Lower Duwamish Waterway Group

Port of Seattle / City of Seattle / King County / The Boeing Company

Technical Memorandum:

Supplement to the Feasibility Study for the LDW Superfund Site, Approaches for Addressing Additional Concerns in Alternative 5C and Development of Alternative 5C Plus Scenarios

Lower Duwamish Waterway

Seattle, Washington

FOR SUBMITTAL TO:

The U.S. Environmental Protection Agency
Region 10
Seattle, WA

The Washington State Department of Ecology
Northwest Regional Office
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1 Introduction

This memorandum supplements the feasibility study (FS) for the Lower Duwamish Waterway (LDW) Superfund Site (the "site") and provides information for evaluating several additional elements that were not included in the remedial alternatives described in the FS (AECOM 2012). These additional elements, referred to as the "Plus elements" in this memorandum, are assembled into remedial alternatives referred to as the Alternative "5C Plus scenarios." The evaluation in this memorandum starts with the remedial technologies and remedial action level (RAL[1]) assumptions for FS Alternative 5C, and then adds the Plus elements described in Section 3.

The Lower Duwamish Waterway Group (LDWG) signed an Administrative Order on Consent (AOC) with the United States Environmental Protection Agency (EPA) and the Washington State Department of Ecology (Ecology) to conduct a remedial investigation/feasibility study (RI/FS) for the LDW site.[2] EPA and Ecology provide oversight for the RI/FS. The evaluation presented in this memorandum was performed under the AOC under the direction of EPA and Ecology to provide adequate assessment and documentation that will allow these scenarios and their results to be considered during development of the Proposed Plan for the site.

1.1 Site Conditions

The LDW is an engineered waterway that encompasses approximately 5 miles of the Duwamish River near its confluence with Elliott Bay in Seattle, Washington. The LDW is an active commercial waterway with port activities, and industrial and commercial uses along much of its shoreline. It has a long history of industrial and manufacturing uses, as well as being used by Native American tribes as a resource and for cultural purposes. Finally, two neighborhoods, South Park and Georgetown, feature a mixture of residential, recreational, commercial, and industrial uses.

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1 Remedial action levels (RALs) are contaminant-specific sediment concentrations that trigger the need for active remediation (i.e., dredging, capping, enhanced natural recovery, or a combination thereof).

2 As stated in the final FS, the LDW site is defined as follows: "The study area evaluated for remedial action in this FS focuses on the sediment and surface water of the LDW (RM 0 to RM 5.0), sometimes referred to as the "site" in this FS for convenience. The terms site, LDW-wide, and site-wide are sometimes used interchangeably in this FS, but generally refer only to the sediment and surface water of the LDW, not to the upland portions of the LDW Superfund Site. The final LDW Superfund Site boundaries, including upland areas that contributed contamination to the LDW, will be determined by EPA and Ecology in future decision documents."

The LDW consists of approximately 441 acres of intertidal and subtidal area within the waterway (River Mile [RM] 0 to 5). The LDW is a two-layer salt wedge estuary, with surface outflow that is mostly freshwater and tidally-influenced saltwater inflow from Puget Sound at depth; the LDW experiences rather large tidal fluctuations averaging about 11.3 feet (ft). The intertidal areas (shallower than -4 ft mean lower low water [MLLW]) total approximately 128 acres (113 acres excluding early action areas [EAAs]; Table 1) and are shown in Figure 3-1 of the FS. The subtidal areas (deeper than -4 ft MLLW) total approximately 313 acres (299 acres excluding EAAs).

The conceptual site model divides the 5-mile-long LDW into three reaches based on sedimentation, river dynamics, and the saltwater wedge: a permanent salt wedge occurs near the mouth of the LDW in Reach 1 (RM 0 to 2.2), a periodic salt wedge occurs in Reach 2 (RM 2.2 to 4), and in Reach 3 (RM 4 to 5), the salt wedge may sometimes occur under mean flow conditions while a predominantly freshwater environment occurs during high-flow events. The LDW is about 400 ft wide and a 200-ft-wide federally authorized navigation channel runs down the center of the LDW, which is maintained at depths between -30 ft MLLW in the downstream reaches to -15 ft MLLW in the upstream reach. The estuary is generally a depositional environment, with estimated net sedimentation rates averaging 1 to 3 centimeters per year (cm/yr) (see FS; Figure 2-11). The Green/Duwamish River annually contributes about 200,000 metric tons of bed load and suspended solids to the LDW and about 50% of this material settles in the LDW. The navigation channel in the upper reaches is periodically dredged to remove accumulated sediment, reduce sediment transport into the lower reaches of the LDW, and maintain appropriate navigation depths.

