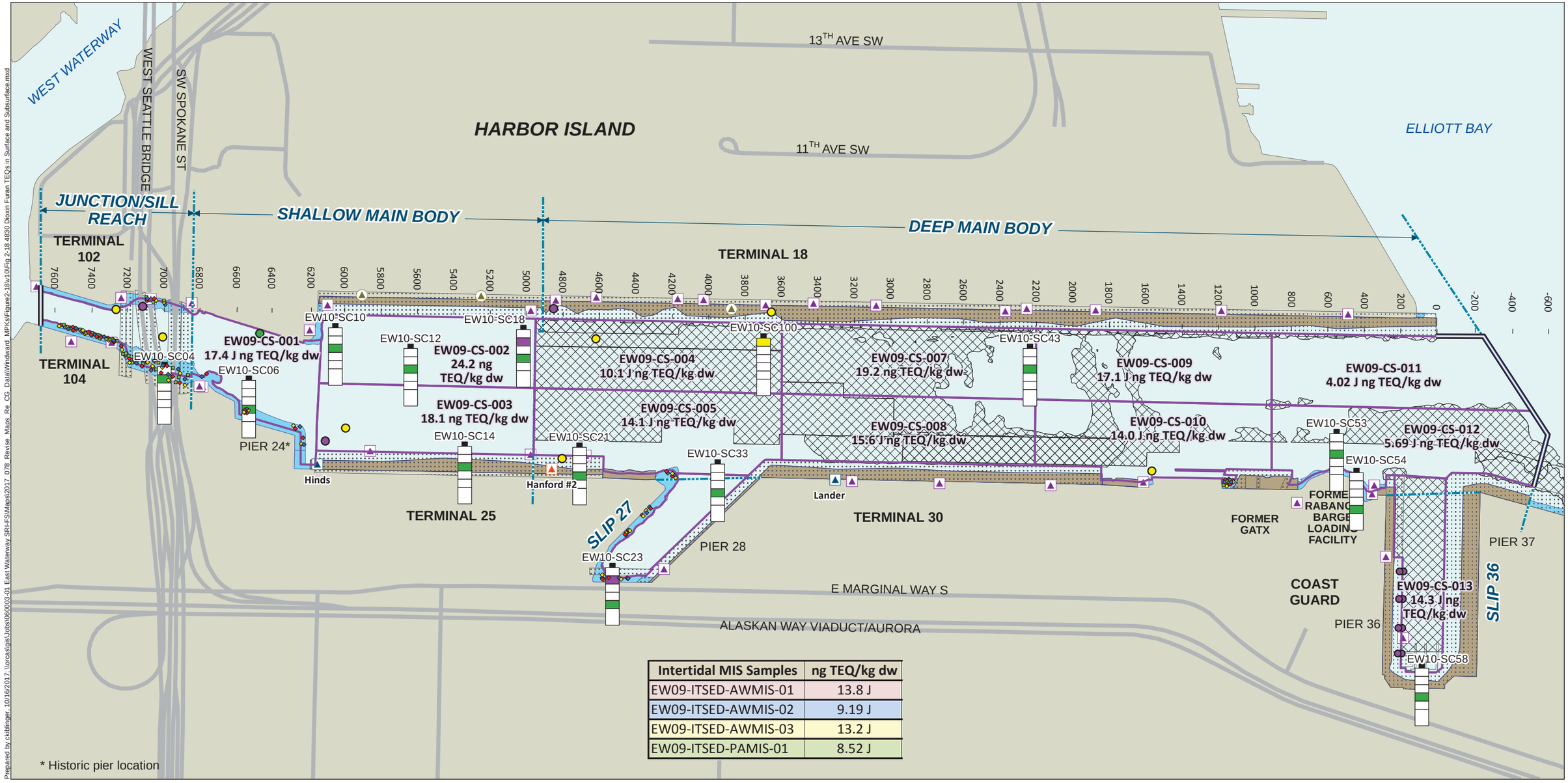
0 - 4 ft
> 4 ft

- Surface Sediment Sampling Location
- CSO
- Storm Drain
- CSO/Storm Drain
- Unknown Outfall
- Area Dredged Since 2000
- Dock/Pier/Bridge
- Riprap without Sediment
- Road
- East Waterway Study Area Boundary



0 600
Scale in feet

Figure B-20c
Surface and Subsurface Sediment Arsenic Concentrations



Intertidal MIS Samples	ng TEQ/kg dw
EW09-ITSED-AWMIS-01	13.8 J
EW09-ITSED-AWMIS-02	9.19 J
EW09-ITSED-AWMIS-03	13.2 J
EW09-ITSED-PAMIS-01	8.52 J

Subsurface Core Depth Charts

- Subsurface Core Location

Dioxin and Furan TEQs in Subsurface and Surface Sediment (ng TEQ/kg dw)

- > 25 (RAL)
- > 10 and ≤ 25
- ≤ 10
- Not Analyzed for This Interval

0 - 2 ft; 2 - 4 ft; 4 - 6 ft; 6 - 8 ft; 8 - 10 ft; > 10 ft

0 - 1 ft; 1 - 2 ft; 2 - 3 ft; 3 - 4 ft

- Grab Sample Location
- Subtidal Composite Area Boundary

Multi-Increment Sampling (MIS) Composite Locations

- EW09-ITSED-AWMIS-01
- EW09-ITSED-AWMIS-02
- EW09-ITSED-AWMIS-03
- EW09-ITSED-PAMIS-01

- Intertidal Zone
- Riprap without Sediment
- CSO
- Storm Drain
- CSO/Storm Drain
- Unknown Outfall
- Area Dredged Since 2000
- Dock/Pier/Bridge
- Road
- East Waterway Study Area Boundary

0 600
Scale in feet

Figure B-21
Dioxin and Furan TEQ Values for Surface and Subsurface Sediment

Prepared by ckiblinger, 10/16/2017; \\orcas\gis\Jobs\060003-01 East Waterway SRI-FS\Maps\2017 078 Revise Maps Re CG DataWindward MPKs\Figure2-18\v10\Fig 2-18 4830 Dioxin Furan TEQs in Surface and Subsurface.mxd

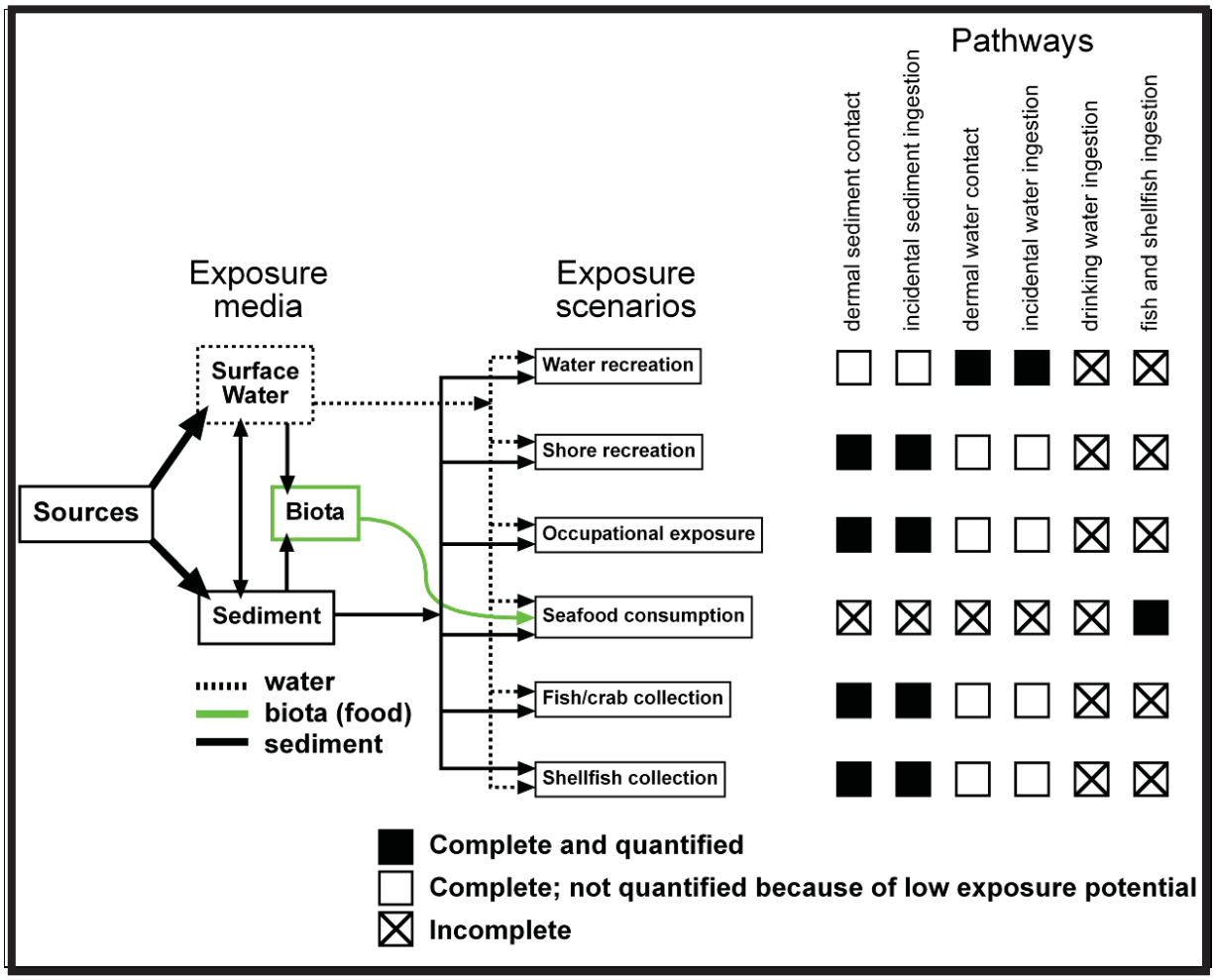


Figure B-22. Exposure Conceptual Site Model for the Human Health Risk Assessment

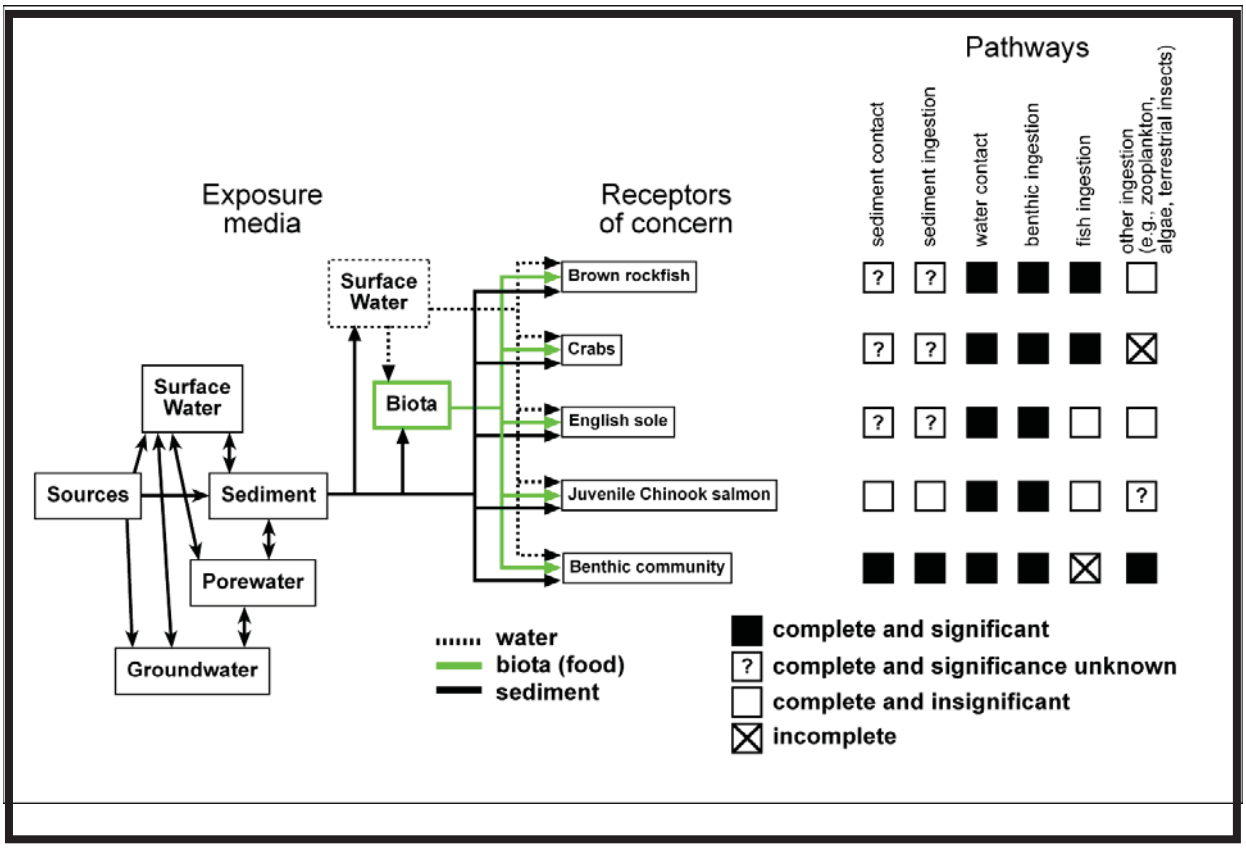


Figure B-23. Exposure Conceptual Site Model for the Ecological Risk Assessment for Aquatic Organisms

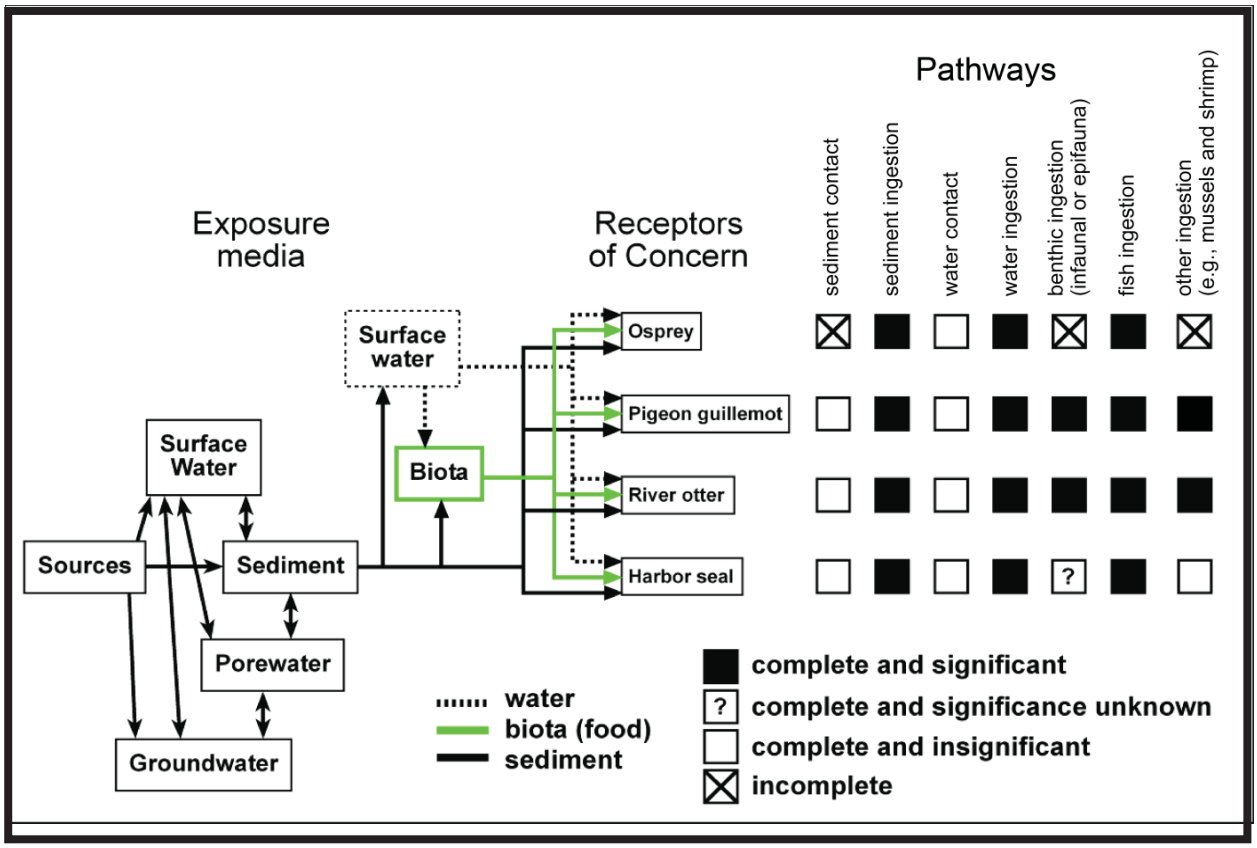


Figure B-24. Conceptual Site Model for Wildlife

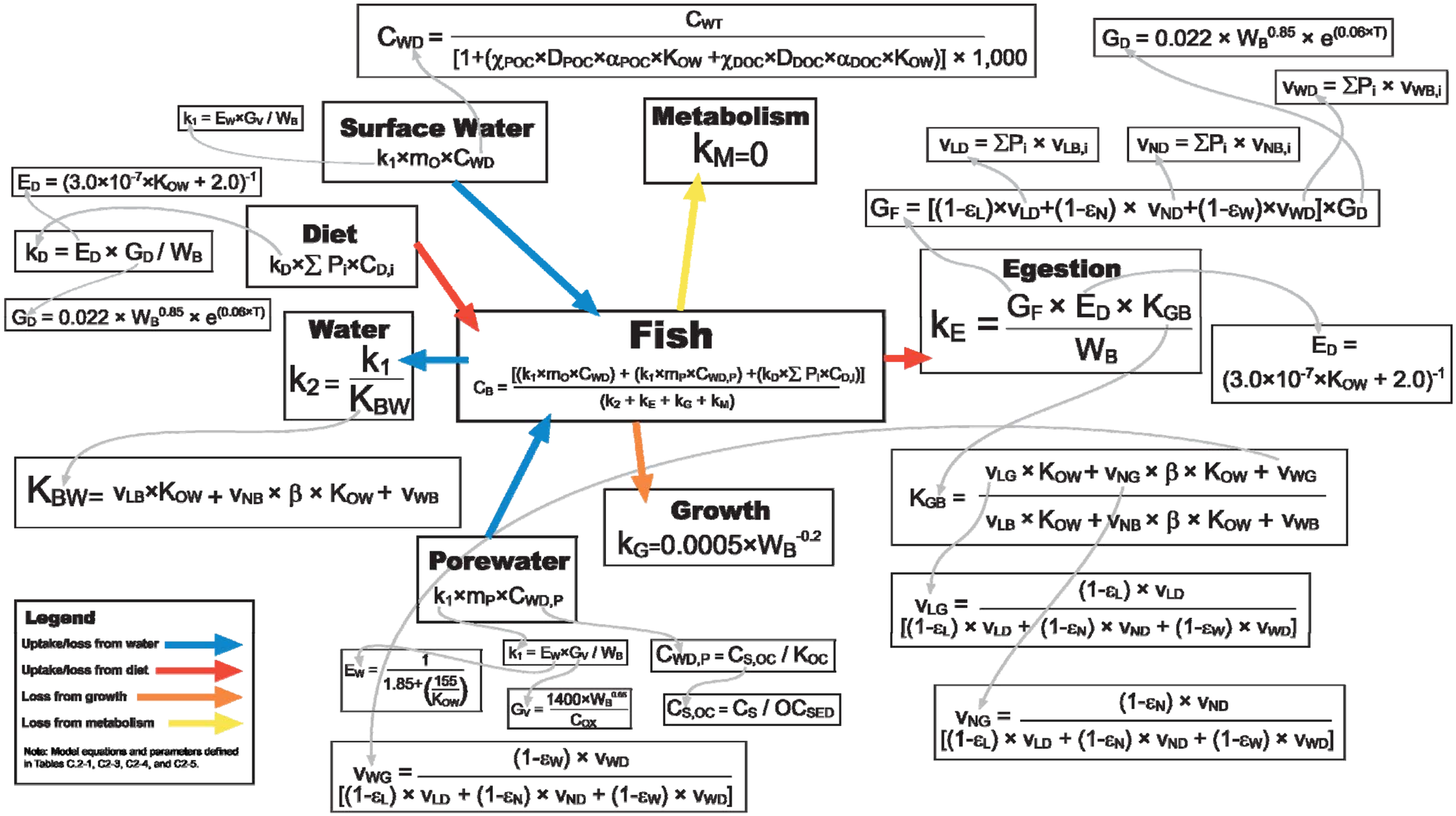
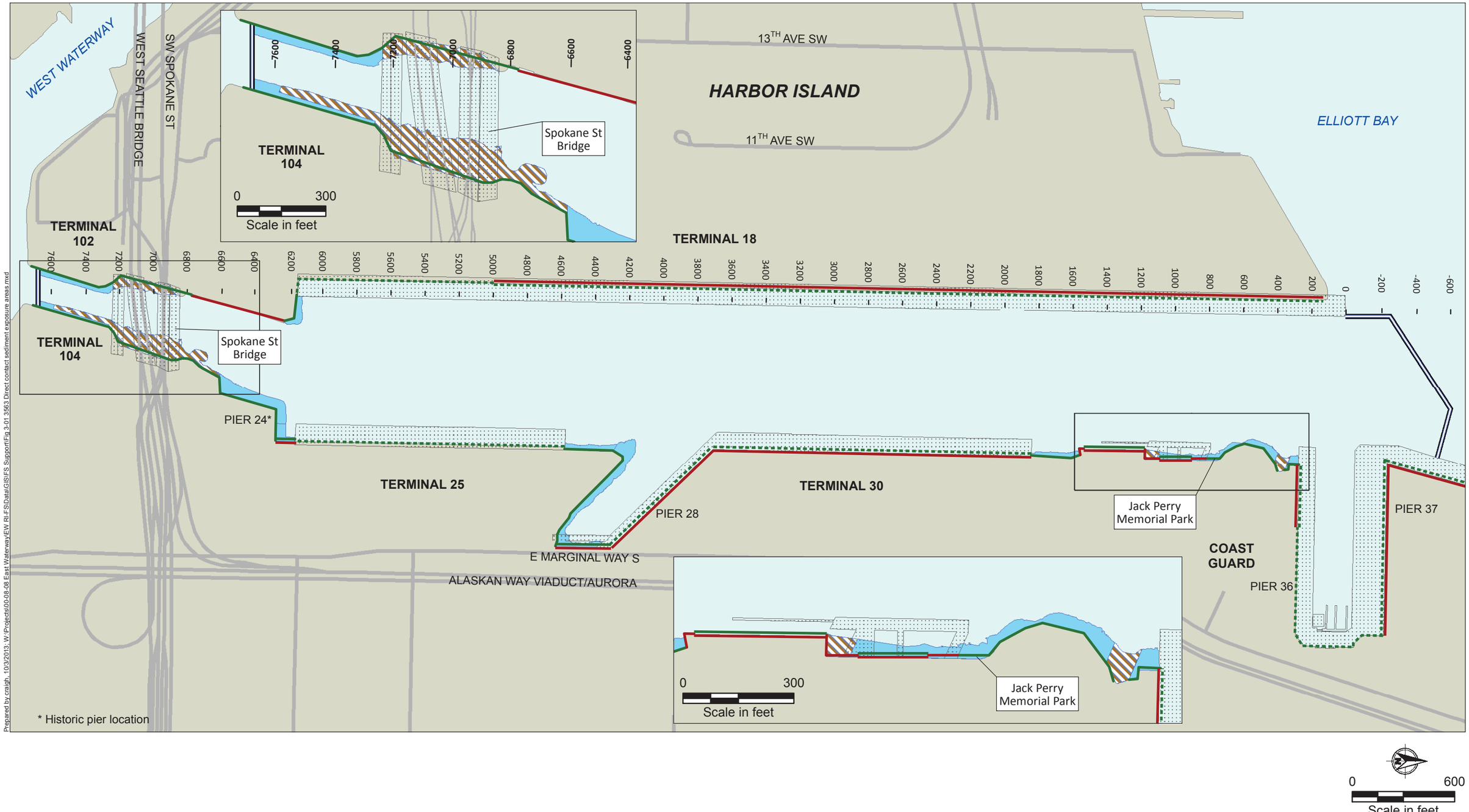


Figure B-25

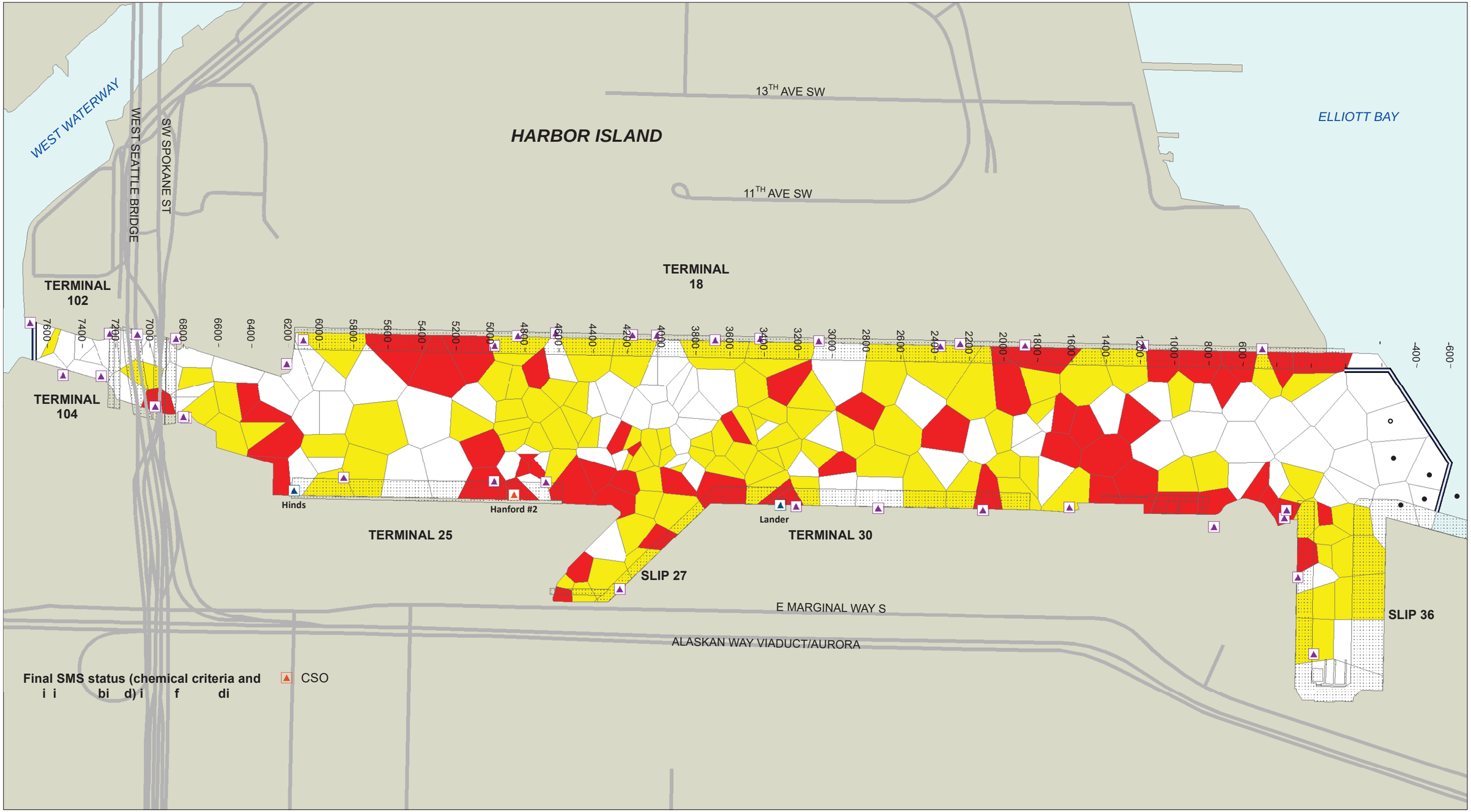
Equations and Parameters Used to Estimate Total PCB Concentrations for Fish in the Arnot and Gobas Model



Sheetpile wall
Exposed riprap
Covered riprap
Sheetpile wall and exposed riprap
Sheetpile wall and covered riprap
Non-tribal clamming areas (public access from upland or walking at low tide)
Tribal clamming and habitat restoration areas (in addition to non-tribal clamming areas)
Dock/Pier/Bridge
Road
East Waterway Study Area Boundary

Figure B-26
East Waterway HHRA Direct Sediment Exposure Areas

Prepared by craigh, 10/3/2013; W:\Projects\00-08-08 East Waterway\EW RI-FS\Data\GIS\FS Support\Fig 3-01 3563 Direct contact sediment exposure areas.mxd



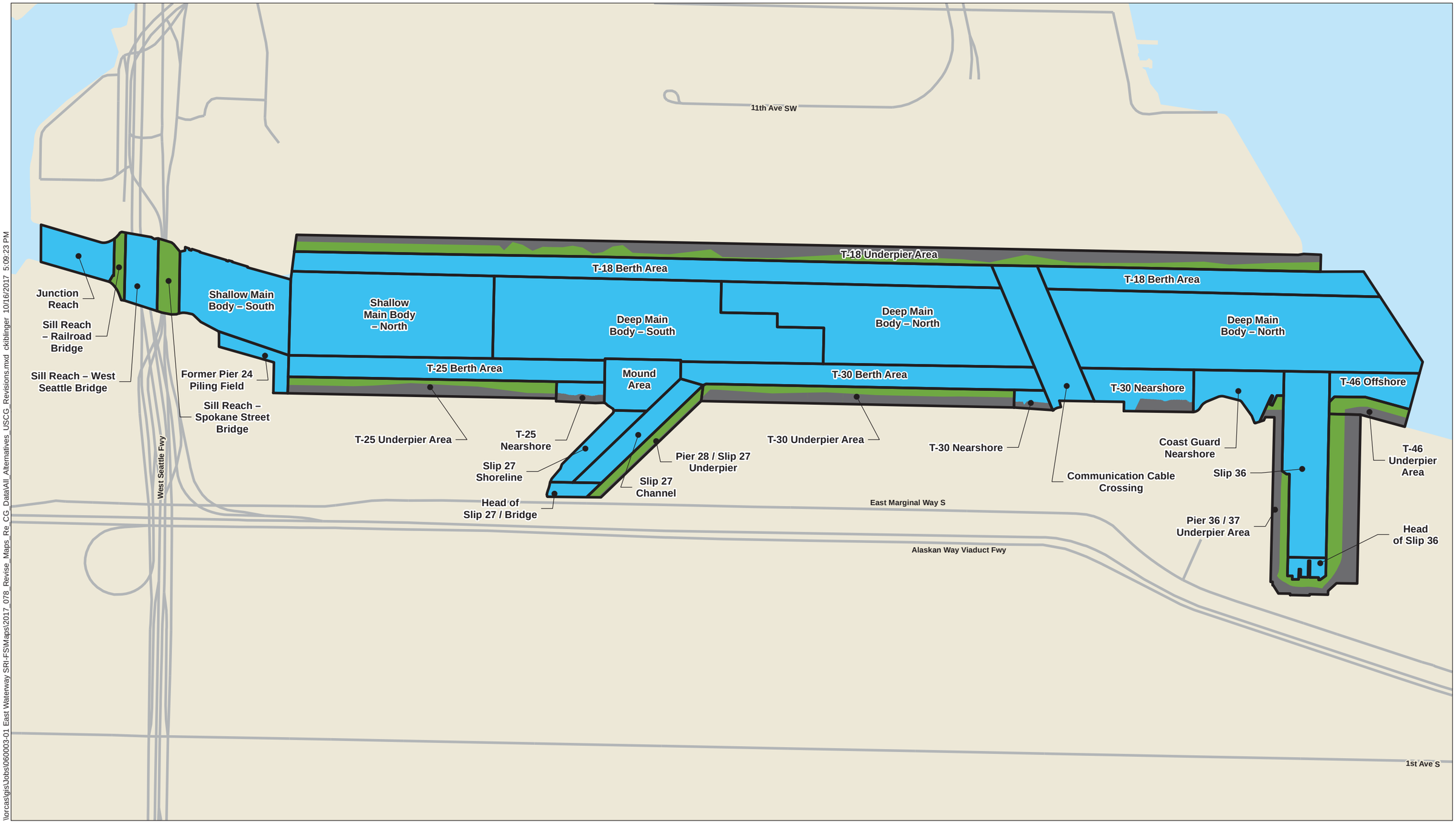
Wind Ward environmental LLC

0 300 600 Feet

0 90 180 Meters

Map B-27 Exceedance of SMS (chemical and toxicity test results combined) using Thiessen Polygons for the Baseline Surface Sediment Dataset

Prepared by craigh, 8/17/2012; W:\Projects\00-08-08 East Waterway\EW RI-FS\Data\GIS\Risk Assessments\ERA\Map A.6-054421 All SMS-DMMP and bioassay trump status Th polys.mxd

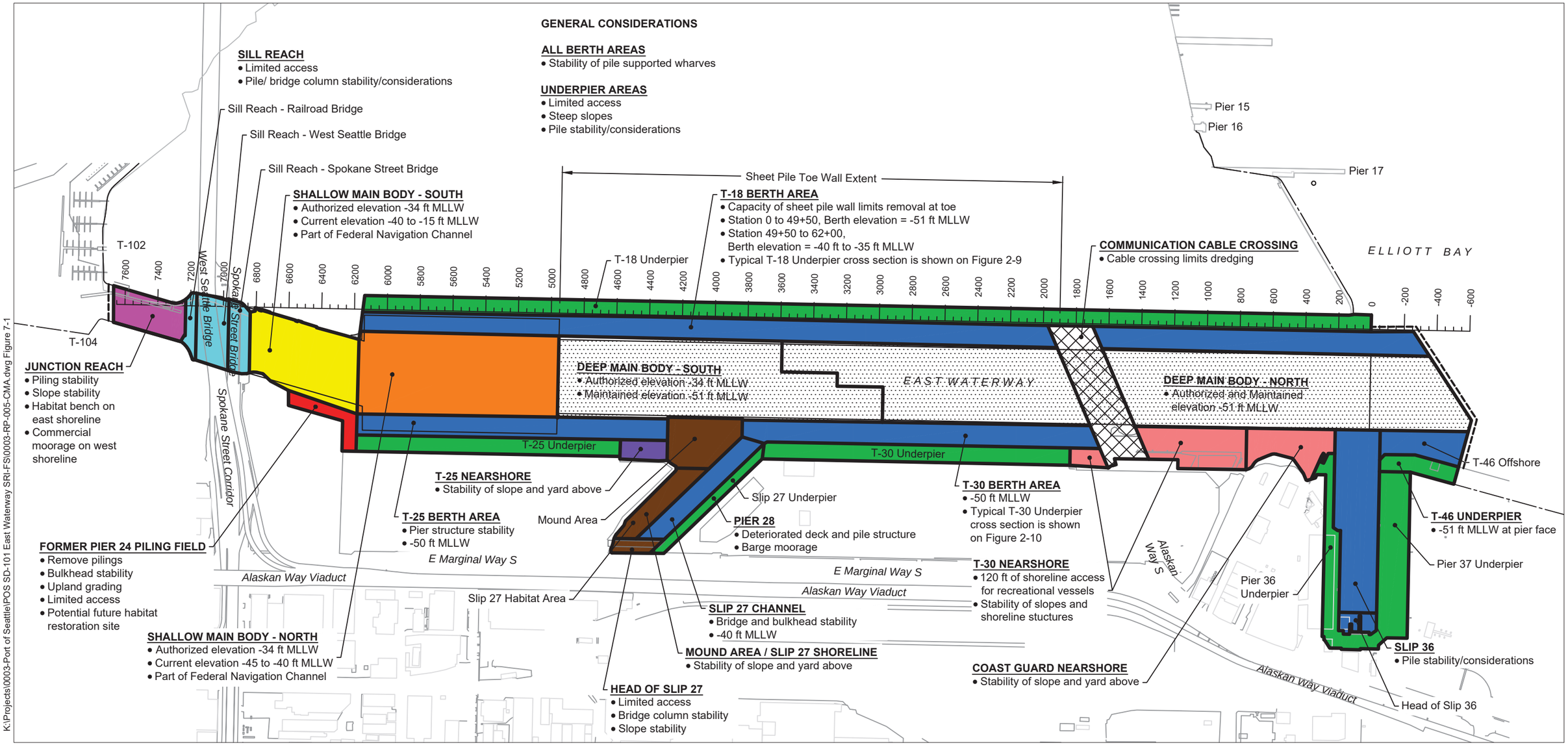


\\orcas\gis\Jobs\060003-01 East Waterway SRI-FS\Maps\2017_078_Revise_Maps_Re_CG_Data\All_Alternatives_USCG_Revisions.mxd ckiblinger 10/16/2017 5:09:23 PM

CMA Boundaries
Limited Access (Underpier and Low Bridge)
Open Water
Riprap (No Action)

0 500 1,000
Scale in Feet

Figure B- 28
Construction Management Area Groups
Feasibility Study
East Waterway Study Area



HORIZONTAL DATUM: Washington State Plane North, NAD83.

NOTES:

1. Previously established station locations for the East Waterway are shown along the western shoreline for reference.
2. Figures 2-9 and 2-10 provide typical underpier cross sections for T-18 and T-30, respectively.

LEGEND:

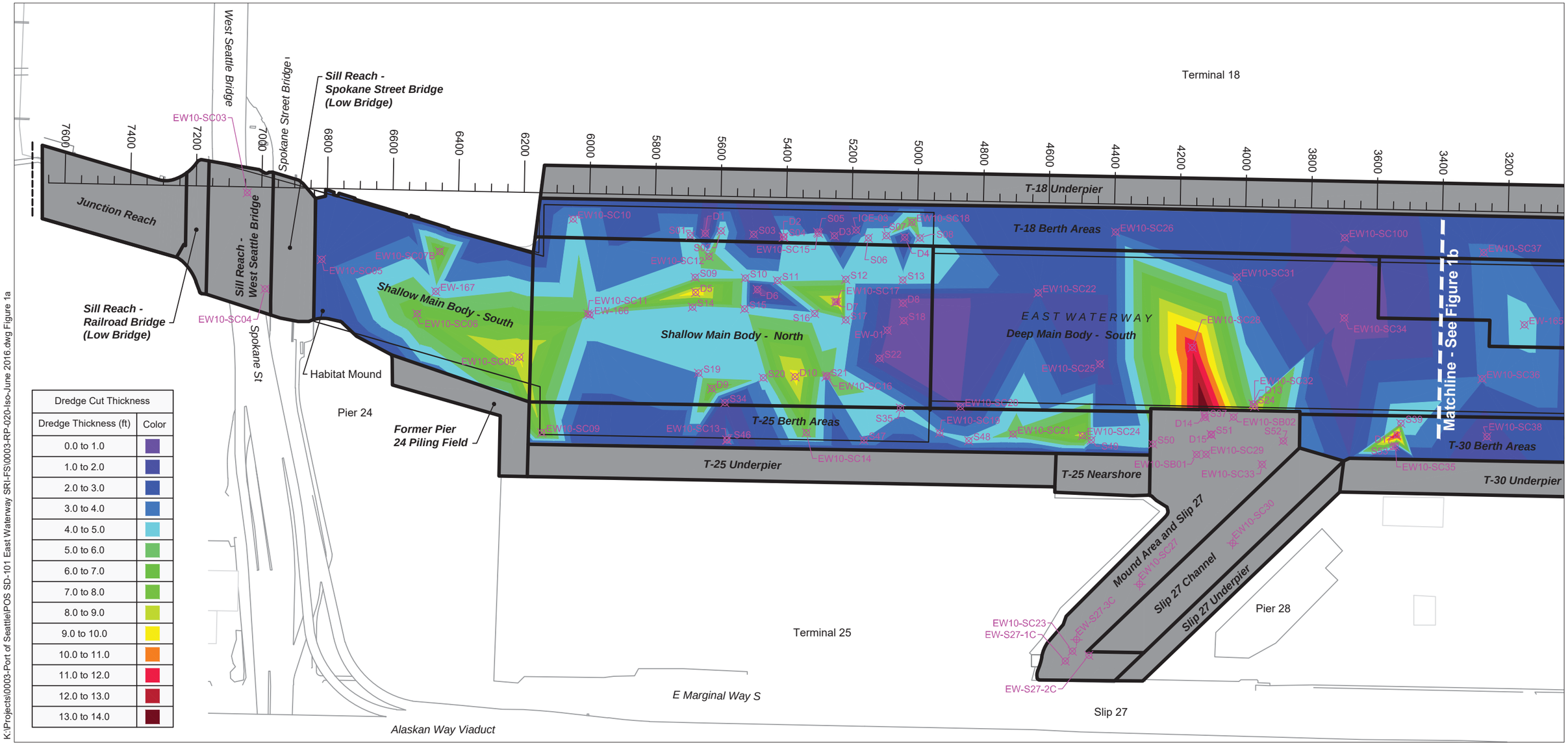
- East Waterway Study Boundary
- MHHW line
- Construction Management Areas
- Deep Draft Berth Areas
- Underpier Areas
- Deep Main Body
- Junction Reach
- Sill Reach
- Shallow Main Body - South
- Shallow Main Body - North
- Mound Area/Slip 27 Shoreline
- T-25 Nearshore
- T-30/Coast Guard Nearshore
- Former Pier 24 Pile Field
- Communication Cable Crossing

0 600
Scale in Feet

N

Figure B-29
Critical Site Restrictions by Construction Management Area

K:\Projects\0003-Port of Seattle\POS SD-101 East Waterway SRI-FS\0003-RP-005-CMA.dwg Figure 7-1
Oct 13, 2017 3:29pm tgrtga



Dredge Cut Thickness	
Dredge Thickness (ft)	Color
0.0 to 1.0	
1.0 to 2.0	
2.0 to 3.0	
3.0 to 4.0	
4.0 to 5.0	
5.0 to 6.0	
6.0 to 7.0	
7.0 to 8.0	
8.0 to 9.0	
9.0 to 10.0	
10.0 to 11.0	
11.0 to 12.0	
12.0 to 13.0	
13.0 to 14.0	

K:\Projects\0003-Port of Seattle\POS SD-101 East Waterway SRI-FS\0003-RP-020-Isc-June 2016.dwg Figure 1a

Aug 07, 2017 10:44am tgriga

HORIZONTAL DATUM: Washington State Plane North, NAD83, U.S. Feet

NOTES:
1. Previously established station locations for the East Waterway are shown along the western shoreline for reference.
2. TIN = Triangulated Irregular Network

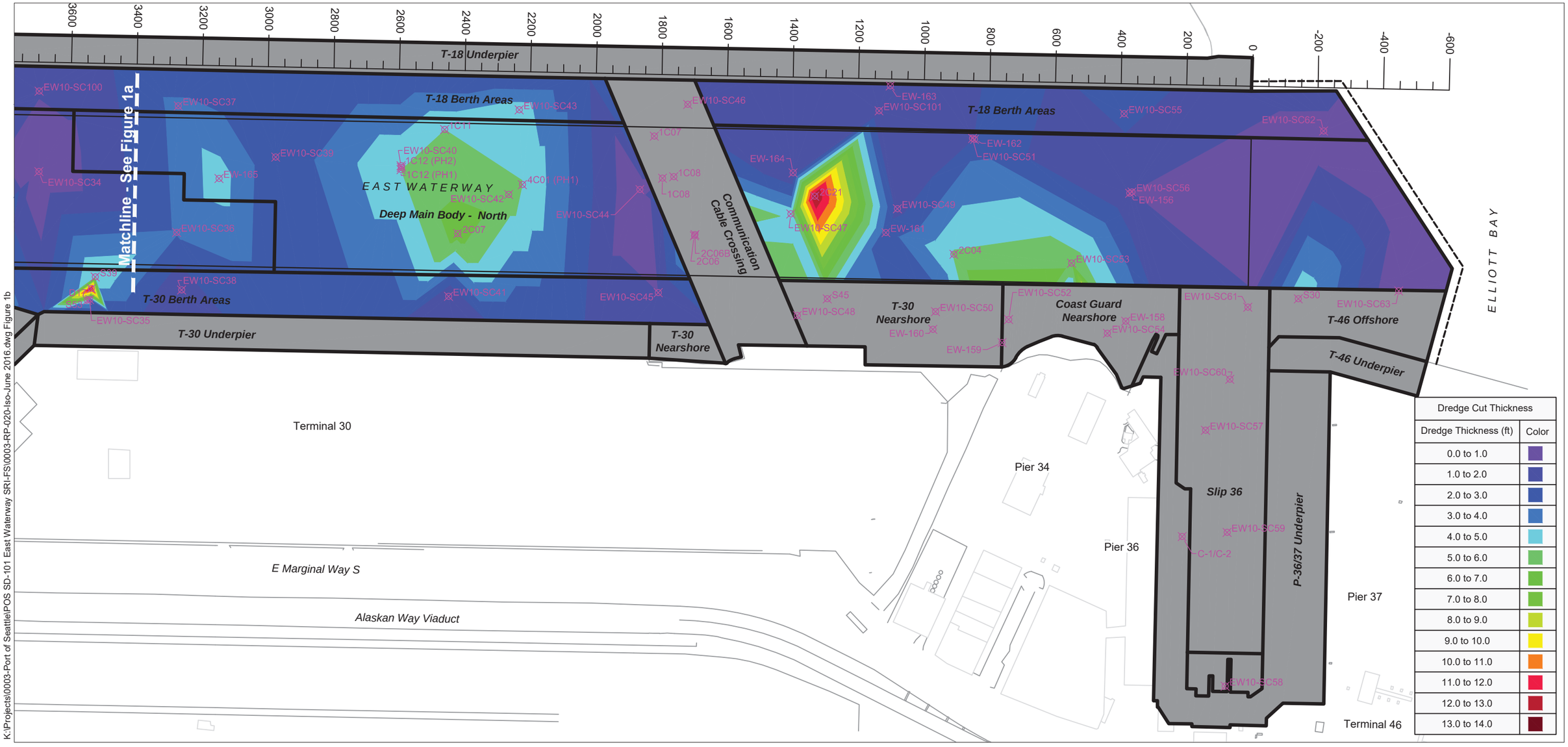
LEGEND:

- East Waterway Study Boundary
- Construction Management Areas
- CMA Areas not included in TIN
- EW-S27-2C Sediment Core

0 300
Scale in Feet

N

Figure B-30a
Full Removal TIN Neatline Isopach (All RALs, PCBs = 12 mg/kg oc)
Feasibility Study - Appendix F
East Waterway Study Area



K:\Projects\0003-Port of Seattle\POS SD-101 East Waterway SRI-FS\0003-RP-020-Iso-June 2016.dwg Figure 1b

Aug 07, 2017 10:44am tgriga

HORIZONTAL DATUM: Washington State Plane North, NAD83, U.S. Feet

NOTES:

1. Previously established station locations for the East Waterway are shown along the western shoreline for reference.
2. TIN = Triangulated Irregular Network

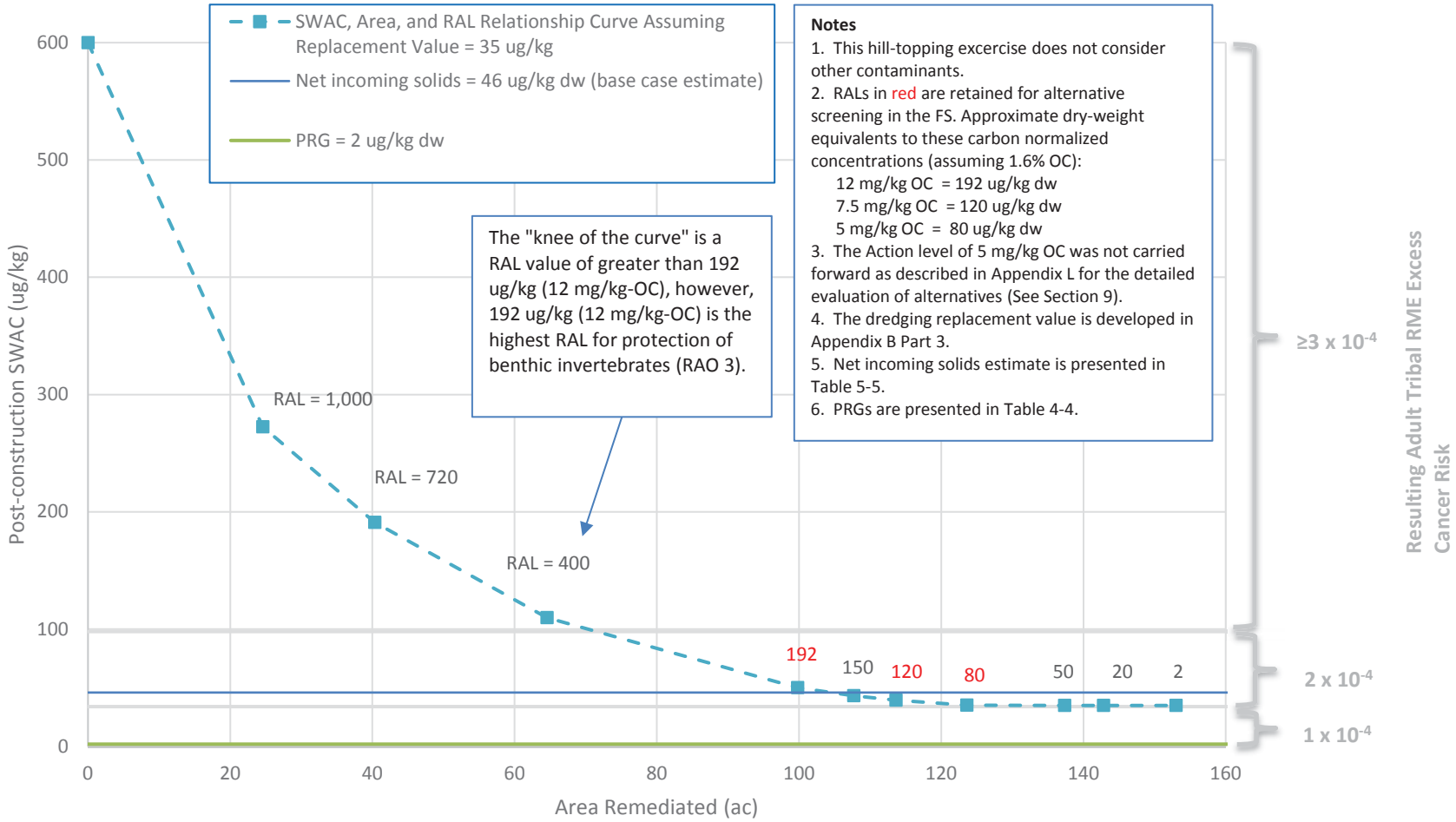
LEGEND:

- East Waterway Study Boundary
- Construction Management Areas
- CMA Areas not included in TIN
- EW-S27-2C Sediment Core

0 300
Scale in Feet

N

Figure B-30b
Full Removal TIN Neatline Isopach (All RALs, PCBs = 12 mg/kg OC)



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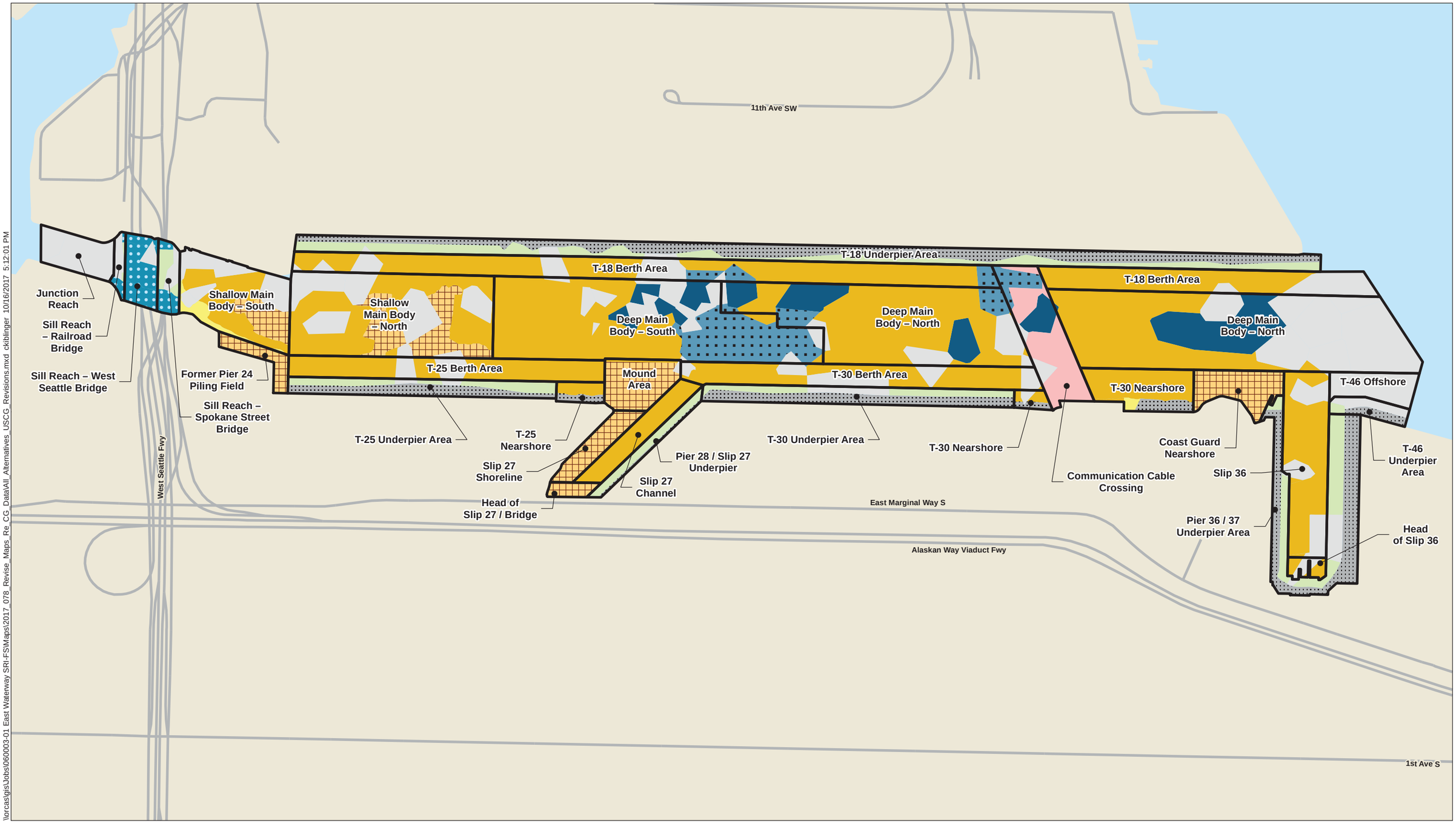
ANCHOR QEA

Figure B-31
PCBs RALs, Remediation Area, and Resulting Post-construction SWACs

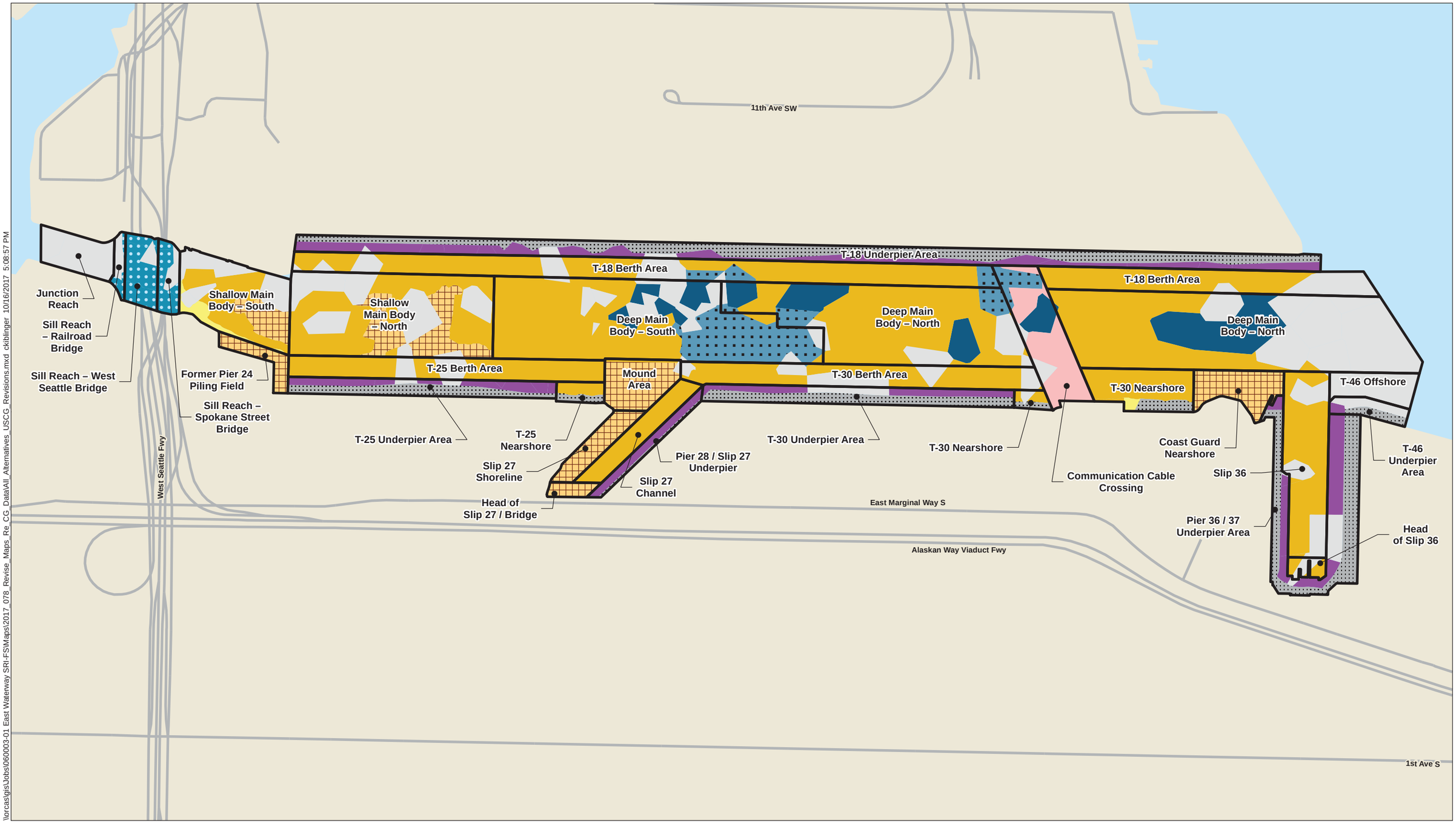


MNR
Removal
Removal and Backfill to Existing Contours
Removal to the Extent Practicable and Backfill
Partial Removal and Cap
Partial Removal and ENR-nav
ENR-sill
ENR-nav
Riprap (No Action)
No Action
CMA Boundaries

0 500 1,000
Scale in Feet

Figure B-32
Alternative 1A(12)
Feasibility Study
East Waterway Study Area

\\orcas\gis\Jobs\060003-01 East Waterway SRI-FS\Maps\2017_078_Revise_Maps_Re_CG_Data\All_Alternatives_USCG_Revisions.mxd ckiblinger 10/16/2017 5:12:01 PM



In Situ Treatment
Removal
Removal and Backfill to Existing Contours
Removal to the Extent Practicable and Backfill
Partial Removal and Cap
Partial Removal and ENR-nav
ENR-sill
ENR-nav
Riprap (No Action)
No Action
CMA Boundaries

0 500 1,000
Scale in Feet

Figure B-33

Alternative 1B(12)
Feasibility Study
East Waterway Study Area

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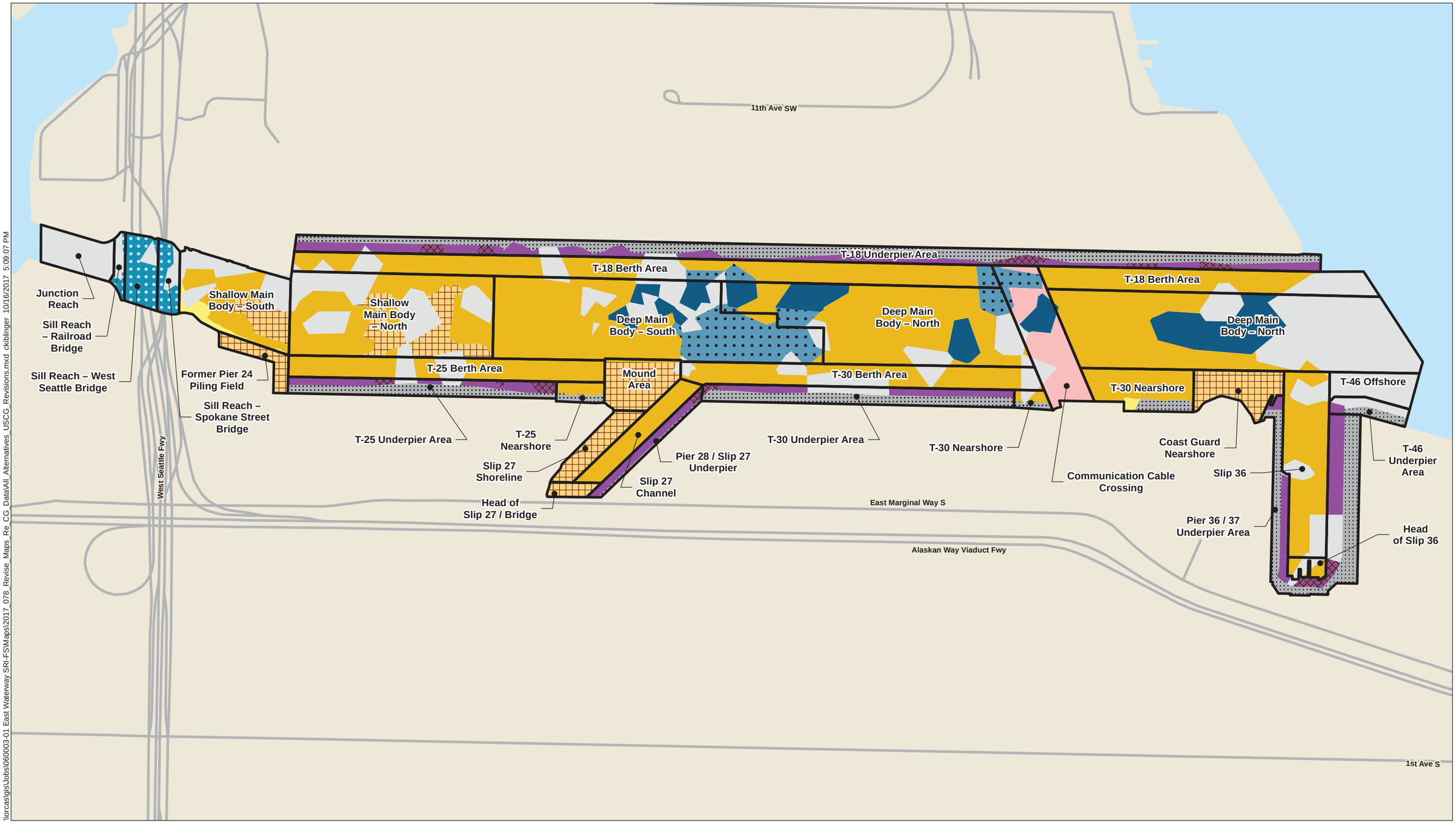


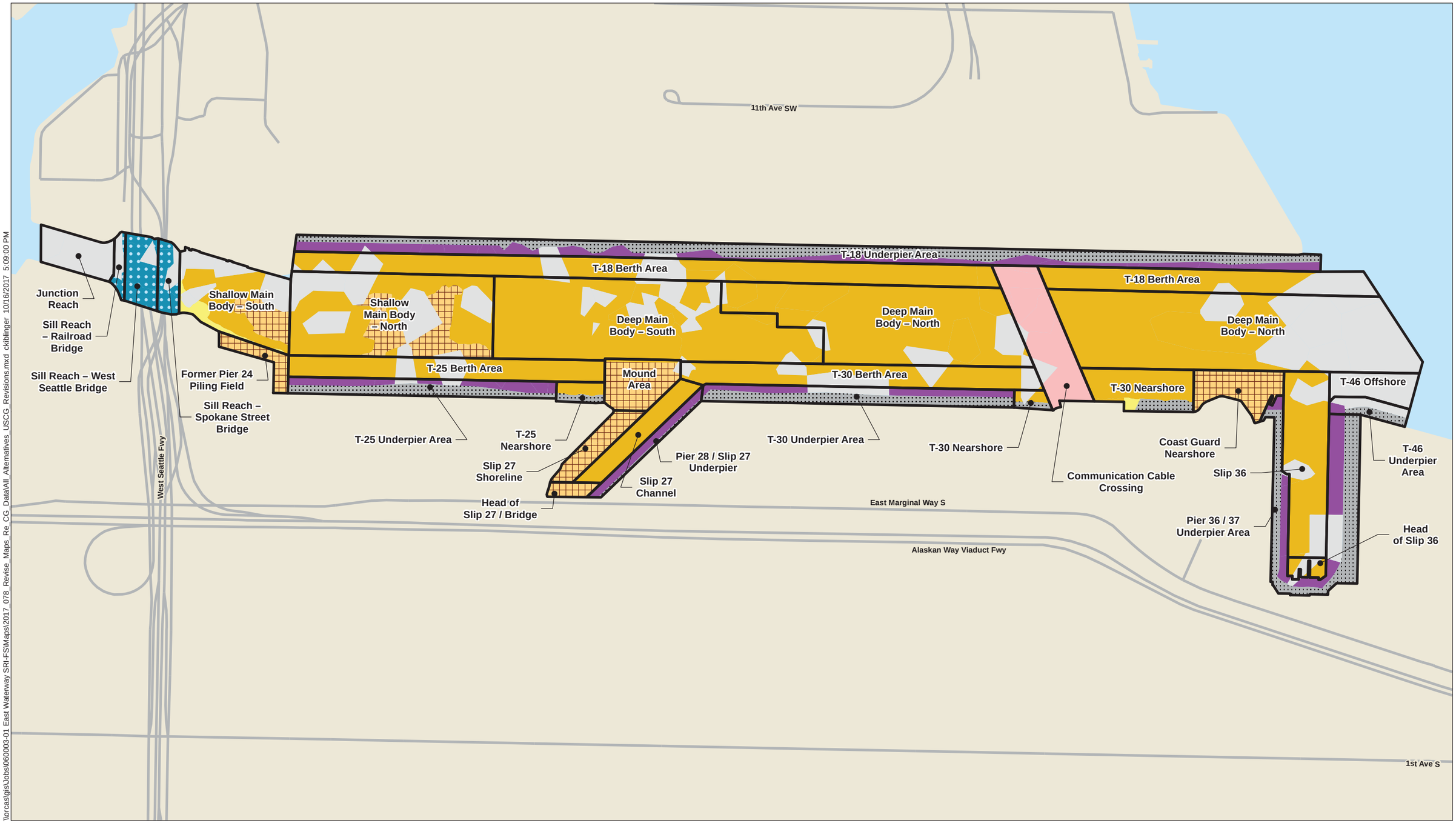
\\orcas\gis\Jobs\060003-01 East Waterway SRI-FS\Maps\2017_078_Revise_Maps_Re_CG_Data\All_Alternatives_USCG_Revisions.mxd ckiblinger 10/16/2017 5:09:07 PM

- Hydraulic Dredging Followed by In Situ Treatment
- In Situ Treatment
- Removal
- Removal and Backfill to Existing Contours
- Removal to the Extent Practicable and Backfill
- Partial Removal and Cap
- Partial Removal and ENR-nav
- ENR-sill
- ENR-nav
- Riprap (No Action)
- No Action
- CMA Boundaries

0 500 1,000
Scale in Feet

Figure B-34

Alternative 1C+(12)
Feasibility Study
East Waterway Study Area



In Situ Treatment
Removal
Removal and Backfill to Existing Contours
Removal to the Extent Practicable and Backfill
Partial Removal and Cap
ENR-sill
Riprap (No Action)
No Action
CMA Boundaries

0 500 1,000
Scale in Feet

Figure B-35

Alternative 2B(12)
Feasibility Study
East Waterway Study Area

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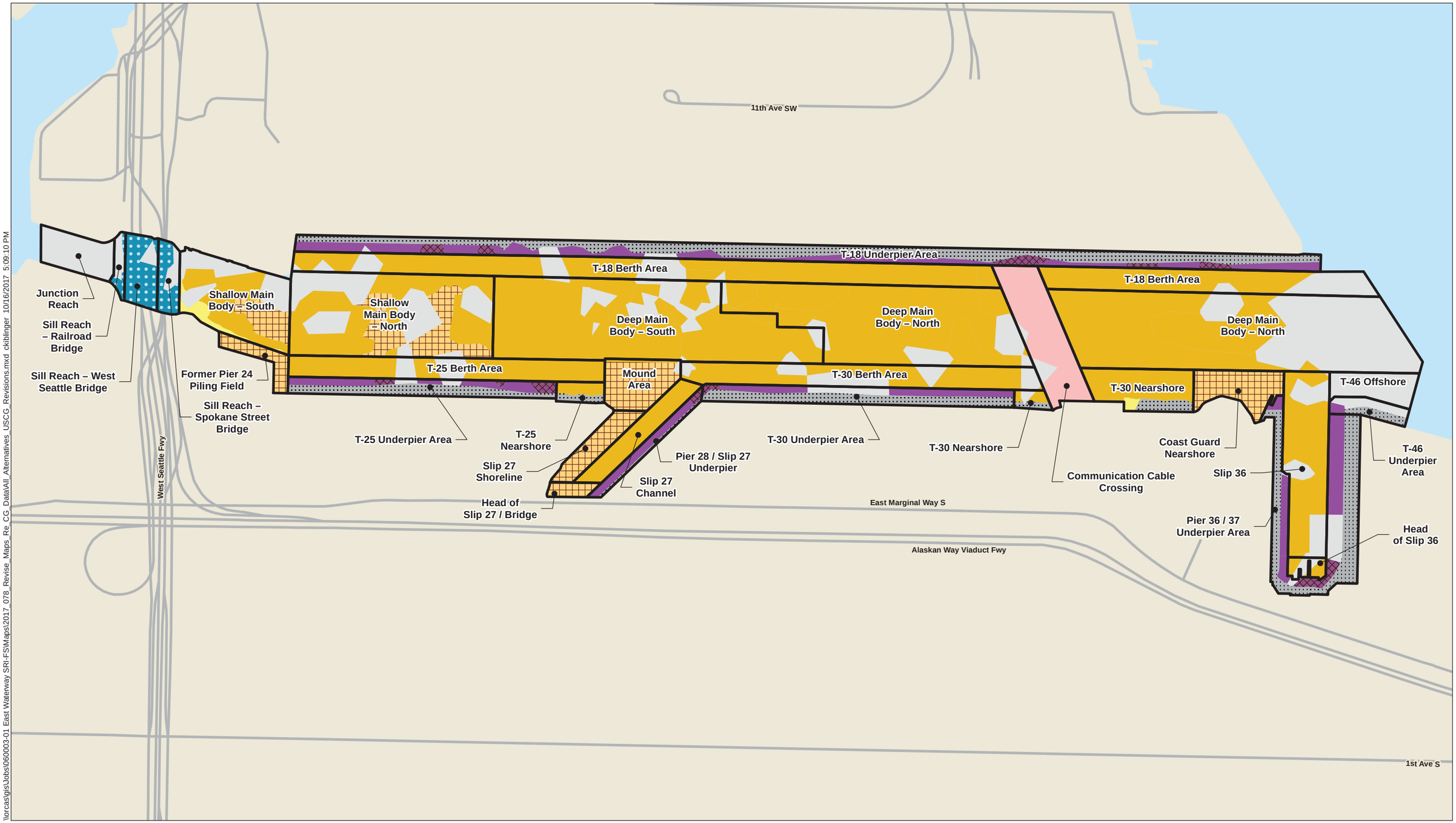

Hydraulic Dredging Followed by In Situ Treatment
In Situ Treatment
Removal
Removal and Backfill to Existing Contours
Removal to the Extent Practicable and Backfill
Partial Removal and Cap
ENR-sill
Riprap (No Action)
No Action
CMA Boundaries

0 500 1,000
Scale in Feet

Figure B-36

Alternative 2C+(12)
Feasibility Study
East Waterway Study Area

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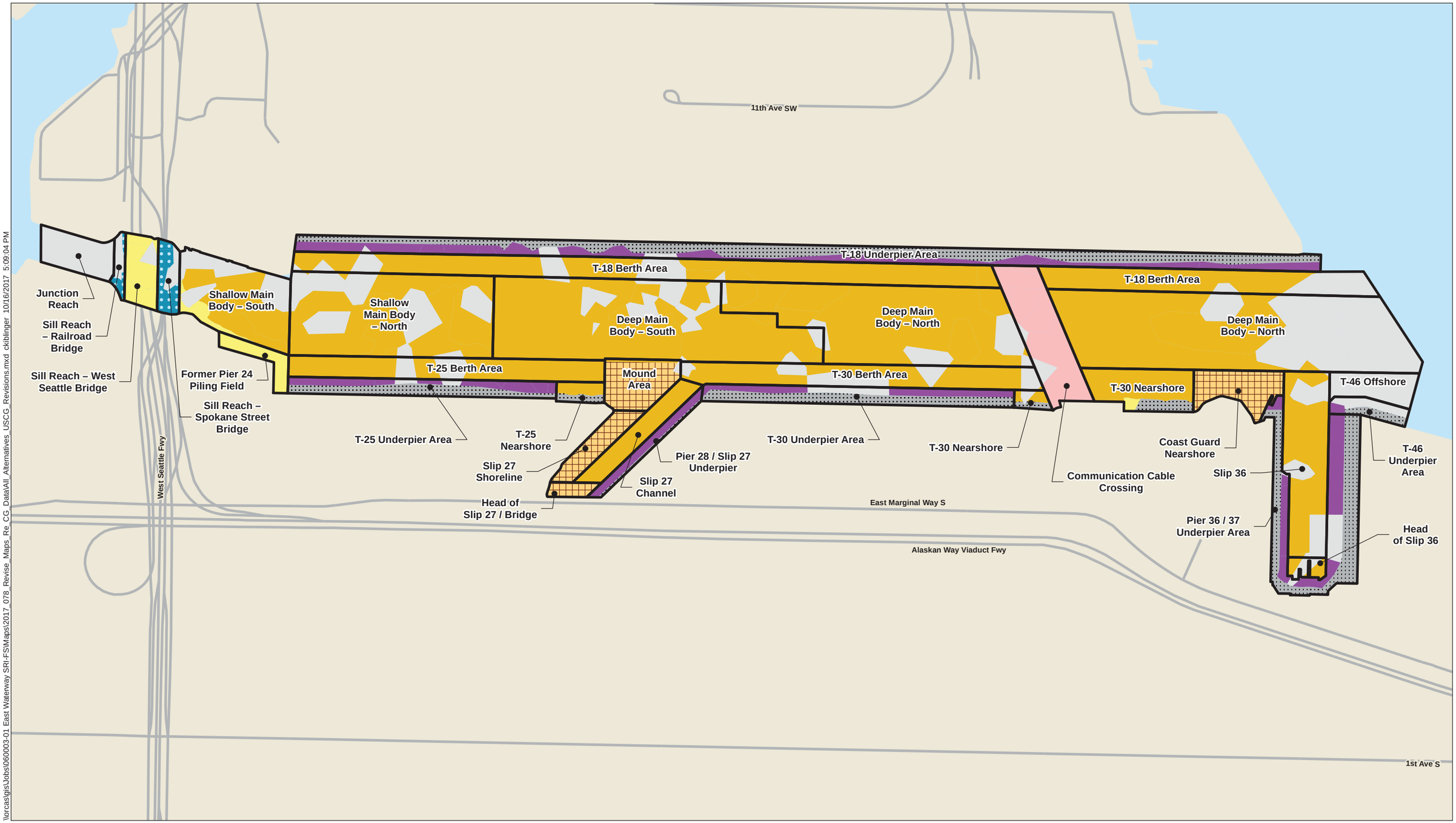


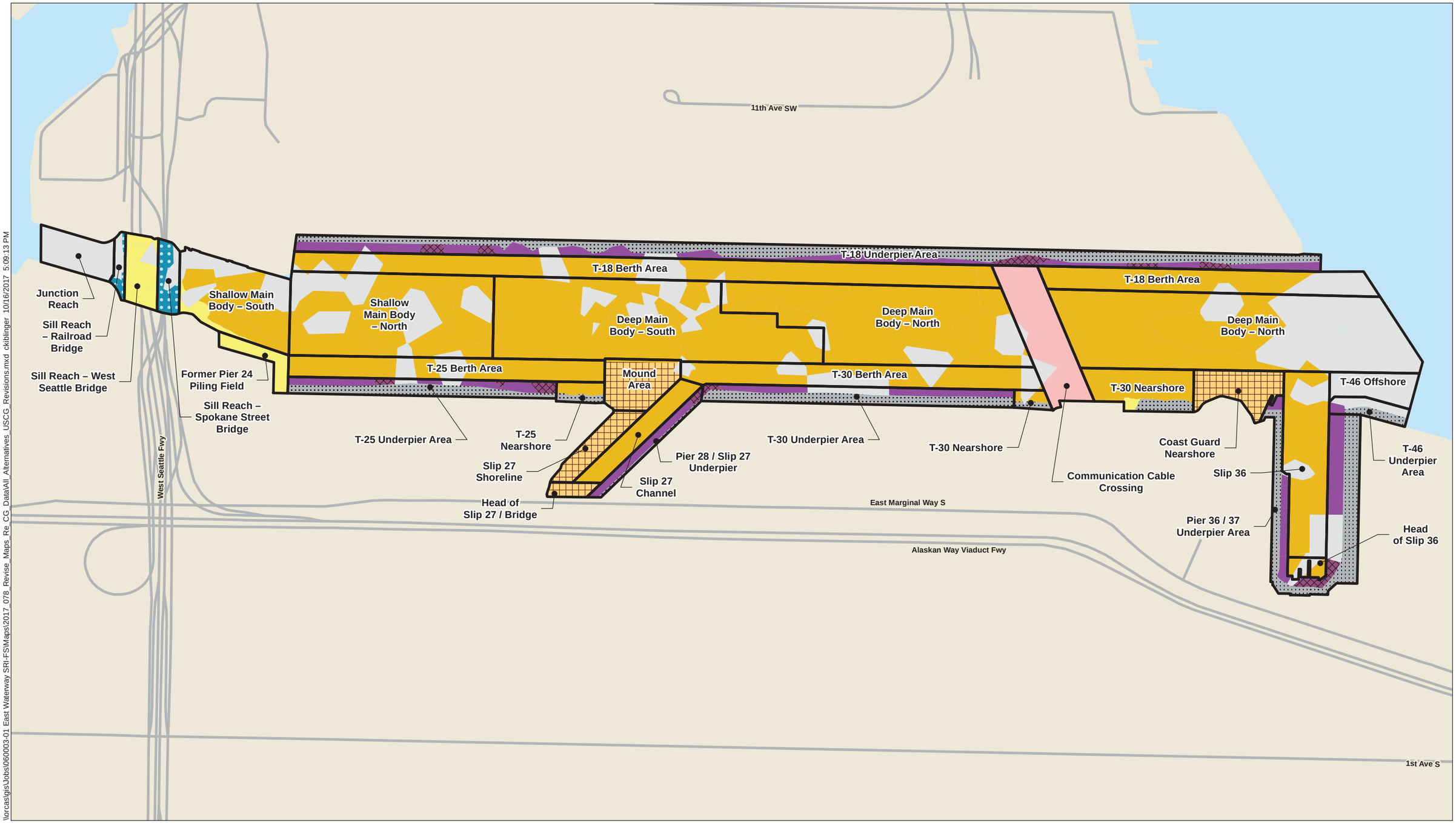
ENR-sill
In Situ Treatment
Removal
Removal and Backfill to Existing Contours
Removal to the Extent Practicable and Backfill
Partial Removal and Cap
Riprap (No Action)
No Action
CMA Boundaries

0 500 1,000
Scale in Feet

Figure B-37

Alternative 3B(12)
Feasibility Study
East Waterway Study Area

\\orcas\gis\Jobs\060003-01 East Waterway SRI-FS\Maps\2017_078_Revise_Maps_Re_CG_Data\All_Alternatives_USCG_Revisions.mxd ckiblinger 10/16/2017 5:09:04 PM



Hydraulic Dredging Followed by In Situ Treatment
ENR-sill
In Situ Treatment
Removal
Removal and Backfill to Existing Contours
Removal to the Extent Practicable and Backfill
Partial Removal and Cap
Riprap (No Action)
No Action
CMA Boundaries

0 500 1,000
Scale in Feet

Figure B-38

Alternative 3C+(12)
Feasibility Study
East Waterway Study Area

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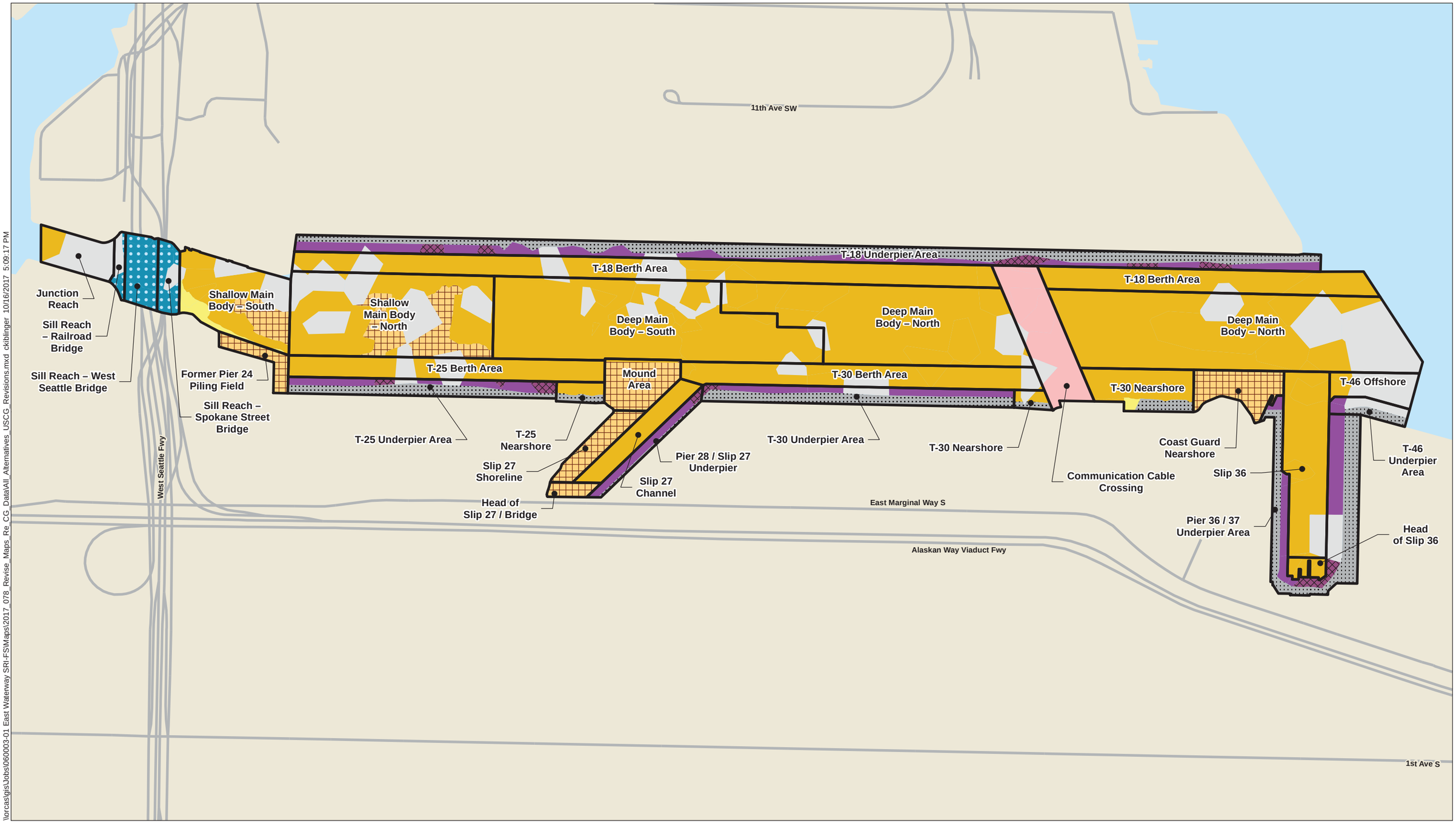

Hydraulic Dredging Followed by In Situ Treatment
In Situ Treatment
Removal
Removal and Backfill to Existing Contours
Removal to the Extent Practicable and Backfill
Partial Removal and Cap
ENR-sill
Riprap (No Action)
No Action
CMA Boundaries

0 500 1,000
Scale in Feet

Figure B-39

Alternative 2C+(7.5)
Feasibility Study
East Waterway Study Area

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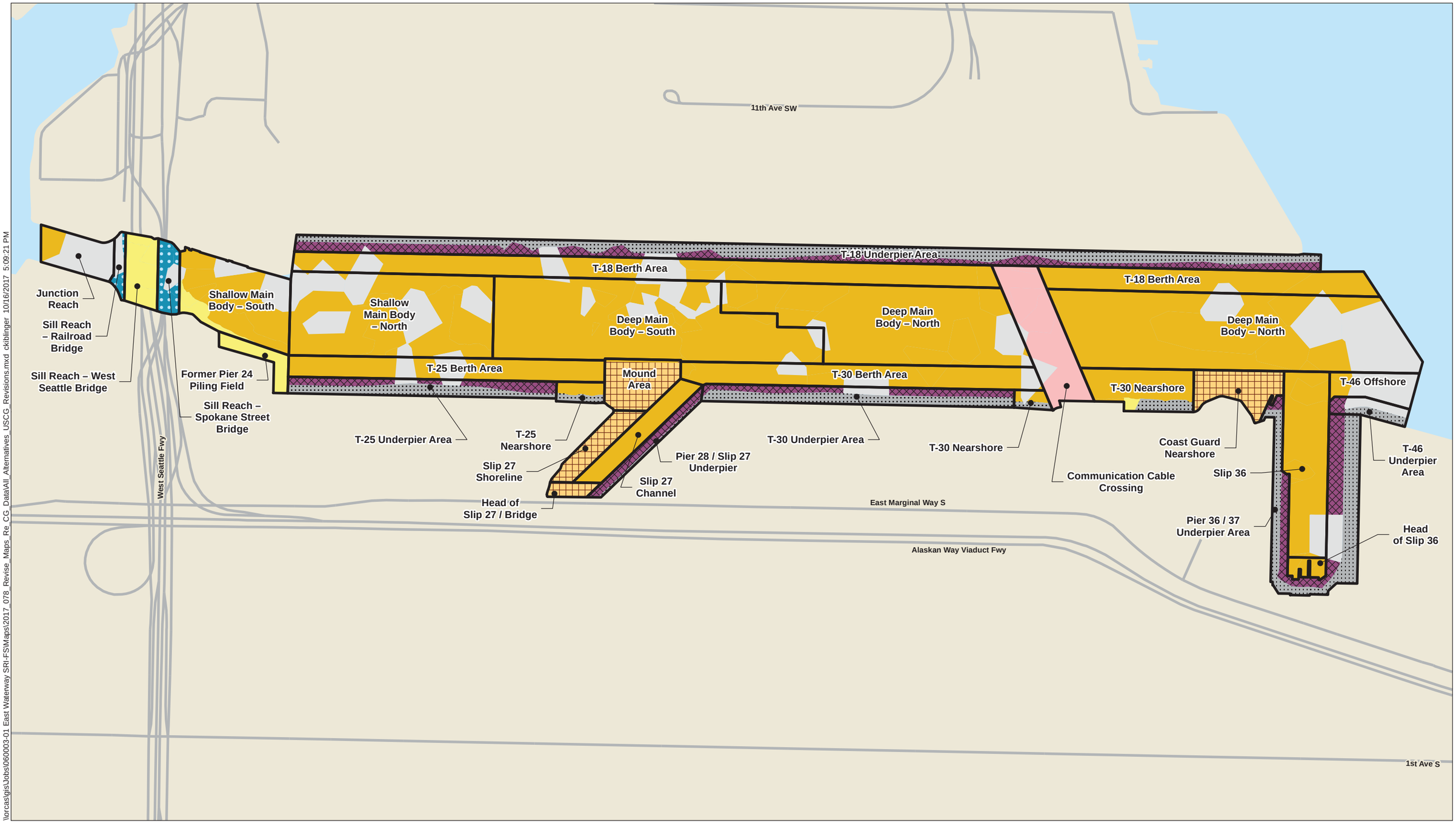

Hydraulic Dredging followed by in situ Treatment
Removal
Removal and Backfill to Existing Contours
Removal to the Extent Practicable and Backfill
Partial Removal and Cap
ENR-sill
Riprap (No Action)
No Action
CMA Boundaries

0 500 1,000
Scale in Feet

Figure B-40

Alternative 3E(7.5)
Feasibility Study
East Waterway Study Area

\\orcas\gis\Jobs\060003-01 East Waterway SRI-FS\Maps\2017_078_Revise_Maps_Re_CG_Data\All_Alternatives_USCG_Revisions.mxd ckiblinger 10/16/2017 5:09:21 PM

	Achieve Threshold Criteria?	Long-term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume Through Treatment	Short-term Effectiveness	Implementability	Cost
No Action	No	⌄⌄	⌄⌄	⌄⌄	⌃⌃	⌃⌃
1A(12)	Yes	I	⌄⌄	⌄	⌃	⌃
1B(12)	Yes	⌃	⌃⌃	⌃⌃	I	⌃
1C+(12)	Yes	⌃	⌃⌃	⌃	⌄	I
2B(12)	Yes	⌃⌃	⌃⌃	⌃	I	I
2C+(12)	Yes	⌃⌃	⌃⌃	I	⌄	I
3B(12)	Yes	⌃⌃	⌃⌃	⌃	I	I
3C+(12)	Yes	⌃⌃	⌃⌃	I	⌄	⌄
2C+(7.5)	Yes	⌃⌃	⌃⌃	⌄	⌄	⌄
3E(7.5)	Yes	⌃⌃	⌃⌃	⌄⌄	⌄⌄	⌄⌄

- ⌃⌃ Ranks very high compared to other alternatives
- ⌃ Ranks relatively high compared to other alternatives
- I Ranks moderate compared to other alternatives
- ⌄ Ranks low-moderate compared to other alternatives
- ⌄⌄ Ranks low compared to other alternatives

Notes:

Low costs are given a high rank, and high costs are given a low rank.

CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act

Figure B-41
CERCLA Comparative Analysis of Alternatives
Feasibility Study
East Waterway Study Area

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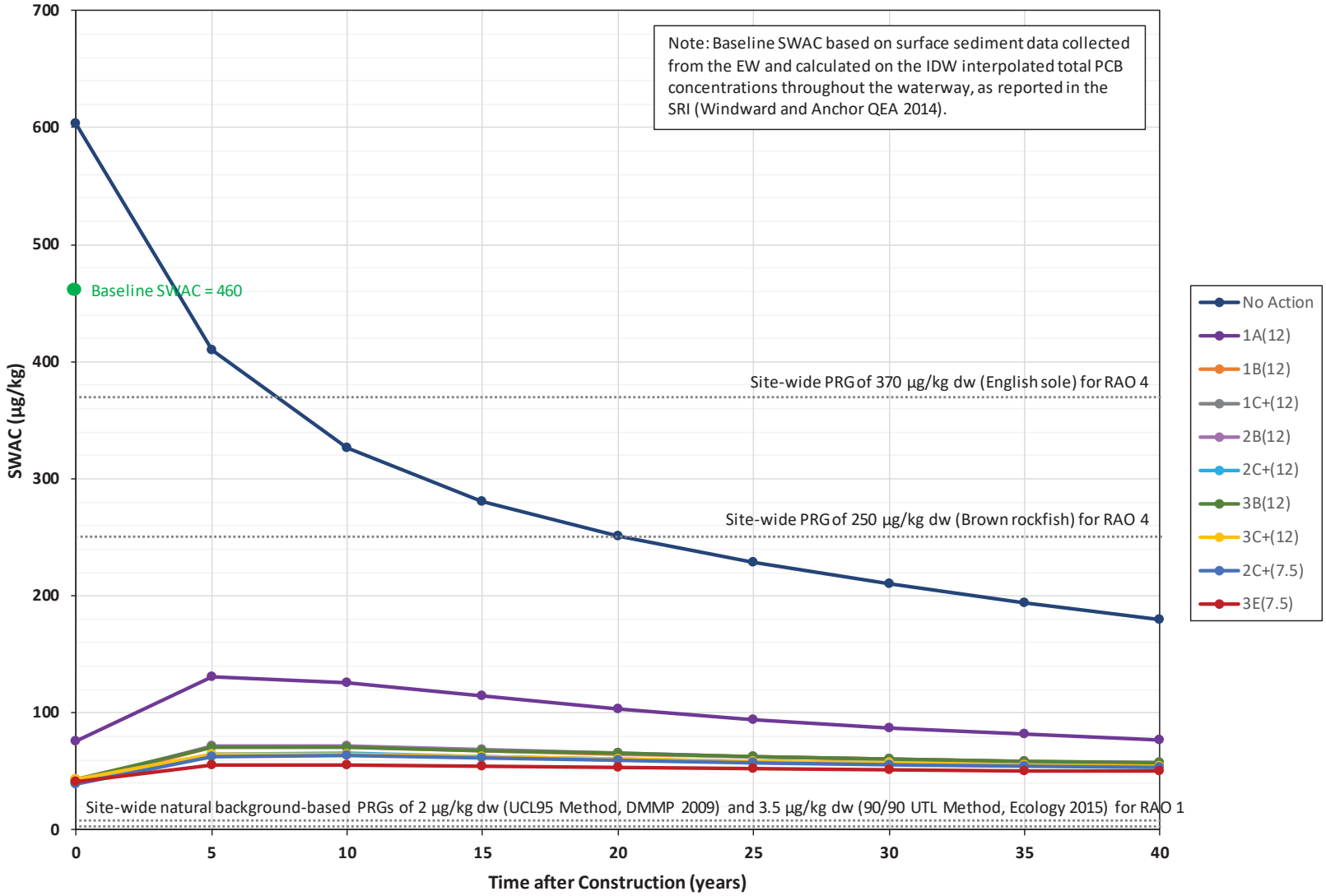

90/90 UTL = 90% upper tolerance limit confidence bound on the 90th percentile of the distribution
µg/kg = microgram per kilogram
dw = dry weight
IDW = inverse distance weighting
PCB = polychlorinated biphenyl
RAO = remedial action objective
SRI = Supplemental Remedial Investigation
SWAC = spatially-weighted average concentration
PRG = preliminary remediation goal
UCL95 = 95% upper confidence limit on the mean

Figure B-42a
Predicted Site-wide SWAC for Total PCBs Over Time
Feasibility Study
East Waterway Study Area

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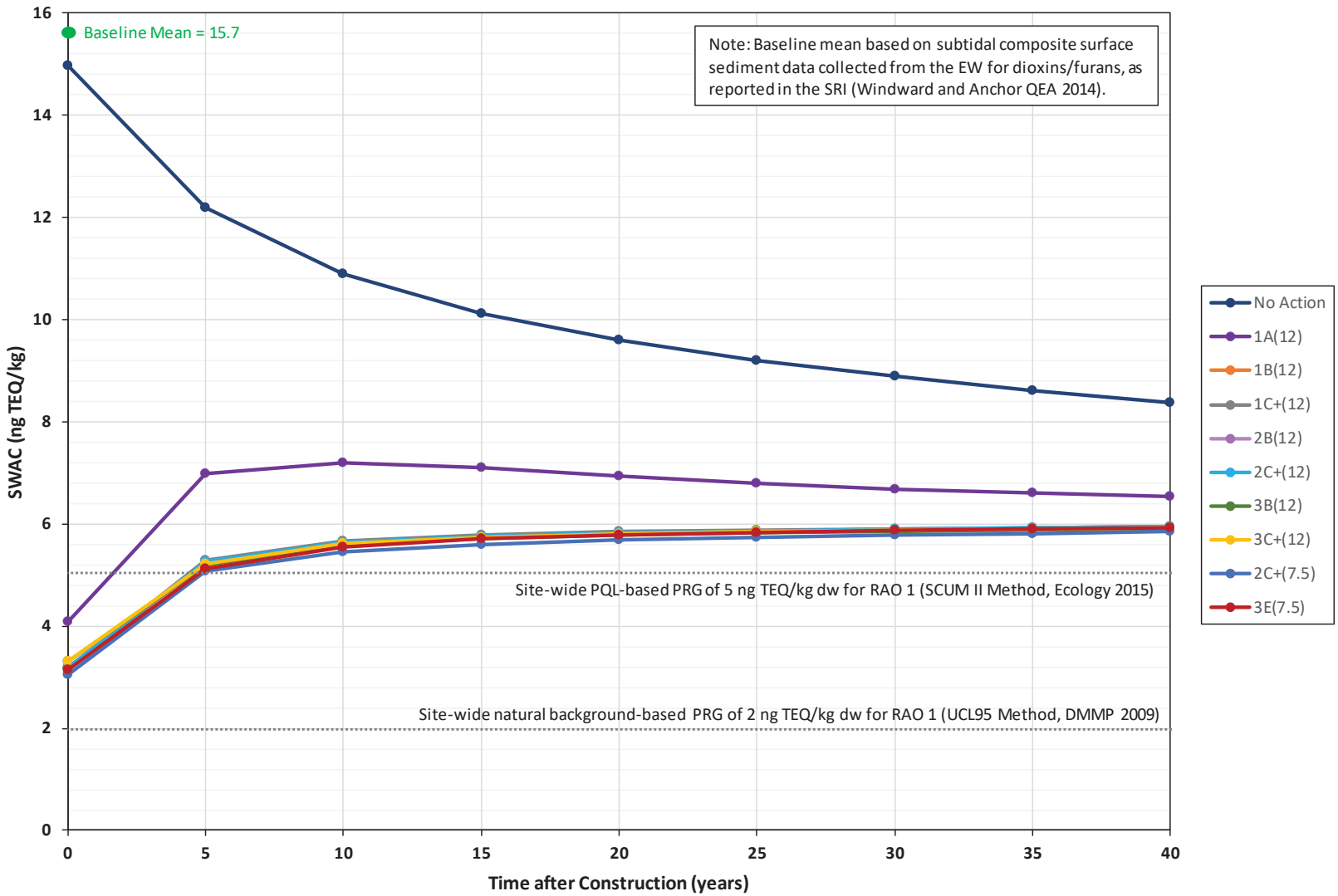

dw = dry weight
kg = kilogram
ng = nanogram
PQL = practical quantitation limit
PRG = preliminary remediation goal
RAO = remedial action objective

SCUM II = Sediment Cleanup User's Manual II
SRI = Supplemental Remedial Investigation
SWAC = spatially-weighted average concentration
TEQ = toxic equivalent
UCL95 = 95% upper confidence limit on the mean

Figure B-42b
Predicted Site-wide SWAC for Dioxins/Furans Over Time
Feasibility Study
East Waterway Study Area

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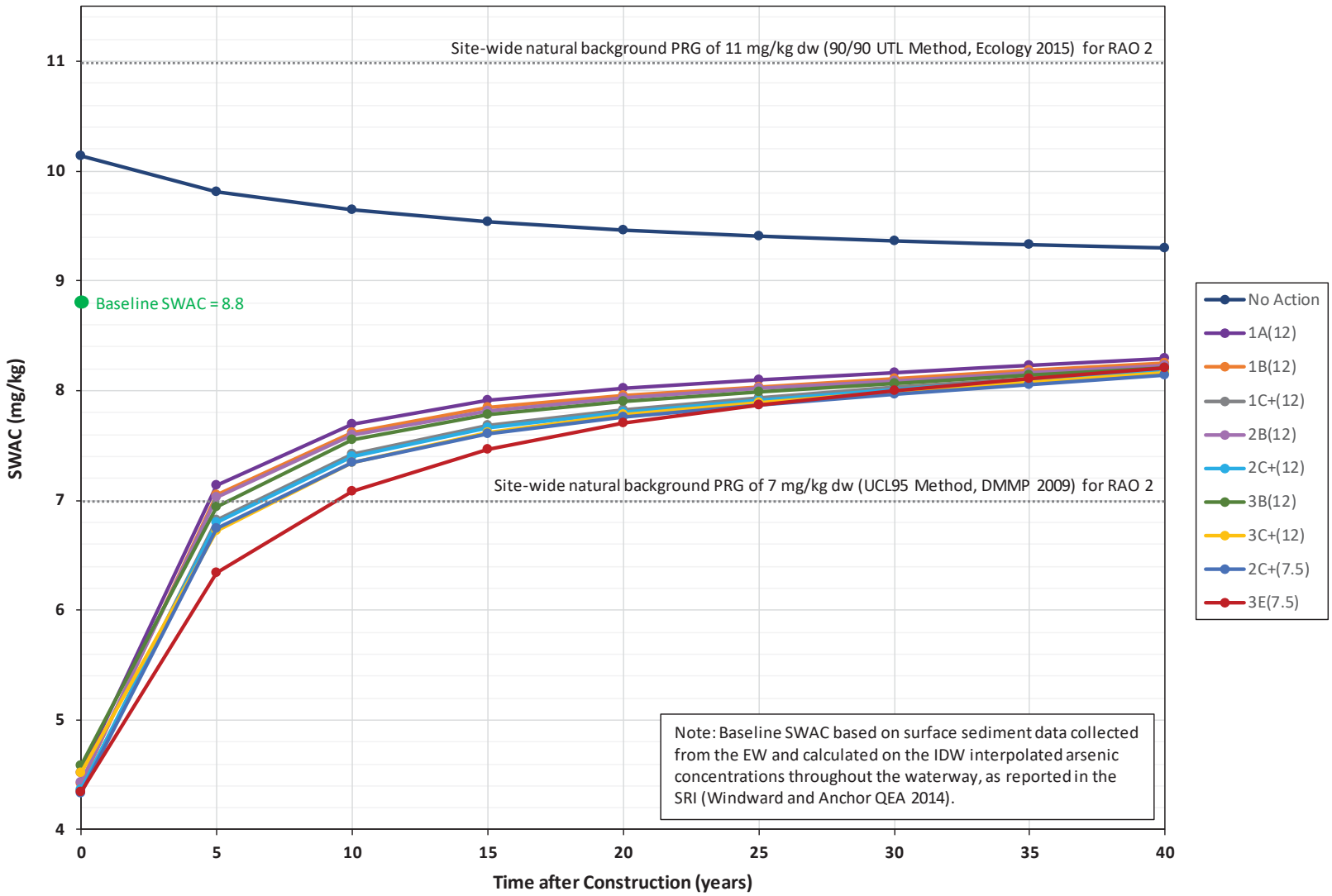

90/90 UTL = 90% upper tolerance limit confidence bound on the 90th percentile of the distribution
dw = dry weight
mg/kg = milligram per kilogram
PRG = preliminary remediation goal
RAO = remedial action objective
SRI = Supplemental Remedial Investigation
SWAC = spatially-weighted average concentration
UCL95 = 95% upper confidence limit on the mean

Figure B-42c
Predicted Site-wide SWAC for Arsenic Over Time
Feasibility Study
East Waterway Study Area

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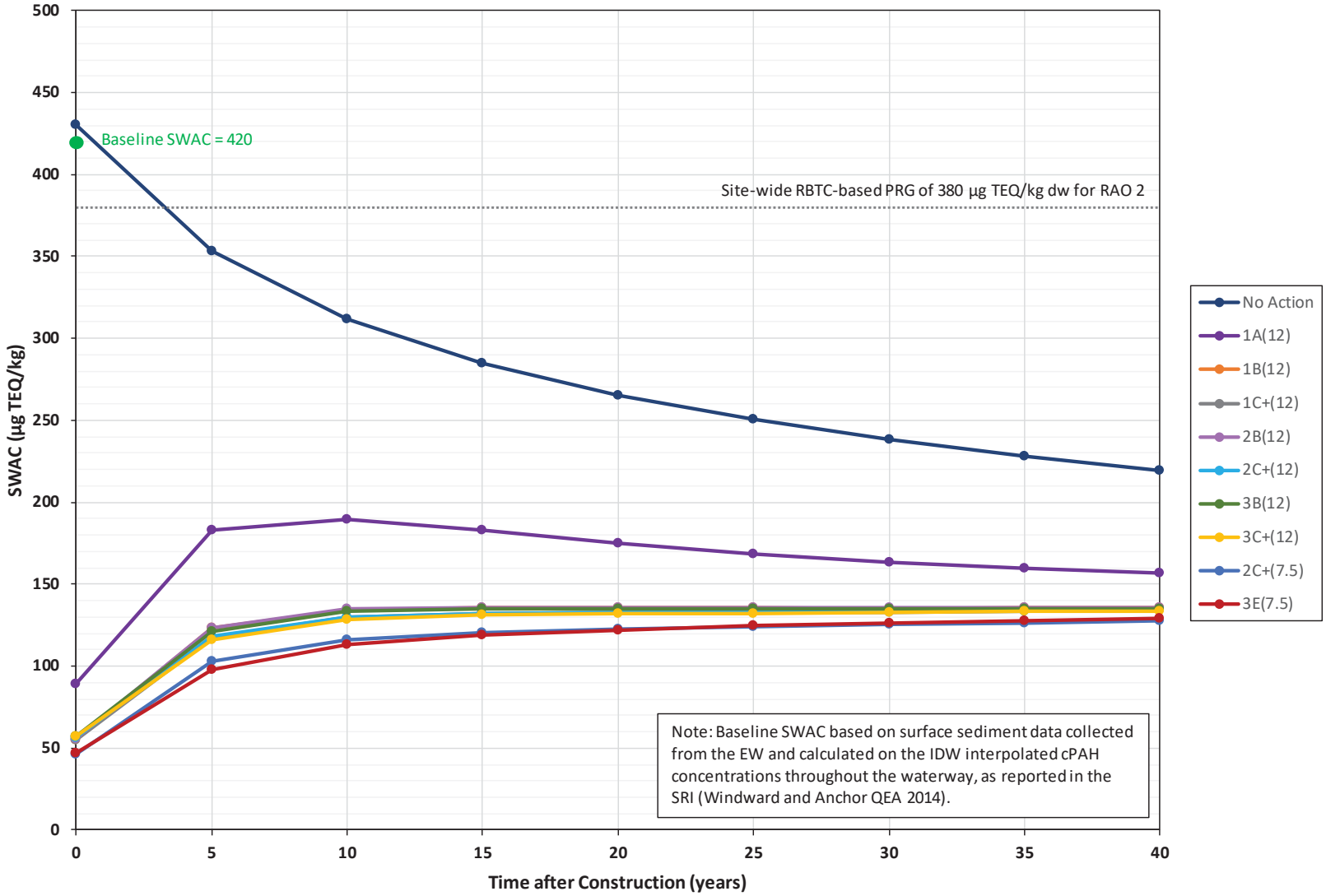

µg = microgram
cPAH = carcinogenic polycyclic aromatic hydrocarbon
dw = dry weight
kg = kilogram
PRG = preliminary remediation goal
RAO = remedial action objective
RBTC = risk-based threshold concentration
SRI = Supplemental Remedial Investigation
SWAC = spatially-weighted average concentration
TEQ = toxic equivalent

Figure B-42d
Predicted Site-wide SWAC for cPAHs Over Time
Feasibility Study
East Waterway Study Area

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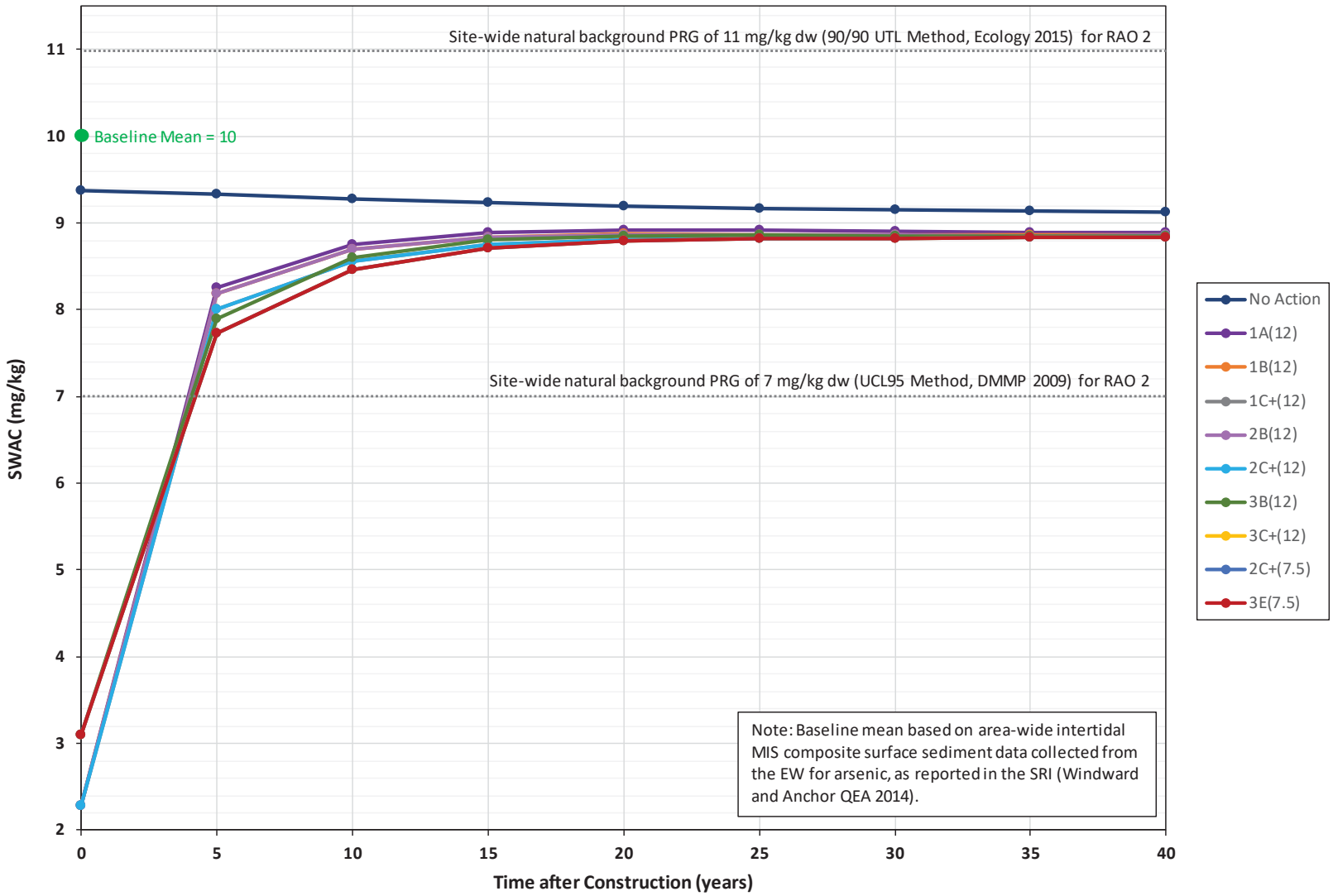

90/90 UTL = 90% upper tolerance limit confidence bound on the 90th percentile of the distribution
dw = dry weight
mg/kg = milligram per kilogram
PRG = preliminary remediation goal
RAO = remedial action objective
SRI = Supplemental Remedial Investigation
SWAC = spatially-weighted average concentration
UCL95 = 95% upper confidence limit on the mean

Figure B-43a
Predicted Clamming Area SWAC for Arsenic Over Time

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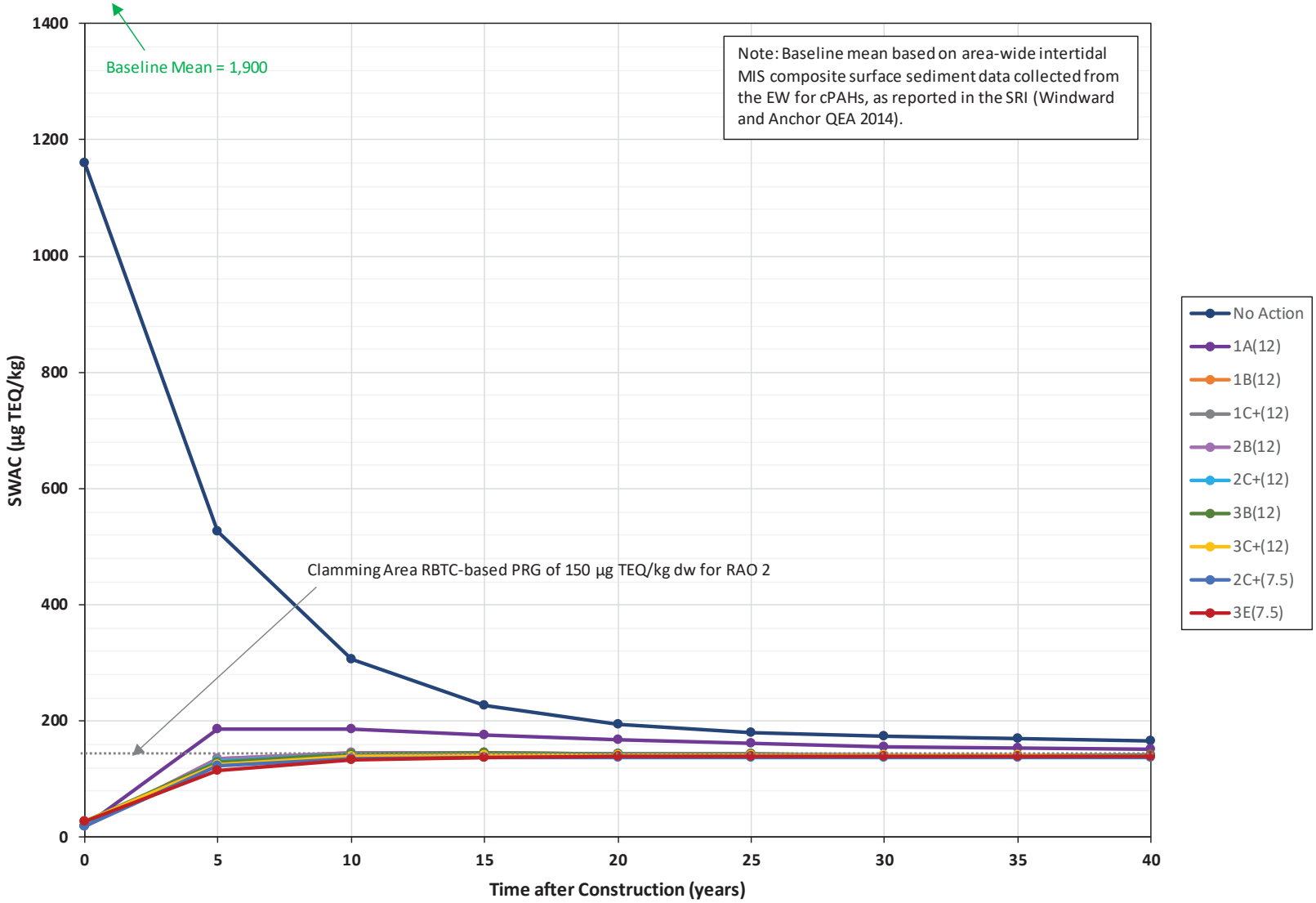

µg = microgram
cPAH = carcinogenic polycyclic aromatic hydrocarbon
dw = dry weight
kg = kilogram
PRG = preliminary remediation goal
RAO = remedial action objective
RBTC = risk-based threshold concentration
SRI = Supplemental Remedial Investigation
SWAC = spatially-weighted average concentration
TEQ = toxic equivalent

Figure B-43b
Predicted Clamming Area SWAC for cPAHs Over Time

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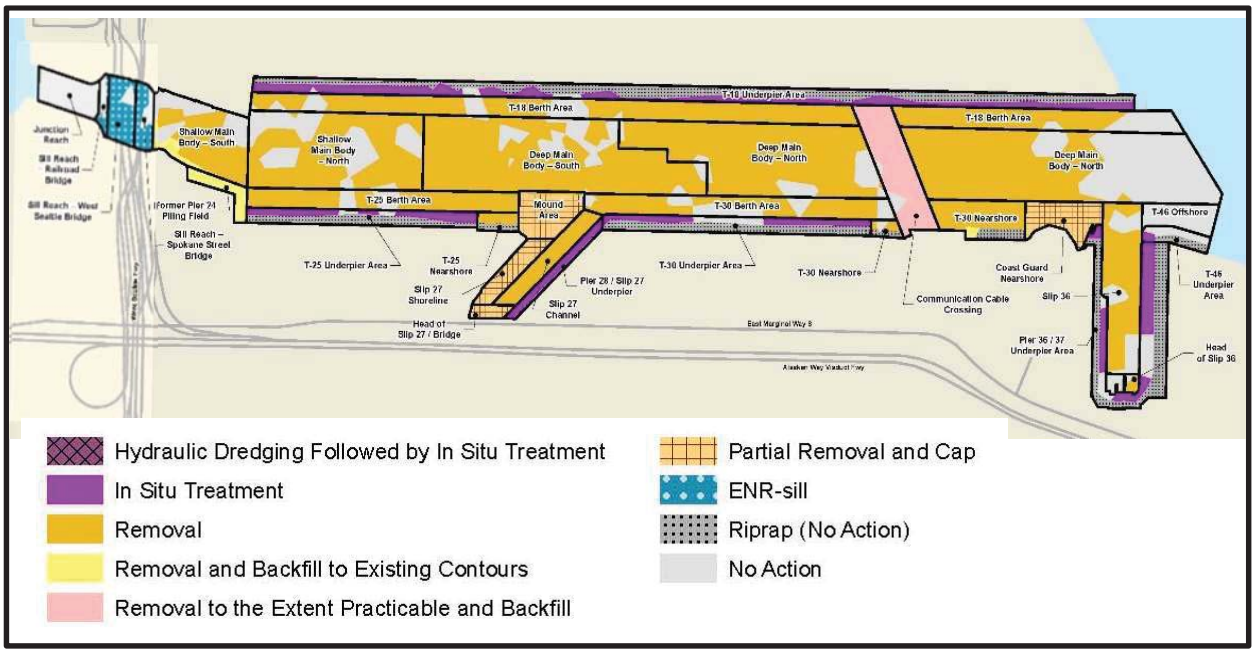

Figure B-44. Alternative 2B/3B(12)

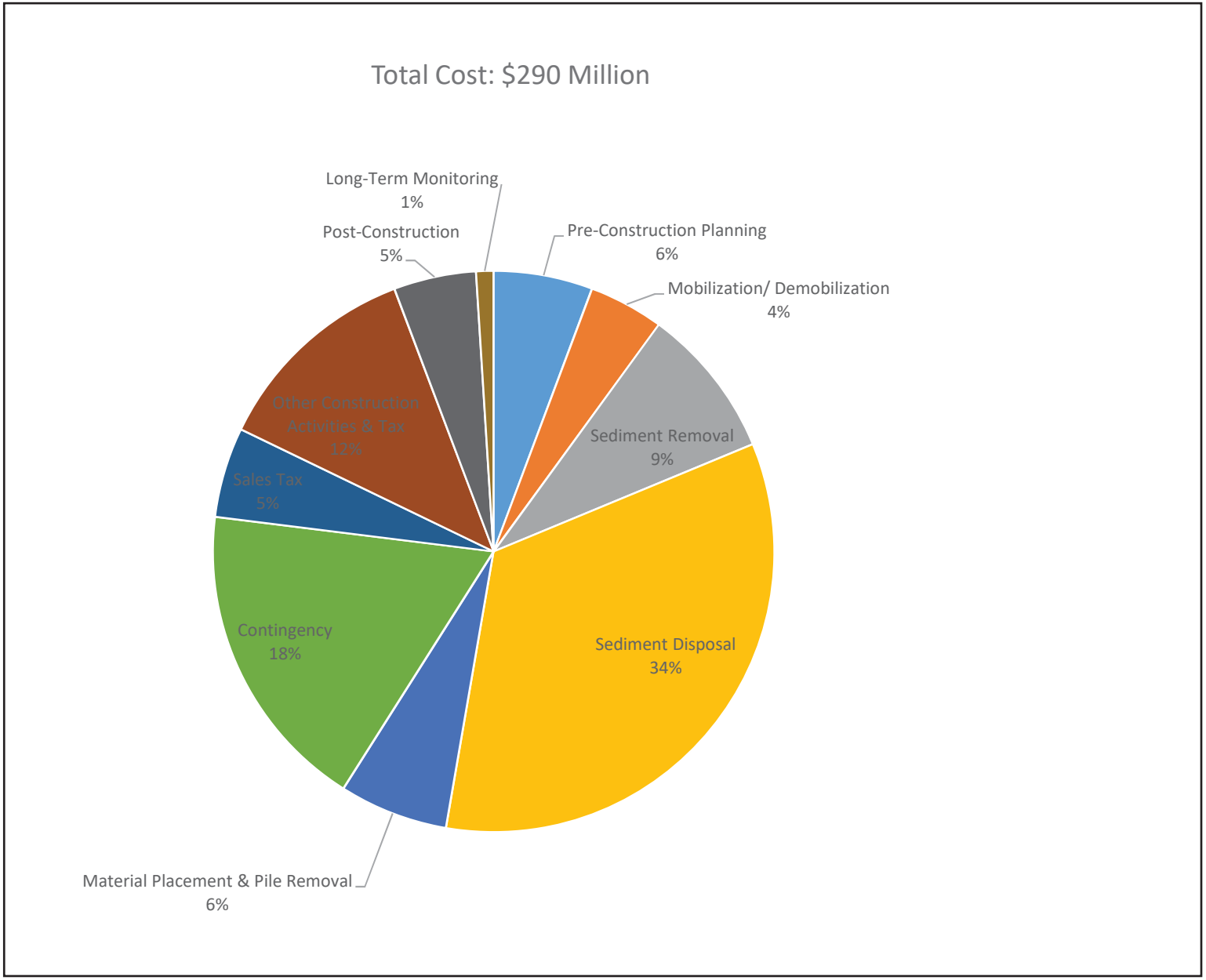

Figure B-45: Cost Details for Preferred Alternative

Appendices

APPENDIX E – COST ESTIMATE

EAST WATERWAY OPERABLE UNIT FEASIBILITY STUDY

Prepared for

Port of Seattle

Prepared by

Anchor QEA, LLC
720 Olive Way, Suite 1900
Seattle, Washington 98101

November 2017

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Table 5 Quantities and Costs for Alternatives

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1 INTRODUCTION

This appendix contains information supporting the detailed remedial alternatives cost estimate prepared for the East Waterway (EW) Operable Unit (OU) Feasibility Study (FS). The cost estimate was developed in accordance with the U.S. Environmental Protection Agency (EPA) guidance document *A Guide to Developing and Documenting Cost Estimates during the Feasibility Study* (EPA 2000), and is consistent with estimates prepared for other similar feasibility studies and construction bids for projects similar to the EW.