In the LDW, risk drivers for human health are polychlorinated biphenyls (PCBs), arsenic, carcinogenic polycyclic aromatic hydrocarbons (cPAHs), and dioxins and furans, and risk-driver contaminants of concern (COCs[3]) for ecological receptors are 41 Washington State Sediment Management Standard (SMS) contaminants.[4] The FS sediment baseline dataset includes 1,438 surface sediment samples and 539 subsurface core samples collected between 1990 and 2010. In surface sediments, the percent fines (sum of clay and silt fractions) range from 13 to 87% and average about 53%. The site-wide average total organic carbon content is 2%. Contaminant distribution patterns can be characterized as having localized areas of relatively high contaminant concentrations separated by relatively large areas of lower concentrations. The average depth of contamination was estimated to be about 4 feet based on whether sediments

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[3] For the purposes of this memorandum, the use of the term contaminants of concern (COCs) refers only to the risk drivers defined in the FS: human health and ecological COCs are listed in Table 4-7 and 4-8 of the FS.

[4] The 41 SMS contaminants are COCs for benthic invertebrates; PCBs is the risk-driver COC for river otters. See FS Section 3.

exceeded the sediment quality standards (SQS) of the SMS. Higher contaminant concentrations were often found in subsurface sediments compared to surface sediments, consistent with historical practices in the LDW, ongoing sedimentation, and natural recovery.

The potential for natural recovery of sediments in the LDW was evaluated as part of the RI/FS. The LDW, excluding the 29 acres of EAAs and 10 acres upstream of RM 4.75, was segregated into three natural recovery categories based on site conditions, scour potential, net sedimentation rates, model predictions, and empirical sediment chemistry trends that indicate whether sediment COC concentrations may be decreasing over time through natural processes. The three natural recovery category areas were:

- Recovery Category 1 = natural recovery of sediments is presumed to be limited (77 acres).
- Recovery Category 2 = natural recovery of sediments is less certain than Recovery Category 3 but includes areas with net sedimentation and mixed empirical contaminant trends (44 acres).
- Recovery Category 3 = natural recovery of sediments is predicted to occur (281 acres).

Another 10 acres of the LDW upstream of RM 4.75 (but not part of the EAAs) was not assigned to one of the three recovery categories because it is upstream of the area represented by the sediment transport model.[5] Figure 1 shows the areas in Recovery Categories 1, 2, and 3. These three recovery categories were used in developing the FS remedial alternatives and remedial technology assignments (e.g., dredging, capping, enhanced natural recovery [ENR], and monitored natural recovery [MNR]).

The cleanup of five EAAs in the LDW is either completed or ongoing; in total, these EAAs comprise 29 acres. A 50% reduction in the site-wide spatially-weighted average concentration (SWAC)[6] of total PCBs is predicted after cleanup of the EAAs. The LDW FS develops remedial alternatives for areas (approximately 412 acres) remaining outside of the EAAs. In addition to SWAC predictions, post-construction conditions in

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[5] The sediment transport model (STM) and the natural recovery model (also referred to as the bed composition model [BCM]) included most of the LDW from RM 0.0 to 4.75 at the Upper Turning Basin. The remaining 10 acres above RM 4.75 up to RM 5.0 were outside of the calibrated model domain. Model predictions were not conducted for this area.

[6] SWACs are calculated using geographic information system (GIS) software following the interpolation methods described in the FS.

this memorandum also refer to SQS and cleanup screening level (CSL) exceedances in sediments in the LDW. Figures D-1 through D-5 in Appendix D of the FS depict stations with surface SMS exceedances, in addition to other information.

1.2 Background

In the fall of 2011, EPA and Ecology informed LDWG and other stakeholders that the Agencies preliminary cleanup plan for the LDW would be referred to as Alternative 5C Plus because Alternative 5C, as presented in the October 2010 Draft Final FS, needed additional modifications. In August, November, and December 2011, LDWG provided EPA and Ecology with some additional technical considerations based on LDWG's understanding of the site and Alternative 5C Plus as it relates to site conditions and trends (AECOM 2011a, AECOM 2011b, AECOM 2011c). In October 2011, EPA and Ecology briefed LDWG and stakeholders on elements of the preliminary cleanup plan, and presented them to the National Remedy Review Board in December 2011. EPA provided additional details on proposed modifications to the cleanup alternative to LDWG in a meeting held on January 11, 2012.

Additional refinements and technical considerations were developed over the following months, culminating in two facilitated meetings held on April 26 and May 9, 2012 with EPA, Ecology, and LDWG (EPA 2012a). On July 6, 2012, meeting notes were organized into a matrix table summarizing topics, perspectives, and comments (EPA 2012b). As a result of the facilitated meetings that framed the issues, EPA and Ecology agreed to develop remedial scenarios to better define Alternative 5C Plus for EPA's Proposed Plan.

In early July 2012, 11 supplemental scenarios were proposed by EPA and Ecology and 2 by LDWG that covered a range of options for applying RALs to subsurface sediments. Subsequent meetings were held on July 27 and August 16, 2012, and based on the evaluations of the initial 13 scenarios, five revised scenarios were retained for detailed analysis.

These meetings and follow-up correspondence provided the foundation for developing the Plus elements and the Alternative 5C Plus scenarios presented in this memorandum. This memorandum presents acres, dredge volumes, costs, construction times, and SWACs for the four human health risk drivers (PCBs, arsenic, cPAHs, and dioxins/furans) in surface sediments for each scenario both at the conclusion of remedy implementation and for some period thereafter. An evaluation of these supplemental scenarios against the CERCLA balancing criteria was also completed and is included in this memorandum. This information is provided for EPA and Ecology to consider in refining the technical elements of the Proposed Plan.

This technical memorandum identifies the problem statement and rationale for adding these elements to Alternative 5C; presents the technical adjustments and assumptions used to create the 5C Plus scenarios; and summarizes the development of these scenarios.

2.0 Identifying the Concerns

EPA and Ecology are considering several additional remedial elements for the preferred cleanup alternative to be identified in the Proposed Plan. These Plus elements, which are being considered as additions to FS Alternative 5C, are designed to address the following concerns:

- EPA and Ecology are concerned that there are various ways contaminated subsurface sediment could be disturbed and exposed to the surface that are not addressed by Alternative 5C in the FS. Potential mechanisms for exposure of subsurface sediments were summarized from early meetings on this issue and are presented in Table 2 (EPA 2012a). Based on this concern, EPA and Ecology proposed development of subsurface sediment RALs that would be compared to sediment COC concentrations (averaged throughout a specified vertical interval) and that they would be used to require dredging or capping in additional areas with subsurface contamination where those sediments have the potential to be disturbed. Subsurface sediment RALs identify sediment areas for remediation based on existing data; these sediment areas will be further defined using remedial design sampling to determine the spatial and vertical extent of remediation[7] (Sections 3.1.4 and 3.1.5).
- EPA and Ecology are concerned that contaminated shoaled areas of the navigation channel will also require active remediation (Section 3.1.1).
- EPA and Ecology are concerned that a 3-ft cap thickness will not be sufficiently protective in potential clamming areas, and increased cap thickness will be needed as a means to limit potential human health and ecological exposures to contaminated subsurface sediments (Sections 2.1 and 3.1.3).
- EPA and Ecology are concerned that the monitoring density and frequency in areas that are not actively remediated and have surface sediment concentrations less than the SQS (referred to as "institutional controls, site-wide

[7] To clarify, while the subsurface RALs identify areas for active remediation, they are not used to define the depth of dredging to occur in an area. Also, for clarification, the application of RALs at a site does not affect or alter the requirement to achieve sediment cleanup levels that will be established in a Record of Decision for the site.

monitoring, and natural recovery areas" on FS maps and tables)[8] would not be sufficient to detect increases in sediment contaminant concentrations should subsurface disturbance and exposure events occur. Therefore, the Alternative 5C Plus increases the monitoring density and frequency of surface sediment in these areas (Sections 2.1 and 3.1.2).

- LDWG is concerned that Alternative 5C does not incorporate natural recovery trends that are already occurring in the LDW, and are predicted to occur for many SMS contaminants. Therefore, Scenarios 5a and 5b in this memorandum include surface sediment RALs that allow for monitored natural recovery for non-human health risk-driver COCs in low to moderately contaminated areas (Sections 2.2 and 3.2).