This cost estimate provides a common basis for comparing the remedial alternatives in the FS and provides a reasonable estimate of anticipated project costs. This appendix summarizes the primary cost assumptions used to complete the estimates for all alternatives, including background on methodology (Section 2), assumptions for estimating construction timeframes (Section 3), a summary of the estimated costs for remedial alternatives (Section 4).

The FS cost estimate contains six tables that are organized as follows:

- Table 1 provides the unit costs for each line item used in the cost estimate and a summary of the basis for each.
- Table 2 presents the production rates and daily cost assumptions behind the unit costs estimates for dredging and placement activities.
- Table 3 presents the monitoring and sampling costs for the alternatives based on the monitoring quantities in Appendix G.
- Table 4 presents the assumption for the construction timeframe calculation for the alternatives.
- Table 5 presents the quantities and costs for the alternatives.
- Table 6 provides an overall summary of the total cost for each alternative.

2 COST ESTIMATING METHODS AND ASSUMPTIONS

The cost estimate was developed by determining the cost items associated with remediation for each of the remedial alternatives, estimating unit costs for these items, and multiplying these unit costs by quantities for each alternative. In developing unit costs, a number of assumptions were made to define the scope of particular unit costs; Table 1 presents the unit costs and the basis for each. The following sources of information were used to estimate unit costs:

- Bids and construction estimates for recent sediment remediation projects
- Best professional judgment based on past experience with similar remedial actions and associated pricing
- Local marine contractor input

In particular, this cost estimate draws heavily from review of recent bid and estimate costs in the greater Pacific Northwest region, where a number of similar sediment remediation projects are currently, or were recently, in design or under construction. Unit costs in Table 1 rely primarily on review of the projects in the following bullets, with the final unit cost determined using the best professional judgement of remediation engineers with knowledge of the EW site. Citations are included for sites with publicly available cost information.

- Lower Duwamish Waterway Feasibility Study. Duwamish River, Seattle, Washington (AECOM 2012)
- Jorgenson Forge Sediment Remediation. Duwamish River, Seattle, Washington (Anchor QEA project experience)
- Slip 4 Early Action Area Cleanup. Duwamish River, Seattle, Washington
- Puget Sound Naval Shipyard Activated Carbon Sediment Amendment Installation. Sinclair Inlet, Bremerton, Washington (Johnston et al. 2013)
- Port of Seattle Terminal 18 (T-18) Maintenance Dredging Project. Seattle, Washington (Anchor QEA project experience)
- Port of Bellingham Whatcom Waterway Remediation. Bellingham Bay, Bellingham, Washington (Anchor QEA project experience)
- Port of Olympia Interim Action Marine Terminal Berth Remediation. Budd Inlet, Olympia, Washington (Anchor QEA project experience)

- Former Scott Mill Sediment Remediation. Anacortes, Washington (Anchor QEA project experience)
- Port of Vancouver Alcoa Facility Sediment Remediation. Vancouver, Washington (Anchor QEA project experience)
- Port of Portland Terminal 4 Sediment Remediation. Lower Willamette River, Portland, Oregon (Anchor QEA project experience)
- Esquimalt Graving Dock Waterlot Remediation Project, Esquimalt Harbour, Esquimalt, British Columbia (Anchor QEA project experience)

The following sections summarize specific key assumptions used to develop individual line items or sections of the cost estimate. Table 1 provides the basis for all unit costs.

2.1 Mobilization, Demobilization, and Other Pre-construction Activities

Mobilization and demobilization include bringing equipment and personnel to the site (mobilization) or removing equipment and personnel (demobilization) to complete the remedial action. This item is assumed to include mobilization and demobilization of removal and placement operations barges, equipment preparation, transload facility, upland equipment, ancillary equipment, procedural costs, insurance, and bonding. Because the scope of unrestricted (i.e., open water) dredging is similar for all remedial alternatives, the base mobilization/demobilization costs are assumed to be the same for all alternatives.

There is currently one sediment transload facility available near the EW that is located on the Lower Duwamish Waterway (LDW); however, the availability of this transload facility is not assured in the future. This cost estimate assumes that the construction and permitting of a transload facility prior to dredging would be a reasonable, cost-effective approach for this project. This approach would also include costs prior to each construction season to maintain or remobilize the transload facility and renew permits. Tasks involved in developing a new transload facility could include land lease or land purchase, permitting, transload crane, temporary containment vault, water treatment system, amendment delivery system, container loading area (truck or rail), and rail spur or container transload area, depending on the location of the site developed for transloading. If an existing transload facility is used, then the total transload and disposal costs are expected to be similar to those

in the FS cost estimate. In this case, the mobilization costs would go down because the transload facility would not need to be constructed specifically for the EW cleanup, but the unit transloading costs would go up to incorporate up-front costs to the entity owning/operating the transload facility for mobilization, permitting, and land lease.

Seasonal construction mobilization/demobilization costs were applied for each year of construction. Therefore, costs are higher for alternatives with more construction seasons. Additional mobilization/demobilization costs were applied to two specific remedial actions: underpier hydraulic dredging, and dredging under the West Seattle Bridge. Diver-assisted hydraulic dredging would require the mobilization of specialized equipment, personnel, and dewatering facilities. Dredging under the West Seattle Bridge would incur additional costs to address access from the uplands and mobilizing smaller equipment capable of working in the limited access area. These were applied to project costs on a construction-season basis (i.e., annually).

Additional pre-construction activities include the preparation of staging areas, stockpile areas, implementation of site controls, land lease, project management labor, office setup, and preparation of pre-construction submittals. These additional mobilization costs were also applied to project costs annually.

2.2 Removal

The unit costs for sediment removal (cost per cubic yard) were estimated based on the sediment removal rates (cubic yards per day) and daily costs (cost per day) associated with construction, as developed in Table 2. For the purpose of providing appropriate unit cost rates, three types of removal scenarios were considered: one for dredging in unrestricted areas (open water), one for dredging under the West Seattle Bridge, and one for diver-assisted hydraulic dredging. The costs for dredging in unrestricted areas were based on recent bids for similar work. The area under the West Seattle Bridge cannot be accessed from the water, but all equipment and materials must be mobilized from the upland. The dredging rate was calculated based on open-water dredging rates, adjusted assuming that the dredge would be used to remove contaminated sediment and to load trucks. The dredging rate also accounts for limited equipment access, limited space for maneuvering equipment,

and cost for truck delivery to the transload area. The costs for diver-assisted hydraulic dredging under piers could be highly variable and were estimated based on discussions with local divers and project experience on other projects. Diver-assisted hydraulic dredging in deep water (e.g., 50 feet) is not commonly performed. Costs are difficult to estimate because there are few project examples to reference. Diver-assisted hydraulic dredging was conducted for the Esquimalt Graving Dock Waterlot Remediation Project in Esquimalt, British Columbia, in 2013 to 2014. This dredging occurred in about 20 feet of open water (not underpier). Costs were approximately $1,100/cy. Few other diver-assisted dredging projects have been recently completed in the northwest. Uncertainties around the costs for diver-assisted hydraulic dredging are driven by uncertainty in conditions under piers (e.g., debris), working durations and conditions for divers, treating large quantities of water, and effectiveness of hydraulic dredging equipment.

Water management is a key cost consideration for removal operations, as varying containment and treatment methods can significantly affect final costs and production rates. The cost estimate assumes that dewatering for mechanically dredged material (i.e., material from unrestricted dredging areas) would be performed using gravity to pass water through specified passive filter material and returning water to the dredging area. Gravity dewatering is facilitated through the use of temporary holding barges equipped with weirs or ballasts and filtration systems. Water generated during the dewatering is typically discharged to receiving waters directly after settling and filtration (see Section 7.5.1.1). This method was recently used during maintenance dredge activities for contaminated sediment along T-18 in the EW and was able to meet water quality standards. If water quality standards cannot be achieved using filtration, then alternative treatment methods will need to be considered during remedial design or construction. For the large quantities of water generated by diver-assisted hydraulic dredging, water will likely need to be treated by a water treatment system installed on a barge or in the uplands. Treated water would be returned to the waterway. Water management costs for mechanical dredging are assumed to be part of unit costs for dredging; water treatment costs for hydraulic dredging are included as a separate line item and are based on recent local construction experience and discussions with contractors, considering the conditions of the EW (e.g., deep water, the need for barge-mounted equipment).

Transloading, transportation, and disposal costs are based on recent project costs in Seattle, Washington. Transportation to the disposal facility would occur by rail car directly from the transloading facility to a facility permitted to receive contaminated sediment.

2.3 Material Placement

Material placement activities include placement materials required for engineered cap, dredging residuals management cover (RMC), dredge backfill to restore elevations in required locations, enhanced natural recovery (ENR), and in situ treatment. Unit costs for furnishing materials include costs for sand (cap isolation material, RMC, backfill, and ENR), gravel (cap filter material), cap armor (assumed to be 6-inch stone), and in situ treatment material (assumed to be a mixture of powdered activated carbon, binding material, and a substrate material such as sand or gravel). Unit costs for material acquisition are based on recent bids and discussions with local suppliers (e.g., CalPortland).

Placement of materials is assumed to occur with dredging equipment in open-water areas, and with other techniques such as a Telebelt in restricted access areas (e.g., under piers and low bridges). The assumptions used to develop the unit costs for placement are provided in Table 2 and are consistent with recent bids. Unit costs for placement in restricted areas are based on the recent underpier in situ treatment pilot study at Bremerton Naval Shipyard (Johnston et al. 2013).

2.4 Contingency, Management, Oversight, and Non-construction Costs

The assumptions for contingency, management, oversight, and non-construction costs are shown in Table 1.

EPA FS cost guidance (EPA 2000) suggests that contingency be factored into a cost estimate to cover unknowns, unforeseen circumstances, and unanticipated conditions reducing the overall risk of cost overruns. For this project, 30% has been applied to the construction costs to cover potential scope and bid contingency costs. This value is in the mid-range of the values specified in the EPA cost guidance document (EPA 2000), is a typical conceptual-level contingency for similar projects.

Pre-construction costs include remedial design (including sampling) and permitting, pre-construction baseline monitoring, project management, and agency review and oversight. Design and permitting are estimated to be 5% of the total construction costs. Pre-construction baseline sampling costs are based on the sampling scope and unit costs provided in Table 3. The basis for the monitoring scope is addressed in Appendix G. Project management is assumed to be 1% of the total construction costs, and agency review and oversight are estimated to be $500,000/year.

Indirect construction costs during construction include construction management support, environmental compliance, project management, and agency review and oversight and are estimated based on project experience and best professional judgement. Construction management support is estimated to be 10% of total construction costs. Water quality monitoring is based on estimated costs per construction day. Confirmational sampling is based on alternative-specific assumptions in Table 3. Project management is estimated to be 4% of the total construction costs, and agency review and oversight are estimated to be $500,000/year during this phase of the project.

Post-construction costs include operations and maintenance and long-term monitoring costs, costs for potential adaptive management actions (contingency remedial actions), project management, and agency review and oversight. Costs for operations and maintenance and long-term monitoring are based on alternative-specific estimates in Table 3. Costs for adaptive management are based on per-acre unit costs for remediation, roughly equivalent to dredging unit capital costs either in open-water or underpier areas. Contingency remediation is assumed to be needed in 15% of MNR, ENR, and in situ treatment areas. Project management is estimated to be 1% of the total construction costs, and agency review and oversight costs are estimated to be $120,000/year during this phase of the project (equivalent to $200,000/year during 5-year reviews and $100,000 between 5-year reviews).

3 CONSTRUCTION TIMEFRAME

Construction timeframe was calculated as part of this cost estimate to determine applicable durations for project elements (Table 4). The construction timeframe was calculated for six separate construction activities based on varying production rates, including the following:

- Removal
  - Open water (unrestricted access)
  - Limited access (under the West Seattle Bridge)
  - Underpier (diver-assisted hydraulic dredging)
- Placement
  - Open-water sand or gravel (applies to engineered cap isolation and filter layers, dredge backfill, ENR)
  - Open-water engineered cap armor layer material
  - Restricted access (underpier and low bridges; in situ treatment or ENR)
  - Open-water residual management cover (assumed to occur after dredging)

For each of these areas, the total number of construction days was calculated based on the volumes to be removed or placed for each alternative and an estimated production rate for each activity. The estimated production rates include an efficiency factor of 70% that accounts for project downtime due to weather delays, equipment maintenance or repair, water quality exceedances, or other reasons (Table 2). The total number of construction days was estimated assuming that one open-water operation, one underpier operation, and one restricted access operation would occur concurrently. Following several seasons of removal, this construction timeframe estimate assumes that placement operations (capping, ENR, or in situ treatment) would happen concurrently with dredging operations, with sufficient distance and controls to avoid contamination from dredging residuals (e.g., if dredging operations start in the south part of the site and move northward, then capping could occur in the south portion of the site while dredging occurs in the north portion of the site). However, the ability to perform concurrent operations while limiting recontamination of placed material is a source of uncertainty in this construction timeframe estimate. Finally, residuals management placement is assumed to occur following all dredging and other

placement operations. Detailed phasing for the EW cleanup will be determined in remedial design.

The number of construction seasons was estimated at 100 work days per season. This corresponds to an approximate construction season (i.e., fish window) from October 1 through February 15, with holidays and weekends removed, assuming a mix of 5- and 6-day work weeks (12-hour days) to allow some contractor flexibility. Estimated construction times range from 8 to 12 years for the alternatives.

If the construction season was expanded to the Elliott Bay in-water construction window that formally applies in the EW from July 16 to February 15, the upper end of the number of work days in a construction season could increase up to around 150 days per season; however, the construction rate is expected to be slower during this time due to potential delays from active tribal fisheries. The extended construction window is estimated to reduce the total number of years of construction by about two construction seasons, consistently across the action alternatives (Table 4). Reducing the number of construction years has a small impact on costs because the number of total construction days would remain unchanged. Annual costs (e.g., annual mobilization and demobilization) would be reduced by about 20%, and all other costs would remain the same.

4 SUMMARY AND ACCURACY

Table 5 presents the detailed costs and Table 6 summarizes the total costs for the remedial alternatives. Costs for the action alternatives range from approximately $256 to $435 million, and are provided in 2016 dollars. Total costs include all contractor costs to complete construction, sales tax, contingency, and allowances for engineering design, permitting, construction monitoring, and agency review.

The *Guide to Developing and Documenting Cost Estimates during the Feasibility Study* (EPA 2000) recommends that a discount rate of 7% be used for estimating the net present value of cleanups conducted by non-federal parties. The present value is the amount of money that would need to be set aside at an initial point in time so that funds for implementing cleanup would be available in the future. The real discount rate approximates the marginal pre-tax rate of return on average investment adjusted to eliminate the effect of expected inflation. The net present value costs are not appropriate for the EW cleanup for the following two reasons:

1. First, three of the potentially responsible parties are public entities and have different capital costs than the private sector. Public entities may not be able to set aside sufficient funds for investment without incurring additional costs of bonding or borrowing and, therefore, would not be able to take advantage of the interest accumulation assumption implied by the net present value calculation.
2. Second, the lending environment has changed significantly since the EPA guidance was published in 2000. The current recommendations in the Office of Management and Budget Circular A-94 Appendix C, revised November 2016, indicates that the discount rate ranges from -0.5% for a 3-year investment to 0.7% for a 30-year investment.

Because many of the entities involved in the EW cleanup are public and the current discount rate is low, a 0% discount rate is appropriate to use for comparing the EW remedial alternatives in this FS. This approach is consistent with Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) guidance that allows for calculation of project-specific net present value calculations. In this case, the net present value cost is equal to the non-discounted cost (0% discount rate).

The costs provided represent the best estimate total costs for the proposed EW remedial alternatives. The major uncertainties between the cost estimate and the eventual actual cleanup costs include the following:

- Changes in the scope of cleanup due to additional characterization (e.g., changes to dredging volume)
- Changes in the scope of cleanup due to changes in remedial approach or adaptive management (e.g., ENR is considered viable in a larger area)
- Changes in unit costs due to changes in acceptable remediation practices (e.g., changes to dewatering or transloading practices)
- Changes in unit costs due to changes in economic conditions (e.g., cost of fuel, availability of contractors)
- Changes in unit costs due to changes in the rate of construction (e.g., additional delays from working around shipping vessels, or tribal fishing vessels associated with salmon runs. The latter may trigger additional standby costs if work is halted entirely while tribal fishing is conducted within the EW)
- Additional costs that were not considered for this FS, such as economic disruption to the Port of Seattle and fisheries mitigation

EPA guidance, according to CERCLA requirements, notes that the amount and quality of remedial investigation data needed to develop and scope remedial alternatives correspond to an expected accuracy for FS cost estimates of approximately –30 to +50% (EPA 2000). Costs provided within this appendix are intended to fall within this range of accuracy.

5 REFERENCES

AECOM, 2012. Feasibility Study, Lower Duwamish Waterway, Seattle, Washington. Final Report. Prepared for Lower Duwamish Waterway Group. October 2012.

EPA (U.S. Environmental Protection Agency), 2000. A Guide to Developing and Documenting Cost Estimates during the Feasibility Study. July 2000.

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TABLES

Table 1
Unit Costs

Item No.	Item Description	Unit Cost (2016)	Unit	Unit Cost Notes
Pre-construction				
1	**Mobilization/Demobilization**			
1a	Mobilization/Demobilization	$ 700,000	Annual	Includes mobilization and demobilization of removal and placement operations, barges, equipment preparation, ancillary equipment, and procedural costs. Equivalent to approximately 20 days of mobilization and 15 days of demobilization (assuming daily costs of 75% of the daily costs during dredging [Table 3]).
1b	Initial Transload Site Setup	$ 1,000,000	Project	Costs would be variable depending on the transload site selected and the design approach. Costs could include land lease or land purchase, permitting, transload crane, temporary containment vault, water treatment system, amendment delivery system, container loading area (truck or rail), and rail spur or container transload area.
1c	Annual Transload Site Setup and Maintenance (After Initial)	$ 500,000	Annual	Costs would be variable depending on the transload site selected and the design approach. Costs could include land lease, permit renewals, equipment setup and maintenance (crane, vault, water treatment, amendment delivery, and truck and rail routes), and demobilization (decontamination and deconstruction).
1d	Mobilization/Demobilization for Underpier Dredging Equipment	$ 250,000	Annual	Includes hydraulic dredge, water treatment facility, and diving equipment. Applied to each year that underpier dredging occurs.
1e	Mobilization/Demobilization for Equipment to Dredge under the West Seattle Bridge	$ 500,000	Annual	Includes mobilization and demobilization of limited access equipment from the uplands, development of a truck loading area under the West Seattle Bridge, and a cost to shutdown the bridge and reroute traffic. Applied to each year that dredging under the West Seattle Bridge occurs.
2	**Pre-construction Activities**			
2a	Pre-construction activities	$ 100,000	Annual	Preparation of staging areas, stockpile areas, implementation of site controls, preparation of pre-construction submittals. Applied to each construction season.
Construction				
3	**Removal, Dewatering, Offloading, and Disposal**			
3a	Open-water Dredging	$ 27	cy	Based on the production rate and daily costs presented in Table 3. The cost per cubic yard includes all equipment and labor necessary for dredging and dewatering.
3b	Restricted Access Dredging (Under West Seattle Bridge)	$ 119	cy	Based on the production rate and daily costs presented in Table 3. The cost per cubic yard includes all equipment and labor necessary for dredging and dewatering. Costs account for limited equipment access, limited space for maneuvering equipment, and cost for trucking to rail (as opposed to barge transportation).
3c	Diver-Assisted Hydraulic Dredging (Underpier)	$ 600	cy	Based on the production rate and daily costs presented in Table 3 developed from contractor input and best professional judgement. EW project conditions including deep water, limited access, and presence of rip rap. This item presents a high uncertainty (recent Anchor QEA project experience shows costs could be as high as $1,100/cy). The cost per cubic yard includes all equipment and labor necessary for dredging. Water treatment is not included.
3d	Water Treatment (Underpier Hydraulic Dredging)	$ 400	cy	Cost based on discussions with contractors involved with water treatment on the LDW, with consideration of specific needs for the EW (barge mounted treatment system and additional barges for surge capacity). With the estimated hydraulic dredging fraction of 10% sediment, 90% water by volume, the unit cost equals $0.22/gallon of water.
3e	Transload, Transportation and Disposal	$ 70	Ton	Cost includes material transfer from barge onto offloading area, water management at transloading facility, load dewatered sediment onto truck with containers, truck transport to rail facility, rail transport to the Subtitle D landfill, offloading of sediments from railcars at Subtitle D landfill. Assume 1.5 ton/cy. Costs based on recent project experience. Costs do not include mobilization, permitting and construction of the transload facility.

Table 1
Unit Costs

Item No.	Item Description	Unit Cost (2016)	Unit	Unit Cost Notes
4	**Pile Removal and Disposal**	$ 1,000	Each	Includes removal and disposal. Based on recent project experience.
5	**Engineered Capping and Residuals Management Cover**			
5a	Furnish Sand	$ 20	cy	Based on recent project experience, cost estimates and CalPortland pricing. Applies to Engineered Cap Isolation Layer, Backfill, RMC, and ENR in open-water areas. Material costs are based on the purchase from local or regional quarries. Unit costs include the cost and transportation of the material.
5b	Furnish Gravel	$ 20	cy	Based on recent project experience, cost estimates and CalPortland pricing. Applies to Engineered Cap Filter Layer. Material costs are based on the purchase from local or regional quarries. Unit costs include the cost and transportation of the material.
5c	Furnish Armor Material	$ 35	cy	Based on recent project experience, cost estimates and CalPortland pricing. Applies to Engineered Cap Armor Layer. Material costs are based on the purchase from local or regional quarries. Unit costs include the cost and transportation of the material.
5d	Furnish In situ Treatment Material (AquaGate+PAC™)	$ 500	cy	Consistent with recent pilot study at the Puget Sound Naval Shipyard in Bremerton, WA. This pilot study was completed using the AquaGate+PAC™ composite aggregate system. Transportation was not factored into the unit cost to account for an assumed cost reduction for a full-scale application.
5e	Place Sand - Unrestricted Access	$ 26	cy	Based on the production rate and daily costs presented in Table 3. The cost per cubic yard includes all equipment and labor necessary for placement and material handling.
5f	Place Gravel - Unrestricted Access	$ 26	cy	Based on the production rate and daily costs presented in Table 3. The cost per cubic yard includes all equipment and labor necessary for placement and material handling.
5g	Place Armor Material - Unrestricted Access	$ 43	cy	Based on the production rate and daily costs presented in Table 3. The cost per cubic yard includes all equipment and labor necessary for placement and material handling.
5h	Place in situ Material in Difficult to Access Areas - Underpier	$ 400	cy	Based on production rate consistent with recent pilot study at the Puget Sound Naval Shipyard in Bremerton, WA. This pilot study was completed using the AquaGate+PAC™ composite aggregate system. See Table 3.
5i	Place ENR Material in Difficult to Access Areas - Low Bridge	$ 400	cy	Based on production rate consistent with recent pilot study at the Puget Sound Naval Shipyard in Bremerton, WA. See Table 3.
6	**Surveys and Monitoring**			
6a	**Payment Surveys**	$ 40,000	Site-wide Event	East Waterway Group project experience. Assume one event before and after each construction season.
6b	Contractor daily progress surveys	$ 2,500	Day	Based on recent project experience and cost estimates.
7	**Sales Tax and Contingency**			
7a	Sales Tax	9.5%	--	Percent of subtotal of pre-construction costs and construction base costs.
7b	Contingency	30%	--	Percent of construction costs. Typical Conceptual-level Contingency; mid-range of EPA FS Cost Guidance for contingency. Percent of pre-construction, construction, and tax.

Table 1
Unit Costs

Item No.	Item Description	Unit Cost (2016)	Unit	Unit Cost Notes
Indirect Construction Costs				
8	**Pre-construction**			
8a	Design and Permitting	5%	--	Percent of construction costs. Typical Conceptual-level Contingency; mid-range of EPA FS Cost Guidance for contingency. Percent of pre-construction, construction, and tax. Includes sampling during remedial design.
8b	Pre-Construction Base-line Monitoring	Alternative-specific	Lump Sum	See Table 4 and Appendix E.
8c	Project Management (Owners)	1%	--	Percent of construction costs.
8d	Agency Review and Oversight	$ 500,000	Annual	Assume 3 years for pre-construction activities.
9	**During Construction**			
9a	Construction Management Support	10%	--	Percent of construction costs. Typical Conceptual-level Contingency; mid-range of EPA FS Cost Guidance for contingency. Percent of pre-construction, construction, and tax.
9b	**Environmental Compliance**			
9bi	Water Quality Monitoring	$ 3,000	Day	Includes labor, equipment, materials, and analytical testing. Analytical cost: assume four monitoring stations approx. 30% of field screening samples required for chemical analysis.
9bii	Confirmational Sampling	Alternative-specific	Lump Sum	See Table 4 and Appendix E.
9c	Project Management (Owners)	4%	--	Percent of construction costs.
9d	Agency Review and Oversight	$ 500,000	Annual	Annually during construction.
10	**Post-construction Costs**			
10a	Operations and Maintenance and Long Term Monitoring 1 through 20 years post-construction	Alternative-specific	Lump Sum	See Table 4 and Appendix E.
10b	Contingency Remediation (Adaptive Management) - Open Water	$ 1,100,000	Acre	Capitol cost for dredging open water without contingencies, design, project management, etc. Assume adaptive management required over 15% of ENR areas. Based on an average neatline dredge depth of 3.5 feet and the unit costs for dredging and disposal.
10c	Contingency Remediation (Adaptive Management) - Underpier and Low Bridge	$ 4,100,000	Acre	Approximate capitol cost for dredging under piers without contingencies, design, project management, etc. Assume adaptive management required over 15% of MNR, ENR, and in situ treatment areas. Based on an average dredge depth of 2.3 feet and the unit costs for dredging, water management and disposal.
10d	Project Management (Owners)	1%	--	Percent of construction costs.
10e	Agency Review and Oversight	$ 120,000	Annual	Assume 25 years for post-construction activities. Equivalent to $200,000/yr during 5-year reviews and $100,000/yr between 5-year reviews.

Table 2
Unit Cost Assumptions for Dredging and Material Placement

Parameter	Unit	Open-water Dredging	Restricted Access Dredging (West Seattle Bridge)	Diver-Assisted Underpier Hydraulic Dredging	Sand and Gravel Placement	Armor Placement	Underpier Placement
Unit Cost Calculation							
Production Rate	cy/day	1,100	270	40	940	560	60
Daily Cost	/day	$30,000	$24,000	$24,000	$24,000	$24,000	$24,000
Additional Trucking Cost (to Rail Facility)	/cy	$0	$30	$0	$0	$0	$0
Cost per Unit Dredge Volume	**/cy**	**$27**	**$119**	**$600**	**$26**	**$43**	**$400**
Production Rate Calculation							
Cycle Time	min	2.50	3.00	n/a	1.50	2.50	n/a
Bucket Capacity	cy	8	4	n/a	4	4	n/a
Effective Bucket Capacity	%	70%	70%	n/a	70%	70%	n/a
Effective Bucket Capacity	cy	5.6	2.8	n/a	2.8	2.8	n/a
Shift Duration	hrs	12	12	n/a	12	12	n/a
Work Day	shift/day	1	1	n/a	1	1	n/a
Efficiency	%	70%	40%	n/a	70%	70%	n/a
Daily Production	cy	1,129	269	n/a	941	564	n/a
Daily Production (rounded)	**cy**	**1,100**	**270**	**40**	**940**	**560**	**60**
Daily Rate Calculation							
Daily Cost - Equipment							
Dredge or Telebelt	/day	$9,000	$6,500	$10,000	$6,500	$6,500	$6,500
Tug	/day	$5,000	$5,000	n/a	$5,000	$5,000	$5,000
Barge(s)	/day	$5,000	$2,500	n/a	$2,500	$2,500	$2,500
Work Boat	/day	$1,500	$1,500	n/a	$1,500	$1,500	$1,500
Front-end loader	/day	$800	$800	n/a	$800	$800	$800
Diving Equipment and Boats	/day	n/a	n/a	$3,500	n/a	n/a	n/a
Total - Equipment	/day	$21,300	$16,300	$13,500	$16,300	$16,300	$16,300
Fuel, Oil and Grease (FOB; 20%)	/day	$4,260	$3,260	$2,700	$3,260	$3,260	$3,260
Total - Equipment + FOB	**/day**	**$25,560**	**$19,560**	**$16,200**	**$19,560**	**$19,560**	**$19,560**
Daily Cost - Labor							
Superintendent	/day	$700	$700	$700	$700	$700	$700
Operator Foreman	/day	$680	$680	n/a	$680	$680	$680
Dredge Operator	/day	$600	$600	n/a	$600	$600	$600
Deck Hands - Dredge	/day	$1,200	$1,200	n/a	$1,200	$1,200	$1,200
Tug Operator	/day	$600	$600	n/a	$600	$600	$600
Deck Hand - Tug	/day	$600	$600	n/a	$600	$600	$600
Divers and Diver Support (6 Crew Members)	/day	n/a	n/a	$6,600	n/a	n/a	n/a
Total - Labor	**/day**	**$4,380**	**$4,380**	**$7,300**	**$4,380**	**$4,380**	**$4,380**
Grand Total Labor + Equipment	**/day**	**$29,940**	**$23,940**	**$23,500**	**$23,940**	**$23,940**	**$23,940**
Grand Total Labor + Equipment (rounded)	**/day**	**$30,000**	**$24,000**	**$24,000**	**$24,000**	**$24,000**	**$24,000**

Notes:
1. Unit cost assumptions based on engineering cost estimate methodology and bids on recent projects.
cy - cubic yard
hrs - hours
min - minute
n/a - not applicable

Table 3
Monitoring Costs

Unit Cost Estimates

Alternative	SAP and Data Report (All Analyses)	Surface Sediment	Porewater	Cores	Tissue	Surface Water	Bathymetric Survey and Physical Inspections
Analytical, data validation, data management	n/a	$1,778	$2,375	$7,112	$1,601	$380	n/a
Samples/day	n/a	10	4	6	4	4	n/a
Mob/ demob/ equipment/ reporting	$100,000	$7,500	$30,500	$2,000	$1,000	$0	$40,000
Sampling cost/day	n/a	$3,300	$3,300	$3,750	$3,300	$3,300	n/a

Note:

1. Unit cost estimates developed from recent Anchor QEA project experience.

Total Quantities and Costs by Event

	Sample Quantity							Cost				
										Sampling		
Alternative	SAP and Data Report (All Analyses)	Surface Sediment	Porewater	Cores	Tissue	Surface Water	Bathymetric Survey and Physical Inspections	Analytical, Data Validation, and Data Management Costs	Mobilization, Demobilization, Equipment, and Reporting Costs	Sampling Days	Sampling Cost	Total Cost
Pre-construction Baseline Sampling												
No Action	0	0	0	0	0	0	0	$0	$0	0	$0	$0
1A(12)	1	62	0	0	20	8	1	$145,280	$148,500	13	$43,560	$337,340
1B(12)	1	62	13	13	20	8	1	$268,606	$181,000	19	$62,410	$512,016
1C+(12)	1	62	13	13	20	8	1	$268,606	$181,000	19	$62,410	$512,016
2A(12)	1	58	0	0	20	8	1	$138,168	$148,500	13	$42,240	$328,908
2B(12)	1	58	13	13	20	8	1	$261,494	$181,000	18	$61,090	$503,584
2C(12)	1	57	11	11	20	8	1	$240,743	$181,000	17	$57,860	$479,603
2C+(12)	1	58	13	13	20	8	1	$261,494	$181,000	18	$61,090	$503,584
3B(12)	1	56	13	13	20	8	1	$257,938	$181,000	18	$60,430	$499,368
3C+(12)	1	56	13	13	20	8	1	$257,938	$181,000	18	$60,430	$499,368
3D(12)	1	50	0	0	20	8	1	$123,945	$148,500	12	$39,600	$312,045
2C+(7.5)	1	56	13	13	20	8	1	$257,938	$181,000	18	$60,430	$499,368
3C+(7.5)	1	54	13	13	20	8	1	$254,382	$181,000	18	$59,770	$495,152
3E(7.5)	1	54	13	13	20	8	1	$254,382	$181,000	18	$59,770	$495,152
2C+(5.0)	1	58	14	14	20	8	1	$270,981	$181,000	19	$62,540	$514,521
3D(5.0)	1	49	0	0	20	8	1	$122,167	$148,500	12	$39,270	$309,937
3E(5.0)	1	56	14	14	20	8	1	$267,425	$181,000	18	$61,880	$510,305

Table 3
Monitoring Costs

Alternative	Sample Quantity							Cost				
	SAP and Data Report (All Analyses)	Surface Sediment	Porewater	Cores	Tissue	Surface Water	Bathymetric Survey and Physical Inspections	Analytical, Data Validation, and Data Management Costs	Mobilization, Demobilization, Equipment, and Reporting Costs	Sampling		Total Cost
										Sampling Days	Sampling Cost	
Confirmational Sampling												
No Action	0	0	0	0	0	0	0	$0	$0	0	$0	$0
1A(12)	1	62	0	0	0	8	1	$113,266	$147,500	8	$27,060	$287,826
1B(12)	1	62	13	13	0	8	1	$236,592	$180,000	14	$45,910	$462,502
1C+(12)	1	62	13	13	0	8	1	$236,592	$180,000	14	$45,910	$462,502
2A(12)	1	58	0	0	0	8	1	$106,154	$147,500	8	$25,740	$279,394
2B(12)	1	58	13	13	0	8	1	$229,480	$180,000	13	$44,590	$454,070
2C(12)	1	57	11	11	0	8	1	$208,729	$180,000	12	$41,360	$430,089
2C+(12)	1	58	13	13	0	8	1	$229,480	$180,000	13	$44,590	$454,070
3B(12)	1	56	13	13	0	8	1	$225,924	$180,000	13	$43,930	$449,854
3C+(12)	1	56	13	13	0	8	1	$225,924	$180,000	13	$43,930	$449,854
3D(12)	1	50	0	0	0	8	1	$91,931	$147,500	7	$23,100	$262,531
2C+(7.5)	1	56	13	13	0	8	1	$225,924	$180,000	13	$43,930	$449,854
3C+(7.5)	1	54	13	13	0	8	1	$222,368	$180,000	13	$43,270	$445,638
3E(7.5)	1	55	13	13	0	8	1	$224,146	$180,000	13	$43,600	$447,746
2C+(5.0)	1	58	14	14	0	8	1	$238,967	$180,000	14	$46,040	$465,007
3D(5.0)	1	49	0	0	0	8	1	$90,153	$147,500	7	$22,770	$260,423
3E(5.0)	1	56	14	14	0	8	1	$235,411	$180,000	13	$45,380	$460,791
Operations and Maintenance Monitoring and Long-term Monitoring												
Year 1												
No Action	1	39	0	0	0	0	0	$69,338	$107,500	4	$12,870	$189,708
1A(12)	1	62	0	0	20	8	1	$145,280	$148,500	13	$43,560	$337,340
1B(12)	1	62	13	13	20	8	1	$268,606	$181,000	19	$62,410	$512,016
1C+(12)	1	62	13	13	20	8	1	$268,606	$181,000	19	$62,410	$512,016
2A(12)	1	58	0	0	20	8	1	$138,168	$148,500	13	$42,240	$328,908
2B(12)	1	58	13	13	20	8	1	$261,494	$181,000	18	$61,090	$503,584
2C(12)	1	57	11	11	20	8	1	$240,743	$181,000	17	$57,860	$479,603
2C+(12)	1	58	13	13	20	8	1	$261,494	$181,000	18	$61,090	$503,584
3B(12)	1	56	13	13	20	8	1	$257,938	$181,000	18	$60,430	$499,368
3C+(12)	1	56	13	13	20	8	1	$257,938	$181,000	18	$60,430	$499,368
3D(12)	1	50	0	0	20	8	1	$123,945	$148,500	12	$39,600	$312,045
2C+(7.5)	1	56	13	13	20	8	1	$257,938	$181,000	18	$60,430	$499,368
3C+(7.5)	1	54	13	13	20	8	1	$254,382	$181,000	18	$59,770	$495,152
3E(7.5)	1	55	13	13	20	8	1	$256,160	$181,000	18	$60,100	$497,260
2C+(5.0)	1	58	14	14	20	8	1	$270,981	$181,000	19	$62,540	$514,521
3D(5.0)	1	49	0	0	20	8	1	$122,167	$148,500	12	$39,270	$309,937
3E(5.0)	1	56	14	14	20	8	1	$267,425	$181,000	18	$61,880	$510,305

Table 3
Monitoring Costs

Alternative	Sample Quantity							Cost				
	SAP and Data Report (All Analyses)	Surface Sediment	Porewater	Cores	Tissue	Surface Water	Bathymetric Survey and Physical Inspections	Analytical, Data Validation, and Data Management Costs	Mobilization, Demobilization, Equipment, and Reporting Costs	Sampling		Total Cost
										Sampling Days	Sampling Cost	
Year 3												
No Action	0	0	0	0	0	0	0	$0	$0	0	$0	$0
1A(12)	1	31	0	0	20	0	0	$87,129	$108,500	8	$26,730	$222,359
1B(12)	1	31	13	13	20	0	0	$210,455	$141,000	14	$45,580	$397,035
1C+(12)	1	31	13	13	20	0	0	$210,455	$141,000	14	$45,580	$397,035
2A(12)	1	23	0	0	20	0	0	$72,906	$108,500	7	$24,090	$205,496
2B(12)	1	23	13	13	20	0	0	$196,232	$141,000	13	$42,940	$380,172
2C(12)	1	21	11	11	20	0	0	$173,703	$141,000	12	$39,380	$354,083
2C+(12)	1	23	13	13	20	0	0	$196,232	$141,000	13	$42,940	$380,172
3B(12)	1	19	13	13	20	0	0	$189,120	$141,000	12	$41,620	$371,740
3C+(12)	1	19	13	13	20	0	0	$189,120	$141,000	12	$41,620	$371,740
3D(12)	1	6	0	0	20	0	0	$42,681	$108,500	6	$18,480	$169,661
2C+(7.5)	1	23	13	13	20	0	0	$196,232	$141,000	13	$42,940	$380,172
3C+(7.5)	1	19	13	13	20	0	0	$189,120	$141,000	12	$41,620	$371,740
3E(7.5)	1	20	13	13	20	0	0	$190,898	$141,000	12	$41,950	$373,848
2C+(5.0)	1	24	14	14	20	0	0	$207,496	$141,000	13	$44,720	$393,216
3D(5.0)	1	6	0	0	20	0	0	$42,681	$108,500	6	$18,480	$169,661
3E(5.0)	1	20	14	14	20	0	0	$200,384	$141,000	13	$43,400	$384,784
Years 5, 10, 15, and 20												
No Action	1	39	0	0	0	0	0	$69,338	$107,500	4	$12,870	$189,708
1A(12)	1	62	0	0	20	8	1	$145,280	$148,500	13	$43,560	$337,340
1B(12)	1	62	13	13	20	8	1	$268,606	$181,000	19	$62,410	$512,016
1C+(12)	1	62	13	13	20	8	1	$268,606	$181,000	19	$62,410	$512,016
2A(12)	1	58	0	0	20	8	1	$138,168	$148,500	13	$42,240	$328,908
2B(12)	1	58	13	13	20	8	1	$261,494	$181,000	18	$61,090	$503,584
2C(12)	1	57	11	11	20	8	1	$240,743	$181,000	17	$57,860	$479,603
2C+(12)	1	58	13	13	20	8	1	$261,494	$181,000	18	$61,090	$503,584
3B(12)	1	56	13	13	20	8	1	$257,938	$181,000	18	$60,430	$499,368
3C+(12)	1	56	13	13	20	8	1	$257,938	$181,000	18	$60,430	$499,368
3D(12)	1	50	0	0	20	8	1	$123,945	$148,500	12	$39,600	$312,045
2C+(7.5)	1	56	13	13	20	8	1	$257,938	$181,000	18	$60,430	$499,368
3C+(7.5)	1	54	13	13	20	8	1	$254,382	$181,000	18	$59,770	$495,152
3E(7.5)	1	54	13	13	20	8	1	$254,382	$181,000	18	$59,770	$495,152
2C+(5.0)	1	58	14	14	20	8	1	$270,981	$181,000	19	$62,540	$514,521
3D(5.0)	1	49	0	0	20	8	1	$122,167	$148,500	12	$39,270	$309,937
3E(5.0)	1	56	14	14	20	8	1	$267,425	$181,000	18	$61,880	$510,305

Notes:
1. Monitoring sample quantities are developed in FS Appendix G.
2. Approximate sampling numbers and costs are for FS purposes only.
FS - Feasibility Study
n/a - not applicable
SAP - sampling and analysis plan

Table 4
Estimated Construction Durations

Construction Description	Unit Assumption	Notes	Unit	Alternative																
				No Action	1A(12)	1B(12)	1C+(12)	2A(12)	2B(12)	2C(12)	2C+(12)	3B(12)	3C+(12)	3D(12)	2C+(7.5)	3C+(7.5)	3E(7.5)	2C+(5.0)	3D(5.0)	3E(5.0)
Dredging																				
Open-water Dredging	1,100 cy/day	Based on dredge production calculations	cy	0	813,120	813,120	813,120	902,212	902,212	902,212	902,212	938,455	938,455	938,455	1,007,892	1,016,453	1,016,453	1,077,140	1,086,121	1,086,121
			days	0	739	739	739	820	820	820	820	853	853	853	916	924	924	979	987	987
Limited Access Dredging (Under West Seattle Bridge)	270 cy/day	Based on dredge production calculations	cy	0	0	0	0	0	0	0	0	16,651	16,651	16,651	0	19,365	19,365	0	19,737	19,737
			days	0	0	0	0	0	0	0	0	62	62	62	0	72	72	0	73	73
Hydraulic Dredging (Underpier)	40 cy/day	Vendor quote and best professional judgment	cy	0	0	0	7,016	0	0	7,016	7,016	0	7,016	43,940	7,016	7,016	46,216	7,016	48,816	48,816
			days	0	0	0	175	0	0	175	175	0	175	1,098	175	175	1,155	175	1,220	1,220
Total Dredging Time		**Assumed concurrent operations**	**days**	**0**	**739**	**739**	**739**	**820**	**820**	**820**	**820**	**853**	**853**	**1,098**	**916**	**924**	**1,155**	**979**	**1,220**	**1,220**
Placement - Capping, Backfill, ENR, and In situ Treatment																				
Placement - Sand or Gravel	940 cy/day	Based on recent Puget Sound project experience	cy	0	166,191	166,796	166,730	137,278	137,883	137,821	137,821	129,695	129,372	128,282	134,884	127,571	125,986	127,790	119,003	119,003
			days	0	177	177	177	146	147	147	147	138	138	136	143	136	134	136	127	127
Placement - Armor	560 cy/day	Based on recent Puget Sound project experience	cy	0	30,931	30,931	30,931	30,931	30,931	30,931	30,931	17,654	17,654	17,654	31,062	17,786	17,786	31,062	17,786	17,786
			days	0	55	55	55	55	55	55	55	32	32	32	55	32	32	55	32	32
Placement - Underpier or Under Low Bridge	60 cy/day	Underpier in situ or ENR under low bridges; based on recent pilot study	cy	0	811	5,678	5,678	1,421	6,288	5,506	6,288	6,288	6,288	1,421	6,675	6,675	6,675	6,963	1,562	6,963
			days	0	14	95	95	24	105	92	105	105	105	24	111	111	111	116	26	116
Total Placement Time		**Assumed concurrent operations in open-water and underpier**	**days**	**0**	**232**	**233**	**233**	**201**	**202**	**202**	**202**	**169**	**169**	**168**	**199**	**167**	**166**	**191**	**158**	**158**
Placement - Dredge Residuals Management Cover																				
Placement - Sand	940 cy/day	Based on recent Puget Sound project experience	cy	0	88,580	88,580	88,580	106,341	106,341	106,341	106,341	111,735	111,735	111,735	118,258	123,607	123,592	127,233	132,566	132,566
			days	0	94	94	94	113	113	113	113	119	119	119	126	131	131	135	141	141
Total Construction Time (Best Estimate)																				
Total construction time assuming some concurrent dredging and placement operations	**100 days/ season**	**Total of dredging and residuals management operations during the anticipated construction window (October 1 through February 15)**	**days**	**0**	**833**	**833**	**833**	**933**	**933**	**933**	**933**	**972**	**972**	**1,217**	**1,042**	**1,056**	**1,287**	**1,115**	**1,361**	**1,361**
			seasons	**0**	**8.3**	**8.3**	**8.3**	**9.3**	**9.3**	**9.3**	**9.3**	**9.7**	**9.7**	**12.2**	**10.4**	**10.6**	**12.9**	**11.1**	**13.6**	**13.6**
Total Construction Time (With Extended Construction Season)																				
Total construction time assuming some concurrent dredging and placement operations	**150 days/ season**	**Assume production during an extended construction window (July 16 to September 30) with 50% production during that time due to tribal fishing.**	**days**	**0**	**833**	**833**	**833**	**933**	**933**	**933**	**933**	**972**	**972**	**1,217**	**1,042**	**1,056**	**1,287**	**1,115**	**1,361**	**1,361**
			seasons	**0**	**6.7**	**6.7**	**6.7**	**7.5**	**7.5**	**7.5**	**7.5**	**7.8**	**7.8**	**9.7**	**8.3**	**8.4**	**10.3**	**8.9**	**10.9**	**10.9**

Notes:
1. See Table 3 for construction rate assumption.
cy - cubic yards
ENR - enhanced natural recovery

Table 5
Quantities and Costs for Alternatives

Item No.	Item Description	Unit Cost	Unit	Quantity by Alternative																
				No Action	1A(12)	1B(12)	1C+(12)	2A(12)	2B(12)	2C(12)	2C+(12)	3B(12)	3C+(12)	3D(12)	2C+(7.5)	3C+(7.5)	3E(7.5)	2C+(5.0)	3D(5.0)	3E(5.0)
Pre-construction																				
1	**Mobilization/Demobilization**																			
1a	Mobilization/Demobilization	$ 700,000	Annual	0	9	9	9	10	10	10	10	10	10	13	11	11	13	12	14	14
1b	Initial Transload Site Setup	$ 1,000,000	Project	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1c	Annual Transload Site Setup and Maintenance (After Initial)	$ 500,000	Annual	0	8	8	8	9	9	9	9	9	9	12	10	10	12	11	13	13
1d	Mobilization/Demobilization for Underpier Dredging Equipment	$ 250,000	Annual	0	0	0	2	0	0	2	2	0	2	11	2	2	12	2	13	13
1e	Mobilization/Demobilization for Equipment to Dredge under the West Seattle Bridge	$ 500,000	Annual	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1
2	**Pre-construction activities**																			
2a	Pre-construction activities	$ 100,000	Annual	0	9	9	9	10	10	10	10	10	10	13	11	11	13	12	14	14
Subtotal Pre-construction				**n/a**																
Construction																				
3	**Removal, Dewatering, Offloading, and Disposal**																			
3a	Open-water Dredging	$ 27	cy	0	813,120	813,120	813,120	902,212	902,212	902,212	902,212	938,455	938,455	938,455	1,007,892	1,016,453	1,016,453	1,077,140	1,086,121	1,086,121
3b	Restricted Access Dredging (Under West Seattle Bridge)	$ 119	cy	0	0	0	0	0	0	0	0	16,651	16,651	16,651	0	19,365	19,365	0	19,737	19,737
3c	Diver-Assisted Hydraulic Dredging (Underpier)	$ 600	cy	0	0	0	7,016	0	0	7,016	7,016	0	7,016	43,940	7,016	7,016	46,216	7,016	48,816	48,816
3d	Water Treatment (Underpier Hydraulic Dredging)	$ 400	cy	0	0	0	7,016	0	0	7,016	7,016	0	7,016	43,940	7,016	7,016	46,216	7,016	48,816	48,816
3e	Transload, Transportation and Disposal	$ 70	Ton	0	1,219,680	1,219,680	1,230,203	1,353,319	1,353,319	1,363,842	1,363,842	1,432,659	1,443,182	1,498,569	1,522,362	1,564,250	1,623,050	1,626,233	1,732,012	1,732,012
4	**Pile Removal and Disposal**	$ 1,000	Each	0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
5	**Engineered Capping and Residuals Management Cover**																			
5a	Furnish Sand	$ 20	cy	0	234,961	235,566	235,500	224,420	225,025	224,962	224,962	231,082	230,759	229,669	233,995	240,883	239,282	235,876	241,274	241,274
5b	Furnish Gravel	$ 20	cy	0	20,620	20,620	20,620	20,620	20,620	20,620	20,620	11,769	11,769	11,769	20,708	11,857	11,857	20,708	11,857	11,857
5c	Furnish Armor Material	$ 35	cy	0	30,931	30,931	30,931	30,931	30,931	30,931	30,931	17,654	17,654	17,654	31,062	17,786	17,786	31,062	17,786	17,786
5d	Furnish In situ Treatment Material (AquaGate+PAC^{TM})	$ 500	cy	0	0	4,867	4,867	0	4,867	4,085	4,867	4,867	4,867	0	5,113	5,113	5,113	5,401	0	5,401
5e	Place Sand - Unrestricted Access	$ 26	cy	0	234,151	234,756	234,690	222,999	223,604	223,541	223,541	229,661	229,338	228,247	232,434	239,322	237,720	234,315	239,712	239,712
5f	Place Gravel - Unrestricted Access	$ 26	cy	0	20,620	20,620	20,620	20,620	20,620	20,620	20,620	11,769	11,769	11,769	20,708	11,857	11,857	20,708	11,857	11,857
5g	Place Armor Material - Unrestricted Access	$ 43	cy	0	30,931	30,931	30,931	30,931	30,931	30,931	30,931	17,654	17,654	17,654	31,062	17,786	17,786	31,062	17,786	17,786
5h	Place in situ Material in Difficult to Access Areas - Underpier	$ 400	cy	0	0	4,867	4,867	0	4,867	4,085	4,867	4,867	4,867	0	5,113	5,113	5,113	5,401	0	5,401
5i	Place ENR Material in Difficult to Access Areas - Low Bridge	$ 400	cy	0	811	811	811	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,562	1,562	1,562	1,562	1,562	1,562
6	**Surveys and Monitoring**																			
6a	**Payment Surveys**	$ 40,000	Site-wide Event	0	17	17	17	19	19	19	19	20	20	25	21	22	26	23	28	28
6b	Contractor daily progress surveys	$ 2,500	Day	0	833	833	833	933	933	933	933	972	972	1,217	1,042	1,056	1,287	1,115	1,361	1,361
Subtotal Construction Base Costs				**n/a**																
7	**Sales Tax and Contingency**																			
7a	Sales Tax	9.5%	--	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7b	Contingency	30%	--	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Subtotal Construction Costs				**n/a**																