Each of these additional remedial elements requires specific decision rules, so that the scope of Alternative 5C Plus can be defined for an FS-type evaluation. Different options for these decision rules were developed into scenarios for further evaluation (Section 3).

2.1 Potential Effects of Exposing Subsurface Sediment Contamination

Potential disturbance mechanisms that could result in exposure of subsurface sediment contamination are presented in Table 2 and Figure 2. Deep disturbance events may occur from vessels maneuvering infrequently under emergency and high-power conditions, vessel groundings, maintenance and construction activities, and seismic events. Individual disturbance events would likely be isolated and infrequent, but the cumulative effects of multiple events could be of concern over the long term. Table 2 also presents how these disturbance mechanisms were addressed in the FS (in Alternative 5C), and potential options to address the disturbance of subsurface sediment contamination (beyond the information provided in the FS).

As presented in Table 2, the FS Alternative 5C already addresses the potential for deep disturbance to expose subsurface sediment contamination in three ways. First, the areas in the LDW that are most likely to experience persistent and regular vessel scour and are predicted to have limited natural recovery of sediments (i.e., Recovery Category 1 areas) are already identified for active remediation in the FS. The technology assignments used in Alternative 5C of the FS select dredging or capping in the 77 acres of Recovery Category 1 areas where shallow subsurface contamination in the upper 2 ft of the sediment profile is above the RALs. Second, in the other areas (Recovery Categories 2 and 3), Alternative 5C already requires that the highest surface

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[8] EPA has indicated that the nomenclature for areas labeled as site-wide monitoring and institutional controls in the FS Alternative 5C may change for the Proposed Plan.

sediment concentrations in areas be capped or dredged, because ENR is proposed only for areas with sediment COCs that are less than three times the RALs in the top 10 cm, and less than 1.5 times the RALs in the top 45 cm of the intertidal areas (see Section 8 of the FS). Figure 3 shows that in FS Alternative 5C, the highest total PCB subsurface concentrations are either dredged from the LDW or remain under engineered caps. Third, a long-term monitoring program is included in the FS with provisions for additional actions (i.e., adaptive management) if the remedy is not performing as predicted.

In addition, the FS includes a separate sensitivity analysis to consider the potential cumulative effect of such disturbance mechanisms on long-term model-predicted SWACs for total PCBs (see FS, Appendix M, Part 5). Because the total area and extent of such disturbances of subsurface sediment contamination is unknown, results from this analysis are presented as long-term model-predicted SWACs as a function of acreage disturbed. In other words, the long-term predicted concentrations for the remedial alternatives are shown as a range from 0 to 40 acres disturbed (hypothetically). The average contaminant concentration remaining in the subsurface after remediation for each remedial alternative is also factored into this analysis (see FS Appendix M, Part 5).[9]

In the FS, the current remedial technology assignments for Alternative 5C, coupled with a long-term sediment monitoring program and scour mitigation measures, are proposed to effectively reduce the potential for subsurface contamination to be exposed. However, despite the design of Alternative 5C, future disturbance events could occur. Therefore, EPA and Ecology are investigating the use of subsurface sediment RALs in the Proposed Plan.

The Plus elements being considered as additions to Alternative 5C to address these concerns and further reduce the chance of future exposure of subsurface sediments contaminated with COCs are:

1) Adding or modifying subsurface sediment RALs for sediments deeper than the biologically active layer (i.e., the top 10 cm).
2) Dredging contaminated shoaled areas in the navigation channel.
3) Increasing the intertidal cap thicknesses.
4) Increasing the density and frequency of long-term sediment monitoring in areas not actively remediated.

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9 This analysis assumed no mixing of the subsurface with surface sediments and assumed that the subsurface sediments would remain exposed over a long period of time.

2.2 SMS Contaminants in Surface Sediment that are not Human Health Risk Drivers

For ecological risk drivers, Alternative 5C in the FS includes surface sediment RALs set at the SQS for 41 SMS contaminants. The LDW RI (Windward 2010) identified 41 hazardous substances as COCs based on detected concentrations above the SQS in one or more surface sediment samples. All SQS exceedances, regardless of contaminant, frequency of exceedance, degree of exceedance, or spatial area of exceedances, are actively remediated in FS Alternative 5C. However, many of these contaminants: 1) are predicted to recover to below the SQS within 10 years or less following construction; 2) only had minor SQS exceedances (less than two times the SQS); 3) were isolated exceedances of the SQS and were surrounded by sediment samples with concentrations below the SQS; 4) exceeded the SQS in less than 5% of the samples; or 5) are contaminants that are considered likely to recontaminate surface sediment after remediation. Although some of these items are not SMS criteria, they all may be considered in the selection of remedial actions.

LDWG's concerns related to SMS contaminants in surface sediment are summarized as two key issues:

- Where applicable, MNR for non-human health SMS COCs would allow for the most efficient cleanup of the LDW and achieve the SQS within 10 years following construction. Active remediation triggered only by relatively minor SQS exceedances of these contaminants may not be needed to comply with the SMS.
- In addition, seven non-human health SMS COCs were identified by LDWG as "problem contaminants" that do not necessarily require active remediation because of either their ubiquitous presence in urban environments that can lead to recontamination or their transient, non-persistent nature in sediments.[10] Thus, LDWG identified that active remediation of these "problem contaminants" may not be appropriate for every exceedance of the SQS.

Allowing for MNR to address non-human health SMS COCs has been determined to be a viable option in the LDW (see FS Sections 5 and 6), based on a site-specific evaluation using a weight-of-evidence approach described in EPA (2005) guidance. First, the LDW is a net depositional system with a net sedimentation rate that is

[10] Two contaminants (bis(2-ethylhexyl)phthalate [BEHP] and butylbenzyl phthalate [BBP]) are likely to recontaminate sediments at concentrations above the SQS because of their ubiquitous nature in urban stormwater. Five contaminants (benzyl alcohol; 2,4-dimethylphenol; 4-methylphenol; phenol, and benzoic acid) typically are transient and non-persistent, and therefore should not require active remediation until there is better understanding about the source and persistence of these contaminants.

greater than 1 cm per year over most of the LDW (see Section 2 of the FS, Figure 2-11). Second, empirical trends indicate that COC concentrations in surface sediments are decreasing in many areas of the LDW. Most of the SMS contaminants have shown more than a 50% decrease in surface sediment concentrations over the past 10 to 15 years, based on locations that have been resampled over time and trend analyses of COCs in sediment cores (see Appendix F of the FS).[11] Lastly, sediment transport modeling combined with chemical modeling predicts that 99% of baseline SQS exceedances will be below the SQS within 10 years after construction of Alternative 4C (FS Section 9). The relatively small areas of sediments that are predicted to exceed the SQS after 10 years are generally associated with recontamination issues and are located near point sources.

There are some contaminants with ongoing urban signatures such as phthalates, or that sometimes have transitory SQS exceedances, such as benzyl alcohol, benzoic acid, and phenolic compounds. Bis(2-ethylhexyl)phthalate and butylbenzyl phthalate have been identified as being associated with ubiquitous, ongoing urban sources. Following active remediation, they are predicted to recontaminate in surface sediment in small areas, primarily associated with point source discharges. Benzyl alcohol, benzoic acid, and phenolic compounds can form naturally as a result of biological processes and degradation of natural substances (e.g., plants and microbial activity) and have been shown to have transitory SQS exceedances in some cases. For example, the Duwamish/Diagonal EAA has 8 years of post-dredge/cap data (2004 through 2011) that demonstrate exceedances of the SQS can occur at a very localized and episodic scale after remediation, or can be transient in nature (Figure 4). At the Duwamish/Diagonal EAA, concentrations of certain contaminants (e.g., benzyl alcohol, benzoic acid, and phenol) have been shown to be highly variable on a year-to-year basis.

The Plus elements under consideration as additions to Alternative 5C to address the concerns identified above and further optimize the remedy include implementing: 1) a surface RAL of 2 times the SQS for non-human health COCs (excluding stations that also have RAL exceedances for human health risk-driver COCs) and 2) a long-term surface sediment monitoring program that would identify any areas of sediments where recovery is not occurring as predicted, and where contingency actions would be implemented as needed to meet the SQS. These elements are further described in Section 3.

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[11] The conceptual site model acknowledges that both the rate and extent of natural recovery of sediments in the LDW are influenced by existing and future sources of contaminants and the extent to which sources are controlled. Source control is important to the success of natural recovery and to the success of all remedial technologies to be implemented at the site.