Table 5
Quantities and Costs for Alternatives

Item No.	Item Description	Unit Cost	Unit	Quantity by Alternative																
				No Action	1A(12)	1B(12)	1C+(12)	2A(12)	2B(12)	2C(12)	2C+(12)	3B(12)	3C+(12)	3D(12)	2C+(7.5)	3C+(7.5)	3E(7.5)	2C+(5.0)	3D(5.0)	3E(5.0)
Indirect Construction Costs																				
8	**Pre-construction**																			
8a	Design and Permitting	5%	--	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8b	Pre-Construction Base-line Monitoring	Alternative-specific	Lump Sum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8c	Project Management (Owners)	1%	--	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8d	Agency Review and Oversight	$500,000	Annual	0	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
9	**During Construction**																			
9a	Construction Management Support	10%	--	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9b	**Environmental Compliance**																			
9bi	Water Quality Monitoring	$ 3,000	Day	0	833	833	833	933	933	933	933	972	972	1,217	1,042	1,056	1,287	1,115	1,361	1,361
9bii	Confirmational Sampling	Alternative-specific	Lump Sum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9c	Project Management (Owners)	4%	--	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9d	Agency Review and Oversight	$ 500,000	Annual	0	9	9	9	10	10	10	10	10	10	13	11	11	13	12	14	14
10	**Post-construction Costs**																			
10a	Operations and Maintenance and Long Term Monitoring 1 through 20 years post-construction	Alternative-specific	Lump Sum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10b	Contingency Remediation (Adaptive Management) - Open Water	$1,100,000	Acre	0	2.6	2.7	2.7	0.2	0.3	0.3	0.3	0.0	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.0
10c	Contingency Remediation (Adaptive Management) - Underpier and Low Bridge	$4,100,000	Acre	0	2.1	2.0	1.7	2.1	2.0	1.7	1.7	2.0	1.7	0.2	1.8	1.8	0.2	1.9	0.2	0.2
10d	Project Management (Owners)	1%	--	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10e	Agency Review and Oversight	$120,000	Annual	0	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Subtotal Indirect Construction Costs				**n/a**																
Total Cost				**n/a**																
Total Cost (rounded)				**n/a**																

Table 5
Quantities and Costs for Alternatives

Item No.	Item Description	Cost by Alternative																
		No Action	1A(12)	1B(12)	1C+(12)	2A(12)	2B(12)	2C(12)	2C+(12)	3B(12)	3C+(12)	3D(12)	2C+(7.5)	3C+(7.5)	3E(7.5)	2C+(5.0)	3D(5.0)	3E(5.0)
Pre-construction																		
1	**Mobilization/Demobilization**																	
1a	Mobilization/Demobilization	$ -	$ 6,300,000	$ 6,300,000	$ 6,300,000	$ 7,000,000	$ 7,000,000	$ 7,000,000	$ 7,000,000	$ 7,000,000	$ 7,000,000	$ 9,100,000	$ 7,700,000	$ 7,700,000	$ 9,100,000	$ 8,400,000	$ 9,800,000	$ 9,800,000
1b	Initial Transload Site Setup	$ -	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000
1c	Annual Transload Site Setup and Maintenance (After Initial)	$ -	$ 4,000,000	$ 4,000,000	$ 4,000,000	$ 4,500,000	$ 4,500,000	$ 4,500,000	$ 4,500,000	$ 4,500,000	$ 4,500,000	$ 6,000,000	$ 5,000,000	$ 5,000,000	$ 6,000,000	$ 5,500,000	$ 6,500,000	$ 6,500,000
1d	Mobilization/Demobilization for Underpier Dredging Equipment	$ -	$ -	$ -	$ 500,000	$ -	$ -	$ 500,000	$ 500,000	$ -	$ 500,000	$ 2,750,000	$ 500,000	$ 500,000	$ 3,000,000	$ 500,000	$ 3,250,000	$ 3,250,000
1e	Mobilization/Demobilization for Equipment to Dredge under the West Seattle Bridge	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 500,000	$ 500,000	$ 500,000	$ -	$ 500,000	$ 500,000	$ -	$ 500,000	$ 500,000
2	**Pre-construction activities**																	
2a	Pre-construction activities	$ -	$ 900,000	$ 900,000	$ 900,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,300,000	$ 1,100,000	$ 1,100,000	$ 1,300,000	$ 1,200,000	$ 1,400,000	$ 1,400,000
	Subtotal Pre-construction	**$ -**	**$ 12,200,000**	**$ 12,200,000**	**$ 12,700,000**	**$ 13,500,000**	**$ 13,500,000**	**$ 14,000,000**	**$ 14,000,000**	**$ 14,000,000**	**$ 14,500,000**	**$ 20,650,000**	**$ 15,300,000**	**$ 15,800,000**	**$ 20,900,000**	**$ 16,600,000**	**$ 22,450,000**	**$ 22,450,000**
Construction																		
3	**Removal, Dewatering, Offloading, and Disposal**																	
3a	Open-water Dredging	$ -	$ 22,175,996	$ 22,175,996	$ 22,175,996	$ 24,605,792	$ 24,605,792	$ 24,605,792	$ 24,605,792	$ 25,594,218	$ 25,594,218	$ 25,594,218	$ 27,487,971	$ 27,721,452	$ 27,721,452	$ 29,376,535	$ 29,621,487	$ 29,621,487
3b	Restricted Access Dredging (Under West Seattle Bridge)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,979,634	$ 1,979,634	$ 1,979,634	$ -	$ 2,302,259	$ 2,302,259	$ -	$ 2,346,533	$ 2,346,533
3c	Diver-Assisted Hydraulic Dredging (Underpier)	$ -	$ -	$ -	$ 4,209,372	$ -	$ -	$ 4,209,372	$ 4,209,372	$ -	$ 4,209,372	$ 26,363,963	$ 4,209,372	$ 4,209,372	$ 27,729,303	$ 4,209,372	$ 29,289,875	$ 29,289,875
3d	Water Treatment (Underpier Hydraulic Dredging)	$ -	$ -	$ -	$ 2,806,248	$ -	$ -	$ 2,806,248	$ 2,806,248	$ -	$ 2,806,248	$ 17,575,976	$ 2,806,248	$ 2,806,248	$ 18,486,202	$ 2,806,248	$ 19,526,583	$ 19,526,583
3e	Transload, Transportation and Disposal	$ -	$ 85,377,585	$ 85,377,585	$ 86,114,225	$ 94,732,297	$ 94,732,297	$ 95,468,938	$ 95,468,938	$ 100,286,107	$ 101,022,747	$ 104,899,801	$ 106,565,327	$ 109,497,535	$ 113,613,523	$ 113,836,299	$ 121,240,859	$ 121,240,859
4	**Pile Removal and Disposal**	$ -	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000
5	**Engineered Capping and Residuals Management Cover**																	
5a	Furnish Sand	$ -	$ 4,699,224	$ 4,711,327	$ 4,710,006	$ 4,488,400	$ 4,500,502	$ 4,499,248	$ 4,499,248	$ 4,621,645	$ 4,615,184	$ 4,593,375	$ 4,679,908	$ 4,817,666	$ 4,785,631	$ 4,717,530	$ 4,825,470	$ 4,825,470
5b	Furnish Gravel	$ -	$ 412,407	$ 412,407	$ 412,407	$ 412,407	$ 412,407	$ 412,407	$ 412,407	$ 235,387	$ 235,387	$ 235,387	$ 414,163	$ 237,144	$ 237,145	$ 414,163	$ 237,144	$ 237,144
5c	Furnish Armor Material	$ -	$ 1,082,570	$ 1,082,570	$ 1,082,570	$ 1,082,570	$ 1,082,570	$ 1,082,570	$ 1,082,570	$ 617,891	$ 617,891	$ 617,891	$ 1,087,177	$ 622,502	$ 622,507	$ 1,087,177	$ 622,502	$ 622,502
5d	Furnish In situ Treatment Material (AquaGate+PAC™)	$ -	$ -	$ 2,433,435	$ 2,433,436	$ -	$ 2,433,435	$ 2,042,296	$ 2,433,436	$ 2,433,435	$ 2,433,436	$ -	$ 2,556,650	$ 2,556,650	$ 2,556,669	$ 2,700,692	$ -	$ 2,700,692
5e	Place Sand - Unrestricted Access	$ -	$ 5,978,311	$ 5,993,761	$ 5,992,074	$ 5,693,581	$ 5,709,031	$ 5,707,430	$ 5,707,430	$ 5,863,681	$ 5,855,433	$ 5,827,592	$ 5,934,480	$ 6,110,341	$ 6,069,445	$ 5,982,507	$ 6,120,304	$ 6,120,304
5f	Place Gravel - Unrestricted Access	$ -	$ 526,478	$ 526,478	$ 526,478	$ 526,478	$ 526,478	$ 526,478	$ 526,478	$ 300,494	$ 300,494	$ 300,494	$ 528,718	$ 302,737	$ 302,739	$ 528,718	$ 302,737	$ 302,737
5g	Place Armor Material - Unrestricted Access	$ -	$ 1,325,595	$ 1,325,595	$ 1,325,595	$ 1,325,595	$ 1,325,595	$ 1,325,595	$ 1,325,595	$ 756,602	$ 756,602	$ 756,602	$ 1,331,237	$ 762,247	$ 762,253	$ 1,331,237	$ 762,247	$ 762,247
5h	Place in situ Material in Difficult to Access Areas - Underpier	$ -	$ -	$ 1,946,748	$ 1,946,749	$ -	$ 1,946,748	$ 1,633,837	$ 1,946,749	$ 1,946,748	$ 1,946,749	$ -	$ 2,045,320	$ 2,045,320	$ 2,045,335	$ 2,160,554	$ -	$ 2,160,554
5i	Place ENR Material in Difficult to Access Areas - Low Bridge	$ -	$ 324,280	$ 324,280	$ 324,280	$ 568,559	$ 568,559	$ 568,559	$ 568,559	$ 568,559	$ 568,559	$ 568,559	$ 624,644	$ 624,644	$ 624,644	$ 624,644	$ 624,644	$ 624,644
6	**Surveys and Monitoring**																	
6a	**Payment Surveys**	$ -	$ 680,000	$ 680,000	$ 680,000	$ 760,000	$ 760,000	$ 760,000	$ 760,000	$ 800,000	$ 800,000	$ 1,000,000	$ 840,000	$ 880,000	$ 1,040,000	$ 920,000	$ 1,120,000	$ 1,120,000
6b	Contractor daily progress surveys	$ -	$ 2,083,584	$ 2,083,584	$ 2,083,584	$ 2,333,304	$ 2,333,304	$ 2,333,304	$ 2,333,304	$ 2,430,019	$ 2,430,019	$ 3,043,414	$ 2,605,179	$ 2,638,864	$ 3,217,170	$ 2,786,429	$ 3,403,597	$ 3,403,597
	Subtotal Construction Base Costs	*$ -*	*$ 125,666,030*	*$ 130,073,766*	*$ 137,823,021*	*$ 137,528,983*	*$ 141,936,719*	*$ 148,982,073*	*$ 149,686,125*	*$ 149,434,421*	*$ 157,171,974*	*$ 194,356,905*	*$ 164,716,394*	*$ 169,134,982*	*$ 213,116,278*	*$ 174,482,105*	*$ 221,043,982*	*$ 225,905,228*
7	**Sales Tax and Contingency**																	
7a	Sales Tax	$ -	$ 13,097,273	$ 13,516,008	$ 14,299,687	$ 14,347,753	$ 14,766,488	$ 15,483,297	$ 15,550,182	$ 15,526,270	$ 16,308,838	$ 20,425,656	$ 17,101,557	$ 17,568,823	$ 22,231,546	$ 18,152,800	$ 23,131,928	$ 23,593,747
7b	Contingency	$ -	$ 45,288,991	$ 46,736,932	$ 49,446,812	$ 49,613,021	$ 51,060,962	$ 53,539,611	$ 53,770,892	$ 53,688,207	$ 56,394,243	$ 70,629,768	$ 59,135,386	$ 60,751,142	$ 76,874,347	$ 62,770,471	$ 79,987,773	$ 81,584,692
	Subtotal Construction Costs	**$ -**	**$ 196,252,294**	**$ 202,526,706**	**$ 214,269,521**	**$ 214,989,757**	**$ 221,264,170**	**$ 232,004,981**	**$ 233,007,199**	**$ 232,648,899**	**$ 244,375,055**	**$ 306,062,330**	**$ 256,253,337**	**$ 263,254,947**	**$ 333,122,172**	**$ 272,005,376**	**$ 346,613,683**	**$ 353,533,667**

Table 5
Quantities and Costs for Alternatives

Item No.	Item Description	Cost by Alternative																
		No Action	1A(12)	1B(12)	1C+(12)	2A(12)	2B(12)	2C(12)	2C+(12)	3B(12)	3C+(12)	3D(12)	2C+(7.5)	3C+(7.5)	3E(7.5)	2C+(5.0)	3D(5.0)	3E(5.0)
Indirect Construction Costs																		
8	**Pre-construction**																	
8a	Design and Permitting	$ -	$ 9,812,615	$ 10,126,335	$ 10,713,476	$ 10,749,488	$ 11,063,208	$ 11,600,249	$ 11,650,360	$ 11,632,445	$ 12,218,753	$ 15,303,116	$ 12,812,667	$ 13,162,747	$ 16,656,109	$ 13,600,269	$ 17,330,684	$ 17,676,683
8b	Pre-Construction Base-line Monitoring	$ -	$ 337,340	$ 512,016	$ 512,016	$ 328,908	$ 503,584	$ 479,603	$ 503,584	$ 499,368	$ 499,368	$ 312,045	$ 499,368	$ 495,152	$ 495,152	$ 514,521	$ 309,937	$ 510,305
8c	Project Management (Owners)	$ -	$ 1,962,523	$ 2,025,267	$ 2,142,695	$ 2,149,898	$ 2,212,642	$ 2,320,050	$ 2,330,072	$ 2,326,489	$ 2,443,751	$ 3,060,623	$ 2,562,533	$ 2,632,549	$ 3,331,222	$ 2,720,054	$ 3,466,137	$ 3,535,337
8d	Agency Review and Oversight	$ -	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000
9	**During Construction**																	
9a	Construction Management Support	$ -	$ 12,566,603	$ 13,007,377	$ 13,782,302	$ 13,752,898	$ 14,193,672	$ 14,898,207	$ 14,968,613	$ 14,943,442	$ 15,717,197	$ 19,435,691	$ 16,471,639	$ 16,913,498	$ 21,311,628	$ 17,448,210	$ 22,104,398	$ 22,590,523
9b	**Environmental Compliance**																	
9bi	Water Quality Monitoring	$ -	$ 2,500,301	$ 2,500,301	$ 2,500,301	$ 2,799,965	$ 2,799,965	$ 2,799,965	$ 2,799,965	$ 2,916,023	$ 2,916,023	$ 3,652,097	$ 3,126,215	$ 3,166,637	$ 3,860,604	$ 3,343,715	$ 4,084,316	$ 4,084,316
9bii	Confirmational Sampling	$ -	$ 287,826	$ 462,502	$ 462,502	$ 279,394	$ 454,070	$ 430,089	$ 454,070	$ 449,854	$ 449,854	$ 262,531	$ 449,854	$ 445,638	$ 447,746	$ 465,007	$ 260,423	$ 460,791
9c	Project Management (Owners)	$ -	$ 7,850,092	$ 8,101,068	$ 8,570,781	$ 8,599,590	$ 8,850,567	$ 9,280,199	$ 9,320,288	$ 9,305,956	$ 9,775,002	$ 12,242,493	$ 10,250,133	$ 10,530,198	$ 13,324,887	$ 10,880,215	$ 13,864,547	$ 14,141,347
9d	Agency Review and Oversight	$ -	$ 4,500,000	$ 4,500,000	$ 4,500,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 5,000,000	$ 6,500,000	$ 5,500,000	$ 5,500,000	$ 6,500,000	$ 6,000,000	$ 7,000,000	$ 7,000,000
10	**Post-construction Costs**																	
10a	Operations and Maintenance and Long Term Monitoring 1 through 20 years post-construction	$ 948,541	$ 1,909,058	$ 2,957,113	$ 2,957,113	$ 1,850,037	$ 2,898,092	$ 2,752,097	$ 2,898,092	$ 2,868,581	$ 2,868,581	$ 1,729,886	$ 2,877,013	$ 2,847,502	$ 2,851,718	$ 2,965,819	$ 1,719,347	$ 2,936,308
10b	Contingency Remediation (Adaptive Management) - Open Water	$ -	$ 2,862,169	$ 2,944,686	$ 2,944,686	$ 197,878	$ 280,395	$ 280,395	$ 280,395	$ -	$ -	$ -	$ 313,544	$ -	$ -	$ 313,544	$ -	$ -
10c	Contingency Remediation (Adaptive Management) - Underpier and Low Bridge	$ -	$ 8,450,982	$ 8,143,418	$ 6,950,606	$ 8,450,982	$ 8,143,418	$ 6,950,606	$ 6,950,606	$ 8,143,418	$ 6,950,606	$ 722,446	$ 7,397,631	$ 7,397,631	$ 793,710	$ 7,836,900	$ 793,710	$ 793,710
10d	Project Management (Owners)	$ -	$ 1,962,523	$ 2,025,267	$ 2,142,695	$ 2,149,898	$ 2,212,642	$ 2,320,050	$ 2,330,072	$ 2,326,489	$ 2,443,751	$ 3,060,623	$ 2,562,533	$ 2,632,549	$ 3,331,222	$ 2,720,054	$ 3,466,137	$ 3,535,337
10e	Agency Review and Oversight	$ -	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,000
	Subtotal Indirect Construction Costs	**$ 948,541**	**$ 59,502,030**	**$ 61,805,349**	**$ 62,679,172**	**$ 60,808,935**	**$ 63,112,254**	**$ 63,611,510**	**$ 63,986,116**	**$ 64,912,066**	**$ 65,782,886**	**$ 70,781,552**	**$ 69,323,132**	**$ 70,224,103**	**$ 77,403,998**	**$ 73,308,307**	**$ 78,899,637**	**$ 81,764,657**
	Total Cost	**$ 948,541**	**$ 255,754,324**	**$ 264,332,055**	**$ 276,948,693**	**$ 275,798,693**	**$ 284,376,424**	**$ 295,616,491**	**$ 296,993,315**	**$ 297,560,965**	**$ 310,157,941**	**$ 376,843,882**	**$ 325,576,469**	**$ 333,479,050**	**$ 410,526,170**	**$ 345,313,684**	**$ 425,513,320**	**$ 435,298,324**
	Total Cost (rounded)	**$ 950,000**	**$ 256,000,000**	**$ 264,000,000**	**$ 277,000,000**	**$ 276,000,000**	**$ 284,000,000**	**$ 296,000,000**	**$ 297,000,000**	**$ 298,000,000**	**$ 310,000,000**	**$ 377,000,000**	**$ 326,000,000**	**$ 333,000,000**	**$ 411,000,000**	**$ 345,000,000**	**$ 426,000,000**	**$ 435,000,000**

Table 6
Alternatives Cost Summary

Item	Alternative																
	No Action	1A(12)	1B(12)	1C+(12)	2A(12)	2B(12)	2C(12)	2C+(12)	3B(12)	3C+(12)	3D(12)	2C+(7.5)	3C+(7.5)	3E(7.5)	2C+(5.0)	3D(5.0)	3E(5.0)
Total Cost	$ 948,541	$ 255,754,324	$ 264,332,055	$ 276,948,693	$ 275,798,693	$ 284,376,424	$ 295,616,491	$ 296,993,315	$ 297,560,965	$ 310,157,941	$ 376,843,882	$ 325,576,469	$ 333,479,050	$ 410,526,170	$ 345,313,684	$ 425,513,320	$ 435,298,324
Total Cost (rounded)	$ 950,000	$ 256,000,000	$ 264,000,000	$ 277,000,000	$ 276,000,000	$ 284,000,000	$ 296,000,000	$ 297,000,000	$ 298,000,000	$ 310,000,000	$ 377,000,000	$ 326,000,000	$ 333,000,000	$ 411,000,000	$ 345,000,000	$ 426,000,000	$ 435,000,000

APPENDIX J – DETAILED CALCULATIONS AND SENSITIVITY ANALYSES FOR PREDICTIVE EVALUATION OF SITE PERFORMANCE OVER TIME AND RECONTAMINATION POTENTIAL

EAST WATERWAY OPERABLE UNIT FEASIBILITY STUDY

Prepared for

Port of Seattle

Prepared by

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November 2017

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1 INTRODUCTION

This appendix provides the mathematical basis for contaminant concentration predictions for East Waterway (EW) remedial alternatives presented in the Feasibility Study (FS). The purpose of each of the predictive evaluations discussed in this appendix is described in detail in FS Section 5. Remedial technologies for use in the EW are described in FS Section 7, and descriptions of remedial alternatives are provided in FS Section 8.

This appendix provides a summary of input information, methodology, mathematical calculations, and rationale for model assumptions for each of the three predictive evaluations presented in Section 5:

- Site-wide Performance Over Time (referred to as the "box model evaluation") (Section 2 of this appendix, FS Section 5.3)
- Remedial action objective (RAO) 3 Performance Over Time (referred to as the "point mixing model evaluation") (Section 3 of this appendix, FS Section 5.5)
- Recontamination Potential (referred to as the "grid model evaluation") (Section 4 of this appendix, FS Section 5.4)

This appendix also summarizes the sensitivity and bounding analyses conducted to determine the relative influence of input parameters on the results of the predictive evaluations (Sections 2.3, 3.4, and 4.5 of this appendix).

2 SITE-WIDE PERFORMANCE OVER TIME (BOX MODEL EVALUATION)

The box model evaluation was used to predict spatially-weighted average concentrations (SWAC) for the alternatives from years 0 to 40 post-construction for the four human health risk driver contaminants of concern (COCs):

1. Polychlorinated biphenyls (PCBs)
2. Arsenic
3. Carcinogenic polycyclic aromatic hydrocarbons (cPAHs)
4. Dioxins/furans

Predicted SWACs were then used for the screening of alternatives (Appendix L) and for the detailed and comparative evaluation of the retained alternatives (FS Sections 9 and 10).

The box model evaluation was conducted using a Microsoft Excel spreadsheet-based analytical model that calculates site-wide and sub-area SWACs within the EW. The SWAC for each human health risk driver COC is calculated beginning at year 0 (immediately following construction) and at 5-year intervals through year 40. The site-wide SWAC for each COC is determined at each 5-year interval (e.g., 0, 5, 10, 15, etc.) through a series of calculations that take into account remedial technology and sediment mixing assumptions, which vary across the EW, and incoming sediment characteristics. A sensitivity and bounding evaluation was also conducted, based on range of values for input variables, to determine the effect of uncertainty in the input information on the SWAC calculations.

This section provides a description of input parameters used in the evaluation, including ranges used for sensitivity and bounding (Section 2.1), mathematical basis for the calculations (Section 2.2), sensitivity and bounding analyses for the model results (Section 2.3), and a brief summary of where the model results are used within the FS (Section 2.4). Section 5 of this appendix provides additional considerations regarding uncertainties associated with predicted SWAC values using the box model evaluation.

2.1 Input Information

The box model evaluation utilized several types of input information to estimate SWAC values over the 40-year post-construction time period, as follows:

- Upstream and lateral solids loading and net sedimentation rates (NSRs) within the EW
- Chemistry assumptions for incoming solids
- Post-construction surface sediment concentrations, including dredge residuals thickness and concentrations
- Sediment mixing and underpier exchange assumptions
- Bioavailability of hydrophobic organic contaminants
- Remedial technologies for the remedial alternatives

Development of best estimates (base case) values for each of these input parameters are discussed in detail in FS Sections 5.3.1 through 5.3.5, and summarized in the following subsections. There are uncertainties in the selection of the best estimate (base case) values for the input parameters. In order to evaluate the sensitivity of the box model calculations (SWAC values) to these uncertainties, high and low values of these input parameters were also developed. A discussion of the high and low values for these inputs is also provided in the following subsections, and the sensitivity analysis is provided in Section 2.3 herein.

A summary of the best estimate (base case) and high and low values for each of the input variables is provided in Chart 1. Chart 1 also provides a road-map, in the last column of the chart, to the location where detailed discussion and justification for the values of each parameter can be found within the EW FS.

Chart 1

Summary of Base Case and High and Low Range Values of Variables used in the Box Model Evaluation

Variable	Range of Values used in Sensitivity Analysis			Basis for Range of Values	Road Map to Sections in the FS for Detailed Discussion
	Low	Base Case	High		
Site-wide NSR (cm/yr)	0.5	1.2	1.8	**Base case**: Estimated as a site-wide area average by assigning areas either 1.6, 0.5, or 0 cm/yr NSRs based on geochronology core data and vessel operations. **Low**: Estimated with the average of the Pb-210 cores with best-fit lines. **High**: Average of high range of values calculated for Cs-137 data for each core where Cs-137 peaks were found.	• Section 2.1.1 herein • FS Sections 5.1.1 and 5.1.2 • FS Figure 5-1
Variable NSR	Three NSRs assigned to different areas with site-wide average net sedimentation equal to 1.2 cm/yr.			Areas assigned either 1.6, 0.5, or 0 cm/yr NSRs based on geochronology core data, vessel operations, and comparison of bathymetric surveys.	
EW Laterals Chemical Concentrations	Low	Base Case	High	Section 2.1.2.1 and Table 1 herein, FS Section 5.3.1, FS Tables 5-3 and 5-4, and FS Appendix B, Part 4.	
Green River Chemical Concentrations	Low	Base Case	High	Section 2.1.2.1 and Table 1 herein, FS Section 5.3.1, FS Tables 5-3 and 5-4, and FS Appendix B, Part 3B.	
Dredge Residuals Thickness - Dredged Areas / Unremediated Islands (cm)	3.1 / 0.6	5.1 / 1.0	7.2 / 1.4	**Base case**: Core-by-core analysis incorporating multiple dredge passes and assuming 5% loss of dredge material. **Low**: Core-by-core analysis incorporating multiple dredge passes and assuming 3% loss of dredge material. **High**: Core-by-core analysis incorporating multiple dredge passes and assuming 7% loss of dredge material.	• Section 2.1.2.1 herein • FS Appendix B, Part 3A
Dredge Residuals Concentration - Dredged Areas / Unremediated Islands (Total PCBs; µg/kg dw)	540 / 470	760 / 640	1280 / 980	**Base case**: Core-by-core analysis incorporating multiple dredge passes. Cores are area-weighted averaged by Thiessen polygon. **Low**: Median value of the core-by-core analysis. **High**: 95% upper confidence limit on the mean (gamma distribution) of the core-by-core analysis.	• Section 2.1.2.1 herein • FS Appendix B, Part 3A
Mixing Depth due to Propwash in Vessel Operation Areas	1[1]	2	3[1]	Vertical mixing depths were variable across the EW in open-water areas as shown in Figure 5-3. For high and low ranges, only open-water areas with best estimate mixing depths equal to 2 feet were varied as part of the sensitivity analysis. Underpier sediments were assumed to be fully mixed by volume for all cases (sensitivity to underpier mixing was evaluated through range in percent exchange). **Base case**: Approximate site-wide average of estimating propwash mixing depth within areas predicted to have mixing depths greater than 0.5 feet, as shown in Figure 5-3. **Low**: Value chosen to be 1 foot lower than the base case in the 2-foot mixing areas shown in Figure 5-3. **High**: Value chosen to be 1 foot higher than the base case, in the 2-foot mixing areas shown in Figure 5-3. This value is not as large as the largest estimated mixing depth (4.7 feet), as that is a conservatively high value (to assign to the entire EW) based on methods used to estimate propwash mixing depths in the SRI[2].	• Section 2.1.4 herein • FS Section 5.1.5 • FS Figure 5-2 • FS Appendix B, Part 2
Percent of EW Open-water Area that is Vertically Mixed Every 5 Years	30%	50%	90%	10-cm biologically active zone mixing is assumed to be the minimum mixing depth in all areas. **Base case**: Approximate percent of the EW area that is either: 1) subject to frequent propwash mixing based on the area of the EW with geochronology cores with Cs-137 peaks or higher correlation Pb-210 data; 2) contains unrecoverable geochronology cores; 3) contains cores without either Cs-137 peaks or Pb-210 correlations; or 4) in areas where cores were not attempted (areas presumed to mix or that were previous dredged). **Low**: Low bound estimated based on areas where NSRs are 0 or 0.5 cm/yr. Although vessels actively navigate 90% of the EW, propeller scour effects from individual vessels create localized effects, so some sediment could remain undisturbed over time. **High**: Approximate percent of the EW that is, or could be, subject to propwash mixing based on vessel operations in each area as documented in the STER[3] and SRI[2]. Areas 1C and 7 are excluded from propwash mixing due to documented lack of current or future planned vessel operations and all other areas are considered propwash areas.	• Section 2.1.5 herein • FS Section 5.3.3

Chart 1

Summary of Base Case and High and Low Range Values of Variables used in the Box Model Evaluation

Variable	Range of Values used in Sensitivity Analysis			Basis for Range of Values	Road Map to Sections in the FS for Detailed Discussion
	Low	Base Case	High		
Percent Exchange Between Underpier and Open-water Sediments Every 5 years	5%	25%	50%	**Base case**: Approximate percent of the pier face length subject to significant propwash impact compared to the total length of the pier face. **Low**: Represents minimal exchange of sediment between open-water and underpier areas. **High**: Represents reasonable high underpier exchange estimate. 100% was not chosen because it is likely that some portion of the underpier areas (even in an extreme case) would not mix every 5 years. Approximate percent of the underpier volume mixed based on a 2-foot mixing depth (low end of predicted range for mixing depth). Average depth of sediments in the underpier areas is approximately 2 feet.	• Section 2.1.6 herein • FS Section 5.3.4
Percent Reduction in Bioavailability of Hydrophobic Organic Contaminants in Underpier Sediments Due to In situ Treatment	50%	70%	90%	**Base case**: Represents bioavailability due to in situ treatment in laboratory and field studies in stable sediment (90%) adjusted downward to account for dilution of AC during mixing and exchange of underpier sediment. **Low**: Represents low estimate of bioavailability reduction due to dilution of AC from mixing and exchange of underpier sediment. **High**: Estimate of the percent reduction in bioavailability due to in situ treatment in laboratory and field studies in stable sediment.	• Section 2.1.7 herein • FS Section 7.2.7.1.1

Notes:
1. High and low range of vertical mixing depths applied to open-water areas where best estimate (base case) vertical mixing depth was equal to 2 feet.
2. *Final Supplemental Remedial Investigation Report* (SRI; Windward and Anchor QEA 2014).
3. *Final Sediment Transport Evaluation Report* (STER; Anchor QEA and Coast & Harbor Engineering 2012).

µg/kg – micrograms per kilogram
AC – activated carbon
cm/yr – centimeters per year
Cs-137 – cesium-137
dw – dry weight
EW – East Waterway
FS – Feasibility Study
NSR – net sedimentation rate
Pb-210 – lead-210
PCB – polychlorinated biphenyl

2.1.1 Solids Loads and Net Sedimentation Rate

Representative site-wide average NSR from all solids sources to the EW (upstream and EW lateral inputs) were estimated using site-specific geochronology core data and delineation of vessel operation areas within the EW (see Sections 3.4.2 and 3.3, respectively, of the *Final Supplemental Remedial Investigation Report* (SRI); Windward and Anchor QEA 2014). Additional evaluation of the site average NSR was conducted following approval of the SRI to explicitly include lead-210 (Pb-210) data in the calculation, and to take into account areas of the EW regularly affected by vessel operations where net sedimentation is likely close to 0. These additional evaluations are documented in detail in FS Sections 5.1.1 and 5.1.2 and Figure 5-1. Based on this work, the base case value for site-wide average NSR for the EW was estimated to be 1.2 centimeters per year (cm/yr). For the purposes of the box model evaluation, the representative NSR was assumed to be a single constant value throughout the EW, recognizing that actual sediment accumulation may vary considerably on location basis (both above and below 1.2 cm/yr) due to propwash effects associated with vessel operations within the waterway.

The high range value of site-wide NSR was 1.8 cm/yr, which is the average of the high range of NSRs calculated from cesium-137 (Cs-137) data from recovered geochronology cores (see Table 3-3 in the EW SRI; Windward and Anchor QEA 2014). The low range value for NSR was 0.5 cm/yr, which is the average of the NSRs estimated using Pb-210 data (see Table 3-3 in the EW SRI). In addition to low and high values of site-wide NSRs, the sensitivity analysis for the box model evaluation included a simulation that used variable NSRs within the EW, as shown in Figure 5-1 (as opposed to a single value for the entire site).

The proportion of incoming sediment attributed to upstream solids sources (i.e., the Green River, Lower Duwamish Waterway [LDW] bed sediments, and LDW lateral inputs) and EW lateral sources was estimated using the results of the LDW sediment transport model (QEA 2008), the updated EW hydrodynamic model (Anchor QEA and Coast & Harbor Engineering 2012), and deposition of sediments from EW lateral sources in the EW estimated from particle tracking model (PTM) results (see FS Appendix B). The estimated amount of solids input to the EW (by source), and the amount predicted to deposit within the EW are shown in Table 1.

2.1.2 Chemistry Assumptions

Chemistry assumptions for use in the box model for the four human health risk driver COCs were developed for incoming solids (i.e., upstream sources [the Green River, LDW bed sediments, and LDW lateral sources] and EW lateral sources), for existing conditions for in situ bed sediments, and for post-construction concentrations in remediation areas (i.e., bed replacement values and dredge residuals concentrations, which vary according to the remedial technology used for the alternatives).

2.1.2.1 Incoming Solids

Chemistry assumptions for incoming solids (upstream sources and EW lateral sources) were estimated from available empirical data as described in FS Section 5.3.1 and Appendix B, Parts 3B and 4. The best estimate (base case), high bounding, and low bounding concentrations from all sources to the EW are listed in FS Tables 5-3 and 5-5. The average net incoming concentrations considering both upstream and lateral sources for total PCBs are presented in Chart 2.

Chart 2

Net Incoming Solids Concentrations[1] Considering Upstream and Lateral Sources

Scenario		PCBs Concentration (µg/kg dw)
Current Case (years 0 to 10 post-construction)	Best Estimate	46
	Low Bounding	8.0
	High Bounding	86
Future Case[2] (years 11 to 40 post-construction)	Best Estimate	45
	Low Bounding	7.7
	High Bounding	85

Notes:
1. See FS Table 5-5 for net incoming concentrations for all upstream sources.
2. Future conditions are based on actions to reduce lateral loads such as CSO control where required to meet NPDES permit conditions and source control in storm drain basins. Upstream incoming solids were not modified for the future case because of uncertainty in the timeframe and scope of those controls, and because they are likely to be captured by the low bounding concentration estimate.

µg/kg – micrograms per kilogram
CSO – combined sewer overflow
dw – dry weight
FS – Feasibility Study
LDW – Lower Duwamish Waterway
NPDES – National Pollutant Discharge Elimination System
PCB – polychlorinated biphenyl

2.1.2.2 Dredge Residuals

Generated dredge residuals are contaminated sediments that are resuspended from the seabed during dredging activities and settle back onto the remediated surface or adjacent unremediated surfaces. Methods for estimating chemistry associated with dredge residuals and dredge residuals thickness are discussed in detail in FS Appendix B, Part 3A (Section 2).

Concentrations for the best estimate (base case) dredge residuals were estimated to be 640 micrograms per kilogram (µg/kg) dry weight (dw) for total PCBs, 490 µg toxic equivalent (TEQ)/kg dw for cPAHs, 10 milligrams per kilogram (mg/kg) dw for arsenic, and 17 nanograms (ng) TEQ/kg dw for dioxin/furans. There are two separate thicknesses of dredge residuals used in the box model calculations; one thickness that is applied over areas that are being actively dredged, and another thickness that is applied over adjacent areas where removal is not occurring. Base case assumptions for dredge residuals thickness are estimated to be 5.1 cm for all dredged areas and 1.0 cm in areas adjacent to dredging areas.

High and low ranges of dredge residuals for PCBs used in the sensitivity evaluation were developed by varying both the dredge residuals concentration and dredge residuals thickness. High and low estimates for dredge residuals chemistry (PCBs) and thickness are shown in Chart 1.

2.1.2.3 Post-construction Concentrations

Methods for estimating post-construction (i.e., bed replacement) values associated with each remedial technology are presented in Table 2 and described in detail in FS Appendix B, Part 3A (Sections 2.4 and 3).

Chemical concentrations for existing (in situ) bed sediments used for the no action alternative and designated no action and monitored natural recovery (MNR) areas within remedial alternatives were determined by interpolating existing surface sediment and shallow subsurface sediment data using Thiessen polygons, as discussed in FS Section 2.

2.1.3 Vertical Mixing Depths

Vertical mixing depth estimates in open-water areas for the box model are spatially variable over the EW and were developed based on predicted scour depths in the EW due to propwash. The predicted scour depths are discussed in FS Section 5.1.5 and Appendix B, Part 2. The justification for the range of vertical mixing depths used in the box model evaluation are discussed in FS Section 5.3.3 and illustrated in FS Figure 5-2. The best estimate (base case) vertical mixing depths used in the box model evaluation range from 2 feet in highly energetic propwash areas to 10 cm in areas impacted by bioturbation only (areas with no vessel operations). Underpier areas are assumed to be full-mixed by volume as the average sediment depth is 2 feet.

The high range value for vertical mixing was set to 3 feet in highly energetic propwash areas, and the low range value vertical mixing was set to 1 foot in these areas. These values were chosen based on the range of propwash scour depths calculated in these areas (see FS Figure 5-2 and the SRI [Anchor QEA and Coast & Harbor Engineering 2012]) and to ensure that there was an equal variation about the base case (1 foot higher and 1 foot lower).

2.1.4 Percent of East Waterway Study Area that is Mixed

In addition to vertical mixing assumptions, the percent of the surface area within the EW that is mixed was also included as a variable in the box model because propwash mixing is not expected to cover the entire waterway. The base case value for percent area mixed was set at 50% of the surface area of the EW (both open-water and underpier areas) every 5 years. Justification for selection of 50% area mixing within the EW is provided in FS Section 5.3.3 considering both vessel scour predictions and geochonological data.

The high range value for percent of EW area mixed was set to 90%, which represents the percent of the EW area that is subject to vessel operations and, therefore, has potential for propwash erosion. This includes all vessel operation areas shown in FS Figure 5-1, except for Areas 1C and 7, where no vessel operations are currently occurring or are planned to occur in the future. The low range value for percent of EW area mixed was set to 30%, which represents the percent of the EW area where NSRs were estimated from geochronology cores to be low (0 to 0.5 cm/yr), see FS Figure 5-1. Propwash erosion results in lower NSR

estimates, therefore, areas of the EW with lower net sedimentation are most likely to be subject to significant propwash erosion[1].

2.1.5 Percent Exchange

Vessel scour by propwash in open-water and underpier areas results in exchange of sediments between those two areas due to resuspension and deposition of bed sediments. In order to account for this mechanism in the box model evaluation, an exchange of sediments between the open-water and underpier areas was programmed into the model. This physical process was simulated in the model by including a volume exchange calculation in the box model that exchanges 25% of the total volume of sediment located in the underpier areas with the same volume of sediment from the open-water areas within the EW (with each of their associated chemistries). The box model evenly distributes the exchanged underpier sediments throughout the open-water areas; this is a conservative assumption because it is more likely that these sediments settle nearer to piers than the middle of the navigation channel, which would result in locally higher concentrations nearer to outfalls compared to the SWAC value. Justification for selection of 25% exchange within the EW is provided in FS Section 5.3.4.

The high range value for percent of underpier sediments exchanged with open water was set to 50%, which is considered a reasonable high bound and is equivalent to the exchange of 1 foot of sediment across the entire underpier area (see FS Figure 5-3). The low range value for percent of underpier sediments exchanged was set to 5%, which is the approximate volume of underpier sediments adjacent to vessel operational Area 1A-4 (shown in FS Figure 5-1) that has been assigned a NSR of 0 due to impacts from propwash.

2.1.6 Bioavailability of Hydrophobic Organic Contaminants

The percent reduction in bioavailability of hydrophobic organic contaminants (including total PCBs) in underpier sediments due to in situ treatment was included as a parameter in the box model evaluation for remedial alternatives that included in situ treatment. The best

[1] In the SRI, the EW was determined to be net depositional (site-wide average) and that near-bed current velocities were not large enough to cause erosion of bed sediments. Therefore, areas within the EW found to have lower or zero net sedimentation are assumed to be subject to erosion by propwash (see FS Section 5.1).

estimate value for reduction in bioavailability (70%) was determined through review of literature and pilot study results and consideration of stability of the material, and is discussed in FS Section 7.2.7.1.1.

High and low values for this parameter were used to examine the sensitivity of the box model calculations to choice of bioavailability. The high range value for reduction in bioavailability was based on laboratory and field studies, and assumes that sediments will be largely stable (90%). The low range value for bioavailability was estimated assuming that effectiveness is further diminished by loss of stability through scour and transport mechanisms in the EW, which lowers activated carbon (i.e., in situ treatment material) concentrations in sediments to less effective levels (50%).

2.1.7 Remedial Technology Assignments

The area of each remedial technology for the screening alternatives is presented in Table 3 herein and depicted in FS Appendix L, Figures 2-1 through 2-16. Table 2 herein provides the post-construction concentrations associated with each remedial technology and screening alternative.

Each remedial technology is represented in the box model by a vertical bed layer model, which consisted of post-construction surface concentrations, dredge residuals layer, enhanced natural recovery (ENR) layer, backfill layer, residuals management cover (RMC) layer, and/or cap material layer, depending on remedial technology. The vertical layers associated with each remedial technology are summarized in Chart 3 and depicted in Figures 1a through 1j.

Chart 3

Remedial Technologies and Associated Actions for Box Model Evaluation

Technology	Model Components (see Figures 1a – 1h herein)			
	Removal	Placement Material	Dredge Residuals Layer	Vertical Sediment Bed Layer Figure (s)
Removal	X	Residuals management cover	X	1a and 1b
Removal and backfill to existing grade	X	Backfill	X	1c
No action (open-water interior unremediated islands)		Residuals management cover	X	1d
No action (Junction Reach and Northern end of EW)		None		1e
MNR		None	X	1f
ENR		ENR sand	X	1g
Partial removal and cap	X	Multi-layer cap with armor	X	1h and 1i
ENR-nav		ENR sand	X	1j
In situ treatment (underpier)		In situ treatment material	X[a]	None – underpier sediment is modeled as a single volume of material

Notes:
a. In situ treatment was placed on a residuals layer in areas that included diver-assisted hydraulic dredging prior to placement of in situ treatment.
ENR – enhanced natural recovery
MNR – monitored natural recovery
EW – East Waterway

2.2 Site-wide SWAC Calculations

The box model evaluation is used to calculate site-wide surface sediment SWAC over time for the four human health risk COCs for the screening alternatives based on the model inputs described above.

This section summarizes the specific mathematical calculations that were conducted as part of the box model evaluation to calculate site-wide SWAC values for all screening alternatives at year 0, directly following construction, and years 5 through 40, post-construction. Justification for the methodology for calculating site-wide SWAC values is discussed in FS Section 5.3.

2.2.1 Definition of East Waterway Sub-areas

The EW is divided up into sub-areas that represent remedial technologies applied within the EW for each alternative. These remedial technology sub-areas are further sub-divided based on vertical mixing depth areas (see FS Figure 5-2). This results in definition of each sub-area within the EW that has a unique remedial technology and vertical mixing depth. Figure 2 shows an example map to illustrate what these sub-areas look like, developed for Alternative 1A(12). All underpier areas are treated as one sub-area for the purpose of these calculations.

2.2.2 Total Incoming Solids Chemistry

A value of 1.2 cm was used for the current condition annual NSR for the EW. The NSR for the future condition was adjusted downward to 1.198 cm to account for the predicted reduction of input from additional source control actions that are expected to take place in the next 10 years that will reduce loads from EW storm drains (SDs) and combined sewer overflows (CSOs).

The average incoming solids concentrations were calculated by calculating the weighted average by mass of the five deposited solids loads to the EW from each of the source locations, which are as follows:

1. Green River
2. LDW bed sediments
3. LDW lateral inputs
4. EW SDs
5. EW CSOs

Equation 1 was used to find the average incoming solids concentrations to the EW from the five source locations.

$$Average\ Incoming\ Solids\ Concentration = \frac{\sum_{i=1}^{5}[Input_i Load * Input_i Concentration]}{\sum_{i=1}^{5} Input_i Load} \quad (1)$$

where:

$Input_i$ Load	=	deposited sediment load from each of the five input locations listed above
$Input_i$ Concentration	=	chemical concentration for each of the COCs associated with the identified solids loads from the five input locations above

Values for average incoming sediment concentrations used for the box model evaluation are provided in FS Section 5, Table 5-5.

2.2.3 Year 0 SWAC

Year 0 SWAC concentrations were calculated based on delineation of remedial technologies and corresponding existing (in situ) sediment chemistry or bed replacement chemistry values for each alternative. Equation 2 was used to calculate year 0 post-construction SWAC values.

$$SWAC_0 = \frac{\sum_{m=1}^{a}[C_{m0}A_m]}{\sum_{m=1}^{a}A_m} \quad (2)$$

where:

$SWAC_0$	=	SWAC at year 0
a	=	Number of unique sub-areas (combinations of remedial technologies and vertical mixing depths, including underpier areas)
A_m	=	Area of each individual sub-area
C_{m0}	=	Surface concentration of year 0 of each individual sub-area

2.2.4 Concentrations of Vertically Mixed Open-water Sub-areas

At year 0, each open-water sub-area is characterized by a vertical bed layer model (thickness and concentration of sediment layers) based on remedial technology as shown in Figures 1a through 1j. At year 5, an additional sediment layer representing deposition of incoming solids is included on top of the year 0 sediment layers. Following deposition, the individual sediment layers shown in Figures 1a through 1j are mixed vertically over the vertical mixing depth for 50% of each sub-area. The other 50% of each sub-area is vertically mixed based on

the bioturbation depth (10 cm). This simulates that only 50% of the open-water area of the EW is mixed by propwash within the 5-year timeframe.

The general formulas used to calculate the vertically mixed surface sediment concentration for each sub-area at year 5 post-remediation are presented in Equations 3 and 4. These general formulas are applicable to all open-water remedial technologies, consistent with vertical bed layer models and vertical mixing processes shown in Figures 1a through 1j.

$$C_{5i(a)} = \left[\frac{(C_{depc} \times T_{ydc}) + (C_{sc(a)} \times T_{sc(a)}) + \left(C_{br(a)} \times T_{br(a)}\right) + (C_{r(a)} \times T_{r(a)})}{T_{mix(a)}} \right] \quad (3)$$

$$T_{br(a)} = T_{mix(a)} - T_{ydc} - T_{sc(a)} \quad (4)$$

where:

$C_{5i(a)}$	=	vertically mixed sediment concentration for sub-area "a" at year 5 prior to exchange (called "intermediate value" in Figures 1a through 1j)
C_{depc}	=	concentration of net deposition sediments (current conditions)
T_{ydc}	=	thickness of net deposition sediments over 5-year timeframe (current conditions)
$C_{sc(a)}$	=	concentration of sand cover layer for sub-area "a"
$T_{sc(a)}$	=	thickness of sand cover layer for sub-area "a"
$C_{br(a)}$	=	concentration of bed replacement layer sediments for sub-area "a"
$T_{br(a)}$[2]	=	thickness of bed replacement layer sediments captured by the vertical mixing depth ($T_{mix(a)}$) for sub-area "a"
$T_{mix(a)}$	=	mixing depth for sub-area "a" (mixing by propwash)

Once the initial vertical mixing of each sub-area is conducted (either to the full mixing depth or the bioturbation depth), exchange with underpier sediments is incorporated into the sub-area sediment concentrations. The exchange calculations between open-water and underpier sediments simulates mixing of bed sediments between the underpier and open-water areas

[2] This variable is not defined in the vertical bed models shown in Figures 1a through 1j.

due to re-suspension from the bed by propwash[3]. This calculation is performed for each sub-area, as shown in Equations 5 and 6 and illustrated in Figures 1a through 1j.

$$C_{5f(a)} = \left[\frac{(C_{5i(a)} \times T_{5i(a)}) + (C_{5ex} \times T_{5ex})}{T_{mix(a)}} \right] \tag{5}$$

$$T_{5i(a)} = T_{mix(a)} - T_{5ex} \tag{6}$$

where:

$C_{5f(a)}$	=	vertically mixed sediment concentration for sub-area "a" at year 5 following exchange (called "final value" in Figures 1a through 1j)
$T_{5i(a)}$[4]	=	thickness of vertically mixed sediment layer prior to exchange at year 5 captured by the vertical mixing depth ($T_{mix(a)}$) for sub-area "a"
C_{5ex}	=	concentration of under pier sediments following mixing at year 5, but prior to exchange with open-water sediments (see Section 2.3.5)
T_{5ex}	=	thickness of volume of under pier sediments exchanged at year 5; this is estimated as the volume of underpier sediments to be exchanged (25% of total volume) spread evenly over the entire surface area of the open-water areas
$T_{mix(a)}$	=	mixing depth for sub-area "a" (mixing by propwash)

The general formulas for year 5 (Equations 3 through 6) are conceptually the same for years 10 through 40 (Equations 7 through 10); however, there are fewer distinct sediment layers present following the first vertical mixing event in year 5. The general formulas used to calculate the vertically mixed surface sediment concentration for each open-water sub-area for years 10 through 40 prior to exchange are presented in Equations 7 and 8 and illustrated in Figures 1a through 1j.

$$C_{Ni(a)} = \left[\frac{(C_{depc} \times T_{ydc}) + (C_{(N-5)f(a)} \times T_{(N-5)f(a)})}{T_{mix(a)}} \right] \tag{7}$$

[3] The rationale for 25% exchange estimate between open-water and underpier areas is provided in FS Section 5.3.4.

[4] This variable is not defined in the vertical bed models shown in Figures 1a through 1j.

$$T_{(N-5)f(a)} = T_{mix(a)} - T_{ydc} \tag{8}$$

where:

$C_{Ni(a)}$ = vertically mixed sediment concentration for sub-area "a" at year N prior to exchange (called "intermediate value" in Figures 1a through 1j)

$C_{(N-5)f(a)}$ = final vertically mixed concentration of sediments for prior 5-year interval (year=N-5) for sub-area "a" after exchange taken into account (called "final value" in Figures 1a through 1j)

C_{depc} = concentration of net deposition sediments (current conditions for year 10, future conditions for years greater than 10)

T_{ydc} = thickness of net deposition sediments over 5-year time period (current conditions for year 10, future conditions for years greater than 10)

$T_{(N-5)f(a)}$[5] = thickness of the vertically mixed layer from prior 5-year interval (year=N-5) captured by the vertical mixing depth ($T_{mix(a)}$) for sub-area "a"

$T_{mix(a)}$ = mixing depth for sub-area "a" (mixing by propwash)

For years 10 through 40 (as with year 5), once the initial vertical mixing of each sub-area is conducted (either to the full mixing depth or the bioturbation depth), exchange with underpier sediments is incorporated into the sub-area sediment concentrations. This is done mathematically for each sub-area, as shown in Equations 9 and 10 and illustrated in Figures 1a through 1j.

$$C_{Nf(a)} = \left[\frac{(C_{Ni(a)} \times T_{Ni(a)}) + (C_{Nex} \times T_{Nex})}{T_{mix(a)}} \right] \tag{9}$$

$$T_{Ni(a)} = T_{mix(a)} - T_{Nex} \tag{10}$$

where:

$C_{Nf(a)}$ = vertically mixed sediment concentration for sub-area "a" at year N following exchange (called "final value" in Figures 1a through 1j)

[5] This variable is not defined in the vertical bed models shown in Figures 1a through 1j.

$T_{Ni(a)}$[6] = thickness of vertically mixed sediment layer prior to exchange at year N captured by the vertical mixing depth ($T_{mix(a)}$) for sub-area "a"

C_{Nex} = concentration of underpier sediments following mixing at year N, but prior to exchange with open-water sediments (see Section 2.3.5)

T_{Nex} = thickness of volume of underpier sediments exchanged at year N; this is estimated as the volume of underpier sediments to be exchanged (25% of total volume) spread evenly over the entire surface area of the open-water areas

$T_{mix(a)}$ = mixing depth for sub-area "a" (mixing by propwash)

2.2.5 Concentrations of Vertically Mixed Underpier Areas

The underpier areas are represented as a single area within the box model. At year 0, the surface concentration of the underpier area is calculated as a SWAC based on the area and concentration for each technology sub-area (Table 2; Equation 1). For years 5 through 40, an additional sediment volume representing deposition of incoming solids over the previous 5-year time period is added to the in situ underpier sediment volume; and the entire volume of material is mixed to calculate a volume-weighted average concentration. The rationale for assumption of complete vertical mixing of underpier sediments is discussed in FS Section 5.3.4.

Equations 11 through 13 show the calculation of underpier sediment concentrations at years 5 to 40 in the box model (prior to exchange with open-water areas).

$$C_{ex_N} = C_{UP_Ni} = \left[\frac{(C_{UP(N-5)f} \times V_{UP(N-5)f}) + (C_{depc} \times V_{depc})}{V_{UP_Ni}} \right] \quad (11)$$

$$V_{UP_Ni} = V_{UP(N-5)f} + (SA_{UP} \times T_{ydc}) \quad (12)$$

$$V_{depc} = SA_{UP} \times T_{ydc} \quad (13)$$

where:

C_{ex_N}, C_{UP_Ni} = concentration of underpier sediments at year N prior to exchange with open-water areas ("intermediate" concentration); this is the

[6] This variable is not defined in the vertical bed models shown in Figures 1a through 1j.

		concentration of underpier sediments exchanged with open-water areas (C_{ex} in Figures 1a through 1j)
$C_{UP_(N-5)f}$	=	final concentration of underpier sediments of prior 5-year interval (where N is current year) after exchange with open-water areas ("final" concentration)
$V_{UP(N-5)f}$	=	total volume of underpier sediments of prior 5-year interval (where N is current year) after exchange with open-water areas
V_{UP_Ni}	=	total volume of underpier sediments at year N (including volume of deposited sediments) prior to exchange with open-water areas
C_{depc}	=	concentration of net deposition sediments
T_{ydc}	=	thickness of net deposition sediments
SA_{UP}	=	surface area of underpier areas where sediment is deposited over the armor rock (see FS Section 2.6)
V_{depc}	=	volume of deposited sediments in underpier areas calculated using Equation 13

For years 5 through 40, once the intermediate concentration of underpier sediments is calculated, exchange with open-water sediments is incorporated into the underpier sediment concentrations. First, 25% of the underpier sediment volume (V_{UP_Ni}) with a concentration equal to C_{ex_N} (concentration of underpier sediments prior to exchange) is evenly deposited over each open-water sub-area. Then, the exchanged underpier sediment is mixed vertically within each open-water sub-area as discussed in Section 2.3.4 to calculate final post-exchange concentrations in each open-water sub-area. The SWAC of the open-water sub-areas (using these post-exchange concentrations) is then calculated. Finally, a volume of open-water sediments equal to 25% of the underpier sediment volume with a concentration equal to the pre-exchange SWAC of the open-water areas is added to the underpier sediments to complete the exchange. The final post-exchange concentration of the underpier sediments is calculated by averaging concentrations of the initially mixed underpier sediments with the exchanged sediment from the open-water areas (volume-weighted average). This is shown mathematically in Equation 14.

$$C_{UP_Nf} = \left[\frac{(C_{UP_Ni} \times V_{UP_Ni}) + (C_{SWAC_OW_Nf} \times V_{ex})}{V_{UP_Ni} + V_{ex}} \right] \quad (14)$$

where:

C_{UP_Nf} = concentration of underpier sediments at year N following to exchange with open-water areas ("final" concentration)

C_{UP_Ni} = concentration of underpier sediments at year N prior to exchange with open-water ("intermediate" concentration)

$C_{SWAC_OW_Nf}$ = SWAC concentration of open-water sediments at year N after exchange with underpier sediments

V_{UP_Ni} = total volume of underpier sediments at year N (including volume of deposited sediments) prior to exchange with open-water areas

V_{ex} = volume of open-water sediment exchanged with underpier areas; 25% of V_{UP_Ni}

2.2.6 Site-wide SWAC (Years 5 to 40)

For each 5-year interval post-construction from years 5 to 40, site-wide SWACs are calculated using the post-exchange fully-mixed surface sediment concentrations for each open-water sub-area and the underpier area using Equation 15.

$$SWAC_{\mathrm{N}} = \frac{\sum_{m=1}^{\mathrm{a}} [C_{m\mathrm{N}} A_m]}{\sum_{m=1}^{\mathrm{a}} A_m} \quad (15)$$

where:

$SWAC_N$ = site-wide EW SWAC for year N, where N is from 5 to 40 years

a = number of unique sub-areas (combinations of remedial technologies and vertical mixing depths, including underpier areas)

A_m = area of each individual sub-area

C_{mN} = surface concentration at year N of each individual sub-area following deposition of incoming solids, vertical mixing, and exchange with underpier

2.3 Sensitivity and Bounding Evaluation

The effects of variability and uncertainty in the physical processes and chemical concentrations in the EW on estimates of site-wide SWACs were evaluated with a sensitivity and bounding analysis. The sensitivity evaluation was completed to examine the relative impact of individual variables on the predicted site-wide SWACs. The bounding evaluation was used to examine the potential range in predicted SWACs based on combinations of specific input variables that were found to significantly impact the SWACs in the sensitivity evaluation.

The sensitivity and bounding evaluations were conducted on Alternatives 1A(12) and 2B(12) (see FS Appendix L, Figures 2-1 and 2-5) using a range of input variable assumptions (see Section 2.3.1 below for more detail). The sensitivity and bounding calculations were conducted using two remedial alternatives so that the analysis could be applied to different remedial technology combinations. Alternative 1A(12) was selected because it relies on natural recovery more than the other alternatives. Alternative 2B(12) was selected because it is representative of the majority of the remedial alternatives that rely more heavily on removal.

Sensitivity and bounding analyses were conducted for total PCBs only. Total PCBs is the COC that contributes the most to site risk for RAOs 1 (human health seafood consumption), 3 (benthic invertebrates), and 4 (ecological risk), and is distributed throughout the waterway. For this modeling analysis, PCBs effectively demonstrate the trends that can be expected for other COCs.

2.3.1 Variables Used in Evaluation

The sensitivity of the SWAC values calculated using the box model evaluation were analyzed for the following input variables to the box model:

- Value of the average NSR for the EW (single value applied across the site)
- Use of variable NSR in the EW
- Vertical mixing depth in the highly energetic propwash mixing areas
- Percent of the EW Study Area that was allowed to fully mix (vertically)
- Percent of underpier sediment volume that is exchanged with open-water areas
- Bioavailability of hydrophobic organic contaminants (including total PCBs) in underpier sediments due to in situ treatment

- Dredge residuals layer thickness and concentrations and replacement values
- Green River solids and chemistry[7]
- EW lateral solids and chemistry

The range of values for each variable used in the sensitivity and bounding analysis are discussed in Section 2.1 above and summarized in Chart 1.

2.3.2 Sensitivity Analysis

A list of sensitivity scenarios is provided in Table 4; 18 different scenarios for Alternative 1A(12) and 20 different scenarios for Alternative 2B(12) were evaluated for total PCBs. Alternative 1A(12) only has 18 scenarios because it does not have underpier in situ treatment, and therefore does not have sensitivity parameters for bioavailability. Table 2 herein provides initial surface sediment chemistry for total PCBs by remedial alternative (for the best-estimate dredging residuals and replacement value assumptions), and FS Table 5-3 provides chemistry assumptions for incoming solids.

The total PCB SWAC values over time calculated using the box model for each of the sensitivity scenarios listed in Table 4 were compared to each other numerically and graphically (see Table 5 and Figures 3a through 4b). Figures 3a and 4a plot the estimated SWAC values from year 0 to year 40 for each of the sensitivity analysis scenarios for Alternatives 1A(12) and 2B(12), respectively. Figures 3b and 4b show the comparative percent change in SWAC value for each sensitivity scenario compared to the base case scenario for Alternatives 1A(12) and 2B(12), respectively at years 10 and 30 post-construction. The comparative changes shown in Figures 3b and 4b were calculated by normalizing the SWAC values calculated for each sensitivity scenario at years 10 and 30 post-construction by the SWAC values calculated for the base case scenario at those same years.

2.3.2.1 Alternative 1A(12)

For Alternative 1A(12), the range in inputs for underpier exchange, NSR, and Green River concentration had a relatively high degree of sensitivity (i.e., resulted in greater than 10%

[7] For upstream chemistry the LDW lateral sources and LDW bed sediments inputs are not changed for the sensitivity analysis.

change in SWAC), and the other parameters (residuals thickness, residuals concentration, mixing depth, area mixed, and concentrations in lateral load) showed a low degree of sensitivity (Figures 3a and 3b).

Underpier exchange was the most sensitive parameter 0 to 10 years following construction, but was not a very sensitive parameter in the long-term. The model results predict that more underpier exchange would result in a higher temporary increase in site-wide SWAC following construction, due to the distribution of higher concentration underpier sediments into the larger, mostly remediated open-water areas. Less underpier exchange reduces the site-wide SWAC because the higher concentration sediments in the underpier remain localized.

The two parameters that are the most sensitive in the long-term are range in inputs for NSR and the concentrations of Green River solids. These two parameters are also the second and third most sensitive parameters 0 to 10 years following construction (after underpier exchange), and are therefore the most influential parameters affecting the box model results. Moreover, the two parameters are related because 99% of the sediment deposited in the EW originates from the Green River upstream of the LDW (Table 1).

A higher NSR reduces the site-wide SWAC by reducing the time needed for the site to equilibrate to net incoming concentrations (i.e., increases the rate of natural recovery). A lower NSR increases the site-wide SWAC by increasing the time needed for the site to equilibrate to net incoming concentrations (i.e., decreases the rate of natural recovery). Use of a variable NSR within the EW (based on FS Figure 5-1) did not have any appreciable effect on the SWAC predictions compared to best estimate calculations for any years (see Figure 3a).

In the very long term (i.e., 30 years post-construction and beyond), Green River chemistry is the primary controlling parameter, because it is the primary determinant of the concentration the site will equilibrate to (i.e., the EW net incoming sediment concentrations). In the long-term, higher Green River concentrations will result in higher site-wide SWACs, and lower Green River concentrations will result in lower site-wide SWACs.

2.3.2.2 Alternative 2B(12)

Compared to Alternative 1A(12), Alternative 2B(12) relies less on natural recovery and more on in situ treatment (Alternative 1A(12) uses MNR in underpier areas, and

Alternative 2B(12) used in situ treatment in underpier areas). In addition, Alternative 2B(12) relies on more removal (Alternative 1A(12) uses some ENR-nav in the navigation channel, and Alternative 2B(12) used removal). As a result, Alternatives 2B(12) is less sensitive to the range in inputs for NSR and underpier exchange than Alternative 1A(12), and more sensitive to the range in inputs for Green River concentrations. Alternative 2B(12) also has a high degree of sensitivity to the range in inputs for percent reduction in bioavailability due to in situ treatment. Consistent with Alternative 1A(12), the impact of the other parameters (i.e., residuals thickness, residuals concentration, mixing depth, area mixed, and concentrations in lateral load) showed a low degree of sensitivity (Figure 4a and 4b).

Percent reduction in bioavailability due to in situ treatment was the most sensitive parameter 0 to 10 years following construction, but was less sensitive in the long term. If in situ treatment is more effective at reducing bioavailability, then site-wide SWACs are predicted to be effectively lower, and if in situ treatment is less effective at reducing bioavailability, then site-wide SWACs are predicted to be higher. FS Section 7.2.7.1 describes the in situ treatment effectiveness estimates based on relevant case studies and guidance.

Similar to Alternative 1A(12), Green River chemistry is the primary controlling parameter in the long term, because it is the primary determinant of the concentration the site will equilibrate to. The effect of the range in inputs for Green River chemistry is higher for Alternative 2B(12) compared to Alternative 1A(12) because site-wide SWACs are lower following construction for Alternative 2B(12) (largely due to the change in remediation technology in underpier areas), and therefore it equilibrates more rapidly to net incoming sediment concentrations.

For Alternative 2B(12), the greatest effects to predicted SWAC values are associated with the Green River chemistry (up to 45%) and NSR (up to 15%). The range in inputs for all other variables result in less than 10% change from the base case SWAC values. The predicted SWAC values for Alternative 2B(12) are not as sensitive to the range in inputs for underpier exchange as Alternative 1A(12) because Alternative 2B(12) has active remedial technology in underpier sediments, which results in a lower initial concentration of underpier sediments for Alternative 2B(12).

Residual inputs have more effect on SWAC predictions for Alternative 2B(12); this is because of the combined effect of lower year 0 SWAC (related to active remediation under piers) and more removal in open-water areas. With lower year 0 SWAC and more removal, the site is more influenced by the higher concentrations of residuals when vertical mixing takes place. Also because of the lower year 0 SWAC in Alternative 2B(12), the NSR inputs have less of an influence compared to Alternative 1A(12). As with Alternative 1A(12), use of a variable NSR within the EW (based on FS Figure 5-1) did not have any appreciable impact on the SWAC calculations for any years (see Figure 4a).

2.3.2.3 Summary

Using the combined results for both Alternative 1A(12) and Alternative 2A(12), a summary of the sensitivity analysis by parameter is provided below:

- The range in inputs for Green River chemistry can change predicted SWAC values by up to 25% through year 10 post-construction, and up to 45% by year 30 post-construction. Green River chemistry has greater effect on alternatives with more active remediation and less reliance on natural recovery.
- The range in inputs for NSR can change predicted SWAC values by up to 15% through year 10 post-construction, and up to 35% by year 30 post-construction. NSR has a greater effect on alternatives with more reliance on natural recovery.
- The range in inputs for underpier exchange can change predicted SWAC values by up to 20% at year 10, but its influence drops off to below 10% by year 30. Underpier exchange has more effect on alternatives with MNR in the underpier area.
- The range in inputs for the percent reduction in bioavailability due to in situ treatment can change predicted SWAC values by up to 30% at year 10, but its influence is reduced to up to 20% by year 30. This parameter only effects alternatives that employ in situ treatment.
- The range in inputs for all other parameters effect predicted SWAC values by 10% or less.

2.3.3 Bounding Analysis

The results of the sensitivity analysis were used to develop scenarios (combinations of input parameter values) that result in the lowest and highest SWAC predictions for Alternatives 1A(12) and 2B(12). This bounding analysis was done to quantify the maximum

uncertainty in predicted SWAC values from the box model evaluation for all remedial alternatives. The lowest and highest bounding scenarios are determined using results of the sensitivity analysis for Alternatives 1A(12) and 2B(12) that showed which parameters caused the SWAC to increase or decrease (Figures 3b and 4b).

For Alternative 1A(12), using Figure 3b, the following conclusions were made to establish the highest and lowest bounds:

- **NSR and Vertical Mixing Depth[8]:** Decreasing the value of these parameters result in a higher predicted SWAC at years 10 and 30. Therefore the low range values were used for the highest bound scenario and the high range values were used for the lowest bound scenario.
- **Residual Thickness, Residual Concentration, Lateral Concentrations, and Green River Concentrations:** Decreasing the value of these parameters results in a lower predicted SWAC at years 10 and 30. Therefore, the low range values were used for the lowest bound scenario and the high range values were used for the highest bound scenario.
- **Area Mixed:** The effect on the SWAC from this parameter is different at years 10 and 30. Because the box model evaluation was developed to look at effectiveness over the long term, the effect at year 30 was used to determine bounding scenarios. At year 30, decreasing the value of this parameter decreases the predicted SWAC value. Therefore, the low range value was used for the lowest bound scenario and the high range value was used for the highest bound scenario.
- **Underpier Exchange:** The effect on the SWAC from this parameter is different at years 10 and 30. At year 30, both decreasing and increasing this parameter results in a lower predicted SWAC value. At year 5, decreasing the value of this parameter reduces the predicted SWAC, and increasing the value increases the predicted SWAC, so the effect from year 5 was used to determine bounding scenarios. The low input value was used for the lowest bound scenario and the high input value was used for the highest bound scenario.

[8] The shallower mixing depth results in a higher concentration post-construction because of reduced dilution of dredge residuals and underpier exchange material with the cleaner underlying sediments.

Alternative 2B(12) followed the same general patterns as Alternative 1A(12), and used the same input parameters for bounding. For the reduction in bioavailability parameter[9], the higher reduction percent resulted in a lower predicted SWAC value. Therefore, the higher reduction percent was used for the lowest bound scenario, and the lower reduction percent was used for the highest bound scenario.

A summary of the input variables associated with the lowest and highest bounding scenarios are provided in Table 4.

The lowest and highest bound scenarios represent conditions where all of the input parameters that would influence either a high or low SWAC would occur at the same time; which has a very low probability of occurrence. As shown in Figures 3b and 4b, and discussed earlier, the NSR and Green River chemistry have the greatest input on the predicted SWAC calculations. Therefore, these input parameters will have the greatest impact on the spread between the lowest and highest bounding scenarios. To illustrate the impact of NSR and Green River chemistry on the uncertainty of the SWAC predictions, four additional bounding scenarios were conducted; two scenarios that retained the NSR and Green River chemistry at base case values and varied all other input parameters, and two scenarios and varied only the Green River chemistry:

- Additional Low
- Additional High
- Green Low
- Green High

The inputs for these four additional scenarios are also summarized in Table 4.

The SWAC values predicted using the bounding and base case scenarios are provided in Table 6 and shown graphically in Figure 5a for Alternative 1A(12) and Figure 5b for Alternative 2B(12). The range of predicted SWAC values shown in Figures 5a and 5b for the highest and lowest bounding scenarios suggest that SWAC values for the EW predicted by the box model could vary by up to +125% and -75% at year 10, and by up to +110% and -80% at year 30 due primarily to the significant influence of Green River chemistry and NSR.

[9] This parameter is not applicable to Alternative 1A(12) because in situ treatment is not one of the technologies used.

Looking at the additional high and low bounding scenarios, which hold the Green River chemistry and NSR at base case values while varying all other parameters, the SWAC values predicted by the box model vary by +50% and -40% at year 10 and by up to +20% and -25% at year 30. Considering only the Green River chemistry effects, the SWAC values predicted by the box model vary by +25% and -25% at year 10, and by up to +40% and -40% at year 30.

3 RAO 3 PERFORMANCE OVER TIME (POINT MIXING MODEL EVALUATION)

The box model evaluation described in Section 2 above was used to estimate SWACs for alternatives to assess achievement of RAOs 1, 2, and 4, which are evaluated based on area-average concentrations. RAO 3 however, while evaluated for the site as a whole, is based on individual point locations as opposed to area averages. Therefore, an additional modeling calculation, referred to as the point mixing model evaluation, was conducted to assist in achieving RAO 3. The point mixing model evaluation was conducted on a subset of seven risk-driver COCs for RAO 3. The seven COCs were selected to be representative of the 29 Washington State Sediment Management Standards (SMS) contaminants identified as benthic invertebrate community COCs in the ERA:

1. PCBs
2. Arsenic
3. Mercury
4. High-molecular-weight polycyclic aromatic hydrocarbons (HPAHs)
5. Low-molecular-weight polycyclic aromatic hydrocarbons (LPAHs)
6. Bis(2-ethylhexyl)phthalate (BEHP)
7. 1,4-dichlorobenzene

The point mixing model was only applied where MNR is used as a remedial technology (Alternative 1A(12) only) because all other surface sediment stations will meet RAO 3 preliminary remediation goals (PRGs) following construction, either through active remediation or because they are currently below RAO 3 PRGs. The point mixing model predicts surface sediment concentrations for years 0 through 40 post-construction for the 18 existing surface sediment sampling station locations in proposed MNR areas that exceed the RAO 3 PRGs.

The calculations were conducted for each point location using similar methodology as the box model evaluation described in Section 2; where deposition of incoming solids and vertical mixing assumptions were applied to each point location. Exchange between underpier and open-water areas was not included in these calculations, to provide a conservative estimate of natural recovery in these locations. This assumption tends to bias

the predicted sediment concentrations high because the calculations do not account for cleaner sediment from open-water areas accumulating in the underpier locations.

3.1 Input Variables

The variables used as input for the point mixing model are outlined in Chart 4 and discussed in more detail below.

Chart 4
Input Variables for the Point Mixing Model

Input or Variable	Variable or Constant for Analysis	Location of Details
Current representative annual NSR at each MNR point (upstream sources)	Constant over the EW and time.	Section 3.3 and Table 7 herein
Future annual sedimentation rate at MNR point (upstream sources)	Constant over the EW and time.	Section 3.3 and Table 7 herein
Current annual sedimentation from EW laterals	Variable by MNR point (based on PTM output), constant over time.	FS Appendix B, Part 1
Future annual sedimentation from EW laterals	Variable by MNR point (based on PTM output), constant over time.	FS Appendix B, Part 1
Chemistry of surface sediment at year 0	Variable by MNR point based on SRI[1] data.	Table 7 herein
Chemistry of current incoming solids for upstream and EW laterals	Chemistry per point varies, but chemistry used at each point is constant for years 1 to 10.	FS Table 5-3
Chemistry of future incoming solids for upstream and EW laterals	Chemistry per point varies, but chemistry used at each point is constant for years 11 to 40, based on future source control.	FS Table 5-3
Vertical mixing depth assumptions	Variable by point (based on estimated propwash depths, see FS Figure 5-3), constant over time.	Section 3.3 herein

Notes:
1. *Final Supplemental Remedial Investigation Report* (SRI; Windward and Anchor QEA 2014).
EW – East Waterway
FS – Feasibility Study
MNR – monitored natural recovery
NSR – net sedimentation rate
PTM – particle tracking model

The point mixing model was used to predict the surface concentrations for 18 points (15 located in underpier areas and three in under-bridge areas) for the seven risk driver COCs

for RAO 3, based on anticipated solids deposition and vertical mixing assumptions. The current surface concentrations for each of the 18 sediment locations were derived from sampling conducted between 2001 and 2009, as shown in Figure 6. These calculations used results from the PTM (FS Appendix B) to establish the deposition from lateral sources at each individual surface point. This is different than the box model evaluation, which assumed that depositing sediments from both upstream and EW lateral sources settled evenly through the EW.

Table 7 lists the MNR points by station name, their locations, the specific deposition rates derived from the PTM results at each MNR point location, and the chemistries used for the calculations. The current surface concentrations were assumed to be the measured concentrations from the EW SRI surface sediment samples collected at each of the 18 locations (Windward and Anchor QEA 2014). The NSR at each point is based on the deposition patterns for the area around the sample location from the PTM (FS Appendix B). As the amount of sediment from the different sources varies by point location, the incoming chemistry concentration is also varied based on the source's chemistry. See Section 3.3 for a calculation of incoming solids concentrations.

The vertical mixing depth assumptions were the same as used in the box model evaluation (FS Figure 5-2). Underpier areas were assumed to be fully mixed by volume in the box model evaluation. Volumetric mixing is not applicable to this evaluation, which focuses on single point locations (as opposed to areas). Therefore, the volumetric mixing of underpier areas used in the box model evaluation had to be changed to an approximate equivalent mixing depth in underpier areas; as was done in the open-water areas for the box model evaluation. Based on vertical mixing assumptions in the EW shown in Figure 5-2, the majority of the underpier areas are adjacent to open-water areas assigned a 2-foot mixing depth. The typical thickness of underpier sediments in the EW is about 2 feet (see FS Section 2.6) based on probing data. Therefore, the mixing depth in underpier areas (15 of the 18 points) was set to 2 feet. Mixing depth in under-bridge areas (3 of the 18 points: EW09-SS-010, EW09-SS-012, and EW-128) was set to 10 cm for bioturbation mixing because there are no vessel operations next to under-bridge areas.

3.2 Calculations

Surface sediment concentrations over time at each of the 18 MNR points were calculated using similar methodology as used for the box model evaluation discussed in Section 2, including vertical bed model for MNR areas (see Figure 1f), vertical mixing assumptions, incoming solids chemistry, and site-wide NSR.

Current surface concentrations and mixing assumptions at each point, solids deposition and chemistry from upstream sources, and solids deposition and chemistry from EW lateral sources were used to predict surface concentrations at each of the 18 MNR points as a function of time post-construction (0 to 40 years) in 5-year intervals. The predicted surface concentrations were compared to PRG (remedial action level [RAL]/sediment quality standards [SQS]) and cleanup screening level (CSL) values for each COC evaluated.

Current surface concentrations at each point are provided in Table 7. Points in underpier areas used a mixing depth of 2 feet, which is the thickness of underpier sediments based on probing data. This is consistent with the box model assumption that underpier sediments are fully mixed by volume over a 5-year period. Points located in under-bridge areas used a mixing depth of 10 cm.

Solids deposition from upstream sources only (i.e., the Green River, LDW bed sediment and LDW lateral sources) were assumed to be constant throughout the EW, and therefore constant at each point location. The value of total annual upstream deposition from all sources was kept constant for each point for current and future conditions and was set to the value used in the recontamination evaluation (grid model evaluation) discussed in FS Section 4 (1.175 cm/yr). A discussion of how this was calculated is provided in Section 4.3, Step 3 in this appendix.

The solids deposition at each point location from EW lateral sources was taken directly from the results of the PTM. The deposition predicted by the PTM for each EW lateral source (see FS Appendix B, Part 1) was extracted from the 50-foot-by-50-foot grid cell where each point is located (see Figure 6). The total deposition from EW lateral sources extracted at each point location was divided into six different source categories (see Figure 2 in FS Appendix B, Part 1) to allow for different chemistry assumptions:

1. Hinds CSO
2. Lander CSO
3. Hanford #2 CSO
4. Nearshore SDs (see Table 1 in FS Appendix B, Part 1: 33 input locations including outfalls for the Port of Seattle, the City of Seattle, and private outfalls)
5. S. Lander St SD
6. Non-nearshore SDs (see Table 1 in FS Appendix B, Part 1: seven input locations including outfalls for S Hinds St SD and U.S. Coast Guard SD)

The chemistry assumptions for EW lateral sources for this evaluation are different than the box model evaluation (Section 2), which assumed a single chemistry assumption for all stormwater and a single chemistry assumption for all CSO discharges, since that evaluation focused on site-wide average calculations. For this evaluation, EW lateral sources were further divided into the six source categories listed above to add additional resolution to the point mixing model calculations. FS Table 5-3 provides chemistry assumptions for each of the seven COCs evaluated as part of this analysis, for the six source categories listed above. The data and development of these chemistry assumptions for EW laterals are described in FS Appendix B, Part 4. FS Table 5-3 also provides chemistry assumptions for these same COCs for upstream sources. Green River chemistry was developed based on methods outlined in the EW FS Appendix B, Part 3, and chemistry for LDW bed and LDW lateral solids was taken from the LDW FS (AECOM 2012).

The total concentration of solids deposited at each point location was calculated as a weighted average on deposited loads to each point from the various input locations. Equation 16 was used to find the input concentration to the EW at each point location.

$$Incoming\ Solids\ Concentration = \frac{\sum_{i=1}^{9} Input_i Solids * Input_i Concentration}{\sum_{i=1}^{9} Input_i Solids} \qquad (16)$$

where:

$Input_i$ Solids	=	solids deposited from each of the three upstream sources and six categories of EW lateral sources discussed above
$Input_i$ Concentration	=	chemistry for each of the COCs based on solids source (Table 11a and 11b)

The surface concentrations were calculated differently for years 0, 5, and 15. Year 10 used the same equation used to calculate year 5. Year 15 represents the first year that future source control scenarios for EW Laterals were assumed to be fully operational and therefore used in the calculations. Years 20 and onward used the same equation for the concentration of year 15.

Year 0 surface concentration was equal to the existing measured surface concentration at each point.

The years 5 and 10 surface concentrations were calculated using Equation 17.

$$C_n = \frac{5T_c * C_{eqc} + (T_{mix} - 5T_c) * C_{n-5}}{T_{mix}} \tag{17}$$

where:

C_n = concentration of surface sediments for year (n)

C_{eqc} = chemistry of incoming sediments (current conditions)

T_c = annual thickness of deposition sediments (current conditions)

T_{mix} = mixing depth

The years 15 and onward surface concentrations were calculated using Equation 18.

$$C_n = \frac{5T_f * C_{eqf} + (T_{mix} - 5T_f) * C_{n-5}}{T_{mix}} \tag{18}$$

where:

C_{eqf} = chemistry of incoming sediments (future conditions)

T_f = annual thickness of deposition sediments (future conditions)

Table 10 provides a summary of estimated concentrations for each MNR point location.

3.3 Sensitivity Evaluation

There was no separate sensitivity evaluation conducted for the point mixing model approach because the box model sensitivity evaluation described in Section 2.4 was considered to be representative of how the surface sediment concentrations for the 18 MNR points could vary for the given input variables. The calculations carried out in the box model are very similar to those of the point mixing model, with two exceptions: 1) the box model encompasses the entire EW Operable Unit as opposed to discrete points within the EW; and 2) exchange between underpier and open-water areas was not included in the point mixing model. For discussion of how the expected variation in calculated surface sediment concentrations at proposed MNR points effects evaluation of RAO 3 compliance within the context of the FS, refer to FS Section 9.

3.4 Results of Calculations

Surface sediment point concentrations and spatial distributions of the point exceedances over time and for the seven key risk driver COCs are provided in Figures 7a and 7b for the 18 MNR points. Figure 7a calls out the points and years that are predicted to exceed the PRG (RAL/SQS), and Figure 7b calls out the points and years that are predicted to exceed the CSL.

FS Table 9-2a outlines how many points are predicted to exceed the CSL and PRG (RAL/SQS) values for the seven COCs over the 40-year period. RAO 3 will be evaluated based on these results in combination with surface and shallow surface sediment concentrations of the approximately 300 additional points that will be remediated using technologies other than MNR or that under current conditions are below RALs. This evaluation is provided in FS Section 9.

4 RECONTAMINATION POTENTIAL EVALUATION (GRID MODEL EVALUATION)

The grid model evaluation was used to identify discrete areas within the EW where recontamination from EW lateral deposition could be a concern post-construction. The spatial distribution of surface concentrations throughout the EW due to deposited solids from upstream and lateral inputs was estimated for years 0 through 40 post-construction. The predicted percentage of EW surface area exceeding RALs at any time over that 40-year time period was used to identify areas where potential recontamination from incoming sediments could occur, inform future source control efforts, and target general areas where post-construction monitoring may be needed. This evaluation, referred to as the grid model evaluation, is different than the box model evaluation because it uses the spatial distribution of EW lateral solids deposition predicted by the PTM as input rather than a cumulative site-wide value. This evaluation was completed from years 0 to 40 post-construction for nine key risk driver COCs: PCBs, cPAHs, dioxins/furans, arsenic, mercury, HPAHs, LPAHs, BEHP, and 1,4-dichlorobenzene (see FS Section 5.4.2 for more detail on selection of COCs for this analysis).

The evaluation of recontamination potential is challenging in the EW due to the influence of anthropogenic activity, such as propwash, which can resuspend recently deposited finer sediments or mix them into the underlying sediments. The effects of propwash on the spatial distribution of EW lateral solids deposition was not taken into account with the PTM because of the difficulty in accurately quantifying the location, mass, and frequency of solids resuspended by vessel activity[10]. Therefore, the recontamination evaluation focused on identifying areas of concern using RALs as metrics without attempting to quantify surface concentrations in the long term with certainty.

Several assumptions were made to simplify the calculations while still meeting the objective of the evaluation, as discussed in Section 4.3. However, there are two primary assumptions that were developed to focus the evaluation on recontamination potential due to incoming solids. The first is that the initial surface concentrations within the EW (at year 0) were

[10] Not accounting for propwash tends to overestimate the predicted concentrations near outfalls, because post-construction propwash will mix and redistribute higher concentration sediments with surrounding lower concentration sediments.

assumed to be zero. This focuses the results of the evaluation on recontamination from incoming sediment sources only and removes the influence of underlying sediment concentrations. The second is that vertical mixing depths were assumed to be constant throughout the EW and thus set to the bioturbation mixing depth assumed for the EW (10 cm). This limits the amount of dilution of incoming sediment sources that could occur due to deeper vertical mixing, which may be sporadic or not occur at any particular location. Ultimately this recontamination evaluation is just an estimate of what might happen in the future, and therefore, monitoring post-construction will be the best method to evaluate recontamination from incoming sediment sources.

4.1 Input Variables

The inputs required for the recontamination potential evaluation are outlined in Chart 5.

Chart 5
Input Variables for the Grid Model

Input or Variable	Variable or Constant for Analysis	Location of Details
Initial surface sediment concentrations (at Time 0 post-construction)	Constant over the EW	Set to 0 for all COCs
Annual upstream NSR	Constant over the EW and over time	FS Section 5.4.3 and Table 5-10
Chemistry assumptions for upstream solids sources	Constant over time	FS Table 5-3
Chemistry assumptions for EW lateral solids sources (current conditions)	Constant for years 1 through 10 post-construction	FS Table 5-3
Chemistry assumptions for EW lateral solids sources (future conditions)	Constant for years 11 through 40 post-construction	FS Table 5-3
Annual deposition rates from EW lateral sources predicted by PTM (current conditions)	Variable over the EW, constant for years 1 through 10 post-construction	FS Appendix B, Part 1 Figures 6 through 8
Annual deposition rates from EW lateral sources predicted by PTM (future conditions)	Variable over the EW, constant for years 11 through 40 post-construction	FS Appendix B, Part 1 Figures 9 through 11

Notes:
COC – contaminant of concern
EW – East Waterway
FS – Feasibility Study
NSR – net sedimentation rate
PTM – particle tracking model

The total annual upstream NSR from all sources (upstream and EW lateral inputs) was set to 1.2 cm/yr based on the evaluation of NSR from geochronological cores in the EW (see FS Section 5.1.2). The portion of the net sedimentation attributed to upstream sources was calculated as the difference between the NSR assumed for the EW from all sources and annual deposition from EW lateral inputs predicted by the PTM (see Step 3 in Section 4.3). Chemistry assumptions for both the upstream solids and lateral inputs for current and future conditions are shown in FS Table 5-3.

4.2 Calculations

The following equations and assumptions were used to complete the recontamination potential evaluation for the EW to identify areas within the EW where recontamination could be a concern post-construction.

Step 1: Assign Surface Concentrations in the East Waterway at Time 0

The surface concentrations throughout the EW at Time 0 (post-construction) for each COC were assumed to be 0. This assumption was made to focus the evaluation on recontamination potential due to incoming solids.

Step 2: Calculate East Waterway Lateral Solids Deposition

The output of the PTM is the initial deposited location of each sediment parcel input into the model. Each parcel of sediment in the PTM represents 0.5 kg of sediment and is assigned an appropriate sediment size or fall velocity based on the particle size distribution in the input solids load. The PTM refers to sediment parcels as particles. Equation 19 was used to develop deposition rates due to EW lateral inputs in equally sized grid cells throughout the EW for the period of the simulation.

$$EW\ Lateral\ Deposition = \frac{\frac{NP*(kilograms\ per\ particle)}{\rho}}{(area\ of\ cell)} \tag{19}$$

where:

NP = number of particles in each 50-square-foot cell (2,500 ft^2 or 232 m^2)

ρ = density of the deposited sediment (estimated to be 1.5 g/cm^3 or 1,500 kg/m^3)[11]

Based on Equation 19, the deposition of one particle in a cell is represented by Equation 20.

$$EW\ Lateral\ Deposition = \frac{\frac{1[particle]*(0.5\,[\frac{kilogram}{particle}])}{1500[\frac{kilogram}{m^3}]}}{232[m^2]} = 0.0000014\ m \qquad (20)$$

This deposition is based on the simulation period, which was 28 days. Therefore, the deposition over the simulation time of 28 days was extrapolated (multiplied by a factor of 13.04) to provide predictions for annual deposition rates. A single particle in a cell would represent an annual deposition of 0.000019 meter or 0.002 centimeter spread evenly across the cell.

The EW lateral inputs were divided into six categories based on chemistry assumptions (Step 4), as was done for the point mixing evaluation. See Section 3.3 of this appendix for more information.

Step 3: Determine Upstream Solids Deposition

The method used to estimate the contribution of upstream solids sources (for current conditions) to the average NSR is different from what was used in the box model evaluation. Instead of using the entire EW surface area to estimate an average deposition rate in cm/yr from upstream and EW lateral inputs, the smaller surface area where the PTM predicts deposition from EW lateral inputs was used (the shaded areas shown in Figures 7 through 12 in FS Appendix B, Part 1). This results in a slightly larger contribution from EW lateral inputs (in cm/yr over that smaller area) in those locations compared to how it was depicted in the box model evaluation, where deposition from EW lateral inputs were spread evenly throughout the entire EW area. The contribution from upstream sources for current conditions in those locations is calculated as shown in Equation 21, by subtracting the

[11] Based on site-specific SEDflume data in the EW.

contribution from EW lateral sources (all six categories combined) from the assumed representative NSR measured by geochronological cores (1.2 cm/yr[12]).

$$Annual\ Upstream\ Sed\ Rate = Annual\ Sed\ Rate - Annual\ EW\ Lateral\ Sed\ Rate \quad (21)$$

where:

Sed Rate = sedimentation rate (or deposition rate)

The specific values for the calculation and a summary of the calculations are outlined in Table 10. The NSR for upstream is estimated to be 1.175 cm/yr for the current base case condition. This upstream deposition is used for both current and future conditions.

Step 4: Assign Concentrations to Upstream and East Waterway Lateral Solids

Different chemistry values are assumed for the six different categories of lateral inputs, and three different chemistry values are included for the upstream portion (i.e., the Green River, LDW bed sediment, and LDW lateral inputs). The chemical concentrations for the EW lateral inputs are discussed in further detail in Part 4 of FS Appendix B, and the upstream chemical concentrations were based on results from the LDW FS (AECOM 2012). Inputs used for the recontamination potential evaluation are outlined in FS Table 5-3 for current and future conditions, respectively.

Step 5: Calculate Lateral input derived Surface Concentrations at 5-year time steps

To calculate the surface concentration, the top 10 cm of the bed is combined including the annual EW lateral deposition, upstream deposition, and in situ sediment. For this analysis all surface concentrations were set to zero at end of construction (year 0).

For each following year, the preceding year is used as the base, with an annual deposition added from upstream and EW lateral inputs. The surface concentration is calculated by mixing the top 10 cm using Equation 22.

[12] This value represents the average of the net sedimentation rate calculated from evaluation of geochronological cores as described in FS Section 5.1.3.

$$Year_n\ Surface\ Concentration = \frac{(Lat_t)*(Lat_C)+(Up_t)*(Up_C)+\left(10\ cm-(Lat_t+Up_t)\right)*Year_{n-1_C}}{10\ cm} \quad (22)$$

where:

cm	=	centimeters
Lat_t	=	lateral deposition thickness
Lat_C	=	lateral concentration
Up_t	=	upstream deposition thickness
Up_C	=	upstream concentration
$Year_{n-1_C}$	=	previous year's surface concentration

Current conditions for lateral inputs were used for years 1 through 10, and future conditions were used for years 11 through 30.

4.3 Results

The results of the recontamination evaluation for all nine COCs are shown in FS Figure 9-7, which are used to highlight areas with elevated potential for recontamination based on results for years 0 to 10 post-remediation. The results of this evaluation are discussed in FS Section 9.

4.4 Bounding Evaluation

The predicted range in annual solids deposition due to EW lateral solids (see FS Appendix B, Part 1) and range of potential chemistry for EW lateral solids (see FS Appendix B, Part 5) were used to develop bounding scenarios for the recontamination potential evaluation. Scenarios are outlined in Table 11 and combine higher predicted solids deposition with higher chemistry assumptions, and lower predicted solids deposition with lower chemistry assumptions to provide bounding runs. The purpose of the bounding runs was to determine changes to the spatial area identified as having an elevated potential for recontamination (Section 4.4) based on potential range of EW solids deposition (FS Appendix B, Part 1) and chemistry values (FS Table 5-3). The bounding evaluation was completed for three representative COCs based on the results of the base case runs as follows:

- One COC where surface concentrations are predicted to be below RAL for all years (PCBs)
- One COC where surface concentrations are predicted to be above RAL initially, and then fall below RAL after year 10 (dioxins/furans)
- One COC where surface concentrations are predicted to be above RAL for all years (BEHP)

The results of the bounding evaluation are shown in Figures 8a and 8b for PCBs, Figures 9a and 9b for dioxins/furans, and Figures 10a and 10b for BEHP.

In Figure 8a, the cells that have a concentration for PCB (Scenarios 1 and 2 of Table 11) that exceed the RAL for years 0 through 10 are highlighted. Figure 8b highlights the cells that have a concentration for PCB that exceed the RAL for years 11 to 40. In the case of PCB scenarios, only the higher bounding scenario (higher deposition and higher chemical concentrations) led to exceedances in a few discrete locations close to outfalls.

Figure 9a shows predicted dioxins/furans exceedances for years 0 to 10, and Figure 9b shows predicted exceedances for years 11 to 40 (Scenarios 3 and 4 of Table 11). In the lower bound scenario (lower deposition and lower chemical concentrations) for years 0 to 10, there was only one discrete area in the EW that exceeded the RAL of 25 ng TEQ/kg dw, and there were no exceedances for the future condition years. In the higher bound scenario for dioxins/furans, there are a few more discrete areas close to outfalls that have RALs exceedances for dioxins/furans.

Figure 10a shows predicted BEHP exceedances for years 0 to 10, and Figure 10b shows predicted exceedances for years 11 to 40 (Scenarios 5 and 6 of Table 11). The lower bound scenario for years 0 to 10 shows discrete locations (less than ten) that show exceedances for both current and future conditions years. In the higher bound scenario, the area of exceedance extends beyond the few discrete locations next to outfalls shown in the lower bounding run, but still represents a small fraction of the EW.

The results of the bounding evaluation show the following trends:

- All COCs had less areas of concern for the low bounding runs. PCB had no areas of concern for the low bounding run.
- All COCs had additional areas of concern based on the high bounding run. However, these areas represent a small portion of the EW area and do not extend far from source outfalls.
- Dioxins/furans had a small reduction in areas of concern once proposed future source control actions were accounted for. PCB and BEHP did not have any reduction in predicted areas of concern due to proposed source control actions.

5 ADDITIONAL CONSIDERATIONS

Results from the sediment transport evaluation (STE) completed for the EW and the updated Physical Processes conceptual site model (CSM) developed as part of the EW SRI (Windward and Anchor QEA 2014) and the EW FS are being used as input to the evaluation of site performance over time and recontamination potential within the EW, post-remediation. The effects on predictions of hydrodynamics and sediment transport due to uncertainty in data collection methods, hydrodynamic and PTM inputs, and specific model parameters were investigated as part of the STE and a description of those analyses are provided in the STER (Anchor QEA and Coast & Harbor Engineering 2012).

Specific discussion of uncertainties associated with prediction of site performance over time and recommendation potential based on the chosen values for input variables are discussed in the previous sections of this appendix summarized below:

- Site performance over time, predicted SWAC values (box model evaluation); see Sections 2.4.2 and 2.4.3
- Site performance over time, proposed MNR areas (point mixing model evaluation); see Section 3.4
- Recontamination potential (grid model evaluation); see Section 4.5

This section provides discussion of other considerations that could introduce uncertainty into the evaluation of site performance over time and/or recontamination potential. Much of this information has already been provided in the STER (Anchor QEA and Coast & Harbor Engineering 2012) or EW SRI (Windward and Anchor QEA 2014); however, it is re-summarized here for the reader's benefit. These considerations have been separated into three general categories as described below:

- Considerations related to estimates of input data (i.e., NSR and vertical mixing) taken from the STE and updated Physical Processes CSM are discussed in Section 5.1.
- Considerations associated with calculation methodology developed to estimate SWAC values over time (box model evaluation) and surface concentrations over time in proposed MNR areas (point mixing model evaluation) are discussed in Section 5.2.
- Considerations associated with methodology developed to evaluate recontamination potential due to deposition of EW lateral sediments are discussed in Section 5.3.

5.1 Considerations Associated with Input Data from Sediment Transport Evaluation

This section discusses other considerations that could introduce uncertainties in the evaluations of site performance over time and recontamination potential in the EW FS associated specifically with measurements or calculations of the input data used. The information provided in this section is a summary of more detailed discussions published previously in the STER (Anchor QEA and Coast & Harbor Engineering 2012) and EW SRI (Windward and Anchor QEA 2014).

5.1.1 Representative Net Sedimentation Rate

A representative NSR of 1.2 cm/yr was assumed for the entire EW for the purposes of the FS modeling (see FS Section 5.1.2). This value is the site-wide area average value of net sedimentation calculated from evaluation of NSRs interpreted from geochronological cores for Cs-137 and Pb-210 collected in the EW as part of the STE (see FS Figure 5-1). There is uncertainty in this assumed value of NSR that can be applied for EW as a whole due to variation of estimates of estimated NSRs throughout the EW from the empirical evaluation conducted as part of the STER (0 to 4.2 cm/yr; Anchor QEA and Coast & Harbor Engineering 2012). There is additional uncertainty associated with extrapolating NSRs measured at discrete geochronological core locations to the entire EW area due to influence of vessel operations in the EW on NSRs (e.g., resuspension and re-distribution of EW bed sediments by propwash).

5.1.2 Propwash Impacts to Deposition Patterns

Patterns of solids deposition within the EW from EW Lateral sources based on PTM (see FS Appendix B, Part 1) represent the initial deposition patterns and do not take into account re-suspension or re-distribution of these sediments due to influence of vessel operations in the EW. Deposition patterns shown in Appendix B, Part 1 would likely be more spread out than shown, but would result in lower surface sediment chemical concentrations due to the deposited material being spread out over a larger area. Therefore, the areas identified as having increased potential for recontamination post-construction are approximate. This will be considered when developing the proposed monitoring plan during design.

5.1.3 Upstream Solids Inputs

Uncertainty exists in the chemistry estimates and solids loadings input from upstream sources (Green River, LDW bed sediments, and LDW laterals). This uncertainty will exist well into the future based on the variable nature of these sources. However, a range of concentrations were developed (in Section 5) to evaluate the uncertainty in upstream values. Specifically, the input (e.g., Base Case) values were bracketed by lower- and upper-bound values.

In general, the value representing a mid-range of the various lines of evidence was considered for the input value, and then values representing upper and lower bounds were selected for the high and low sensitivity input values, respectively. One goal of including a range in the input values is to account for uncertainty in all the datasets representing upstream inputs and show how these data ranges affect the long term predictions for the remedial alternatives.

The high end of the range (high chemistry and high solids) is intended to capture variability in the source concentrations, typical seasonal high flows, and the less frequent high flow events (e.g., 100-year flood) that is considered likely to overestimate contaminant concentrations. The low end of the range (low chemistry and low solids) represents a non-conservative set of assumptions that is considered likely to underestimate contaminant concentrations.

The incoming solids from upstream to the EW were based on the outgoing solids estimated from the LDW Sediment Transport Modeling Report (STM; Windward and QEA 2008), which, like all models, has uncertainty. The upstream load from the LDW STM was used to partition the upstream load between the three contributing sources (Green River, LDW bed, and LDW laterals). There is some uncertainty that the distribution of inputs upstream of the EW/WW split matches the distribution entering the EW.

Chemistry assumptions for LDW bed and LDW lateral sediment sources were taken from values provided in the LDW FS (AECOM 2012). LDW bed and lateral sediment inputs were not varied for the sensitivity analysis because the mass of sediment that enters the EW from these sources are small compared to other upstream inputs (i.e., Green River) and do not

have a large effect on long-term SWACs for the alternatives. Chemistry assumptions for Green River input (as described in FS Appendix B, Part 3B) considered the same datasets for use in the LDW (AECOM 2012), but selected different concentrations of certain parameters due to a lower percentage of coarse-grained sediment entering the EW from upstream. These datasets are considered reasonable lines of evidence for developing incoming concentrations to the EW from upstream, although each type of data collection tends to bias the results toward lower or higher values (e.g., low percent fines versus high percent fines; single collection events instead of seasonal collection events; potential influence of sources).

5.1.4 East Waterway Lateral Solids Inputs

The uncertainties in the incoming solids input from EW laterals include particle size distributions, stormwater and CSO flows, and total suspended solids concentrations. Appendix F of the EW STER (Anchor QEA and Coast & Harbor Engineering 2012) provides detailed information on how this information was developed for use in the PTM.

There is additional uncertainty associated with the use of shorter-term PTM simulations performed to provide information used to evaluate long-term deposition in the EW from lateral sources. This involved using a representative tidal condition and temporally-constant mean annual average riverine inflow (for the hydrodynamic model used as input to the PTM) and annual average sediment source input rates. This information, while not representative of any particular storm event, provided average initial deposition rates and patterns from EW lateral solids inputs into the EW.

Uncertainties in chemistry assumptions include assignments of the same chemistry values to different outfalls, future concentrations following additional source control actions, as well as chemistry associated with the specific particle sizes that will settle onto EW bed sediments. For example, the same chemistry value was assigned to all nearshore storm drain basins in the point mixing model and grid model evaluations for the reasons listed in FS Appendix B, Part 4 (e.g., consideration of number of samples for a given basin). In addition, the source tracing dataset for SDs included catch basins that are related to a smaller area within the basin and may not be representative of what ultimately is discharged through

the outfall. Collectively, these assumptions may lead to over or underestimation of contaminant concentrations for an individual basin.

5.1.5 Vertical Mixing Assumptions

5.1.5.1 Delineation of Vessel Operational Areas

The EW was divided into areas in which vessel operations activities and vessel types were similar as part of the EW STE. These vessel operational areas were used in the FS to calculate scour depths and develop vertical mixing depth assumptions in the EW. Fourteen separate areas and sub-areas were identified. The areas and operations were developed through interviews and personal conversations with individuals that work within the EW including pilots, operations managers, U.S. Coast Guard officials, Port planners, and others (see Section 5.1.2 of the STER; Anchor QEA and Coast & Harbor Engineering 2012). Therefore, uncertainty in the delineation of vessel operational areas is primarily dependent on the reliability of this information for specific areas and changes over time. This uncertainty is taken into account by using conservative operational criteria for the propwash simulations (conducted as part of the STE) based on an understanding of vessel operations. However, there is still some uncertainty in the definitions of specific vessel operation parameters for each scenario (e.g., percent power used for bow thrusters and actual tug operations). Additional uncertainties exist in the location of transitions between operational areas.

5.1.5.2 Prediction of Scour Depths

Scenarios used to estimate scour depths in the EW have been chosen to represent extreme conditions, as defined in Section 5.1.2 of the STER (Anchor QEA and Coast & Harbor Engineering 2012), within each of the defined vessel operational areas in the EW (see Section 5.1.5.1 above). These scenarios are anticipated to drive sediment mobilization in the EW (due to propwash) to a larger extent than a single emergency maneuver or event. The scour depths were predicted by propwash modeling is outlined in FS Appendix B, Part 2.

Uncertainty in estimates of scour depth, as with the delineation of operational areas, are primarily associated with uncertainty in information gathered about vessel operations during the STE. Additional uncertainty is associated with estimates of critical shear stress of surface sediments in the EW. The uncertainties in estimates of critical shear stress, as evaluated from

SEDflume data as part of the STE, include collection effects on sediment properties, experimental error during testing, methodology used to estimate critical shear stress, and spatial variability in erosion properties. While spatial variability in critical shear stress in the EW based on SEDflume data does exist, the representative range in critical shear stress for surface sediments was estimated to be about 0.20 to 0.37 Pa.

Additional uncertainty in prediction of scour depths in the EW can be attributed to the methodology and equations used to complete the calculations (FS Appendix B, Part 2). The equations used in the described methodology have constants that were developed through empirical methods that may not be completely representative of vessel operations and conditions within the EW. Uncertainties in calculation of scour depths were taken into account through use of conservative assumptions, including shallower water depths (operations at mean lower low water) and relatively high power assumptions for vessel operations.

5.1.6 Bed Replacement Values

Post-construction sediment bed replacement values are used as input for modeling for post-construction starting conditions. These values are predictions that represent the initial (or end of construction - Time 0) bed sediment contaminant concentrations following completion of remedial activities involving dredging and placement of RMC, capping, or ENR material. Bed replacement values affect the short term surface concentrations but other variables contribute to the long term predictions of surface concentrations in the EW. Evidence from other sediment sites has shown that contaminant concentrations in the sediment bed after completing a remedial action cannot be assumed to be zero (NRC 2008; EPA 2005), as a result of resettling of contaminated sediments suspended during remedial activities, material being used for RMC following dredging may contain low concentrations of key risk driver COCs, and propwash from large ships in the EW will mix dredge residuals, RMC, and existing sediments around the site. The degree of residual contamination is dependent on the type of remedial activity, specific design elements, construction methods; best management practices (BMPs), engineering controls, contingency measures, and other variables, the effects of which cannot be accurately predicted through modeling.

In the EW, replacement values were developed for 1) remediated areas and 2) interior unremediated areas. FS Appendix B, Part 3A describes the input, low, and high replacement values. This range is intended to capture the uncertainty associated with any of the variables that contribute to the actual post-construction surface sediment concentration.

The most important variables that affect the post-construction surface sediment concentration estimated for the EW are the dredge residuals concentrations and thickness. Thickness of dredge cut, type of dredge equipment, and use of BMPs will affect the dredge residuals thickness. The concentration of sediment being dredged (especially the last pass for dredging areas where multiple passes are required) also varies throughout the EW and will influence dredge residuals concentrations. As described in FS Appendix B, Part 5, variables that affect the dredge residuals thickness, concentration, and distribution include hydrodynamic and operational conditions within the EW during dredging and placement of RMC, including water depth, anticipated duration it would take to place clean material over the entire open-water remediation area (which could require a full construction season due to the extensive size of the anticipated remediation area), and frequency of ongoing vessel traffic in the EW that causes sediment resuspension and sediment bed mixing.

In addition, actual undredged sediment concentrations in remediated and interior unremediated areas following construction affect the post-construction sediment concentration. In areas where limited or no dredge residuals have been deposited and sediment with low concentrations is exposed, the post-construction concentrations may be closer to the low replacement value shown in FS Appendix B, Part 3A. Alternately, where a thicker layer of dredge residuals have deposited, dredge residuals concentrations are higher, or mixing from propwash or placement of RMC spreads contaminated sediment, post-construction concentrations may result in concentrations closer to the high estimate shown in FS Appendix B, Part 3A.

5.2 Considerations Associated with Calculation Methodology for SWAC Values (Box Model Evaluation and Point Mixing Model Evaluation)

In addition to uncertainty in input data, additional uncertainty in predicted SWAC values from the box and point mixing models can be attributed to the methodology developed for

those calculations (i.e., vertical mixing assumptions, time frame assumed for mixing to occur, etc.). In order to account for this uncertainty, bounding and sensitivity evaluations were conducted as described in Sections 2.3 and 2.4 of this appendix. Additional considerations that could introduce uncertainty in predictions of SWAC values using the box model evaluation or point mixing model evaluation are discussed in the following sections.

5.2.1 Post-construction (Year 0) Sediment Concentrations

The post-construction (year 0) sediment concentrations estimated for each remedial technology have not taken into account that construction will take place over multiple in-water construction seasons. Instead, the model assumes that all remediation is completed at one time; bed disturbance and deposition that occurs between construction seasons is not taken into account in the estimates of year 0 sediment concentrations.

5.2.2 Vertical Bed Mixing Model and Mixing Depth Assumptions

The vertical bed mixing models (shown in Figures 1a through 1j) are idealized models used to represent the sediment bed post-construction (year 0) for each remedial alternative, as well as sediment deposition and vertical mixing for years following year 0. It is understood that existing bottom sediments, placed sediment, and natural sedimentation within the EW will not resemble even constant layers of sediment as shown in Figures 1a through 1j. This simplification was used to facilitate calculations of long term surface concentrations within the EW.

Vertical mixing assumptions were developed based on calculations of scour depth within the EW, which varied from 0.5 to almost 5 feet depending on location and vessel use (see FS Figure 5-2). However, the range of predicted scour depths was simplified in the evaluation of site performance over time by dividing the EW into areas which were assigned one of four mixing depths: 10 cm (bioturbation), 0.5 feet, 1 foot, and a maximum mixing depth of 2 feet (see Section 2.2.4).

5.2.3 Exchange between Open-water and Underpier Areas

An exchange of sediment between open-water and underpier areas is expected to occur in the EW due to resuspension and distribution of sediments due to impacts from vessel

operations, including use of bow thrusters and other propwash scenarios. It is not possible to calculate this exchange rate with any precision due to the variability in vessel operations and underpier sediment characteristics. Therefore, the physical process was simulated in the model through a mass-balance exchange of sediment between open-water and underpier areas.

5.2.4 Timeframe for Complete Mixing in the East Waterway

The timeframe for the EW to completely mix both spatially and vertically to the estimated mixing depths is difficult to predict due to spatial and temporal variability in vessel operations and spatial variability of sediment conditions within the EW. Therefore, the timeframe assumed for complete mixing (i.e., sediments in all open-water areas in the EW are mixed between 10 cm and 2 feet below mudline depending on location) to occur was assumed to be 5 years. Since this timeframe is difficult to predict using available empirical data (due to complexity of vessel operations in the EW), the uncertainty associated with the timeframe of mixing in the EW was parameterized in the sensitivity analysis using two other related variables: vertical mixing depth and percent of the EW area that was fully mixed in the assumed 5-year timeframe.

5.3 Considerations Associated with the Methodology for Recontamination Evaluation (Grid Model Evaluation)

Considerations associated with the methodology used to evaluate recontamination potential that could introduce uncertainty in the evaluation include assumptions for surface concentrations at year 0 post-remediation and vertical mixing assumptions. Year 0 surface sediment concentrations were all set to zero to focus the evaluation on impacts of sediment deposition on recontamination potential. This will result in lower surface concentrations for a short duration following remediation. However, by Year 10 post-remediation, surface sediment within the top 10 cm will consist almost entirely of deposited sediment from upstream and EW lateral sources based on the representative NSR for the EW used in the FS (1.2 cm/yr). This is because vertical mixing due to vessel operations was not considered as part of the recontamination evaluation; and mixing depths in the EW were all set to the bioturbation mixing depth of 10 cm. The deposition patterns predicted by the PTM for EW laterals do not take into account impacts of re-suspension due to vessel operations. Therefore, deposition patterns predicted by the PTM (used as input for the grid model evaluation)

would likely be more spread out and would have lower calculated surface sediment chemical concentrations due to the deposited material being spread out over a larger area. Therefore, the areas identified as having increased potential for recontamination post-restoration are approximate. This will be considered when developing the proposed monitoring plan during design.

6 REFERENCES

AECOM, 2012. Feasibility Study, Lower Duwamish Waterway, Seattle, Washington. Final Report. Prepared for Lower Duwamish Waterway Group. October 2012.

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QEA (Quantitative Environmental Analysis), 2008. Lower Duwamish Waterway Sediment Transport Modeling (STM) Report, Final. Prepared for USEPA, Region 10, and the Washington State Department of Ecology. Quantitative Environmental Analysis, Montvale, NJ. October.

Windward and Anchor QEA, 2014. Supplemental Remedial Investigation. East Waterway Operable Unit Supplemental Remedial Investigation/Feasibility Study. Final. January 2014.

TABLES

Table 1

Summary of Solids Inputs to the East Waterway

Current Conditions

Input	Source	Total Annual Incoming Sediment (kg)[1]	Cumulative Total Annual Incoming Sediment (kg)[2]	Annual Incoming Sediment by Size (kg)[3]				Total Annual Deposited Sediment (kg)[4]	% Total Deposited Sediment[4]
				A (0.005 mm)	B (0.02 mm)	C (0.13 mm)	D (0.54 mm)		
Upstream	Green River	32,159,000 to 53,598,000[5]	32,415,000 to 53,998,000[5]	29,013,000 to 48,355,000	3,145,000 to 5,242,000	199 to 332	29 to 49	15,116,510	99%
	LDW Lateral	178,000 to 296,000[5]		161,000 to 267,000	17,000 to 29,000	1.1 to 1.8	0.1 to 0.3	83,803	0.55%
	LDW Bed	78,000 to 131,000[5]		70,000 to 118,000	7,600 to 12,800	0.5 to 0.8	0.07 to 0.12	36,569	0.24%
EW Laterals	Hinds CSO	326	37,471	137	133	55	0	176	0.00%
	Lander CSO	12,957		5,442	5,312	2,203	0	8,000	0.05%
	Hanford #2 CSO	24,188		10,159	9,917	4,112	0	13,642	0.09%
	Nearshore SD[6]	33,357	75,623	5,137	7,706	8,706	11,809	27,682	0.18%
	S Lander St SD	31,940		4,919	7,378	8,337	11,307	27,089	0.18%
	Non-nearshore SD[7]	10,326		1,590	2,385	2,695	3,655	8,040	0.05%

Future Source Control Conditions (Values are the same as current conditions [grey text] except where noted [bold black text])

Input	Source	Total Annual Incoming Sediment (kg)[1]	Cumulative Total Annual Incoming Sediment (kg)[2]	Annual Incoming Sediment by Size (kg)[3]				Total Annual Deposited Sediment (kg)[4]	% Total Deposited Sediment[4]
				A (0.005 mm)	B (0.02 mm)	C (0.13 mm)	D (0.54 mm)		
Upstream	Green River	32,159,000 to 53,598,000[5]	32,415,000 to 53,998,000[5]	29,013,000 to 48,355,000	3,145,000 to 5,242,000	199 to 332	29 to 49	15,116,510	99%
	LDW Lateral	178,000 to 296,000[5]		161,000 to 267,000	17,000 to 29,000	1.1 to 1.8	0.1 to 0.3	83,803	0.55%
	LDW Bed	78,000 to 131,000[5]		70,000 to 118,000	7,600 to 12,800	0.5 to 0.8	0.07 to 0.12	36,569	0.24%
EW Laterals	Hinds CSO	**207**	**16,744**	**87**	**85**	**35**	**0**	**111**	0.00%
	Lander CSO	**195**		**82**	**80**	**33**	**0**	**124**	0.00%
	Hanford #2 CSO	**16,342**		**16,154**	**133**	**55**	**0**	**2,919**	0.02%
	Nearshore SD[6]	**15,594**	**57,860**	**4,115**	**3,819**	**3,251**	**4,409**	**11,206**	0.07%
	S Lander St SD	31,940		4,919	7,378	8,337	11,307	27,089	0.18%
	Non-nearshore SD[7]	10,326		1,590	2,385	2,695	3,655	7,987	0.05%

Notes:

1. Categories of solids sources used for recontamination potential evaluation and Point Mixing Model.
2. Categories of solids sources used for evaluation of site performance over time (SWACs).
3. Upstream annual incoming sediment by size was based on suspended sediment size classes predicted to leave the model domain boundary upstream of the EW and WW split, and averaged over 30 years predicted by the LDW Sediment Transport Model (AECOM 2012).
4. Deposition values based on Base Case PTM Model runs for EW Laterals (see Appendix B, Part 1 of the FS) and average net sedimentation rate for the EW from geochronology cores (see Section 5.1.2 of the FS).
5. Range in values based on range in the estimated split in flow between the EW and WW, 50% to 30% to EW from LDW.
6. Nearshore SDs include SW Florida St SD (B-21), B-25, all Port SDs, and all private SDs along waterfront (A-6, B-40, B-41, B-42, B-43).
7. Non-nearshore SDs include S Hinds St SD, SW Spokane St EOF/SD (B-5), SW Spokane St SD (B-4), S Spokane St SD (B-36), and all bridges (BR-2, BR-4, BR-34, BR-39).