3.0 Development of Supplemental 5C Plus Scenarios

This section describes the Plus elements under consideration as additions to Alternative 5C and the development of the Alternative 5C Plus scenarios (supplemental scenarios that expand on Alternative 5C as presented in the FS). Six Plus elements are included in the supplemental Alternative 5C Plus scenarios; five elements were developed to address subsurface sediment contamination, and the sixth element was developed to address surface sediment SQS contamination. Section 3.1 identifies the five Plus elements applied to the scenarios to help reduce the potential for disturbance and exposure of subsurface sediment contamination. Section 3.2 describes the sixth Plus element that allows for more targeted remediation of surface sediment contamination (i.e., MNR for non-human health COCs). Section 3.3 presents the Alternative 5C Plus scenarios, including additional refinements used to distinguish among the five scenarios.

3.1 Alternative 5C Plus Elements for Reducing Potential Future Exposure of Subsurface Sediment Contamination

Five elements were added to Alternative 5C to address concerns regarding potential exposure of subsurface sediment contamination. These elements include the following:

- Dredging contaminated shoaled areas in the navigation channel
- Increasing the density and frequency of sediment monitoring in areas not actively remediated
- Increasing the cap thickness in intertidal clamming areas
- Applying subtidal subsurface sediment RALs in Recovery Category 2 and 3 areas.
- Applying intertidal subsurface sediment RALs for total PCBs.

The first three elements are common to all of the 5C Plus scenarios, and are referred to as "base elements." The remaining two elements vary in how they are applied within each Alternative 5C Plus scenario.

3.1.1 Dredging Contaminated Shoaled Areas in the Navigation Channel

In the federally-authorized navigation channel of the LDW, additional dredging or partial dredging/capping may be required in areas where the mudline elevation is above the authorized navigation depth[12] (referred to as shoaled areas) and the

[12] The authorized depth of the channel in the Lower Duwamish Waterway varies from -15 to -30 ft MLLW.

subsurface sediment in those areas is contaminated above the RALs. The shoaling areas of the navigation channel were determined in this analysis based on the 2003 bathymetric survey used in the FS baseline dataset.[13] In these shoaled areas, the accumulated sediment may require dredging to maintain navigable water depths, but the dredged material may be contaminated and thus may not be suitable for disposal at an unconfined, open-water disposal site managed by the Dredged Material Management Program (DMMP). For these reasons, dredging of sediments in shoaled areas (based on the 2003 bathymetric survey) is considered for incorporation into Alternative 5C Plus scenarios. While FS Alternative 5C assumes appropriate clearance requirements in the navigation channel for areas undergoing active remediation (based on contamination in surface sediments), it does not assume any additional active remediation that may be required as a result of subsurface contaminant concentrations in areas where surface sediment concentrations are less than the RALs.

For the Alternative 5C Plus scenarios described in this memorandum, dredging or partial dredging/capping are included in areas of the navigation channel where shoaling is occurring and the sediment COC concentrations in the top 2 ft are greater than the Alternative 5C RALs. The remedial technology assumptions used in the FS are applied to these areas for dredging or partial dredging/capping determinations. Based on these criteria, this analysis estimates the additional dredging volume in the navigation channel to be approximately 70,000 cubic yards (cy), and for cost estimating purposes, all of the dredge volume is assumed to require upland disposal.

3.1.2 Increasing the Density and Frequency of Sediment Monitoring in Areas not Actively Remediated

EPA and Ecology are concerned that the density and frequency of sediment monitoring in areas with surface sediment less than the SQS (called "institutional controls, site-wide monitoring, and natural recovery areas" in the FS) would not be sufficient to detect potential increases in sediment contaminant concentrations.[14] Therefore, the Alternative 5C Plus increases the monitoring density from 1 sample/4

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[13] Additional shoaling of sediments that exceed the authorized channel depth in the LDW was observed in bathymetric profiles obtained by the USACE in April 2012 (USACE 2012, HDR Engineering et al. 2012) but were not incorporated into this analysis to keep the dataset consistent with the FS.