CSO – Combined Sewer Overflow; EW – East Waterway; FS – Feasibility Study; kg – kilogram; LDW – Lower Duwamish Waterway; mm – millimeter; PTM – particle tracking model; SD – Storm Drain; SWAC – spatially-weighted average concentration; WW – West Waterway

Table 2

Alternative-specific Post-construction Concentrations by Technology Application Area

Technology[1]	Total PCBs (µg/kg considering bioavailability)[5]															
	Alternative															
	1A(12)	1B(12)	1C+(12)	2A(12)	2B(12)	2C(12)	2C+(12)	3B(12)	3C+(12)	3D(12)	3E(7.5)	3E(5.0)	2C+(7.5)	2C+(5.0)	3C+(7.5)	3D(5.0)
Open-water																
Removal[2]	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Removal to the Extent Practicable and Backfill[2]	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Removal and Backfill to Existing Contours[3]	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Partial Removal and Cap	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Partial Removal and ENR-nav[4]	35	35	35													
ENR-sill[2]	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
ENR-nav[4]	8	8	8													
MNR	1268			1268												
Interior Unremediated Island[2]	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Exterior Unremediated Island	54	54	54	54	54	54	54	54	54	54	27	20	27	20	27	20
Underpier																
Hydraulic Dredging Followed by In situ Treatment			411				411		411		173	165	411	411	411	0
Hydraulic Dredging						1,371				596						550
In situ Treatment		179	135		179	135	135	179	135				130	124	130	
MNR	596			596												
No Action	81	81	81	81	81	81	81	81	81	81	40	23	40	23	40	23

Technology	Total cPAHs TEQ (µg/kg considering bioavailability)[5]															
	Alternative															
	1A(12)	1B(12)	1C+(12)	2A(12)	2B(12)	2C(12)	2C+(12)	3B(12)	3C+(12)	3D(12)	3E(7.5)	3E(5.0)	2C+(7.5)	2C+(5.0)	3C+(7.5)	3D(5.0)
Open-water																
Removal[2]	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
Removal to the Extent Practicable and Backfill[2]	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
Removal and Backfill to Existing Contours[3]	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
Partial Removal and Cap	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Partial Removal and ENR-nav[4]	28	28	28													
ENR-sill[2]	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
ENR-nav[4]	13	13	13													
MNR	582			582												
Interior Unremediated Island[2]	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
Exterior Unremediated Island	164	164	164	164	164	164	164	164	164	164	170	186	170	186	170	186
Underpier																
Hydraulic Dredging Followed by In situ Treatment			423				423		423		196	187	423	423	423	
Hydraulic Dredging						1,409				596						622
In situ Treatment		179	132		179	132	132	179	132				155	147	155	
MNR	596			596												
No Action	540	540	540	540	540	540	540	540	540	540	106	121	106	121	106	121

Table 2

Alternative-specific Post-construction Concentrations by Technology Application Area

Technology[1]	Total Dioxins/Furans TEQ (ng/kg considering bioavailability)[5]															
	Alternative															
	1A(12)	1B(12)	1C+(12)	2A(12)	2B(12)	2C(12)	2C+(12)	3B(12)	3C+(12)	3D(12)	3E(7.5)	3E(5.0)	2C+(7.5)	2C+(5.0)	3C+(7.5)	3D(5.0)
Open-water																
Removal[2]	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Removal to the Extent Practicable and Backfill[2]	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Removal and Backfill to Existing Contours[3]	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Partial Removal and Cap	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Partial Removal and ENR-nav[4]	2.8	2.8	2.8													
ENR-sill[2]	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
ENR-nav[4]	2.2	2.2	2.2													
MNR	17			17												
Interior Unremediated Island[2]	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Exterior Unremediated Island	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.9	8.7	7.9	8.7	7.9	8.7
Underpier																
Hydraulic Dredging Followed by In situ Treatment			4.8				4.8		4.8		4.9	4.9	4.8	4.8	4.8	
Hydraulic Dredging						16				17						16
In situ Treatment		5.0	5.0		5.0	5.0	5.0	5.0	5.0				5.0	4.9	5.0	
MNR	17			17												
No Action	12	12	12	12	12	12	12	12	12	12	12	10	12	10	12	10

Technology[1]	Arsenic (mg/kg)[5]															
	Alternative															
	1A(12)	1B(12)	1C+(12)	2A(12)	2B(12)	2C(12)	2C+(12)	3B(12)	3C+(12)	3D(12)	3E(7.5)	3E(5.0)	2C+(7.5)	2C+(5.0)	3C+(7.5)	3D(5.0)
Open-water																
Removal[2]	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Removal to the Extent Practicable and Backfill[2]	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Removal and Backfill to Existing Contours[3]	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Partial Removal and Cap	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Partial Removal and ENR-nav[4]	4.2	4.2	4.2													
ENR-sill[2]	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
ENR-nav[4]	4.0	4.0	4.0													
MNR	14.8			14.8												
Interior Unremediated Island[2]	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Exterior Unremediated Island	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.3	5.0	5.3	5.0	5.3
Underpier																
Hydraulic Dredging Followed by In situ Treatment			13				13		13		8.4	8.2	13	13	13	
Hydraulic Dredging						20				12						11
In situ Treatment		11	9.5		11	9.5	9.5	11	9.5				10	9.3	10	
MNR	12			12												
No Action	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	4.6	4.5	4.6	4.5	4.6	4.5

Table 2

Alternative-specific Post-construction Concentrations by Technology Application Area

Notes:
1. Residuals thickness varies by alternative; see FS Appendix L and FS Section 8 for this information.
2. Includes 9 inches of sand cover in ENR sill areas in calculations.
3. Includes 4 feet of sand cover in calculations.
4. Includes 1.5 feet of sand cover in ENR-nav areas in calculations.
5. Post-construction concentrations are calculated in the top 10 centimeters of bed sediments.

µg/kg – microgram per kilogram
cPAH – carcinogenic polycyclic aromatic hydrocarbon
ENR – enhanced natural recovery
mg – milligram
MNR – monitored natural recovery
ng – nanogram
PCB – polychlorinated biphenyl
TEQ – toxic equivalent

Table 3

Sub-area Input Values by Remedial Alternative for SWAC Calculations (Box Model Evaluation)

(Total Area of EW for all Remedial Alternatives is 157.4 acres)

Technology[1]	Areas (acres)															
	Alternative															
	1A(12)	1B(12)	1C+(12)	2A(12)	2B(12)	2C(12)	2C+(12)	3B(12)	3C+(12)	3D(12)	3E(7.5)	3E(5.0)	2C+(7.5)	2C+(5.0)	3C+(7.5)	3D(5.0)
Open-water																
Removal[2]	73.2	73.2	73.2	87.9	87.9	87.9	87.9	92.3	92.3	92.3	102.1	109.6	97.7	105.2	102.2	109.6
Removal to the Extent Practicable and Backfill[2]	3.3	3.3	3.3	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Removal and Backfill to Existing Contours[3]	0.7	0.7	0.7	0.7	0.7	0.7	0.7	3.5	3.5	3.5	3.8	3.8	0.8	0.8	3.8	3.8
Partial Removal and Cap	12.8	12.8	12.8	12.8	12.8	12.8	12.8	7.3	7.3	7.3	7.3	7.3	12.8	12.8	7.3	7.3
Partial Removal and ENR-nav[4]	7.4	7.4	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ENR-sill[2]	2.4	2.9	2.9	2.4	2.9	2.9	2.9	1.2	1.2	1.2	1.3	1.3	3.2	3.2	1.3	1.3
ENR-nav[4]	8.7	8.7	8.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MNR	0.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action-Interior Unremediated Island[2]	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	15.1	9.2	15.1	9.2	15.1	9.2
No Action-Exterior Unremediated Island	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	8.5	6.9	8.5	6.9	8.5	6.9
Underpier																
Hydraulic Dredging Followed by In situ Treatment	0.0	0.0	1.9	0.0	0.0	0.0	1.9	0.0	1.9	0.0	12.7	13.4	1.9	1.9	1.9	0.0
Hydraulic Dredging	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	12.1	0.0	0.0	0.0	0.0	0.0	13.4
In situ Treatment	0.0	12.1	10.1	0.0	12.1	10.1	10.1	12.1	10.1	0.0	0.0	0.0	10.7	11.5	10.7	0.0
MNR	12.1	0.0	0.0	12.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action-Underpier Unremediated	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	1.8	1.1	1.9	1.1	1.8	1.1

Notes:
1. Residuals thickness varies by alternative; see FS Appendix L and FS Section 8 for this information.
2. Includes 9 inches of sand cover in ENR-sill areas in calculations.
3. Includes 4 feet of sand cover in calculations.
4. Includes 1.5 feet of sand cover in ENR-nav areas in calculations.
ENR – enhanced natural recovery
EW – East Waterway
MNR – monitored natural recovery
SWAC – spatially-weighted average concentration

Table 4

Sensitivity and Bounding Scenarios for SWAC Calculations (Box Model Evaluation)

Sensitivity Analysis-Review Influence of Each Parameter (Alternatives 1A(12) and 2B(12))

Scenario	Scenario Name	1: Net Sedimentation Rate	2: Residuals Thickness[2]	3: Residuals Concentration	4: Mixing Depth	5: Area Mixed	6: Underpier Exchange	7: Lateral Concentrations[3]	8: Green River Concentrations[3]	9: Bioavailability[4]
1[1]	Base Case	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
2	1: Net Sedimentation Rate-Low	0.5 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
3	1: Net Sedimentation Rate-High	1.8 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
4	1a: Variable NSR	0 cm/0.5 cm/1.6 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
5	2: Residuals Thickness-Low	1.2 cm	3.1 cm; 0.6 cm	640 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
6	2: Residuals Thickness-High	1.2 cm	7.2 cm; 1.4 cm	640 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
7	3: Residuals Concentration-Low	1.2 cm	5.1 cm; 1.0 cm	470 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
8	3: Residuals Concentration-High	1.2 cm	5.1 cm; 1.0 cm	980 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
9	4: Mixing Depth-Low	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	1 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
10	4: Mixing Depth-High	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	3 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
11	5: Area Mixed-Low	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	30%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
12	5: Area Mixed-High	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	90%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
13	6: Underpier Exchange-Low	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	5%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
14	6: Underpier Exchange-High	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	50%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
15	7: Lateral Concentrations-Low	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	25%	45.36 µg/kg; 44.44 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
16	7: Lateral Concentrations-High	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	25%	48.54 µg/kg; 45.52 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
17	8: Green Concentrations-Low	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	9.58 µg/kg; 8.44 µg/kg	70%
18	8: Green Concentrations-High	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	83.38 µg/kg; 82.31 µg/kg	70%
19	9: Bioavailability-Low	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	50%
20	9: Bioavailability-High	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	90%

Notes:

1. Scenario 1 used as base case for conducting all evaluations (box model, point-by-point mixing model, and grid model).
2. See Appendix B, Part 3A.
3. See Appendix B, Part 4.
4. Underpier bioavailability for underpier areas. Only valid for Alternative 2B(12); Alternative 1A(12) stays constant.

Shaded boxes indicate that the parameter changed compared to the Sensitivity Analysis, Scenario 1.

µg/kg – microgram per kilogram; cm – centimeters; NSR – net sedimentation rate; SWAC – spatially-weighted average concentration

Table 4

Sensitivity and Bounding Scenarios for SWAC Calculations (Box Model Evaluation)

Bounding Scenarios (Alternatives 1A(12) and 2B(12))

Scenario	1: Net Sedimentation Rate	2: Residuals Thickness	3: Residuals Concentration	4: Mixing Depth	5: Area Mixed	6: Underpier Exchange	7: Lateral Concentrations	8: Green River Concentrations	9: Bioavailability[1]
Lowest Bound	High	Low	Low	High	Low	Low	Low	Low	High
Highest Bound	Low	High	High	Low	High	High	High	High	Low
Additional Low	Base	Low	Low	High	Low	Low	Low	Base[2]	High
Additional High	Base	High	High	Low	High	High	High	Base[2]	Low
Green River Low	Base	Base	Base	Base	Base	Base	Base	Low	Base
Green River High	Base	Base	Base	Base	Base	Base	Base	High	Base

Notes:

1. Bioavailability is only applied to sensitivity and bounding runs for Alternative 2B(12); Alternative 1A(12) stays constant.
2. NSR and Green River concentrations left as base case to illustrate the impact these parameters have on the SWAC predictions (see Section 2.3.3).

Table 5

Site-wide Total PCB SWAC (µg/kg dw) Results for Box Model Sensitivity Scenarios[1]

Alternative 1A(12)		Years Post-construction								
Scenario	**Scenario Name**	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1	Base Case	76	131	126	114	103	95	87	82	77
2	1: Net Sedimentation Rate-Low	76	123	143	142	135	127	119	112	106
3	1: Net Sedimentation Rate-High	76	125	111	97	88	81	75	71	67
4	1a: Variable NSR	76	127	122	113	104	97	91	86	82
5	2: Residuals Thickness-Low	76	127	122	110	100	91	84	79	74
6	2: Residuals Thickness-High	76	136	130	118	107	98	91	85	80
7	3: Residuals Concentration-Low	76	128	123	111	101	92	85	80	75
8	3: Residuals Concentration-High	76	138	132	120	109	100	92	86	81
9	4: Mixing Depth-Low	76	131	127	116	105	95	88	81	76
10	4: Mixing Depth-High	76	130	124	112	101	93	86	80	76
11	5: Area Mixed-Low	76	137	132	118	105	95	87	81	76
12	5: Area Mixed-High	76	119	114	107	100	94	89	84	80
13	6: Underpier Exchange-Low	76	98	97	93	89	86	83	80	77
14	6: Underpier Exchange-High	76	173	143	117	101	90	82	77	73
15	7: Lateral Concentrations-Low	76	131	126	114	103	94	87	82	77
16	7: Lateral Concentrations-High	76	132	127	115	104	95	88	83	78
17	8: Green Concentrations-Low	76	118	108	94	81	70	62	55	50
18	8: Green Concentrations-High	76	144	144	136	127	119	114	109	106

Alternative 2B(12)		Years Post-construction								
Scenario	**Scenario Name**	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1	Base Case	42	72	71	68	65	63	60	59	57
2	1: Net Sedimentation Rate-Low	42	67	74	75	74	72	70	68	67
3	1: Net Sedimentation Rate-High	42	71	68	64	61	58	56	55	53
4	1a: Variable NSR	42	69	69	66	63	61	59	58	56
5	2: Residuals Thickness-Low	42	67	67	64	61	59	57	55	54
6	2: Residuals Thickness-High	42	77	76	73	70	67	64	62	60
7	3: Residuals Concentration-Low	42	68	68	65	62	60	58	56	55
8	3: Residuals Concentration-High	42	79	78	75	71	68	66	64	62
9	4: Mixing Depth-Low	42	70	70	67	64	61	58	56	55
10	4: Mixing Depth-High	42	67	67	64	61	59	57	56	54
11	5: Area Mixed-Low	42	71	71	68	65	62	59	58	56
12	5: Area Mixed-High	42	72	71	69	67	64	62	61	59
13	6: Underpier Exchange-Low	42	62	63	62	60	59	58	57	56
14	6: Underpier Exchange-High	42	84	77	70	66	63	60	58	57
15	7: Lateral Concentrations-Low	42	71	71	68	65	62	60	58	57
16	7: Lateral Concentrations-High	42	72	73	69	66	63	61	59	58
17	8: Green Concentrations-Low	42	59	54	48	43	39	35	32	30
18	8: Green Concentrations-High	42	84	89	89	88	87	86	86	85
19	9: Bioavailability-Low	51	90	89	83	78	73	69	66	64
20	9: Bioavailability-High	32	53	54	54	53	52	52	51	50

Notes:
1. All sensitivity runs were conducted using total PCBs, sensitivity scenarios are listed in Table 4.
µg/kg – microgram per kilogram
dw – dry weight
NSR – net sedimentation rate
PCB – polychlorinated biphenyl
SWAC – spatially-weighted average concentration

Table 6

Site-wide Total PCB SWAC (µg/kg dw) Results for Box Model Bounding Scenarios[1]

Alternative 1A(12)	Years Post-construction								
	0	5	10	15	20	25	30	35	40
Base Case	76	131	126	114	103	95	87	82	77
Lowest Bound	76	68	60	54	49	44	41	38	36
Highest Bound	76	196	212	202	192	183	175	168	161
Reasonable Low	76	94	93	90	86	83	80	77	75
Reasonable High	76	162	144	126	111	99	90	83	76
Green Low	76	118	108	94	81	70	62	55	50
Green High	76	144	144	136	127	119	114	109	106

Alternative 2B(12)	Years Post-construction								
	0	5	10	15	20	25	30	35	40
Base Case	42	72	71	68	65	63	60	59	57
Lowest Bound	32	21	19	17	16	15	14	14	13
Highest Bound	51	154	160	149	137	127	118	109	101
Reasonable Low	32	43	45	45	45	45	45	45	45
Reasonable High	51	116	105	95	86	79	73	69	65
Green Low	42	59	54	48	43	39	35	32	30
Green High	42	84	89	89	88	87	86	86	85

Note:
1. All bounding runs were conducted using total PCBs, bounding scenarios are listed in Table 4.
µg/kg – microgram per kilogram
dw – dry weight
PCB – polychlorinated biphenyl
SWAC – spatially-weighted average concentration

Table 7

Point Mixing Model Solids Inputs and Chemistry Assumptions for Calculations

Point	Location[1]		PTM-derived Annual Deposition		Arsenic (mg/kg dw)			Mercury (mg/kg dw)			Total HPAHs (µg/kg dw)			Total LPAHs (µg/kg dw)		
	X Latitude	Y Longitude	Current (cm)	Future[2] (cm)	Current Surface	Current Incoming	Future Incoming	Current Surface	Current Incoming	Future Incoming	Current Surface	Current Incoming	Future Incoming	Current Surface	Current Incoming	Future Incoming
EW09-SS-010	1267383	212101	**1.356**	**1.347**	8.4	9.2	9.2	0.11	0.11	0.11	3040	2343	1940	370	354	300
EW09-SS-012	1267207	212224	**1.199**	**1.199**	6.0	9.0	9.0	0.02	0.10	0.10	2680	1338	1338	360	138	138
EW09-SS-027	1267850	213108	**1.212**	**1.204**	12.1	9.1	9.1	0.40	0.10	0.10	3270	1383	1357	500	147	142
EW09-SS-038	1267846	214050	**1.197**	**1.197**	9.1	9.0	9.0	0.46	0.10	0.10	4240	1331	1331	340	137	137
EW09-SS-100	1267016	214210	**1.210**	**1.199**	6.8	9.1	9.0	0.29	0.10	0.10	2220	1376	1338	350	146	138
EW09-SS-101	1267840	214257	**1.197**	**1.197**	7.5	9.0	9.0	0.47	0.10	0.10	3180	1331	1331	630	137	137
EW09-SS-110	1268243	215019	**1.197**	**1.197**	9.2	9.0	9.0	0.48	0.10	0.10	2120	1331	1331	310	137	137
EW09-SS-114	1267035	215406	**1.197**	**1.197**	22.7	9.0	9.0	0.32	0.10	0.10	1700	1331	1331	250	137	137
EW09-SS-126	1267067	217295	**1.208**	**1.201**	6.4	9.1	9.1	0.17	0.10	0.10	1080	1370	1344	82	145	139
EW09-SS-211	1267130	218822	**1.197**	**1.197**	3.6	9.0	9.0	0.17	0.10	0.10	1940	1331	1331	280	137	137
EW09-SS-219	1267959	219386	**1.197**	**1.197**	3.1	9.0	9.0	0.16	0.10	0.10	1370	1331	1331	400	137	137
EW-109	1267155	218459	**1.197**	**1.197**	9.0	9.0	9.0	0.16	0.10	0.10	6200	1331	1331	1230	137	137
EW-128	1267088	212098	**1.201**	**1.204**	20.0	9.1	9.1	0.31	0.10	0.10	6100	1344	1363	940	139	145
EW-132	1267138	218690	**1.197**	**1.197**	8.0	9.0	9.0	0.19	0.10	0.10	2970	1331	1331	400	137	137
EW-135	1267878	215761	**1.223**	**1.208**	12.0	9.0	9.0	0.47	0.10	0.10	6500	1547	1399	1180	179	150
EW-136	1268185	215025	**1.212**	**1.201**	10.0	9.0	9.0	0.49	0.10	0.10	7600	1431	1354	1700	156	141
EW-138	1267049	213522	**1.197**	**1.197**	10.0	9.0	9.0	0.50	0.10	0.10	6500	1331	1331	750	137	137
LSO-01	1267897.4	215773.5	**1.223**	**1.208**	7.3	9.0	9.0	0.27	0.10	0.10	3910	1547	1399	930	179	150

Table 7

Point Mixing Model Solids Inputs and Chemistry Assumptions for Calculations

Point[1]	Yearly Deposition		BEHP (µg/kg dw)			1,4-DCB (µg/kg dw)			Total PCBs (µg/kg dw)		
	Current (cm)	Future[2] (cm)	Current Surface	Current Incoming	Future Incoming	Current Surface	Current Incoming	Future Incoming	Current Surface	Current Incoming	Future Incoming
EW09-SS-010	**1.356**	**1.347**	520	2357	1700	10.0	17.7	17.0	1130	73.0	61.6
EW09-SS-012	**1.199**	**1.199**	36	172	172	5.8	1.7	1.7	78	44.5	44.5
EW09-SS-027	**1.212**	**1.204**	310	260	210	6.0	2.5	2.0	160	45.7	45.0
EW09-SS-038	**1.197**	**1.197**	340	159	159	460.0	1.6	1.6	1600	44.3	44.3
EW09-SS-100	**1.210**	**1.199**	320	248	172	24.0	2.4	1.7	160	45.6	44.5
EW09-SS-101	**1.197**	**1.197**	1000	159	159	4200.0	1.6	1.6	310	44.3	44.3
EW09-SS-110	**1.197**	**1.197**	180	159	159	17.0	1.6	1.6	140	44.3	44.3
EW09-SS-114	**1.197**	**1.197**	230	159	159	10.0	1.6	1.6	220	44.3	44.3
EW09-SS-126	**1.208**	**1.201**	120	235	185	28.0	2.3	1.8	880	45.4	44.7
EW09-SS-211	**1.197**	**1.197**	830	159	159	10.0	1.6	1.6	180	44.3	44.3
EW09-SS-219	**1.197**	**1.197**	56	159	159	6.1	1.6	1.6	20	44.3	44.3
EW-109	**1.197**	**1.197**	220	159	159	31.0	1.6	1.6	1900	44.3	44.3
EW-128	**1.201**	**1.204**	770	185	237	2.0	1.8	2.3	2400	44.7	45.2
EW-132	**1.197**	**1.197**	300	159	159	1.4	1.6	1.6	330	44.3	44.3
EW-135	**1.223**	**1.208**	1400	363	270	2.0	4.9	2.6	740	45.4	45.0
EW-136	**1.212**	**1.201**	500	255	196	1.9	3.9	1.9	370	44.7	44.5
EW-138	**1.197**	**1.197**	760	159	159	1.8	1.6	1.6	590	44.3	44.3
LSO-01	**1.223**	**1.208**	37000	363	270	20.0	4.9	2.6	340	45.4	45.0

Notes:
1. Locations of points are shown on Figure 5.
2. Future deposition is based on expected future source control conditions for EW Laterals.
µg/kg – microgram per kilogram
BEHP – bis(2-ethylhexyl) phthalate
cm – centimeters
DCB – dichlorobenzene
dw – dry weight
EW – East Waterway
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
mg/kg – milligram per kilogram
PCB – polychlorinated biphenyl
PTM – particle tracking model

Table 8

Concentrations at Point Locations - Years 0 to 40 Post-construction

PCB (mg/kg OC)[1]				Years Post-construction								
	Mixing Depth	1-year Deposition (cm)		Current Conditions			Future Conditions					
Point	(cm)	Current	Future[2]	0	5	10	15	20	25	30	35	40
EW09-SS-010	10	**1.356**	**1.347**	70.6	25.8	11.4	6.3	4.7	4.1	3.9	3.9	3.9
EW09-SS-012	10	**1.199**	**1.199**	4.9	3.6	3.1	2.9	2.8	2.8	2.8	2.8	2.8
EW09-SS-027	60.96	**1.212**	**1.204**	10.0	9.3	8.7	8.1	7.6	7.1	6.7	6.3	5.9
EW09-SS-038	60.96	**1.197**	**1.197**	100.0	90.5	81.8	74.1	67.1	60.8	55.1	49.9	45.3
EW09-SS-100	60.96	**1.210**	**1.199**	10.0	9.3	8.7	8.1	7.6	7.1	6.7	6.3	5.9
EW09-SS-101	60.96	**1.197**	**1.197**	19.4	17.7	16.3	14.9	13.8	12.7	11.7	10.8	10.0
EW09-SS-110	60.96	**1.197**	**1.197**	8.8	8.2	7.6	7.2	6.7	6.3	6.0	5.7	5.4
EW09-SS-114	60.96	**1.197**	**1.197**	13.8	12.7	11.7	10.8	10.0	9.3	8.7	8.1	7.6
EW09-SS-126	60.96	**1.208**	**1.201**	55.0	49.8	45.2	41.0	37.2	33.8	30.8	28.0	25.5
EW09-SS-211	60.96	**1.197**	**1.197**	11.3	10.4	9.7	9.0	8.4	7.8	7.3	6.9	6.5
EW09-SS-219	60.96	**1.197**	**1.197**	1.3	1.4	1.5	1.7	1.8	1.9	2.0	2.0	2.1
EW-109	60.96	**1.197**	**1.197**	118.8	107.4	97.1	87.8	79.5	72.0	65.2	59.0	53.5
EW-128	10	**1.201**	**1.204**	150.0	61.6	26.3	12.2	6.5	4.3	3.4	3.1	2.9
EW-132	60.96	**1.197**	**1.197**	20.6	18.9	17.3	15.9	14.6	13.4	12.4	11.4	10.6
EW-135	60.96	**1.223**	**1.208**	46.3	41.9	38.0	34.5	31.4	28.5	26.0	23.7	21.6
EW-136	60.96	**1.212**	**1.201**	23.1	21.1	19.3	17.7	16.2	14.9	13.7	12.6	11.6
EW-138	60.96	**1.197**	**1.197**	36.9	33.5	30.5	27.8	25.3	23.1	21.1	19.3	17.7
LSO-01	60.96	**1.223**	**1.208**	21.3	19.4	17.7	16.3	14.9	13.7	12.6	11.7	10.8

Mercury (mg/kg)				Years Post-construction								
	Mixing Depth	1-year Deposition (cm)		Current Conditions			Future Conditions					
Point	(cm)	Current	Future[1]	0	5	10	15	20	25	30	35	40
EW09-SS-010	10	**1.356**	**1.347**	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
EW09-SS-012	10	**1.199**	**1.199**	0.02	0.07	0.09	0.10	0.10	0.10	0.10	0.10	0.10
EW09-SS-027	60.96	**1.212**	**1.204**	0.4	0.37	0.34	0.32	0.30	0.28	0.26	0.25	0.23
EW09-SS-038	60.96	**1.197**	**1.197**	0.46	0.42	0.39	0.36	0.34	0.32	0.29	0.28	0.26
EW09-SS-100	60.96	**1.210**	**1.199**	0.29	0.27	0.25	0.24	0.23	0.21	0.20	0.19	0.18
EW09-SS-101	60.96	**1.197**	**1.197**	0.47	0.43	0.40	0.37	0.35	0.32	0.30	0.28	0.26
EW09-SS-110	60.96	**1.197**	**1.197**	0.48	0.44	0.41	0.38	0.35	0.33	0.31	0.29	0.27
EW09-SS-114	60.96	**1.197**	**1.197**	0.32	0.30	0.28	0.26	0.25	0.23	0.22	0.21	0.20
EW09-SS-126	60.96	**1.208**	**1.201**	0.17	0.16	0.16	0.15	0.15	0.14	0.14	0.14	0.13
EW09-SS-211	60.96	**1.197**	**1.197**	0.17	0.16	0.16	0.15	0.15	0.14	0.14	0.14	0.13
EW09-SS-219	60.96	**1.197**	**1.197**	0.16	0.15	0.15	0.14	0.14	0.14	0.13	0.13	0.13
EW-109	60.96	**1.197**	**1.197**	0.16	0.15	0.15	0.14	0.14	0.14	0.13	0.13	0.13
EW-128	10	**1.201**	**1.204**	0.31	0.19	0.14	0.12	0.11	0.10	0.10	0.10	0.10
EW-132	60.96	**1.197**	**1.197**	0.19	0.18	0.17	0.17	0.16	0.15	0.15	0.14	0.14
EW-135	60.96	**1.223**	**1.208**	0.47	0.43	0.40	0.37	0.34	0.32	0.30	0.28	0.26
EW-136	60.96	**1.212**	**1.201**	0.49	0.45	0.42	0.39	0.36	0.33	0.31	0.29	0.27
EW-138	60.96	**1.197**	**1.197**	0.5	0.46	0.43	0.39	0.37	0.34	0.32	0.30	0.28
LSO-01	60.96	**1.223**	**1.208**	0.274	0.26	0.24	0.23	0.22	0.20	0.19	0.19	0.18

Table 8

Concentrations at Point Locations - Years 0 to 40 Post-construction

BEHP (mg/kg OC)[1]				Years Post-construction								
	Mixing Depth	1-year Deposition (cm)		Current Conditions			Future Conditions					
Point	(cm)	Current	Future[1]	0	5	10	15	20	25	30	35	40
EW09-SS-010	10	**1.356**	**1.347**	32.5	110.4	135.4	115.8	109.3	107.2	106.6	106.3	106.3
EW09-SS-012	10	**1.199**	**1.199**	2.3	7.4	9.4	10.2	10.5	10.7	10.7	10.7	10.8
EW09-SS-027	60.96	**1.212**	**1.204**	19.4	19.1	18.8	18.2	17.7	17.3	16.9	16.5	16.2
EW09-SS-038	60.96	**1.197**	**1.197**	21.3	20.1	19.1	18.2	17.4	16.7	16.0	15.4	14.9
EW09-SS-100	60.96	**1.210**	**1.199**	20.0	19.6	19.1	18.3	17.6	16.9	16.3	15.8	15.3
EW09-SS-101	60.96	**1.197**	**1.197**	62.5	57.3	52.7	48.5	44.7	41.3	38.2	35.5	32.9
EW09-SS-110	60.96	**1.197**	**1.197**	11.3	11.1	11.0	10.9	10.8	10.7	10.7	10.6	10.5
EW09-SS-114	60.96	**1.197**	**1.197**	14.4	13.9	13.6	13.2	12.9	12.6	12.3	12.1	11.9
EW09-SS-126	60.96	**1.208**	**1.201**	7.5	8.2	8.9	9.1	9.4	9.6	9.8	9.9	10.1
EW09-SS-211	60.96	**1.197**	**1.197**	51.9	47.8	44.0	40.7	37.7	35.0	32.5	30.3	28.3
EW09-SS-219	60.96	**1.197**	**1.197**	3.5	4.1	4.7	5.2	5.7	6.1	6.5	6.8	7.1
EW-109	60.96	**1.197**	**1.197**	13.8	13.4	13.0	12.7	12.5	12.2	12.0	11.8	11.6
EW-128	10	**1.201**	**1.204**	48.1	26.2	17.4	15.8	15.2	15.0	14.9	14.8	14.8
EW-132	60.96	**1.197**	**1.197**	18.8	17.9	17.1	16.4	15.8	15.2	14.7	14.2	13.8
EW-135	60.96	**1.223**	**1.208**	87.5	81.0	75.1	69.4	64.2	59.5	55.3	51.4	48.0
EW-136	60.96	**1.212**	**1.201**	31.3	29.7	28.4	26.8	25.3	24.1	22.9	21.8	20.9
EW-138	60.96	**1.197**	**1.197**	47.5	43.8	40.5	37.5	34.8	32.4	30.2	28.2	26.4
LSO-01	60.96	**1.223**	**1.208**	2313	2083	1876	1692	1526	1376	1242	1120	1011

1,4-DCB (mg/kg OC)[1]				Years Post-construction								
	Mixing Depth	1-year Deposition (cm)		Current Conditions			Future Conditions					
Point	(cm)	Current	Future[1]	0	5	10	15	20	25	30	35	40
EW09-SS-010	10	**1.356**	**1.347**	0.63	0.95	1.06	1.06	1.06	1.06	1.06	1.06	1.06
EW09-SS-012	10	**1.199**	**1.199**	0.36	0.21	0.15	0.12	0.11	0.11	0.11	0.11	0.11
EW09-SS-027	60.96	**1.212**	**1.204**	0.38	0.35	0.33	0.31	0.29	0.28	0.26	0.25	0.24
EW09-SS-038	60.96	**1.197**	**1.197**	28.75	25.94	23.40	21.11	19.05	17.19	15.51	14.00	12.63
EW09-SS-100	60.96	**1.210**	**1.199**	1.50	1.37	1.25	1.13	1.03	0.94	0.86	0.78	0.72
EW09-SS-101	60.96	**1.197**	**1.197**	263	237	214	193	174	157	141	127	115
EW09-SS-110	60.96	**1.197**	**1.197**	1.06	0.97	0.88	0.81	0.74	0.67	0.62	0.57	0.52
EW09-SS-114	60.96	**1.197**	**1.197**	0.63	0.57	0.53	0.48	0.45	0.41	0.38	0.35	0.33
EW09-SS-126	60.96	**1.208**	**1.201**	1.75	1.59	1.45	1.32	1.20	1.09	0.99	0.91	0.83
EW09-SS-211	60.96	**1.197**	**1.197**	0.63	0.57	0.53	0.48	0.45	0.41	0.38	0.35	0.33
EW09-SS-219	60.96	**1.197**	**1.197**	0.38	0.35	0.33	0.31	0.29	0.27	0.25	0.24	0.22
EW-109	60.96	**1.197**	**1.197**	1.94	1.76	1.59	1.45	1.31	1.20	1.09	0.99	0.90
EW-128	10	**1.201**	**1.204**	0.13	0.12	0.12	0.13	0.14	0.14	0.15	0.15	0.15
EW-132	60.96	**1.197**	**1.197**	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
EW-135	60.96	**1.223**	**1.208**	0.13	0.14	0.16	0.16	0.16	0.16	0.16	0.16	0.16
EW-136	60.96	**1.212**	**1.201**	0.12	0.13	0.14	0.14	0.14	0.14	0.13	0.13	0.13
EW-138	60.96	**1.197**	**1.197**	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.10
LSO-01	60.96	**1.223**	**1.208**	1.25	1.16	1.07	0.98	0.90	0.83	0.76	0.70	0.65

Table 8

Concentrations at Point Locations - Years 0 to 40 Post-construction

Arsenic (mg/kg)				Years Post-construction								
	Mixing Depth	1-year Deposition (cm)		Current Conditions			Future Conditions					
Point	(cm)	Current	Future[1]	0	5	10	15	20	25	30	35	40
EW09-SS-010	10	**1.356**	**1.347**	8.4	8.9	9.1	9.1	9.1	9.2	9.2	9.2	9.2
EW09-SS-012	10	**1.199**	**1.199**	6.0	7.8	8.6	8.9	9.0	9.0	9.0	9.0	9.0
EW09-SS-027	60.96	**1.212**	**1.204**	12.1	11.8	11.5	11.3	11.1	10.9	10.7	10.5	10.4
EW09-SS-038	60.96	**1.197**	**1.197**	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
EW09-SS-100	60.96	**1.210**	**1.199**	6.8	7.0	7.2	7.4	7.6	7.7	7.8	8.0	8.1
EW09-SS-101	60.96	**1.197**	**1.197**	7.5	7.7	7.8	7.9	8.0	8.1	8.2	8.3	8.4
EW09-SS-110	60.96	**1.197**	**1.197**	9.2	9.2	9.2	9.2	9.1	9.1	9.1	9.1	9.1
EW09-SS-114	60.96	**1.197**	**1.197**	22.7	21.4	20.2	19.1	18.1	17.2	16.4	15.7	15.0
EW09-SS-126	60.96	**1.208**	**1.201**	6.4	6.7	6.9	7.1	7.3	7.5	7.6	7.8	7.9
EW09-SS-211	60.96	**1.197**	**1.197**	3.6	4.1	4.6	5.1	5.4	5.8	6.1	6.4	6.7
EW09-SS-219	60.96	**1.197**	**1.197**	3.1	3.7	4.2	4.7	5.1	5.5	5.8	6.2	6.4
EW-109	60.96	**1.197**	**1.197**	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
EW-128	10	**1.201**	**1.204**	20.0	13.4	10.8	9.7	9.3	9.2	9.1	9.1	9.1
EW-132	60.96	**1.197**	**1.197**	8.0	8.1	8.2	8.3	8.4	8.4	8.5	8.5	8.6
EW-135	60.96	**1.223**	**1.208**	12.0	11.7	11.4	11.2	11.0	10.8	10.6	10.5	10.3
EW-136	60.96	**1.212**	**1.201**	10.0	9.9	9.8	9.7	9.7	9.6	9.6	9.5	9.5
EW-138	60.96	**1.197**	**1.197**	10.0	9.9	9.8	9.7	9.7	9.6	9.6	9.5	9.5
LSO-01	60.96	**1.223**	**1.208**	7.3	7.5	7.6	7.8	7.9	8.0	8.1	8.2	8.3

HPAH (mg/kg OC)[1]				Years Post-construction								
	Mixing Depth	1-year Deposition (cm)		Current Conditions			Future Conditions					
Point	(cm)	Current	Future[1]	0	5	10	15	20	25	30	35	40
EW09-SS-010	10	**1.356**	**1.347**	190	160	151	131	124	122	122	121	121
EW09-SS-012	10	**1.199**	**1.199**	168	117	97	89	86	84	84	84	84
EW09-SS-027	60.96	**1.212**	**1.204**	204	193	182	172	164	156	149	143	137
EW09-SS-038	60.96	**1.197**	**1.197**	265	247	231	217	203	192	181	171	163
EW09-SS-100	60.96	**1.210**	**1.199**	139	134	129	124	120	117	113	111	108
EW09-SS-101	60.96	**1.197**	**1.197**	199	187	177	168	160	152	145	139	134
EW09-SS-110	60.96	**1.197**	**1.197**	133	128	123	119	116	113	110	107	105
EW09-SS-114	60.96	**1.197**	**1.197**	106	104	102	100	98	97	96	94	93
EW09-SS-126	60.96	**1.208**	**1.201**	68	69	71	72	73	74	75	76	77
EW09-SS-211	60.96	**1.197**	**1.197**	121	118	114	111	108	106	104	102	100
EW09-SS-219	60.96	**1.197**	**1.197**	86	85	85	85	85	85	85	84	84
EW-109	60.96	**1.197**	**1.197**	388	358	331	306	284	265	247	231	216
EW-128	10	**1.201**	**1.204**	381	203	131	104	93	88	86	86	85
EW-132	60.96	**1.197**	**1.197**	186	176	167	158	151	144	138	133	128
EW-135	60.96	**1.223**	**1.208**	406	375	347	321	298	277	259	242	226
EW-136	60.96	**1.212**	**1.201**	475	437	402	371	343	317	294	274	255
EW-138	60.96	**1.197**	**1.197**	406	375	346	320	297	276	257	240	225
LSO-01	60.96	**1.223**	**1.208**	244	230	216	203	192	182	172	164	156

Table 8

Concentrations at Point Locations - Years 0 to 40 Post-construction

LPAH (mg/kg OC)[1]				Years Post-construction								
	Mixing Depth	1-year Deposition (cm)		Current Conditions			Future Conditions					
Point	(cm)	Current	Future[1]	0	5	10	15	20	25	30	35	40
EW09-SS-010	10	**1.356**	**1.347**	23.1	22.5	22.2	19.9	19.1	18.8	18.8	18.7	18.7
EW09-SS-012	10	**1.199**	**1.199**	22.5	14.2	10.9	9.5	9.0	8.8	8.7	8.6	8.6
EW09-SS-027	60.96	**1.212**	**1.204**	31.3	29.1	27.1	25.3	23.7	22.2	20.9	19.7	18.6
EW09-SS-038	60.96	**1.197**	**1.197**	21.3	20.0	18.9	17.9	16.9	16.1	15.4	14.7	14.1
EW09-SS-100	60.96	**1.210**	**1.199**	21.9	20.6	19.5	18.4	17.4	16.6	15.8	15.1	14.5
EW09-SS-101	60.96	**1.197**	**1.197**	39.4	36.3	33.6	31.2	28.9	26.9	25.1	23.5	22.0
EW09-SS-110	60.96	**1.197**	**1.197**	19.4	18.3	17.4	16.5	15.7	15.0	14.4	13.8	13.3
EW09-SS-114	60.96	**1.197**	**1.197**	15.6	14.9	14.3	13.7	13.2	12.8	12.4	12.0	11.6
EW09-SS-126	60.96	**1.208**	**1.201**	5.1	5.5	5.9	6.1	6.4	6.6	6.8	7.0	7.2
EW09-SS-211	60.96	**1.197**	**1.197**	17.5	16.6	15.8	15.1	14.5	13.9	13.4	12.9	12.5
EW09-SS-219	60.96	**1.197**	**1.197**	25.0	23.4	21.9	20.6	19.4	18.4	17.4	16.5	15.7
EW-109	60.96	**1.197**	**1.197**	76.9	70.2	64.1	58.7	53.7	49.3	45.3	41.7	38.4
EW-128	10	**1.201**	**1.204**	58.8	28.7	16.7	12.1	10.3	9.5	9.2	9.1	9.1
EW-132	60.96	**1.197**	**1.197**	25.0	23.4	21.9	20.6	19.4	18.4	17.4	16.5	15.7
EW-135	60.96	**1.223**	**1.208**	73.8	67.5	61.8	56.6	51.9	47.7	43.9	40.5	37.4
EW-136	60.96	**1.212**	**1.201**	106.3	96.7	88.0	80.2	73.2	66.9	61.1	56.0	51.3
EW-138	60.96	**1.197**	**1.197**	46.9	43.1	39.7	36.7	33.9	31.4	29.2	27.1	25.3
LSO-01	60.96	**1.223**	**1.208**	58.1	53.4	49.2	45.2	41.7	38.5	35.6	33.0	30.7

Notes:
1. TOC assumed to be 1.6% for the EW.
2. Future deposition is based on expected future source control conditions for EW Laterals.
BEHP – bis(2-ethylhexyl) phthalate
cm – centimeters
DCB – dichlorobenzene
EW – East Waterway
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
mg/kg – milligram per kilogram
OC – organic carbon
PCB – polychlorinated biphenyl

Table 9a

Chemistry Assumptions for Solids Inputs to the EW for Recontamination Potential Evaluation – Current Conditions

Input Location	Contaminant of Concern								
	Arsenic (mg/kg dw)	Mercury (mg/kg dw)	Total HPAHs (µg/kg dw)	Total LPAHs (µg/kg dw)	Total cPAHs (µg TEQ/kg dw)	BEHP (µg/kg dw)	1,4-DCB (µg/kg dw)	Total PCBs (µg/kg dw)	Dioxin/Furan TEQ (ng TEQ/kg dw)
Hinds CSO									
mean[1]	5	1.71	4,000	870	680	6,700	820	260	16
median[2]	6	0.36	2,900	640	430	3,000	260	240	7.6
90th percentile[3]	9	2.57	10,000	1,900	1,500	23,000	2,000	630	37
Lander CSO									
mean[1]	2	0.21	1,800	280	250	1,000	320	11	1.8
median[2]	2	0.25	2,200	220	300	800	230	11	1.8
90th percentile[3]	2	0.26	2,700	500	380	1,700	560	18	2.6
Hanford #2 CSO									
mean[1]	6	2.00	3,900	880	670	7,700	990	270	30
median[2]	6	0.72	3,100	670	540	3,300	320	250	30
90th percentile[3]	9	2.94	6,200	1,600	930	27,000	2,300	510	44
Nearshore SDs[4]									
mean[1]	10	0.09	5,500	1,000	820	8,300	75	160	15
median[2]	10	0.08	4,400	740	550	6,200	17	39	7.9
90th percentile[3]	15	0.14	14,000	1,900	2,100	19,000	180	440	32
S Lander St SD									
mean[1]	9	0.15	14,000	2,600	2,100	12,000	110	120	68
median[2]	10	0.13	5,500	810	670	9,300	90	53	68
90th percentile[3]	20	0.29	17,000	3,400	2,400	21,000	200	280	93
Non-nearshore SDs[5]									
mean[1]	10	0.19	10,000	2,000	1,400	19,000	140	290	68
median[2]	7	0.12	4,000	680	450	9,400	90	58	68
90th percentile[3]	20	0.32	11,000	3,400	1,700	24,000	280	460	93
LDW Laterals[6]									
base	13	0.14	3,900	880	1,400	15,475	990	300	20
low bounding	9	n/a	n/a	n/a	500	n/a	n/a	100	10
high bounding	30	n/a	n/a	n/a	3,400	n/a	n/a	1,000	40
LDW Bed[6]									
base	16	0.53	3,800	700	390	590	23	350	26
Green River									
base	9	0.10	1,300	130	135	120	1.20	42	6
low bounding	7	0.06	160	17	40	75	0.84	5	2
high bounding	10	0.20	1,900	230	270	210	1.30	80	8

Notes:
1. Mean chemistry values are used for Base Case scenarios.
2. Median chemistry values are used for Low Bounding Case scenarios.
3. 90th percentile chemistry values are used for High Bounding Case scenarios.
4. Nearshore SDs include SW Florida St SD (B-21), B-25, all Port SDs, and all private SDs along the waterfront (A-6, B-40, B-41, B-42, and B-43).
5. Non-nearshore SDs include S Hinds St SD, SW Spokane St EOF/SD (B-5), SW Spokane St SD (B-4), S Spokane St SD (B-36), and all bridges (BR-2, BR-4, BR-34, and BR-39).
6. Values for LDW Bed and Laterals are taken from the LDW FS (AECOM 2012).
See EW FS Appendix B, Part 4 for details on EW lateral chemistry analysis, and EW FS Appendix B, Part 3 for Green River chemistry.
µg/kg – microgram per kilogram; BEHP – bis(2-ethylhexyl) phthalate; cPAH – carcinogenic polycyclic aromatic hydrocarbon; CSO – combined sewer overflow; DCB – dichlorobenzene; dw – dry weight; EOF – emergency overflow; EW – East Waterway; FS – Feasibility Study; HPAH- – high-molecular-weight polycyclic aromatic hydrocarbon; LDW – Lower Duwamish Waterway; LPAH – low-molecular-weight polycyclic aromatic hydrocarbon; mg/kg – milligram per kilogram; ng – nanogram; PCB – polychlorinated biphenyl; SD – storm drain; TEQ – toxicity equivalent

Table 9b

Chemistry Assumptions for Solids Inputs to the EW for Recontamination Potential Evaluation – Future Source Control Conditions

Input Location	Contaminant of Concern								
	Arsenic (mg/kg dw)	Mercury (mg/kg dw)	Total HPAHs (µg/kg dw)	Total LPAHs (µg/kg dw)	Total cPAHs (µg TEQ/kg dw)	BEHP (µg/kg dw)	1,4-DCB (µg/kg dw)	Total PCBs (µg/kg dw)	Dioxin/Furan TEQ (ng TEQ/kg dw)
Hinds CSO (same as current conditions)									
mean[1]	5	1.71	4,000	870	680	6,700	820	260	16
median[2]	6	0.36	2,900	640	430	3,000	260	240	7.6
90th percentile[3]	9	2.57	10,000	1,900	1,500	23,000	2,000	630	37
Lander CSO (same as current conditions)									
mean[1]	2	0.21	1,800	280	250	1,000	320	11	1.8
median[2]	2	0.25	2,200	220	300	800	230	11	1.8
90th percentile[3]	2	0.26	2,700	500	380	1,700	560	18	2.6
Hanford #2 CSO (same as current conditions)									
mean[1]	6	2.00	3,900	880	670	7,700	990	270	30
median[2]	6	0.72	3,100	670	540	3,300	320	250	30
90th percentile[3]	9	2.94	6,200	1,600	930	27,000	2,300	510	44
Nearshore SDs (same as current conditions)									
mean[1]	10	0.09	5,500	1,000	820	8,300	75	160	15
median[2]	10	0.08	4,400	740	550	6,200	17	39	7.9
90th percentile[3]	15	0.14	14,000	1,900	2,100	19,000	180	440	32
S Lander St SD (values in BOLD are different than current conditions, all other values same as current conditions)									
mean[1]	9	0.15	**8,600**	**1,600**	2,100	12,000	110	120	**22**
median[2]	10	0.13	5,500	810	670	9,300	90	53	**12**
90th percentile[3]	20	0.29	17,000	3,400	2,400	21,000	200	280	**37**
Non-nearshore SDs (values in BOLD are different than current conditions, all other values same as current conditions)									
mean[1]	10	0.16	**6,800**	**1,600**	**930**	**14,000**	140	**200**	**22**
median[2]	7	0.12	4,000	680	450	9,400	90	58	**12**
90th percentile[3]	20	0.32	11,000	3,400	**1,600**	24,000	**260**	460	**37**
LDW Laterals[6] (same as current conditions)									
base	13	0.14	3,900	880	1,400	15,475	990	300	20
low bounding	9	n/a	n/a	n/a	500	n/a	n/a	100	10
high bounding	30	n/a	n/a	n/a	3,400	n/a	n/a	1,000	40
LDW Bed[6] (same as current conditions)									
base	16	0.53	3,800	700	390	590	23	350	26
Green River (same as current conditions)									
base	9	0.10	1,300	130	135	120	1.20	42	6
low bounding	7	0.06	160	17	40	75	0.84	5	2
high bounding	10	0.20	1,900	230	270	210	1.30	80	8

Notes:
1. Mean chemistry values are used for Base Case scenarios.
2. Median chemistry values are used for Low Bounding Case scenarios.
3. 90th percentile chemistry values are used for High Bounding Case scenarios.
4. Nearshore SDs include SW Florida St SD (B-21), B-25, all Port SDs, and all private SDs along the waterfront (A-6, B-40, B-41, B-42, and B-43).
5. Non-nearshore SDs include S Hinds St SD, SW Spokane St EOF/SD (B-5), SW Spokane St SD (B-4), S Spokane St SD (B-36), and all bridges (BR-2, BR-4, BR-34, and BR-39).
6. Values for LDW Bed and Laterals are taken from the LDW FS (AECOM 2012).

Values are the same as current conditions (grey text) except where noted (**bold black text**).

See EW FS Appendix B, Part 4 for details on EW lateral chemistry analysis, and EW FS Appendix B, Part 3 for Green River chemistry.

µg/kg – microgram per kilogram; BEHP – bis(2-ethylhexyl) phthalate; cPAH – carcinogenic polycyclic aromatic hydrocarbon; CSO – combined sewer overflow; DCB – dichlorobenzene; dw – dry weight; EOF – emergency overflow; EW – East Waterway; FS – Feasibility Study; HPAH – high-molecular-weight polycyclic aromatic hydrocarbon; LDW – Lower Duwamish Waterway; LPAH – ow-molecular-weight polycyclic aromatic hydrocarbon; mg/kg – milligram per kilogram; ng – nanogram; PCB – polychlorinated biphenyl; SD – storm drain; TEQ – toxicity equivalent

Table 10

Calculation of Net Sedimentation Rates Used for Recontamination Potential Evaluation

PTM Model Simulation: Base Case Current Conditions			**PTM Model Simulation: Lower Bound Current Conditions**			**PTM Model Simulation: Upper Bound Current Conditions**		
Calculate total area in EW where PTM model predicts deposition of solids from EW laterals to occur over simulation period:								
Cells with Deposition	949		Cells with Deposition	710		Cells with Deposition	1086	
Area per cell	232	m^2	Area per cell	232	m^2	Area per cell	232	m^2
Total Area of Footprint:	220,525	m^2	Total Area of Footprint:	164,987	m^2	Total Area of Footprint:	252,361	m^2
Calculate the total mass and volume of the deposition of solids from EW lateral sources within the deposition footprint over an annual basis:								
Total Mass (kg)	84,630	per yr	Total Mass (kg)	45,475	per yr	Total Mass (kg)	114,117	per yr
Total Mass (g)	84,629,860	per yr	Total Mass (g)	45,474,710	per yr	Total Mass (g)	114,116,740	per yr
Density	1.5	g/cm^3	Density	1.5	g/cm^3	Density	1.5	g/cm^3
Volume of Solids Deposited	56,419,906	cm^3	Volume of Solids Deposited	30,316,473	cm^3	Volume of Solids Deposited	76,077,826	cm^3
Calculate the net sedimentation rate (cm/yr) of EW lateral sources in the deposition footprint (volume divided by area):								
NSR (laterals)	0.026	cm/yr		0.018	cm/yr		0.030	cm/yr
Total NSR (from upstream and EW lateral sources) taken from evaluation of geochronology core, see Section 5.1.2 in EW FS):								
NSR (Total)	1.20	cm/yr		1.20	cm/yr		1.20	cm/yr
Estimate the NSR due to upstream sources (Green River and LDW laterals) within the deposition footprint as the difference between the EW laterals NSR and the total NSR from geochronology cores:								
NSR (upstream contribution)	**1.175**	**cm/yr**	**NSR (upstream contribution)**	**1.18**	**cm/yr**	**NSR (upstream contribution)**	**1.17**	**cm/yr**

Notes:
cm – centimeters
cm^3 – cubic centimeters
EW – East Waterway
FS – Feasibility Study
g – gram
kg – kilogram
LDW – Lower Duwamish Waterway
m^2 – square meters
NSR – net sedimentation rate
PTM – particle tracking model
yr – year

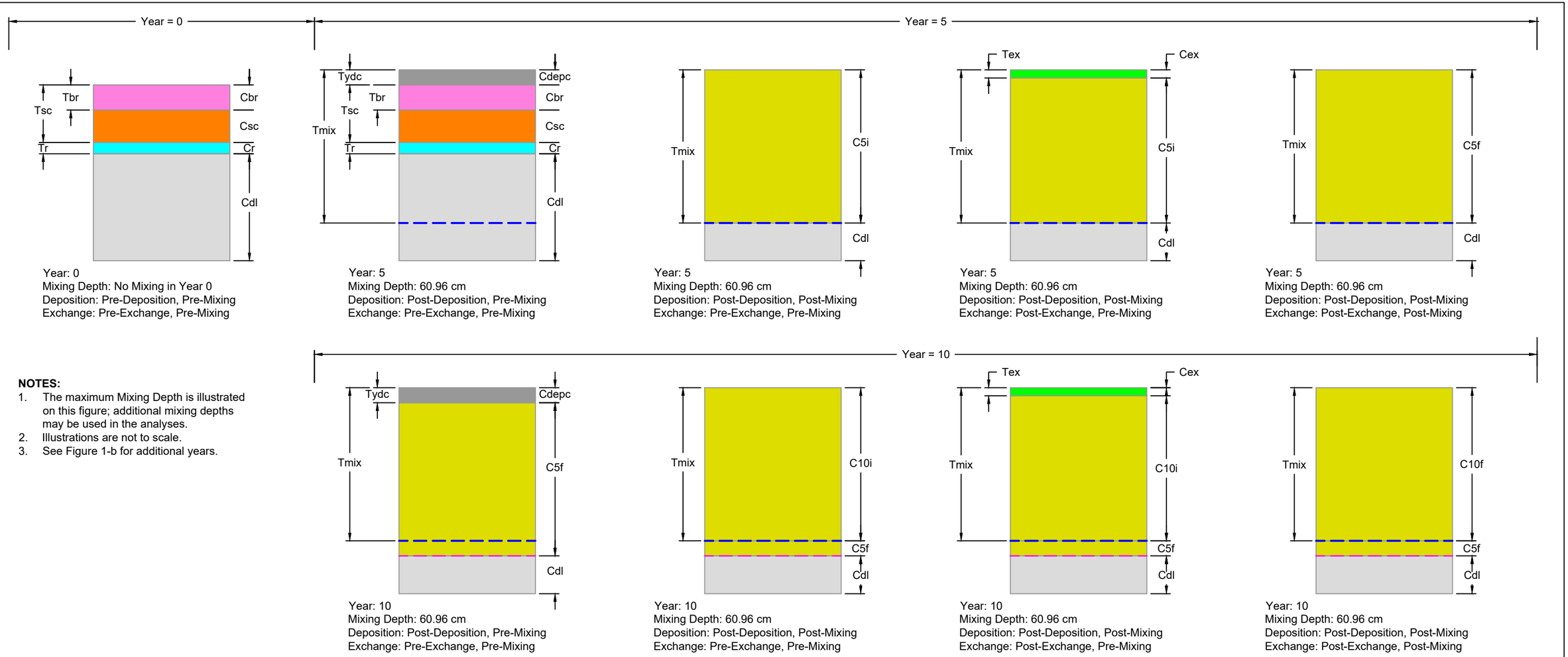
Table 11
Bounding Scenarios for Recontamination Potential Evaluation

Scenario	COC	EW Lateral Deposition[1]	EW Lateral Chemistry[2]	Upstream Deposition[3]	Upstream Chemistry[4]
1a	PCBs	High bound	High bound	1.175 cm/yr (Base)	Base/Mean
1b	PCBs	Low bound	Low bound		
2a	Dioxins/Furans	High bound	High bound		
2b	Dioxins/Furans	Low bound	Low bound		
3a	BEHP	High bound	High bound		
3b	BEHP	Low bound	Low bound		

Notes:
1. EW Lateral Deposition details can be found in Section 4.2 of Appendix J, and Figures 7 to 12 of FS Appendix B.
2. EW Lateral Chemistry details can be found in Section 4.2 and Tables 9a and 9b of Appendix J.
3. Upstream Deposition details can be found in Section 4.2 and Table 10 of Appendix J.
4. Upstream Chemistry details can be found in Section 4.2 and Tables 9a and 9b of Appendix J.

BEHP – bis(2-ethylhexyl)phthalate
cm/yr – centimeters per year
COC – contaminant of concern
EW – East Waterway
FS – Feasibility Study
PCB – polychlorinated biphenyl

FIGURES



NOTES:

1. The maximum Mixing Depth is illustrated on this figure; additional mixing depths may be used in the analyses.
2. Illustrations are not to scale.
3. See Figure 1-b for additional years.

LEGEND

- Bed Replacement Layer
- Residuals Management Cover (RMC) Layer
- Dredge Residuals Layer
- In-Situ Sediment Below Dredge Neatline
- Depositional Sediment Layer
- Exchanged Under-Pier Depositional Layer
- Homogeneous Mixed Sediment Layer
- Vertical Limit of Mix Depth
- Vertical Limit of Previous Mix Depth

CONCENTRATION VARIABLES

Cbr	Conc. of Bed Replacement Layer
Csc	Conc. of Residuals Management Cover (RMC)
Cr	Conc. of Dredge Residual Sediment
Cdl	Conc. of In-Situ Sediment Below Dredge Neatline
Cdepc	Conc. of Depositional Sediment (Current Conditions)
Cex	Conc. of Exchanged Sediment (Under-Pier / Open-Water)
Cni	Conc. of Mixed Sediments at Year n, Intermediate Value
Cnf	Conc. of Mixed Sediments at Year n, Final Value

DEPTH VARIABLES

Tbr	Depth of Bed Replacement Layer (10 cm)
Tsc	Depth of Residuals Management Cover (RMC, 9 in = 23 cm)
Tr	Depth of Dredge Residual Sediment (5.1 cm minus 10% loss during placement for the base case)
Tydc	Depth of Depositional Sediment (Current Conditions, 1.2 cm/ year for the base case)
Tex	Depth of Exchanged Sediment (Under-Pier / Open-Water, 0.4 cm to 2 cm per year depending on the alternative)
Tmix	Vertical Depth of Mixing (10 cm to 61 cm depending on the location; 61 cm shown in this example)

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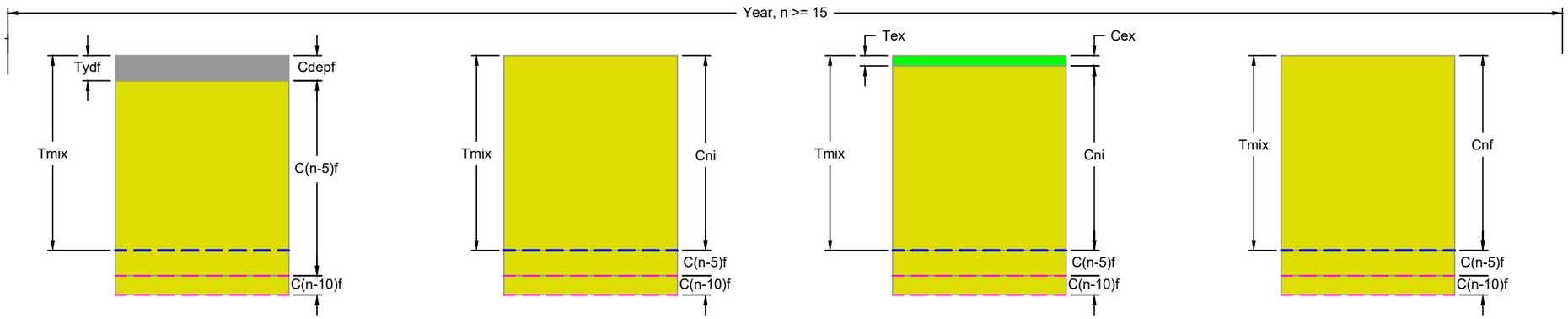
Figure 1a
Box Model: Removal Through Year 10
Feasibility Study - Appendix J
East Waterway Study Area



Year: n >=15
Mixing Depth: 60.96 cm
Deposition: Post-Deposition, Pre-Mixing
Exchange: Pre-Exchange, Pre-Mixing

Year: n >=15
Mixing Depth: 60.96 cm
Deposition: Post-Deposition, Post-Mixing
Exchange: Pre-Exchange, Pre-Mixing

Year: n >=15
Mixing Depth: 60.96 cm
Deposition: Post-Deposition, Post-Mixing
Exchange: Post-Exchange, Pre-Mixing

Year: n >=15
Mixing Depth: 60.96 cm
Deposition: Post-Deposition, Post-Mixing
Exchange: Post-Exchange, Post-Mixing

NOTES:

1. The maximum Mixing Depth is illustrated on this figure; additional mixing depths may be used in the analyses.
2. Illustrations are not to scale.
3. See other Figures for years 0 through 10; applies to Figures 1a, 1c, 1d, 1e, and 1j.

DEPTH VARIABLES

Tbr	Depth of Bed Replacement Layer (10 cm)
Tsc	Depth of Residuals Management Cover (RMC, 9 in = 23 cm)
Tr	Depth of Dredge Residual Sediment (5.1 cm minus 10% loss during placement for the base case)
Tydc	Depth of Depositional Sediment (Current Conditions, 1.2 cm/ year for the base case)
Tex	Depth of Exchanged Sediment (Under-Pier / Open-Water, 0.4 cm to 2 cm per year depending on the alternative)
Tmix	Vertical Depth of Mixing (10 cm to 61 cm depending on the location; 61 cm shown in this example)

LEGEND

- Depositional Sediment Layer
- Exchanged Under-Pier Depositional Layer
- Homogeneous Mixed Sediment Layer
- Vertical Limit of Mix Depth
- Vertical Limit of Previous Mix Depth

CONCENTRATION VARIABLES

Cdepf	Conc. of Depositional Sediment (Future Conditions)
Cex	Conc. of Exchanged Sediment (Under-Pier / Open-Water)
Cni	Conc. of Mixed Sediments at Year n, Intermediate Value
Cnf	Conc. of Mixed Sediments at Year n, Final Value

DEPTH VARIABLES

Tydf	Depth of Depositional Sediment (Future Conditions, 1.2 cm/ year for the base case)
Tex	Depth of Exchanged Sediment (Under-Pier / Open-Water, 0.4 cm to 2 cm per year depending on the alternative)
Tmix	Vertical Depth of Mixing (10 cm to 61 cm depending on the location; 61 cm shown in this example)

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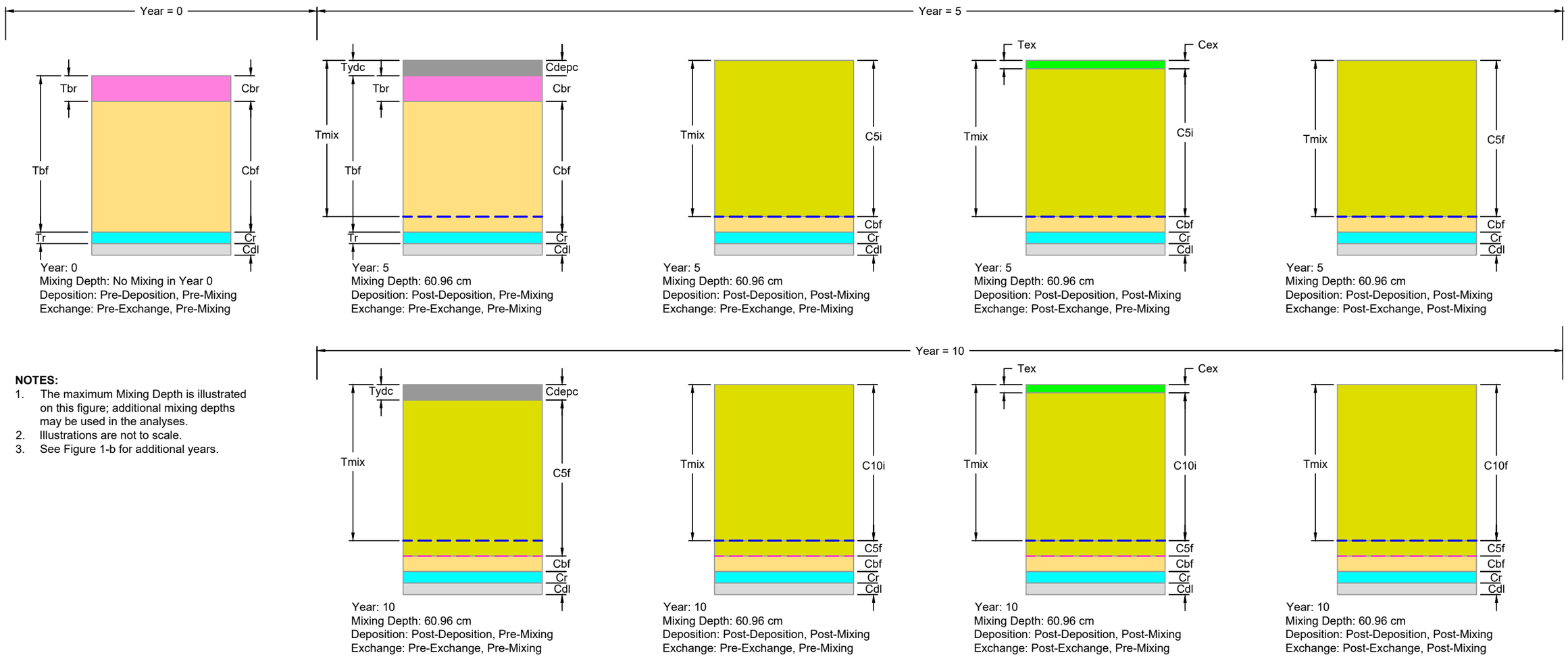
Figure 1b
Box Model: Select Remedies Beyond Year 10
Feasibility Study - Appendix J
East Waterway Study Area



NOTES:

1. The maximum Mixing Depth is illustrated on this figure; additional mixing depths may be used in the analyses.
2. Illustrations are not to scale.
3. See Figure 1-b for additional years.

LEGEND

- Bed Replacement Layer
- Placement Layer
- Dredge Residuals Layer
- In-Situ Sediment Below Dredge Neatline
- Depositional Sediment Layer
- Exchanged Under-Pier Depositional Layer
- Homogeneous Mixed Sediment Layer
- Vertical Limit of Mix Depth
- Vertical Limit of Previous Mix Depth

CONCENTRATION VARIABLES

Cbr	Conc. of Bed Replacement Layer
Cbf	Conc. of Placement Layer
Cr	Conc. of Dredge Residual Sediment
Cdl	Conc. of In-Situ Sediment Below Dredge Neatline
Cdepc	Conc. of Depositional Sediment (Current Conditions)
Cex	Conc. of Exchanged Sediment (Under-Pier / Open-Water)
Cni	Conc. of Mixed Sediments at Year n, Intermediate Value
Cnf	Conc. of Mixed Sediments at Year n, Final Value

DEPTH VARIABLES

Tbr	Depth of Bed Replacement Layer (10 cm)
Tbf	Depth of Backfill (Location Specific but Greater Than 61 cm Mixing Depth)
Tr	Depth of Dredge Residual Sediment (5.1 cm minus 10% loss during placement for the base case)
Tydc	Depth of Depositional Sediment (Current Conditions, 1.2 cm/ year for the base case)
Tex	Depth of Exchanged Sediment (Under-Pier / Open-Water, 0.4 cm to 2 cm per year depending on the alternative)
Tmix	Vertical Depth of Mixing (10 cm to 61 cm depending on the location; 61 cm shown in this example)

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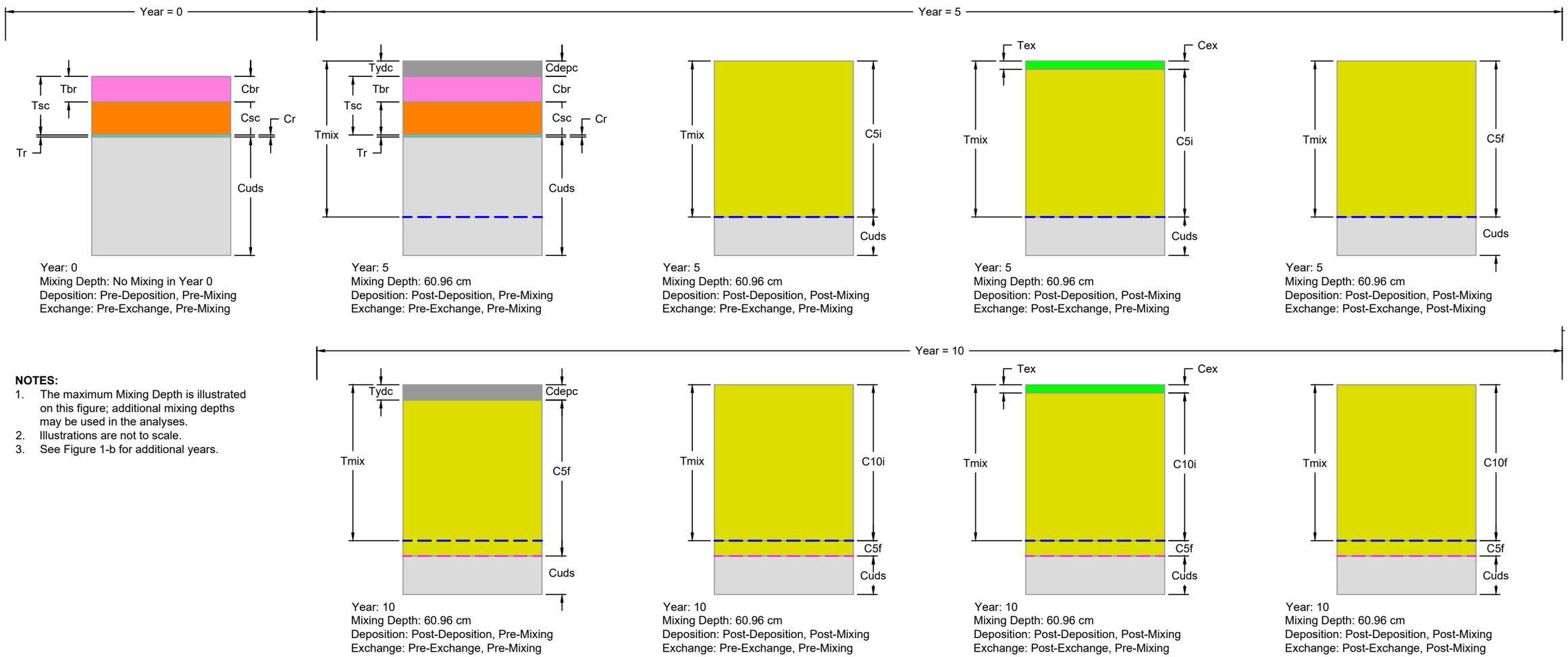
Figure 1c
Box Model: Removal and Fill to Existing Contours Through Year 10
Feasibility Study - Appendix J
East Waterway Study Area



NOTES:

1. The maximum Mixing Depth is illustrated on this figure; additional mixing depths may be used in the analyses.
2. Illustrations are not to scale.
3. See Figure 1-b for additional years.

LEGEND

- Bed Replacement Layer
- Residuals Management Cover (RMC) Layer
- Dredge Residuals Layer
- In-Situ (Undisturbed) Sediment
- Depositional Sediment Layer
- Exchanged Under-Pier Depositional Layer
- Homogeneous Mixed Sediment Layer
- Vertical Limit of Mix Depth
- Vertical Limit of Previous Mix Depth

CONCENTRATION VARIABLES

Cbr	Conc. of Bed Replacement Layer
Csc	Conc. of Residuals Management Cover (RMC)
Cr	Conc. of Dredge Residual Sediment
Cuds	Conc. of In-Situ Undisturbed Sediment
Cdepc	Conc. of Depositional Sediment (Current Conditions)
Cex	Conc. of Exchanged Sediment (Under-Pier / Open-Water)
Cni	Conc. of Mixed Sediments at Year n, Intermediate Value
Cnf	Conc. of Mixed Sediments at Year n, Final Value

DEPTH VARIABLES

Tbr	Depth of Bed Replacement Layer (10 cm)
Tsc	Depth of Residuals Management Cover (RMC, 9 in = 23 cm)
Tr	Depth of Dredge Residual Sediment (5.1 cm minus 10% loss during placement for the base case)
Tydc	Depth of Depositional Sediment (Current Conditions, 1.2 cm/ year for the base case)
Tex	Depth of Exchanged Sediment (Under-Pier / Open-Water, 0.4 cm to 2 cm per year depending on the alternative)
Tmix	Vertical Depth of Mixing (10 cm to 61 cm depending on the location; 61 cm shown in this example)

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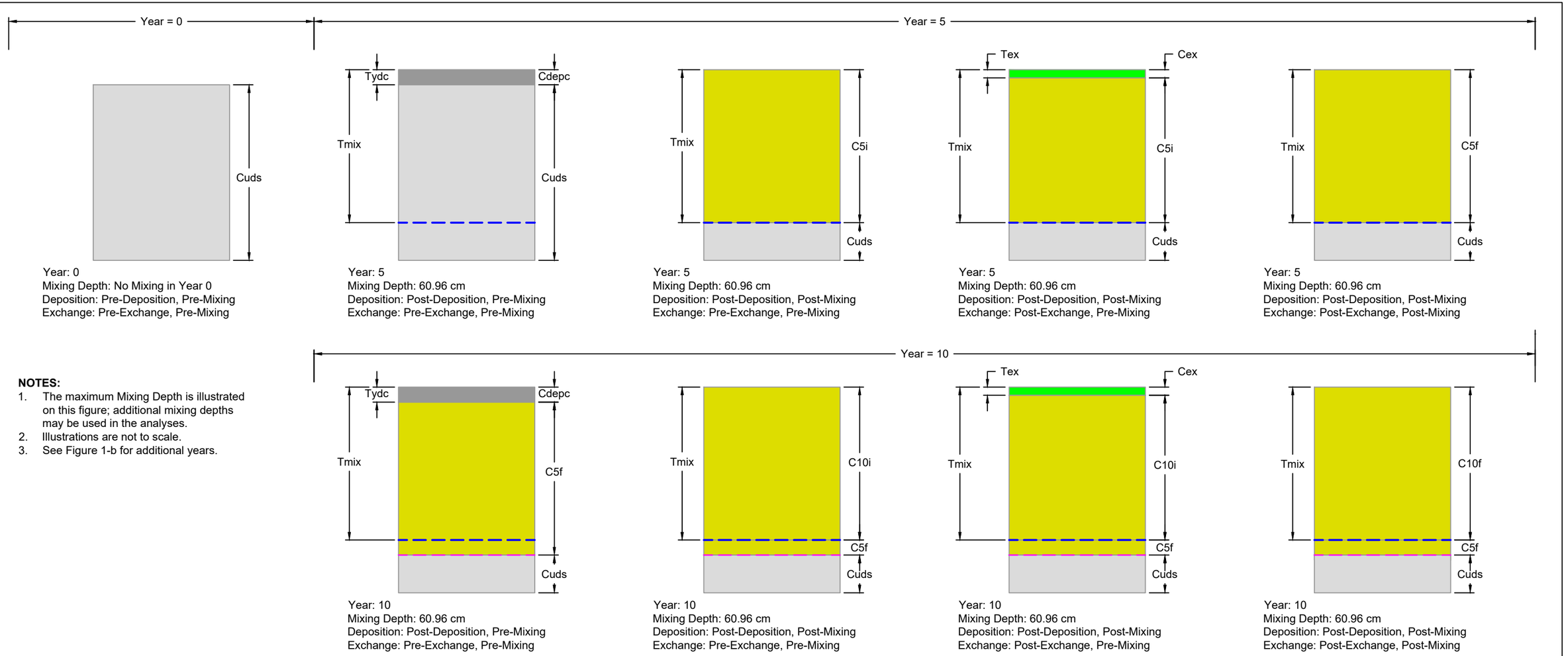
Figure 1d
Box Model: No Action (Open Water; Internal Unremediated Islands) Through Year 10
Feasibility Study - Appendix J
East Waterway Study Area



NOTES:

1. The maximum Mixing Depth is illustrated on this figure; additional mixing depths may be used in the analyses.
2. Illustrations are not to scale.
3. See Figure 1-b for additional years.

LEGEND

- In-Situ (Undisturbed) Sediment
- Depositional Sediment Layer
- Exchanged Under-Pier Depositional Layer
- Homogeneous Mixed Sediment Layer
- Vertical Limit of Mix Depth
- Vertical Limit of Previous Mix Depth

CONCENTRATION VARIABLES

Cuds	Conc. of In-Situ Undisturbed Sediment
Cdepc	Conc. of Depositional Sediment (Current Conditions)
Cex	Conc. of Exchanged Sediment (Under-Pier / Open-Water)
Cni	Conc. of Mixed Sediments at Year n, Intermediate Value
Cnf	Conc. of Mixed Sediments at Year n, Final Value

DEPTH VARIABLES

Tydc	Depth of Depositional Sediment (Current Conditions, 1.2 cm/ year for the base case)
Tex	Depth of Exchanged Sediment (Under-Pier / Open-Water, 0.4 cm to 2 cm per year depending on the alternative)
Tmix	Vertical Depth of Mixing (10 cm to 61 cm depending on the location; 61 cm shown in this example)

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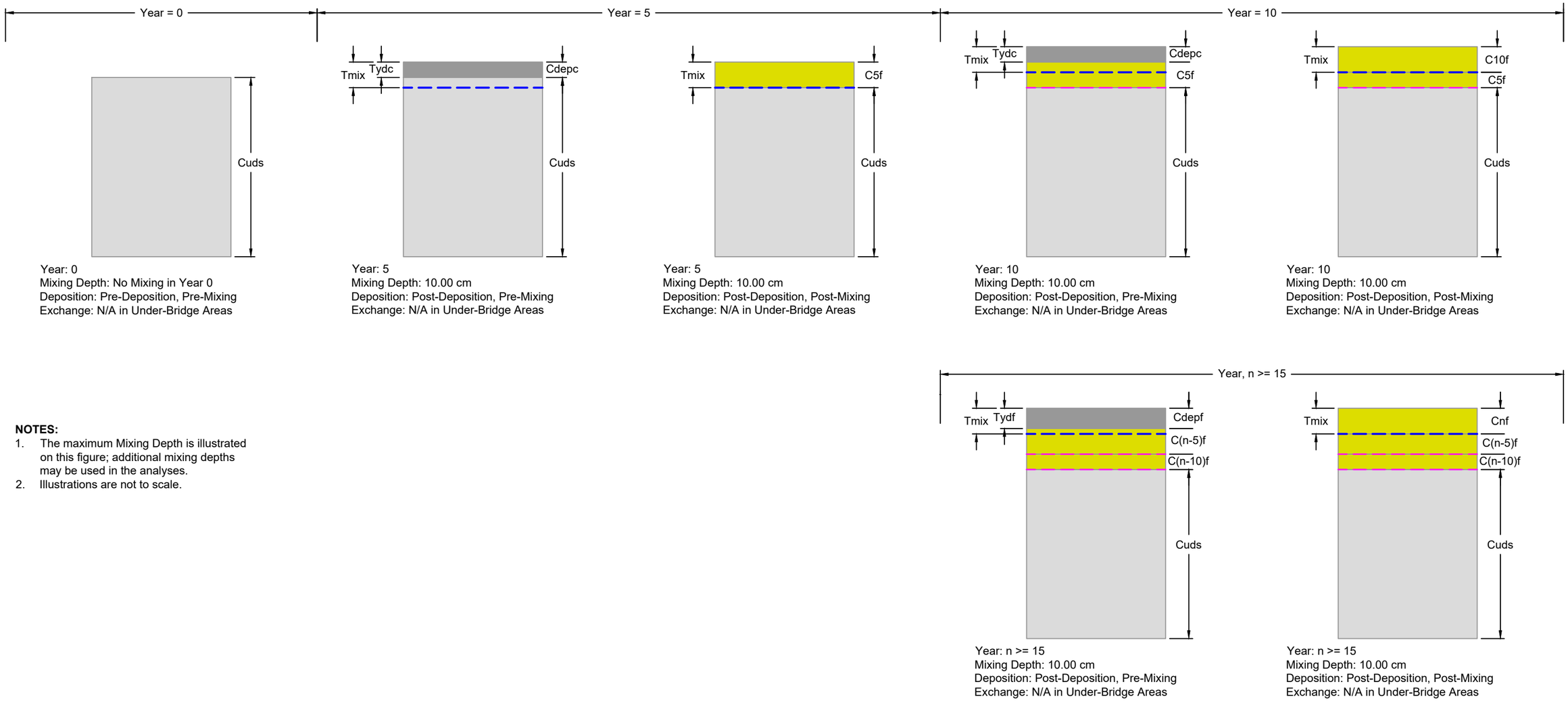
Figure 1e
Box Model: No Action (External Unremediated Areas) Through Year 10
Feasibility Study - Appendix J
East Waterway Study Area



NOTES:

1. The maximum Mixing Depth is illustrated on this figure; additional mixing depths may be used in the analyses.
2. Illustrations are not to scale.

LEGEND

- In-Situ (Undisturbed) Sediment
- Depositional Sediment Layer
- Homogeneous Mixed Sediment Layer
- Vertical Limit of Mix Depth
- Vertical Limit of Previous Mix Depth

CONCENTRATION VARIABLES

Cuds	Conc. of In-Situ Undisturbed Sediment
Cdepc	Conc. of Depositional Sediment (Current Conditions)
Cdepf	Conc. of Depositional Sediment (Future Conditions)
Cnf	Conc. of Mixed Sediments at Year n, Final Value

DEPTH VARIABLES

Tydc	Depth of Depositional Sediment (Current Conditions, 1.2 cm/ year for the base case)
Tydf	Depth of Depositional Sediment (Future Conditions, 1.2 cm/ year for the base case)
Tmix	Vertical Depth of Mixing (10 cm)

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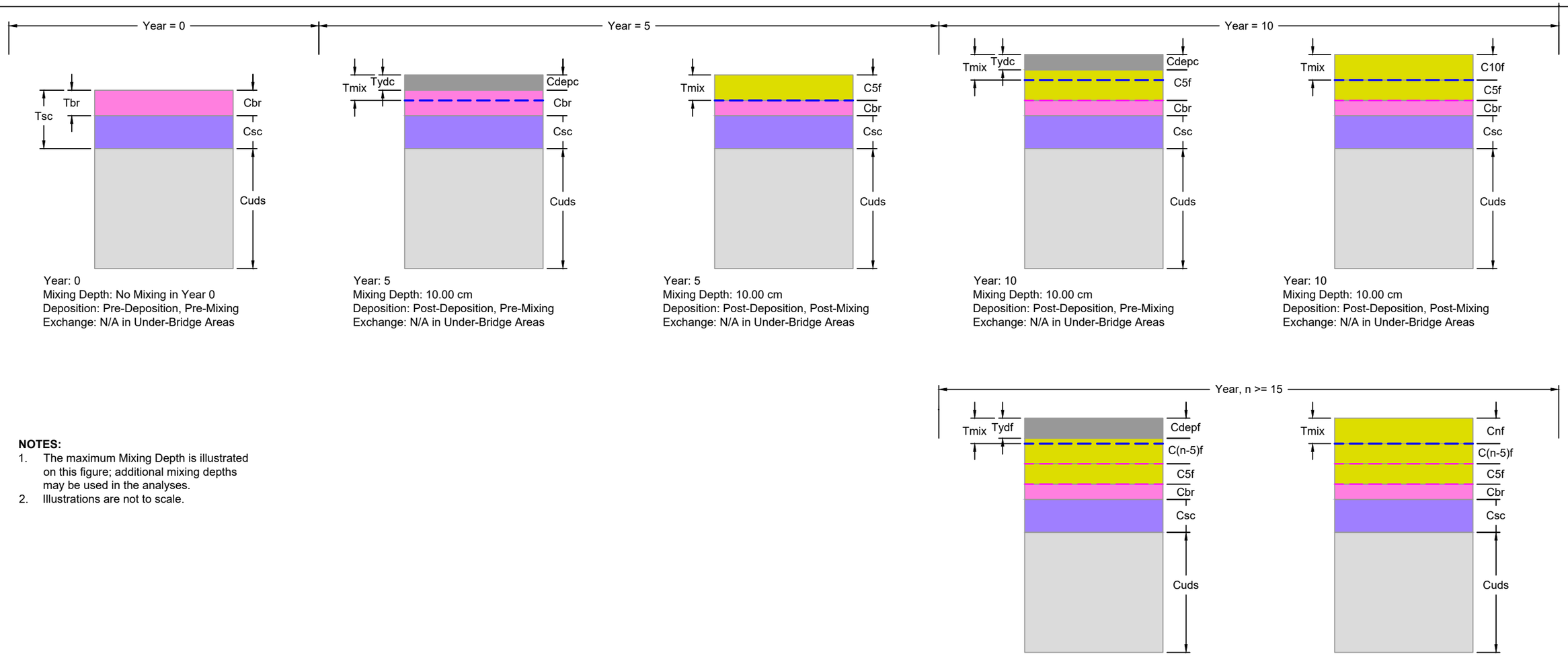
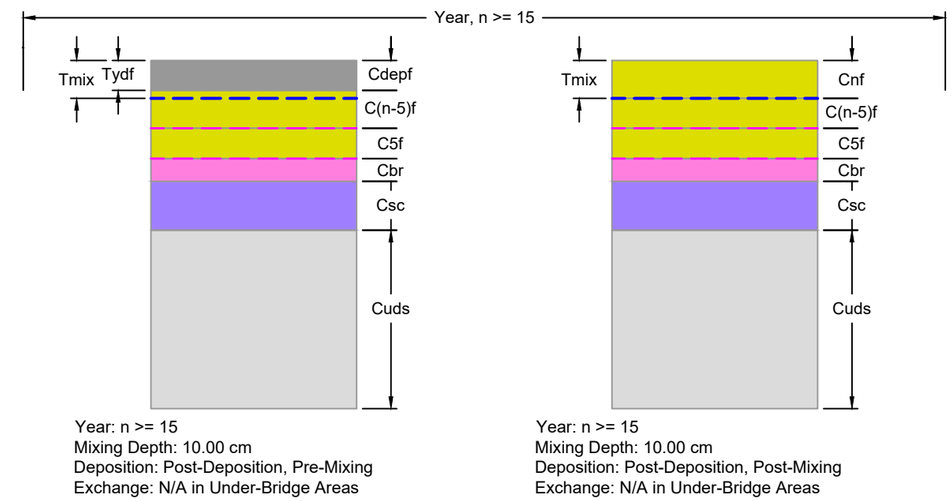
Figure 1f
Box Model: Monitored Natural Recovery (MNR) in the Sill Reach All Years
Feasibility Study - Appendix J
East Waterway Study Area





NOTES:

1. The maximum Mixing Depth is illustrated on this figure; additional mixing depths may be used in the analyses.
2. Illustrations are not to scale.

LEGEND

- Bed Replacement Layer
- Enhanced Natural Recovery (ENR) Layer
- In-Situ (Undisturbed) Sediment
- Depositional Sediment Layer
- Homogeneous Mixed Sediment Layer
- Vertical Limit of Mix Depth
- Vertical Limit of Previous Mix Depth

CONCENTRATION VARIABLES

Cbr	Conc. of Bed Replacement Layer
Csc	Conc. of Enhanced Natural Recovery (ENR) Layer
Cuds	Conc. of In-Situ Undisturbed Sediment
Cdepc	Conc. of Depositional Sediment (Current Conditions)
Cdepf	Conc. of Depositional Sediment (Future Conditions)
Cnf	Conc. of Mixed Sediments at Year n, Final Value

DEPTH VARIABLES

Tbr	Depth of Bed Replacement Layer (10 cm)
Tsc	Depth of Enhanced Natural Recovery (ENR) Layer (9 in = 23 cm)
Tydc	Depth of Depositional Sediment (Current Conditions, 1.2 cm/ year for the base case)
Tydf	Depth of Depositional Sediment (Future Conditions, 1.2 cm/ year for the base case)
Tmix	Vertical Depth of Mixing (10 cm)

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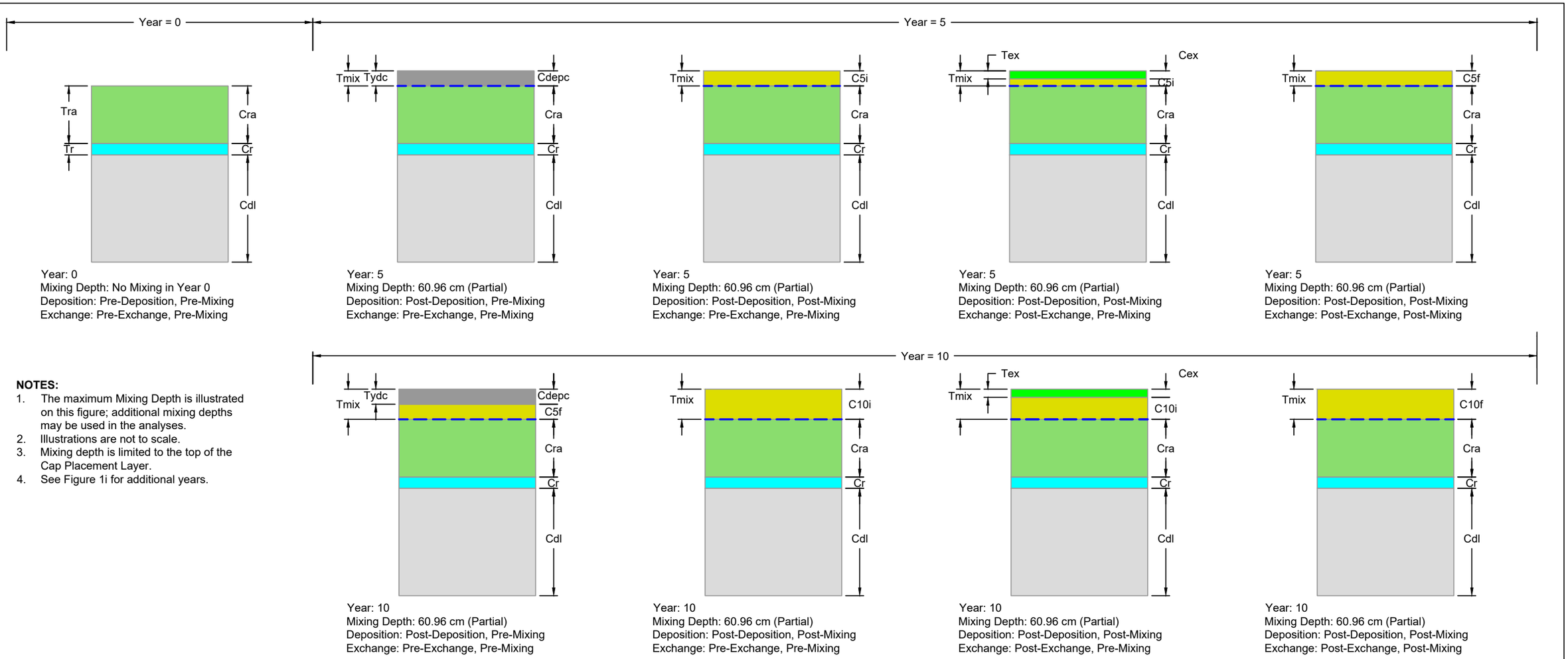
Figure 1g
Box Model: Enhanced Natural Recovery in the Sill Reach (ENR-sill) All Years
Feasibility Study - Appendix J
East Waterway Study Area



NOTES:

1. The maximum Mixing Depth is illustrated on this figure; additional mixing depths may be used in the analyses.
2. Illustrations are not to scale.
3. Mixing depth is limited to the top of the Cap Placement Layer.
4. See Figure 1i for additional years.

LEGEND

- Cap Placement Layer (Including Armor Rock)
- Dredge Residuals Layer
- In-Situ Sediment Below Dredge Neatline
- Depositional Sediment Layer
- Exchanged Under-Pier Depositional Layer
- Homogeneous Mixed Sediment Layer
- Vertical Limit of Mix Depth
- Vertical Limit of Previous Mix Depth

CONCENTRATION VARIABLES

Cra	Conc. of Cap Placements (Including Armor Rock)
Cr	Conc. of Dredge Residual Sediment
Cdl	Conc. of In-Situ Sediment Below Dredge Neatline
Cdepc	Conc. of Depositional Sediment (Current Conditions)
Cex	Conc. of Exchanged Sediment (Under-Pier / Open-Water)
Cni	Conc. of Mixed Sediments at Year n, Intermediate Value
Cnf	Conc. of Mixed Sediments at Year n, Final Value

DEPTH VARIABLES

Tra	Depth of Cap Placements (Including Armor Rock, depth n/a - armored)
Tr	Depth of Dredge Residual Sediment (depth n/a - isolated in armored cap)
Tydc	Depth of Depositional Sediment (Current Conditions, 1.2 cm/ year for the base case)
Tex	Depth of Exchanged Sediment (Under-Pier / Open-Water, 0.4 cm to 2 cm per year depending on the alternative)
Tmix	Vertical Depth of Mixing (up to 10 cm to 61 cm depending on the location; maximum depth of mixing down to the cap armor)

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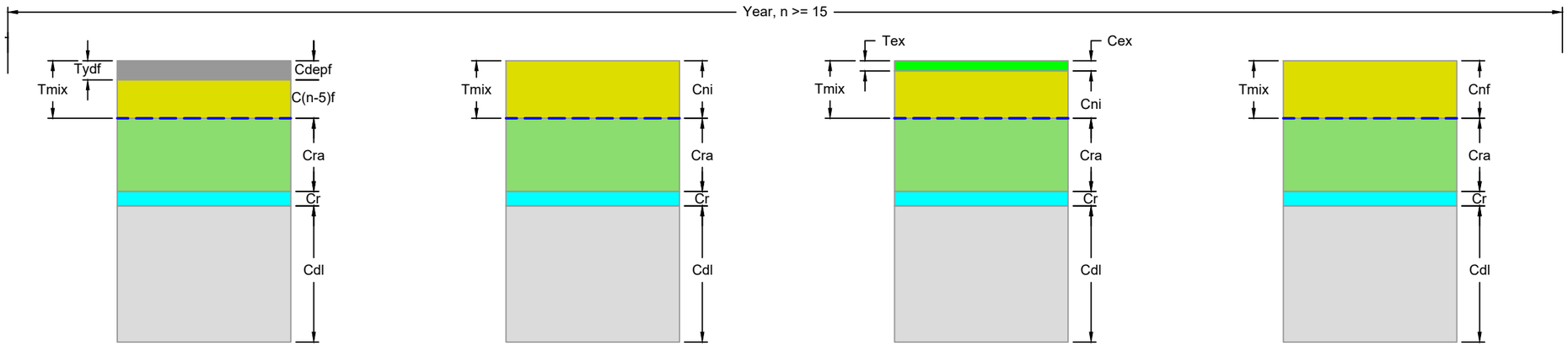
Figure 1h
Box Model: Partial Removal and Cap Through Year 10
Feasibility Study - Appendix J
East Waterway Study Area



Year: n>=15
Mixing Depth: 60.96 cm (Partial)
Deposition: Post-Deposition, Pre-Mixing
Exchange: Pre-Exchange, Pre-Mixing

Year: n>=15
Mixing Depth: 60.96 cm (Partial)
Deposition: Post-Deposition, Post-Mixing
Exchange: Pre-Exchange, Pre-Mixing

Year: n>=15
Mixing Depth: 60.96 cm (Partial)
Deposition: Post-Deposition, Post-Mixing
Exchange: Post-Exchange, Pre-Mixing

Year: n>=15
Mixing Depth: 60.96 cm (Partial)
Deposition: Post-Deposition, Post-Mixing
Exchange: Post-Exchange, Post-Mixing

NOTES:

1. The maximum Mixing Depth is illustrated on this figure; additional mixing depths may be used in the analyses.
2. Illustrations are not to scale.
3. Mixing depth is limited to the top of the Cap Placement Layer.
4. See Figure 1h for years 0 through 10.

LEGEND

- Cap Placement Layer (Including Armor Rock)
- Dredge Residuals Layer
- In-Situ Sediment Below Dredge Neatline
- Depositional Sediment Layer
- Exchanged Under-Pier Depositional Layer
- Homogeneous Mixed Sediment Layer
- Vertical Limit of Mix Depth
- Vertical Limit of Previous Mix Depth

CONCENTRATION VARIABLES

Cra	Conc. of Cap Placements (Including Armor Rock)
Cr	Conc. of Dredge Residual Sediment
Cdl	Conc. of In-Situ Sediment Below Dredge Neatline
Cdepf	Conc. of Depositional Sediment (Future Conditions)
Cex	Conc. of Exchanged Sediment (Under-Pier / Open-Water)
Cni	Conc. of Mixed Sediments at Year n, Intermediate Value
Cnf	Conc. of Mixed Sediments at Year n, Final Value

DEPTH VARIABLES

Tra	Depth of Cap Placements (Including Armor Rock, depth n/a - armored)
Tr	Depth of Dredge Residual Sediment (depth n/a - isolated in armored cap)
Tydf	Depth of Depositional Sediment (Future Conditions, 1.2 cm/ year for the base case)
Tex	Depth of Exchanged Sediment (Under-Pier / Open-Water, 0.4 cm to 2 cm per year depending on the alternative)
Tmix	Vertical Depth of Mixing (up to 10 cm to 61 cm depending on the location; maximum depth of mixing down to the cap armor)

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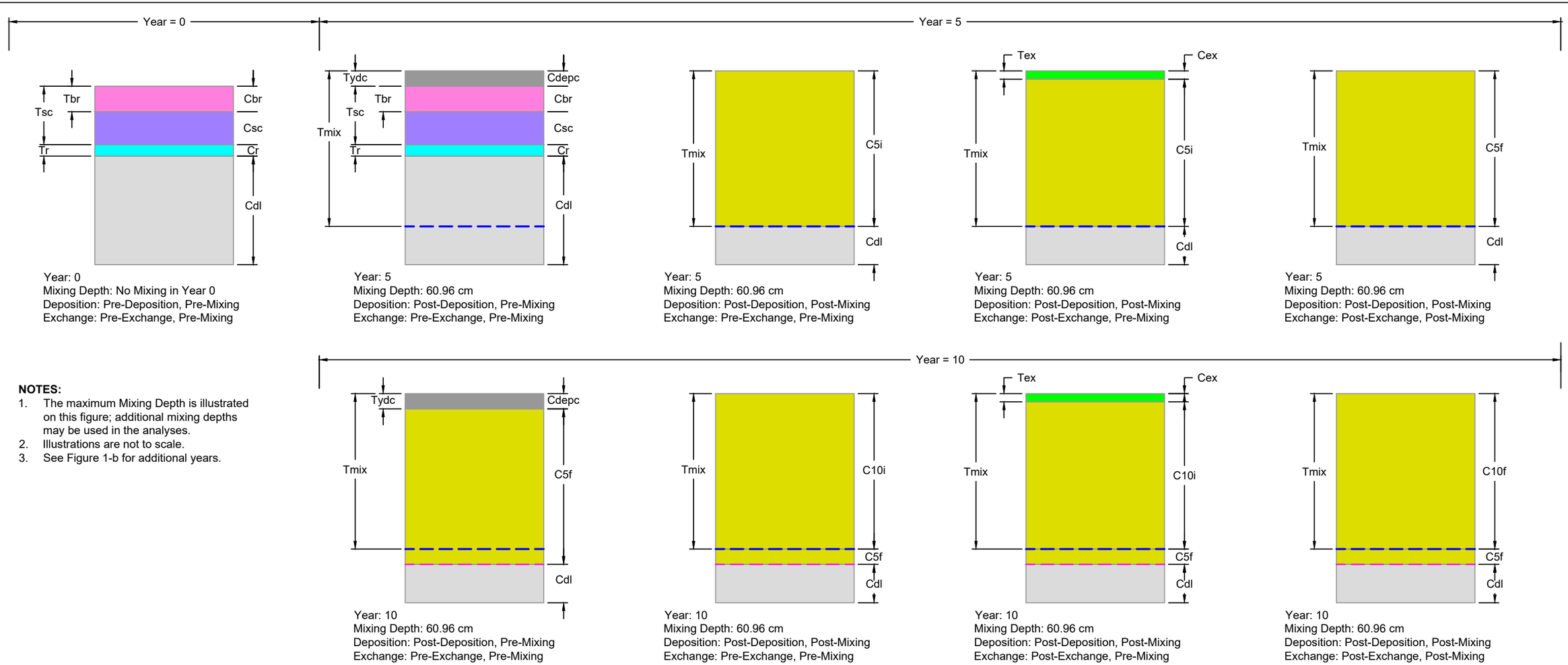
Figure 1i
Box Model: Partial Removal and Cap Beyond Year 10
Feasibility Study - Appendix J
East Waterway Study Area



NOTES:

1. The maximum Mixing Depth is illustrated on this figure; additional mixing depths may be used in the analyses.
2. Illustrations are not to scale.
3. See Figure 1-b for additional years.

LEGEND

- Bed Replacement Layer
- Enhanced Natural Recovery (ENR) Layer
- Dredge Residuals Layer
- In-Situ Sediment Below Dredge Neatline
- Depositional Sediment Layer
- Exchanged Under-Pier Depositional Layer
- Homogeneous Mixed Sediment Layer
- Vertical Limit of Mix Depth
- Vertical Limit of Previous Mix Depth

CONCENTRATION VARIABLES

Cbr	Conc. of Bed Replacement Layer
Csc	Conc. of Enhanced Natural Recovery (ENR) Layer
Cr	Conc. of Dredge Residual Sediment
Cdl	Conc. of In-Situ Sediment Below Dredge Neatline
Cdepc	Conc. of Depositional Sediment (Current Conditions)
Cex	Conc. of Exchanged Sediment (Under-Pier / Open-Water)
Cni	Conc. of Mixed Sediments at Year n, Intermediate Value
Cnf	Conc. of Mixed Sediments at Year n, Final Value

DEPTH VARIABLES

Tbr	Depth of Bed Replacement Layer (10 cm)
Tsc	Depth of Enhanced Natural Recovery (ENR) Layer (18 in = 46 cm)
Tr	Depth of Dredge Residual Sediment (in ENR-nav areas, 1.0 cm minus 10% loss during placement for the base case; in partial removal and ENR-nav areas, 5.1 cm minus 10% loss during placement for the basecase)
Tydc	Depth of Depositional Sediment (Current Conditions, 1.2 cm/ year for the base case)
Tex	Depth of Exchanged Sediment (Under-Pier / Open-Water, 0.4 cm to 2 cm per year depending on the alternative)
Tmix	Vertical Depth of Mixing (10 cm to 61 cm depending on the location; 61 cm shown in this example)

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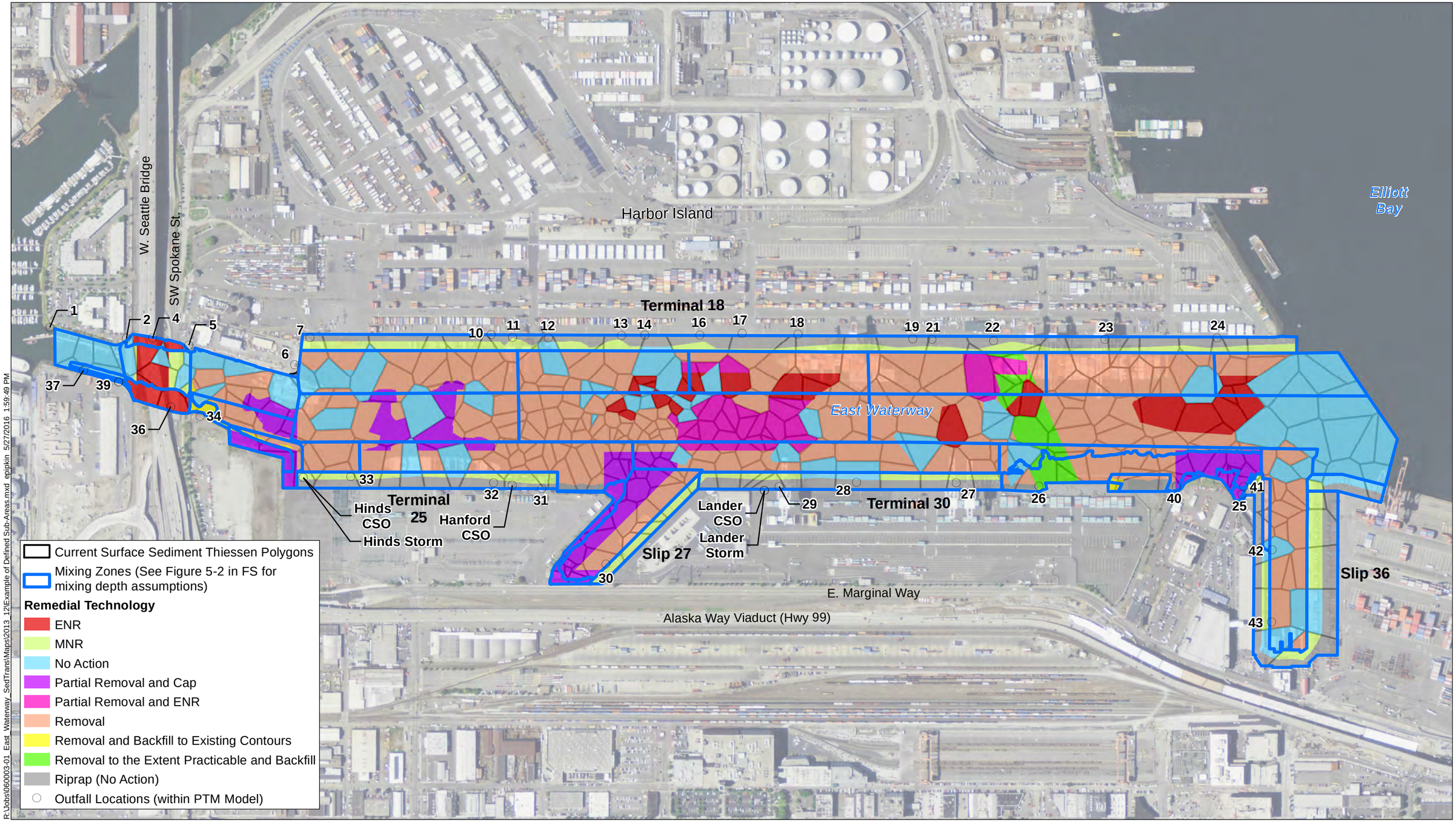
Figure 1j
Box Model: Enhanced Natural Recovery Navigation (ENR-nav) All Years
Feasibility Study - Appendix J
East Waterway Study Area



R:\Jobs\060003-01_East_Waterway_SedTrans\Maps\2013_12\Example of Defined Sub-Areas.mxd epipkin 5/27/2016 1:59:49 PM

NOTES:

1. Horizontal Datum: WA State Plane North, NAD83, Meters.
2. Aerial photo is NAIP, 2011.
3. Remedial technology sub-areas shown are for Alternative 3 (see Map 9-2 in Section 8 of the FS).
4. Current surface sediment thiessen polygons presented are for

0 500 1,000

Scale in Feet

Figure 2

Example of Development of Box-model Sub-areas based on Alternative 1A(12)

Feasibility Study - Appendix J

East Waterway Study Area

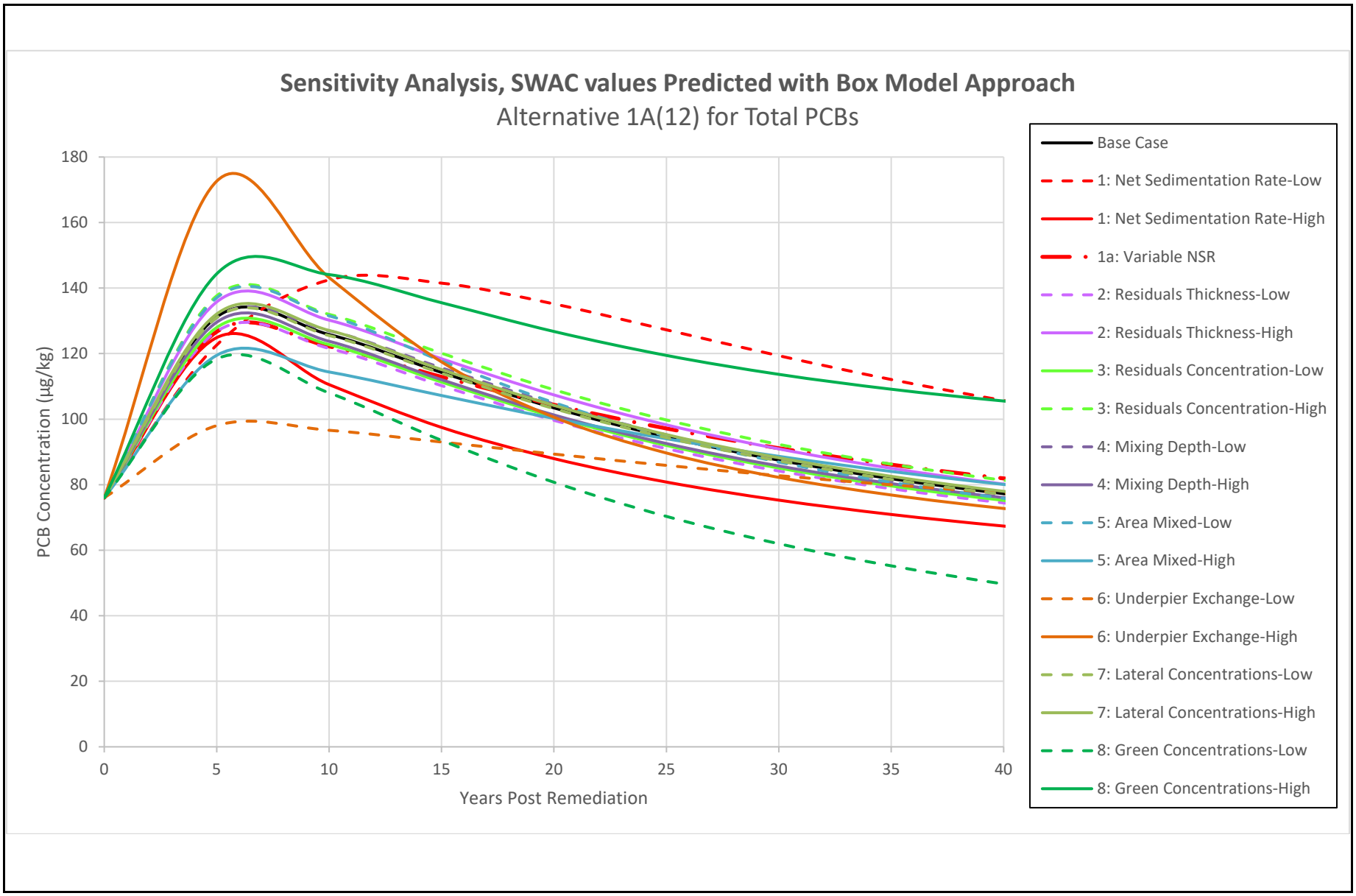


Figure 3a
Sensitivity Analysis, SWAC Values Predicted with Box Model Approach, Alternative 1A(12)
Feasibility Study - Appendix J
East Waterway Study Area

\\fuji\anchor\Projects\Port of Seattle\060003-01 East WW SRI_FS\FS\App J - Recon Potential\Figures\EW FS_DRAFT FINAL_Appendix J Figure 3a_10-21-16_draft removed.docx

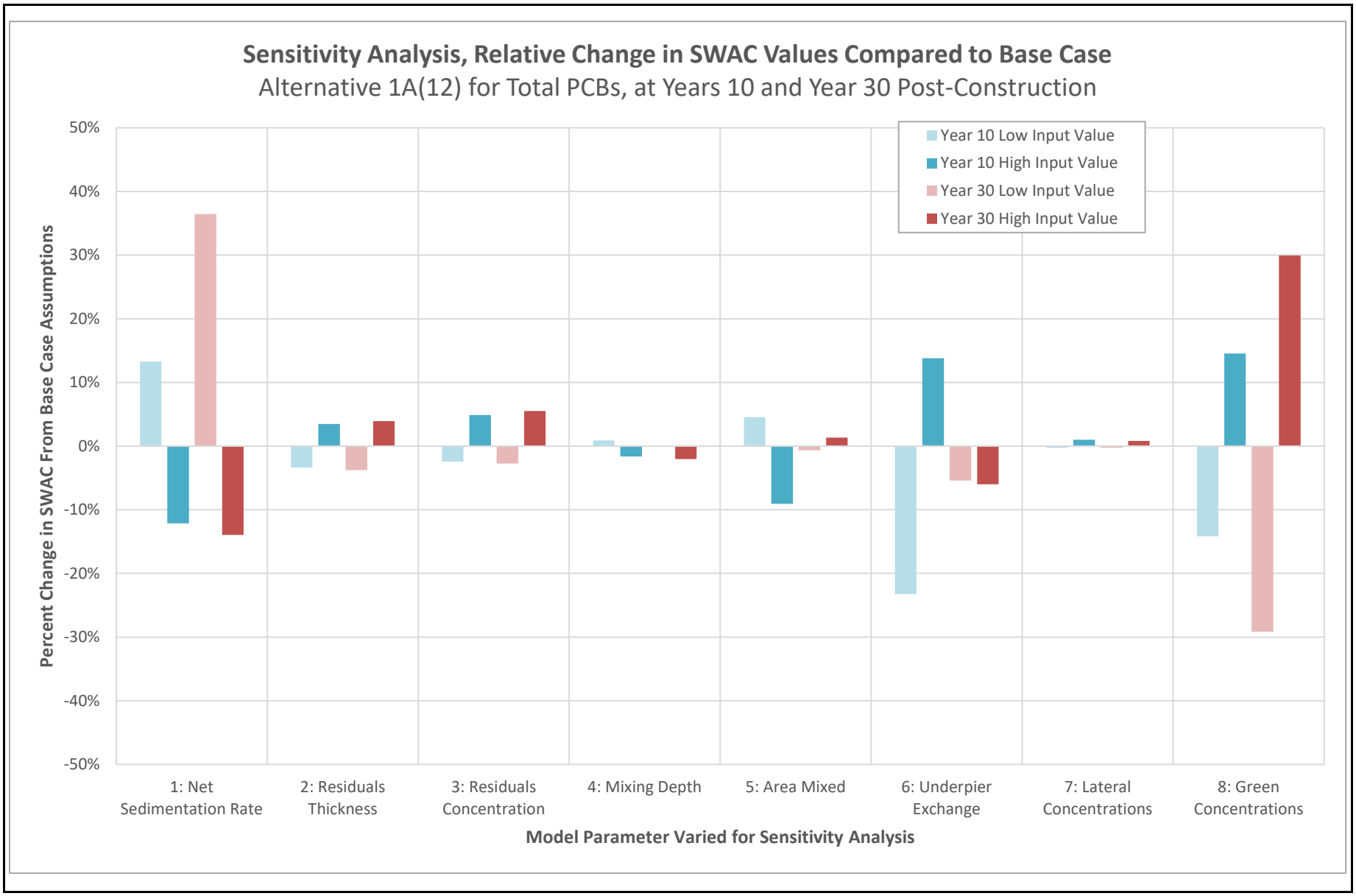


Figure 3b
Sensitivity Analysis, Relative Change in SWAC Values Compared to Base Case, Alternative 1A(12)
Feasibility Study - Appendix J
East Waterway Study Area

\\fuji\anchor\Projects\Port of Seattle\060003-01 East WW SRI_FS\FS\App J - Recon Potential\Figures\EW FS_DRAFT FINAL_Appendix J Figure 3b_10-21-16_draft removed.docx

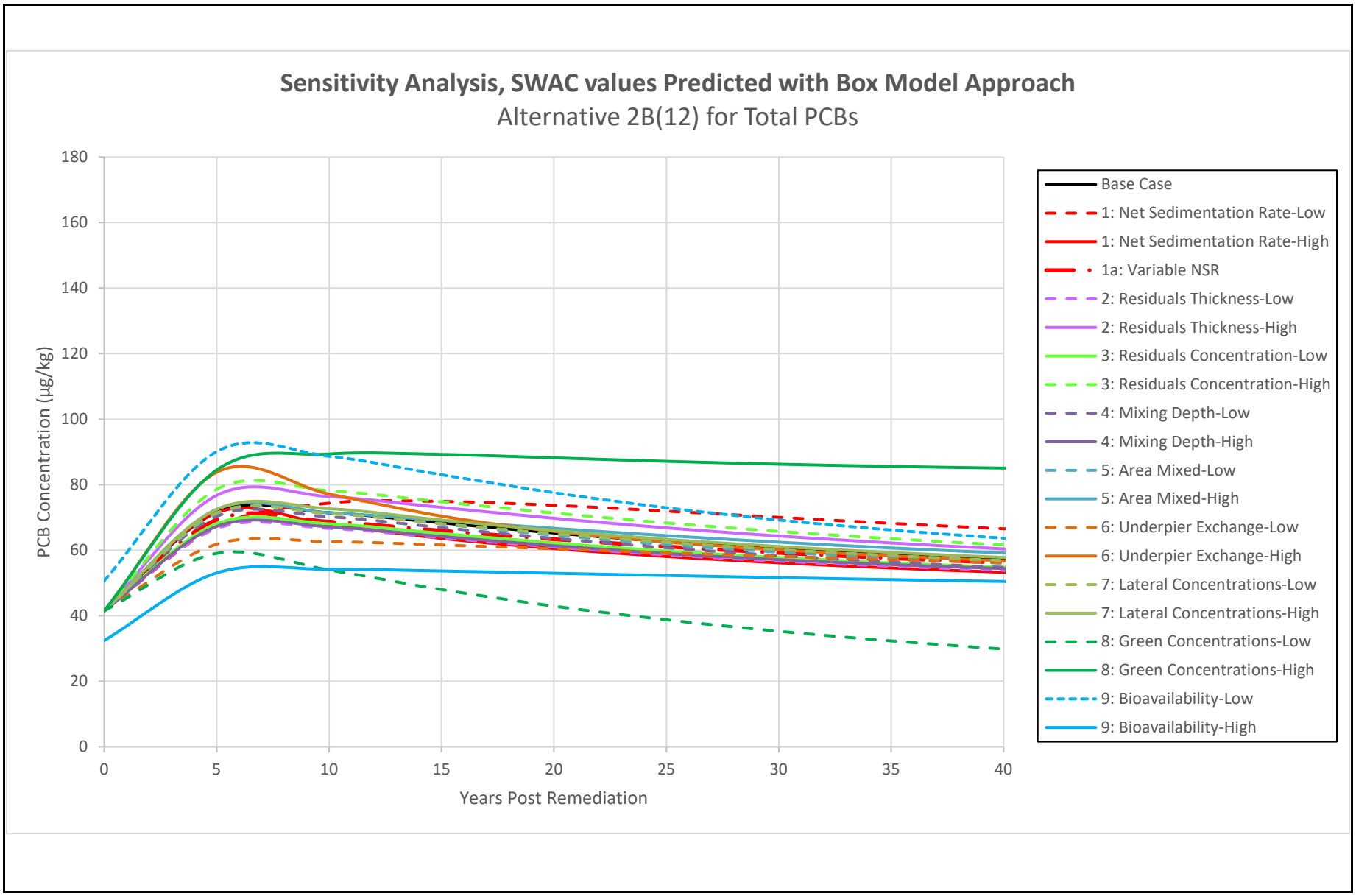


Figure 4a
Sensitivity Analysis, SWAC Values Predicted with Box Model Approach, Alternative 2B(12)
Feasibility Study - Appendix J
East Waterway Study Area

\\fuji\anchor\Projects\Port of Seattle\060003-01 East WW SRI_FS\FS\App J - Recon Potential\Figures\EW FS_DRAFT FINAL_Appendix J Figure 4a_10-21-16_draft removed.docx

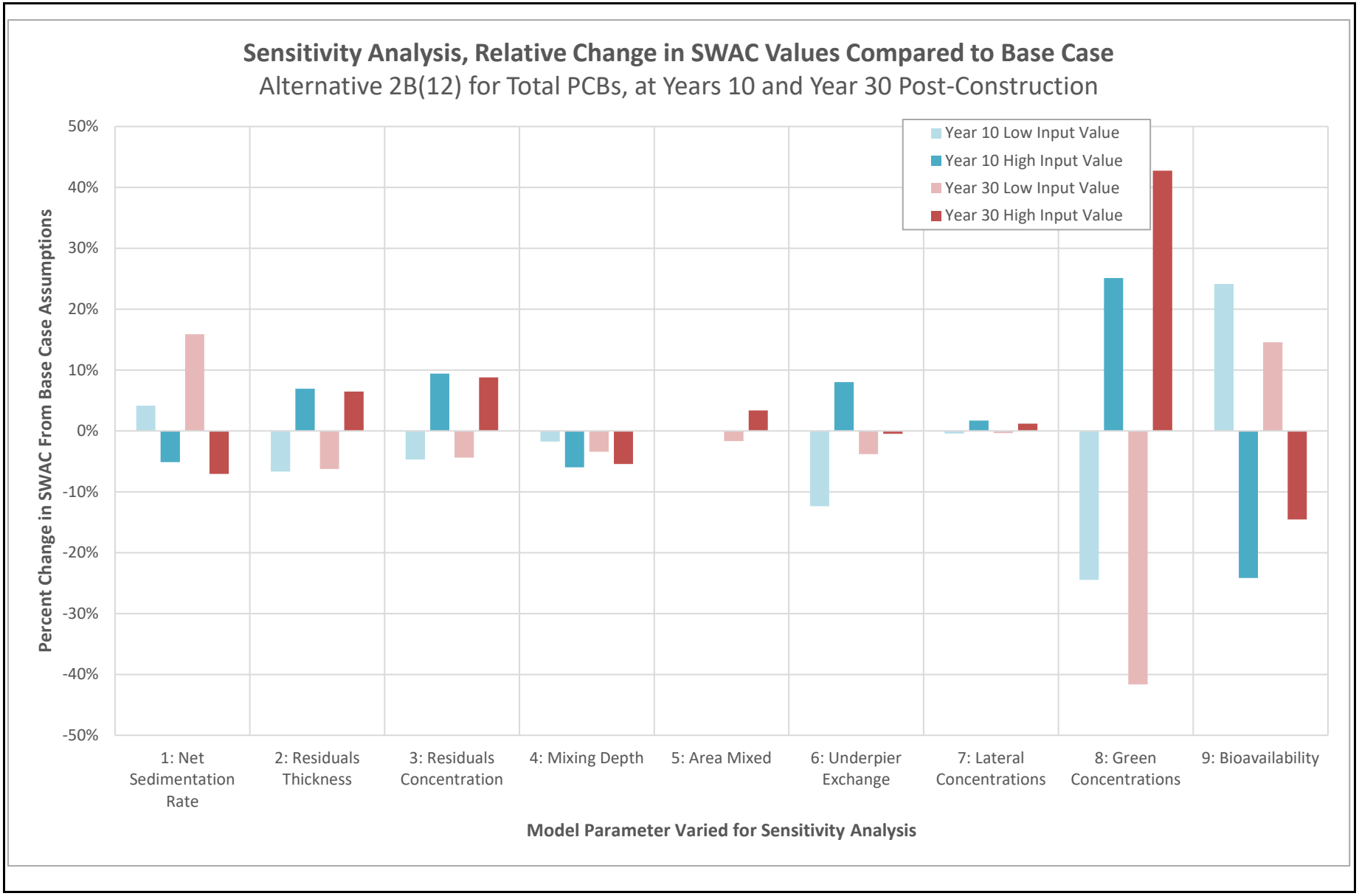


Figure 4b
Sensitivity Analysis, Relative Change in SWAC Values Compared to Base Case, Alternative 2B(12)
Feasibility Study - Appendix J
East Waterway Study Area

\\fuji\anchor\Projects\Port of Seattle\060003-01 East WW SRI_FS\FS\App J - Recon Potential\Figures\EW FS_DRAFT FINAL_Appendix J Figure 4b_10-21-16_draft removed.docx

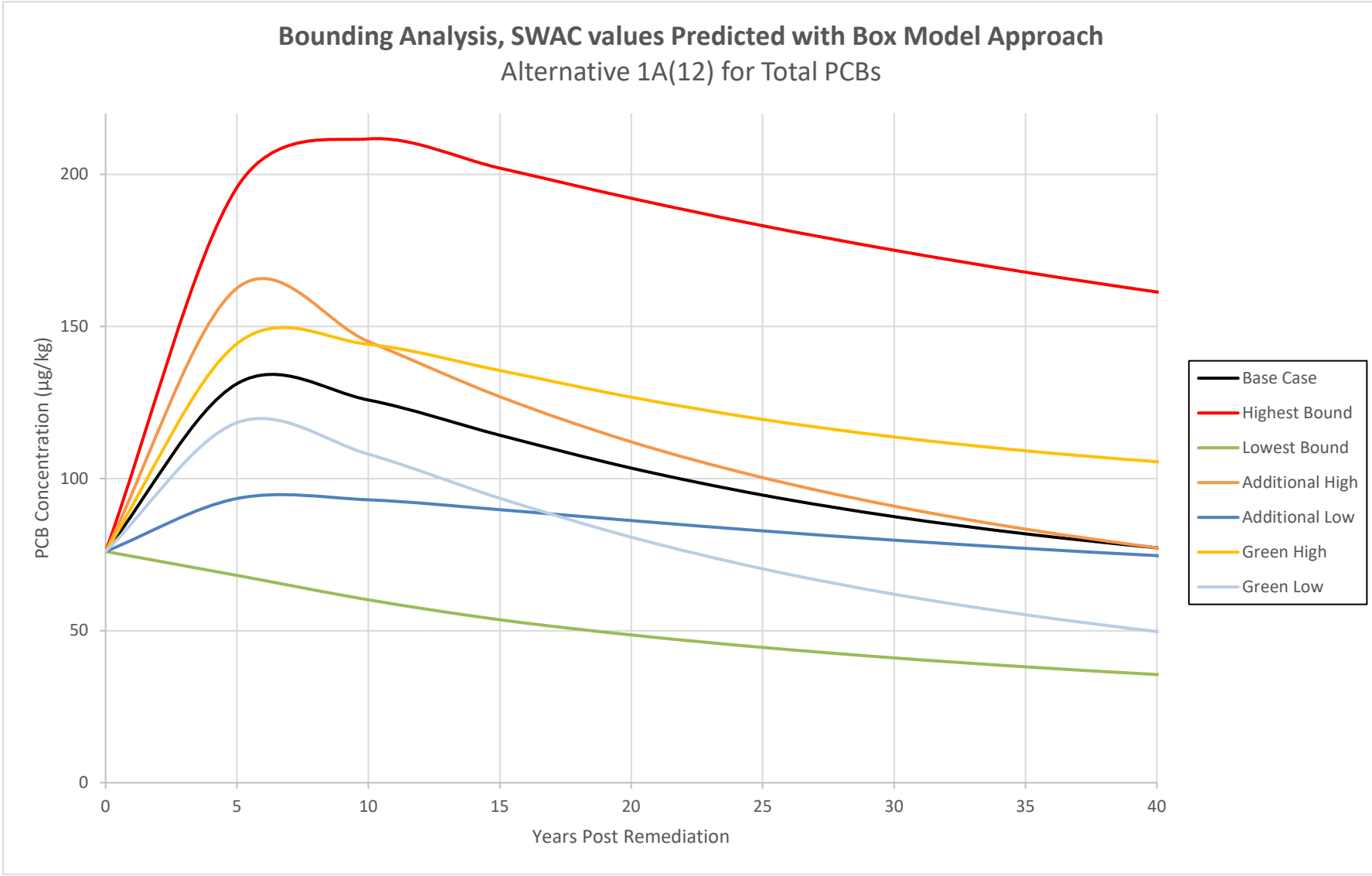


Figure 5a
Bounding Analysis, SWAC Values Predicted with Box Model Approach, Alternative 1A(12)
Feasibility Study - Appendix J
East Waterway Study Area

\\fuji\anchor\Projects\Port of Seattle\060003-01 East WW SRI_FS\FS\App J - Recon Potential\Figures\EW FS_DRAFT FINAL_Appendix J Figure 5a_10-21-16_draft removed.docx

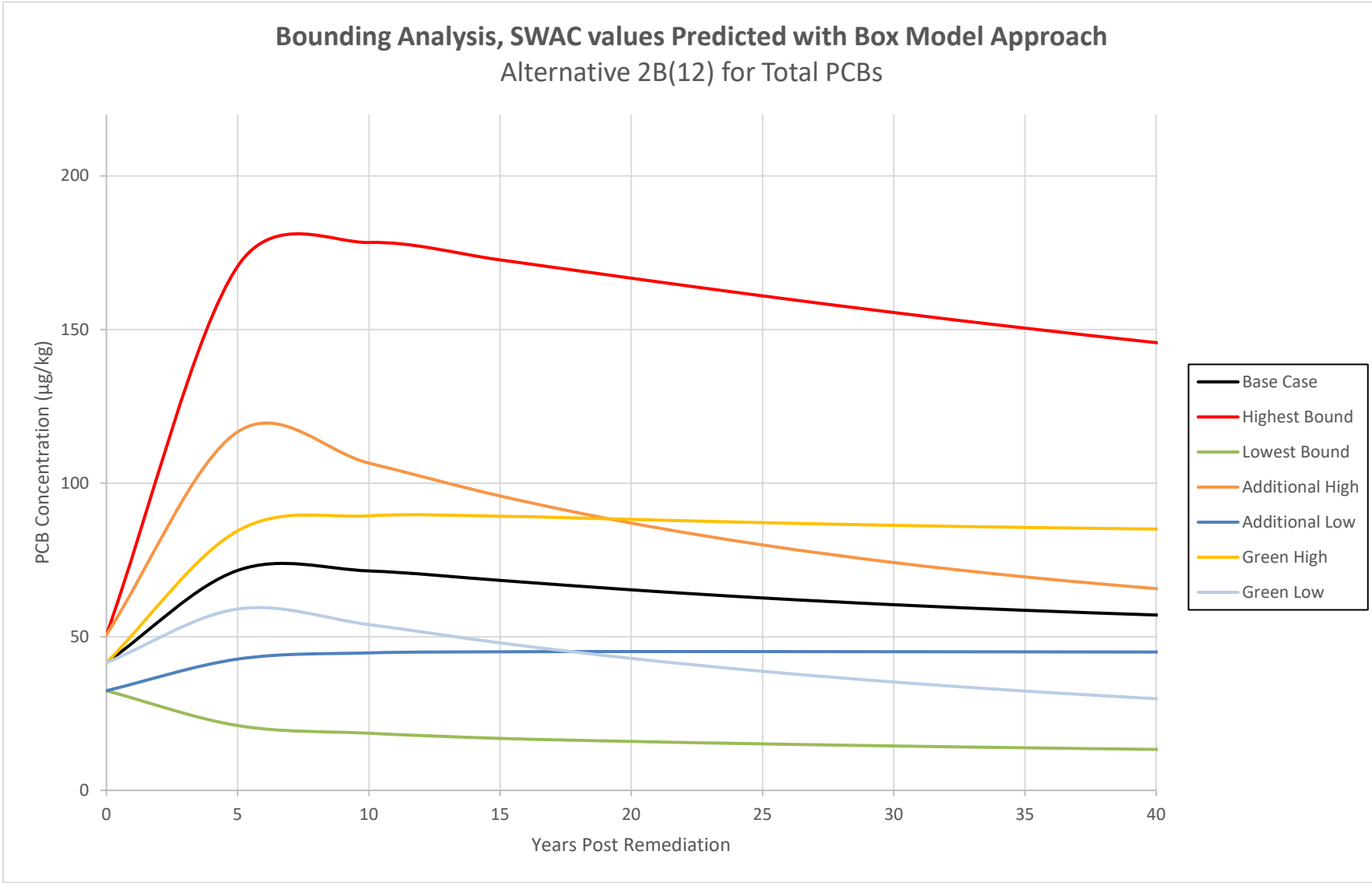
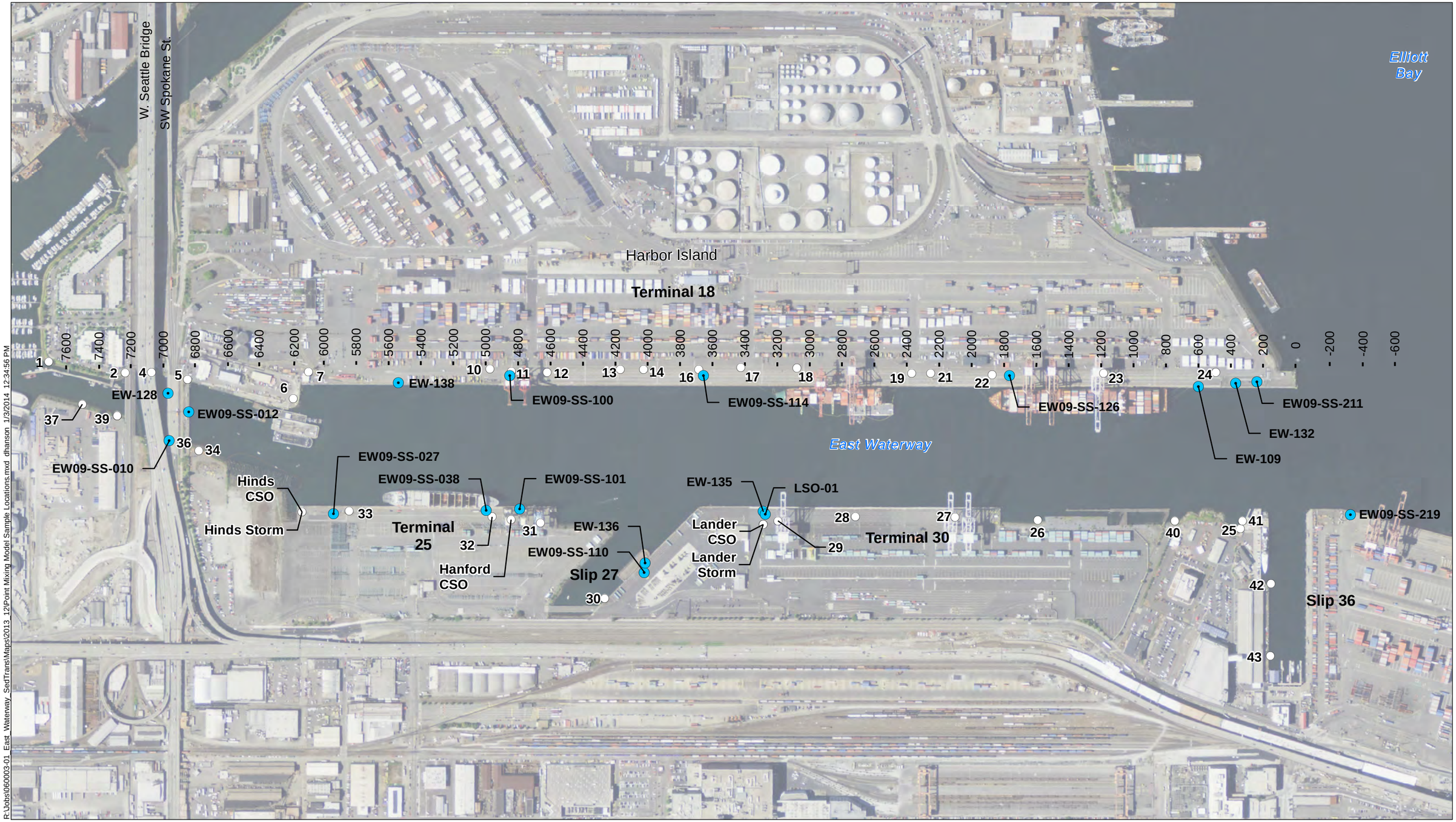


Figure 5b
Bounding Analysis, SWAC Values Predicted with Box Model Approach, Alternative 2B(12)
Feasibility Study - Appendix J
East Waterway Study Area

\\fuji\anchor\Projects\Port of Seattle\060003-01 East WW SRI_FS\FS\App J - Recon Potential\Figures\EW FS_DRAFT FINAL_Appendix J Figure 5b_10-21-16_draft removed.docx



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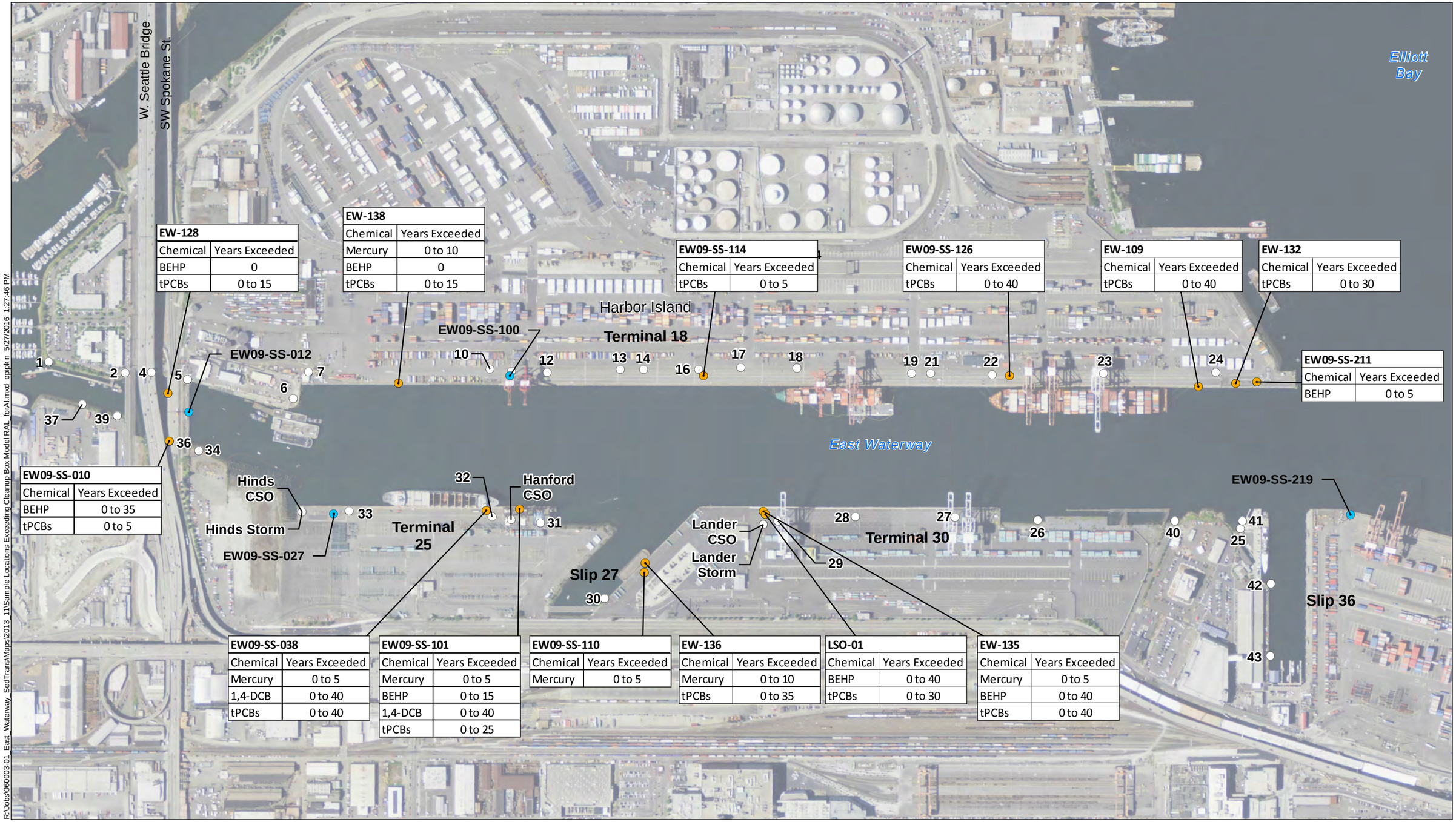
NOTES:
1. Horizontal Datum: WA State Plane North, NAD83, Meters.
2. Aerial photo is NAIP, 2011.

Point Mixing Model Sample Location
Outfall Locations (within PTM Model)

0 500 1,000
Scale in Feet

Figure 6
Point Mixing Model Sample Locations
Feasibility Study - Appendix J
East Waterway Study Area



EW-128	
Chemical	Years Exceeded
BEHP	0
tPCBs	0 to 15

EW-138	
Chemical	Years Exceeded
Mercury	0 to 10
BEHP	0
tPCBs	0 to 15

EW09-SS-114	
Chemical	Years Exceeded
tPCBs	0 to 5

EW09-SS-126	
Chemical	Years Exceeded
tPCBs	0 to 40

EW-109	
Chemical	Years Exceeded
tPCBs	0 to 40

EW-132	
Chemical	Years Exceeded
tPCBs	0 to 30

EW09-SS-211	
Chemical	Years Exceeded
BEHP	0 to 5

EW09-SS-010	
Chemical	Years Exceeded
BEHP	0 to 35
tPCBs	0 to 5

EW09-SS-038	
Chemical	Years Exceeded
Mercury	0 to 5
1,4-DCB	0 to 40
tPCBs	0 to 40

EW09-SS-101	
Chemical	Years Exceeded
Mercury	0 to 5
BEHP	0 to 15
1,4-DCB	0 to 40
tPCBs	0 to 25

EW09-SS-110	
Chemical	Years Exceeded
Mercury	0 to 5

EW-136	
Chemical	Years Exceeded
Mercury	0 to 10
tPCBs	0 to 35

LSO-01	
Chemical	Years Exceeded
BEHP	0 to 40
tPCBs	0 to 30

EW-135	
Chemical	Years Exceeded
Mercury	0 to 5
BEHP	0 to 40
tPCBs	0 to 40

NOTES:
1. Horizontal Datum: WA State Plane North, NAD83, Meters.
2. Aerial photo is NAIP, 2011.
3. Only COCs predicted to exceed the RAL are shown; other COCs that are not predicted to exceed the RAL are not shown.

- Sample Location
- Sample Location with RAL Exceedance
- Outfall Locations (within PTM Model)

0 500 1,000
Scale in Feet

Figure 7a
Point Mixing Model Results, Benthic RAL Exceedances
Feasibility Study - Appendix J
East Waterway Study Area

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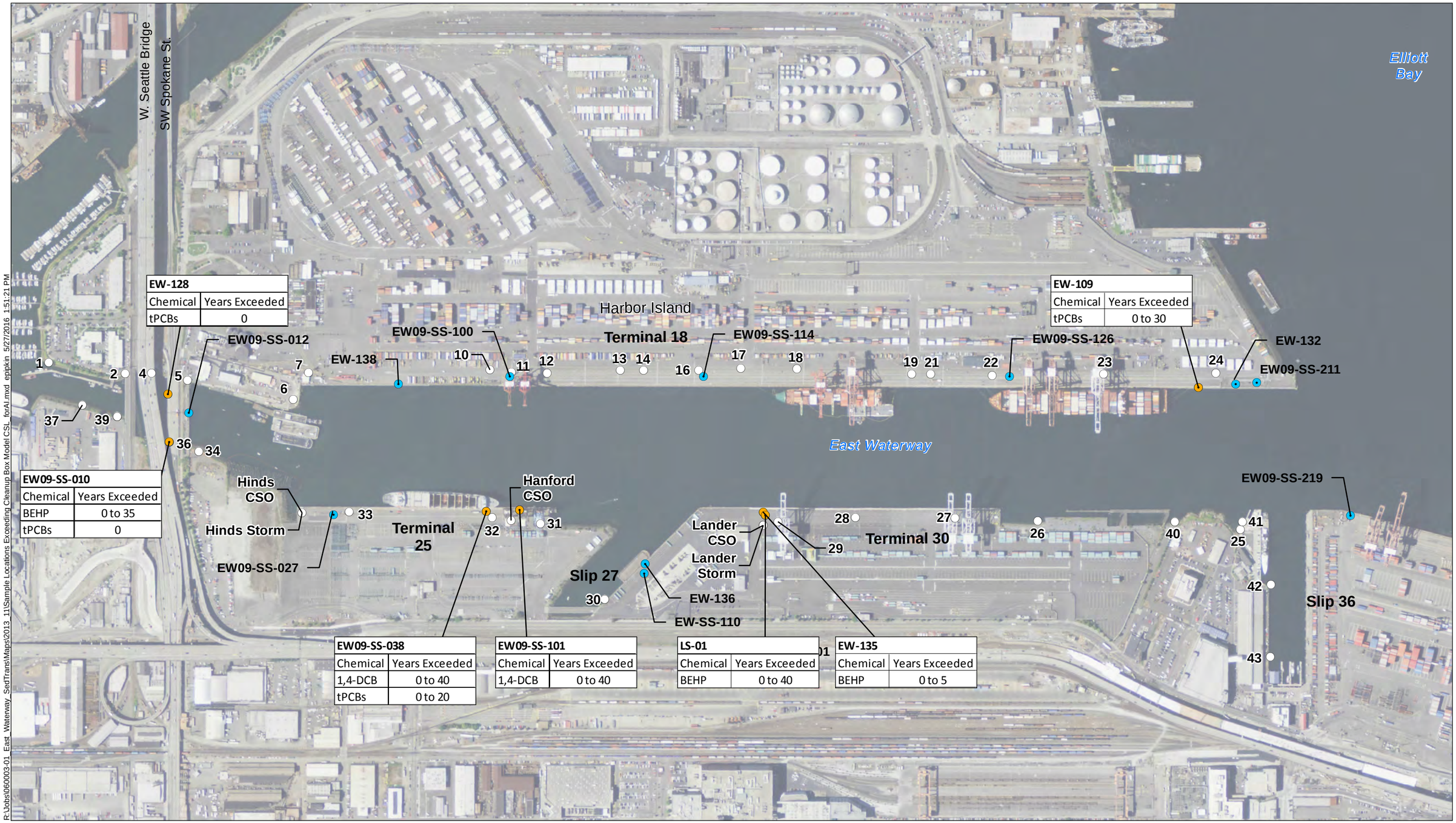

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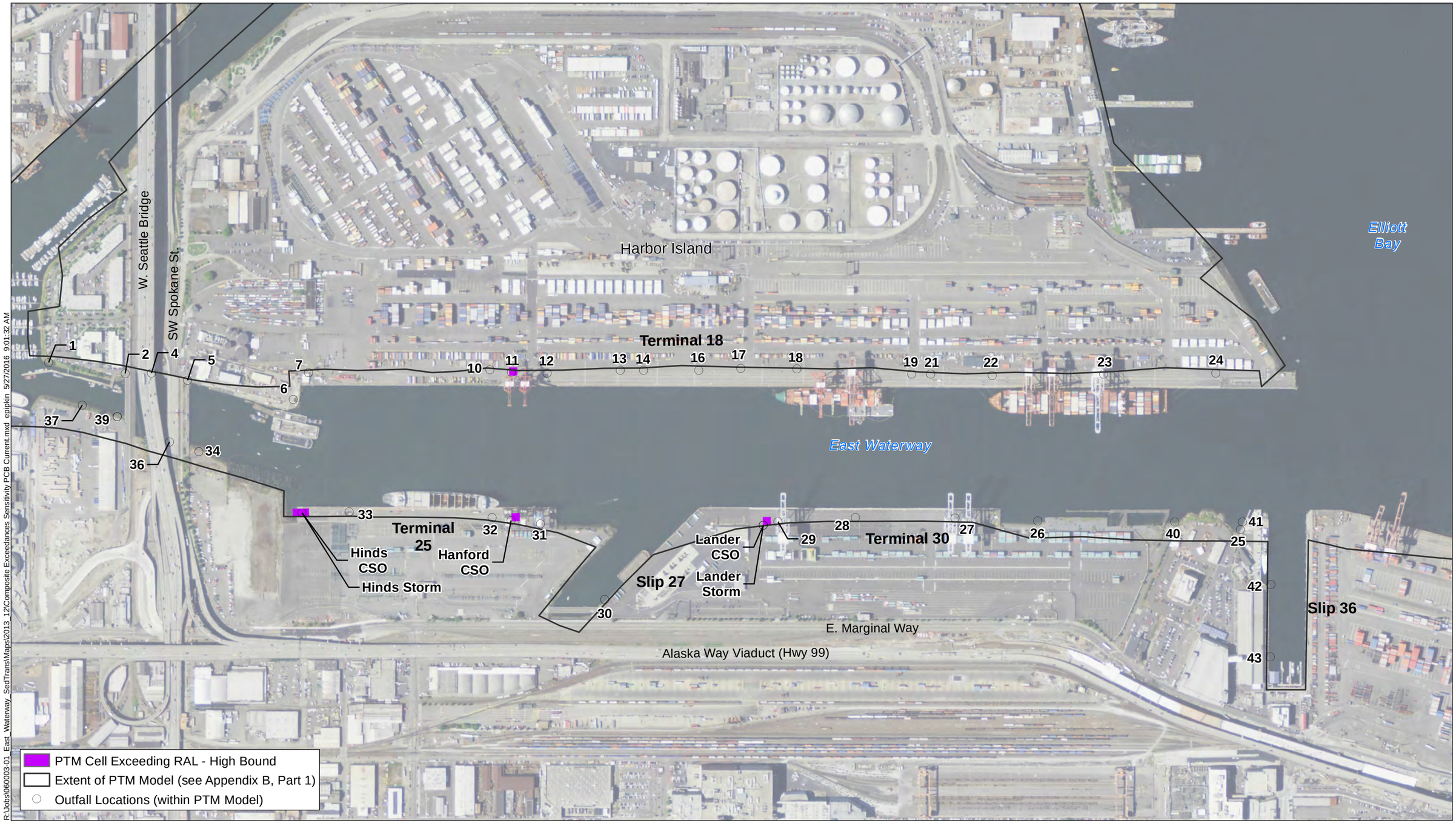
NOTES:
1. Horizontal Datum: WA State Plane North, NAD83, Meters.
2. Aerial photo is NAIP, 2011.
3. Only COCs predicted to exceed the CSL are shown; other COCs that are not predicted to exceed the CSL are not shown.

- Sample Location
- Sample Location with CSL Exceedance
- Outfall Locations (within PTM Model)

0 500 1,000
Scale in Feet

Figure 7b
Point Mixing Model Results, Benthic CSL Exceedances
Feasibility Study - Appendix J
East Waterway Study Area



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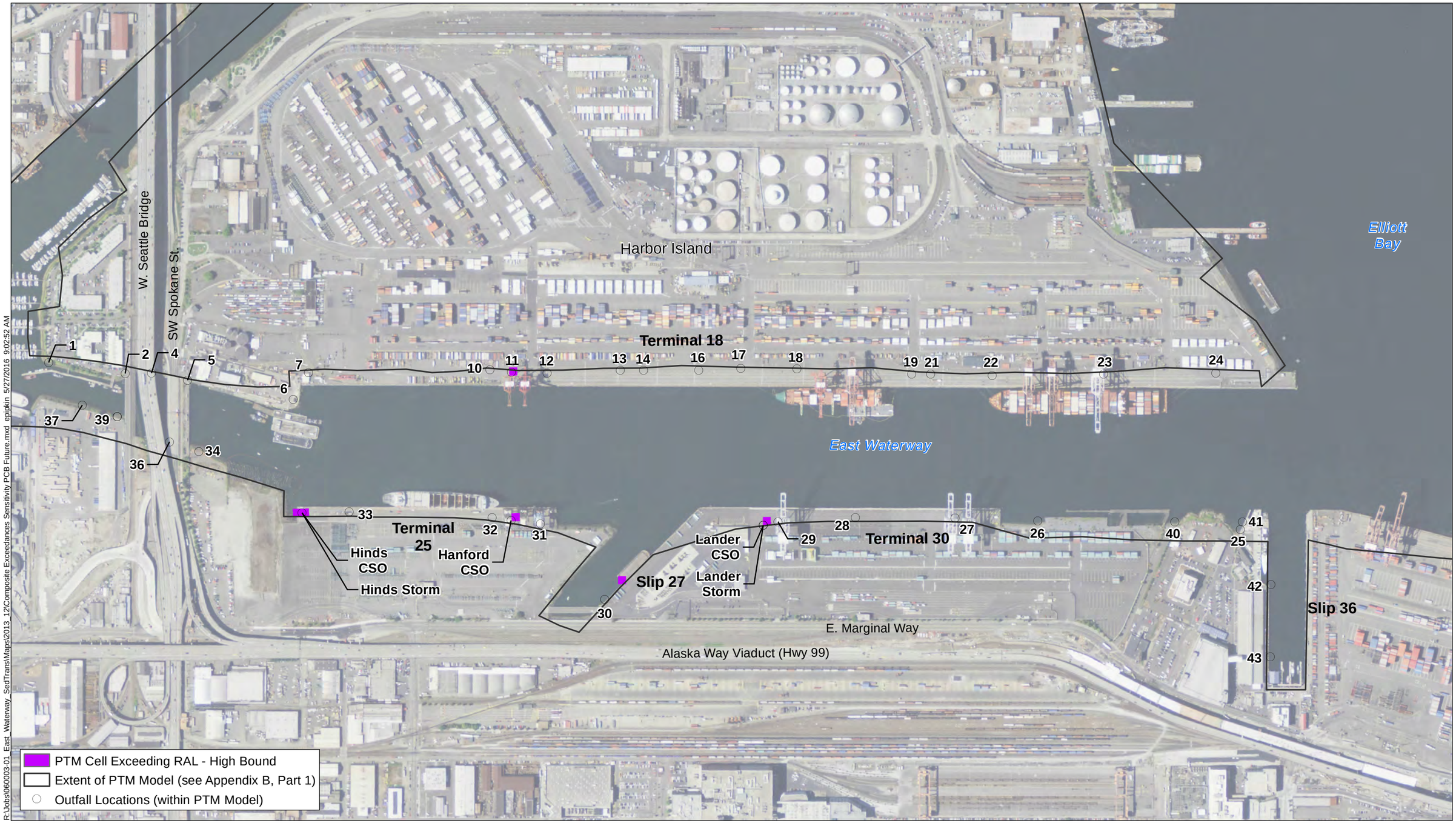
NOTES:
1. Horizontal Datum: WA State Plane North, NAD83, Meters.
2. Aerial photo is NAIP, 2011.
3. tPCB SQS is 12 mg/kg-OC.
4. RAL is equal to SQS.
5. No Exceedences for Low Bound Simulation.

0 500 1,000
Scale in Feet

Figure 8a
Grid Model Bounding Analysis, tPCB Years 0 to 10
Feasibility Study - Appendix J
East Waterway Study Area

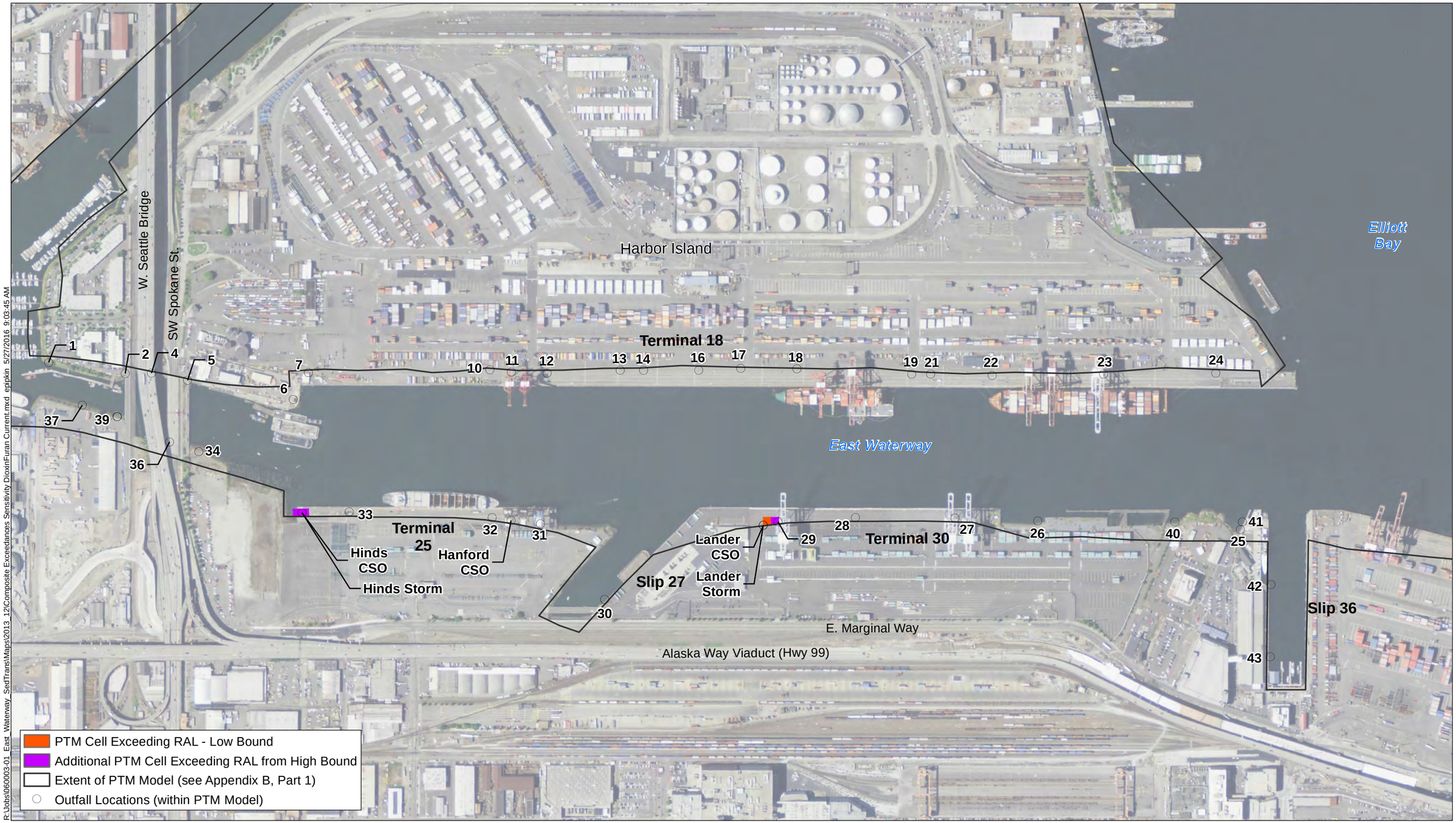


R:\Jobs\060003-01_East_Waterway_SedTrans\Maps\2013_12\Composite Exceedances Sensitivity PCB Future.mxd epipkin 5/27/2016 9:02:52 AM

NOTES:
1. Horizontal Datum: WA State Plane North, NAD83, Meters.
2. Aerial photo is NAIP, 2011.
3. tPCB SQS is 12 mg/kg-OC.
4. RAL is equal to SQS.
5. No Exceedences for Low Bound Simulation.

0 500 1,000
Scale in Feet

Figure 8b
Grid Model Bounding Analysis, tPCB Years 11 to 30
Feasibility Study - Appendix J
East Waterway Study Area



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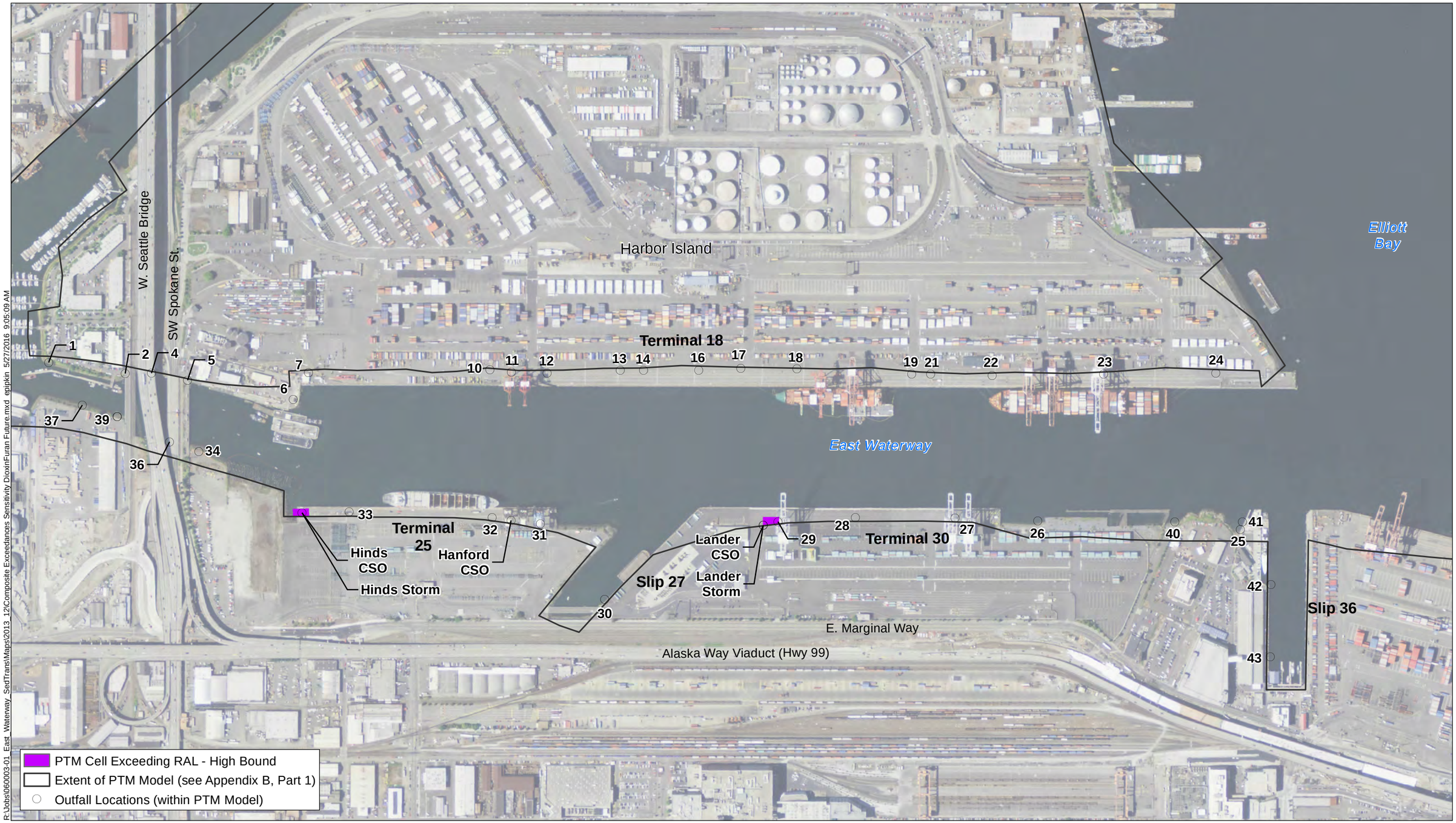
NOTES:
1. Horizontal Datum: WA State Plane North, NAD83, Meters.
2. Aerial photo is NAIP, 2011.
3. Dioxin/Furan RAL is 25 ng TEQ/kg dw.

0 500 1,000
Scale in Feet

Figure 9a
Grid Model Bounding Analysis, Dioxin/Furan Years 0 to 10
Feasibility Study - Appendix J
East Waterway Study Area

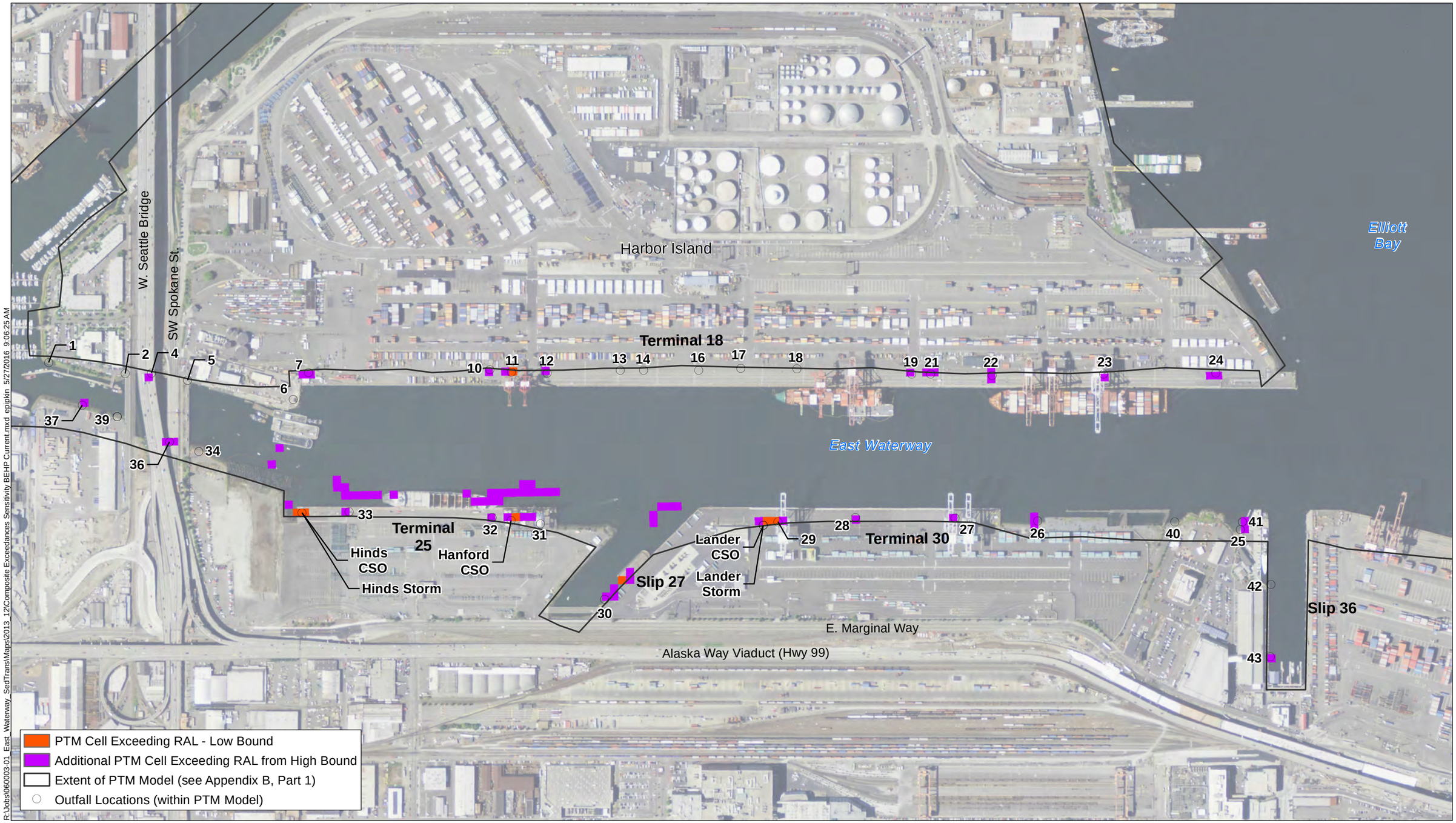


R:\Jobs\060003-01_East_Waterway_SedTrans\Maps\2013_12\Composite Exceedances Sensitivity DioxinFuran Future.mxd epipkin 5/27/2016 9:05:09 AM

NOTES:
1. Horizontal Datum: WA State Plane North, NAD83, Meters.
2. Aerial photo is NAIP, 2011.
3. Dioxin/Furan RAL is 25 ng TEQ/kg dw.
4. No Exceedences for Low Bound Simulation.

0 500 1,000
Scale in Feet

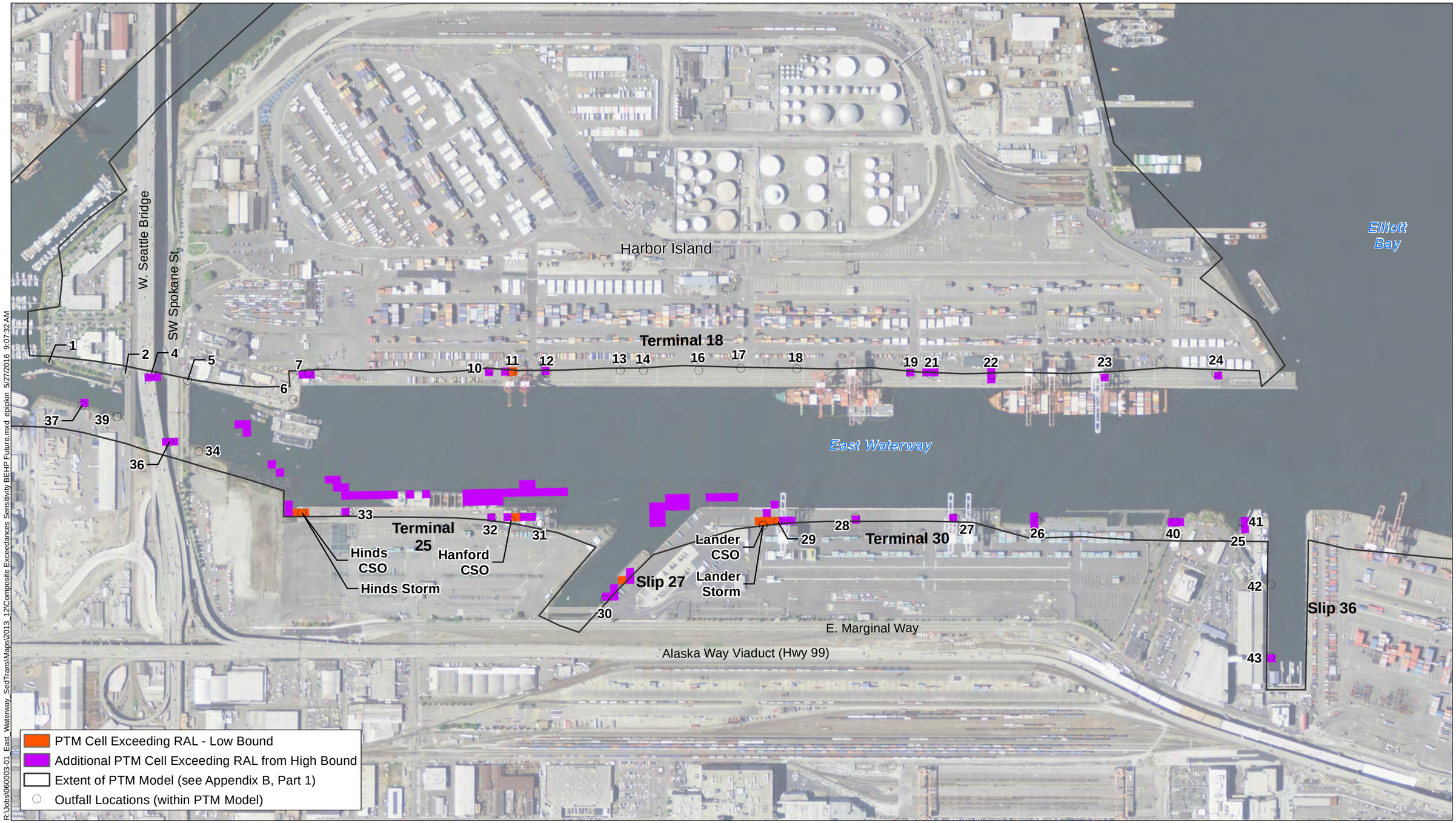
Figure 9b
Grid Model Bounding Analysis, Dioxin/Furan Years 11 to 30
Feasibility Study - Appendix J
East Waterway Study Area



R:\Jobs\060003-01_East_Waterway_SedTrans\Maps\2013_12\Composite Exceedances Sensitivity BEHP Current.mxd epipkin 5/27/2016 9:06:25 AM

NOTES:
1. Horizontal Datum: WA State Plane North, NAD83, Meters.
2. Aerial photo is NAIP, 2011.
3. BEHP SQS is 47 mg/kg-OC.
4. RAL is equal to SQS.

Figure 10a
Grid Model Bounding Analysis, BEHP Years 0 to 10
Feasibility Study - Appendix J
East Waterway Study Area



NOTES:
1. Horizontal Datum: WA State Plane North, NAD83, Meters.
2. Aerial photo is NAIP, 2011.
3. BEHP SQS is 47 mg/kg-OC.
4. RAL is equal to SQS

0 500 1,000
Scale in Feet

Figure 10b
Grid Model Bounding Analysis, BEHP Years 11 to 30
Feasibility Study - Appendix J
East Waterway Study Area