[14] In the FS (and in this memorandum), the areas not addressed through active remediation but subject to natural recovery have several naming conventions depending on surface concentrations. These areas are referred to as monitored natural recovery (MNR) for areas above the SQS, verification monitoring for areas expected to be below the SQS during design, and "institutional controls, site-wide monitoring, and natural recovery" for the rest of the LDW. Each of these areas has different assumptions for monitoring density, frequency, and potential contingency actions. A multimedia, 30-year conceptual monitoring plan is described in Appendix K of the FS for long-term monitoring.

acres to 1 sample/acre and increases the sampling frequency from every 5 years after construction (up to 30 years) to sampling at years 2, 3, 5, 7, and 10 and every five years thereafter for a period of 30 years after construction. Both the FS alternatives and the 5C Plus alternatives assume that no contingency actions would be taken in areas below the SQS in surface sediment based on monitoring results.

The monitoring density, frequency, and contingency assumptions for MNR areas and verification monitoring areas are the same for 5C Plus alternatives and the FS alternatives. In this memorandum, four 5C Plus scenarios (Scenarios 1 through 4) include only active remediation to the SQS (i.e., no MNR) for all areas with RAL exceedances. In contrast, two 5C Plus scenarios (Scenarios 5a and 5b) select MNR as one of the remedial technologies.

3.1.3 Increasing the Cap Thickness in Intertidal Clamming Areas

FS Alternative 5C assumes that all engineered isolation caps would be approximately 3 ft thick. In intertidal areas, 3 ft of contaminated sediment must first be excavated to accommodate an isolation cap without changing the existing mudline elevation. In areas where clamming might occur (which comprise 91 acres of the LDW, excluding EAAs, see FS Figure 3-1), it is anticipated that people may physically dig for clams down to a 45-cm depth (1.5 ft) below mudline. For all of the Alternative 5C Plus scenarios, the cap thickness in areas where clamming might occur has been increased to 4 ft so that clamming activities will not compromise the cap thickness needed to keep contaminants isolated below the cap. However, cap designs will be re-evaluated during remedial design; in some cases, a thinner isolation cap may be acceptable, especially if the cap design incorporates enhanced treatment technologies such as carbon amendments.

3.1.4 Applying Subtidal Subsurface Sediment RALs in Recovery Category 2 and 3 Areas

One method for addressing potential exposure of subsurface sediment contamination is to apply a RAL to deeper sediments not already addressed in Alternative 5C. In the FS, Alternative 5C applies sediment RALs in all Recovery Category 1 areas (77 acres with identified scour potential) to a depth of 2 ft because of the increased potential that subsurface sediments could become exposed. In the Recovery Category 1 areas, if the maximum COC concentration anywhere in the upper 2 ft of a sediment core was above the RAL,[15] then either dredging or capping was selected as the remedial technology.

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[15] During remedial design, RAL exceedance will be determined based on the average concentration (not the maximum concentration) in the upper 2 ft of sediment.

Alternative 5C Plus Scenarios 1 through 5 include an array of different subsurface RALs applied to the upper 2 ft of the sediment profile in Recovery Category 2 and 3 areas. The application of these RALs is focused on specific areas of the waterway that are most likely to be subject to potential tug scour. In Recovery Category 2 and 3 areas, the likelihood of scour caused by maneuvering tugs is greatest at elevations above -24 ft MLLW north of the First Avenue Bridge at RM 2.0 (approximately 62 acres) and above -18 ft MLLW south of the First Avenue South Bridge (approximately 66 acres), which is a total of approximately 128 of 335 acres of sediments in Recovery Category 2 and 3 areas (Figure 5; note the area upstream of RM 4.75 outside of the EAAs is assumed to be either Recovery Category 2 or 3). These elevations are based on tug drafts and locations where tugs may navigate in the LDW. Only smaller tugs go south of the 1st Avenue South Bridge at RM 2.0; the potential tug scour area was not extended upstream of the Oxbow Bridge at RM 4.8 because the water depth and bridge height prevent tugs from accessing this area. Sediments at depths above -4 ft MLLW were excluded from this analysis because intertidal areas are addressed separately (see Section 3.1.5). There are no subsurface RALs proposed for the remaining 105 acres in Recovery Categories 2 and 3 where tug scour was not identified as a concern. Details of this scour analysis are provided in Section 3.3.1.

Table 4 summarizes the subsurface RALs for each of the Alternative 5C Plus scenarios and the depth and area over which they apply. An exceedance of the subsurface RAL triggers active remediation regardless of surface concentrations. The technology options are dredging, partial dredging/capping, or capping, and the remedial technology assignments are made following the same technology assumptions used in the FS (except there is no MNR in FS Alternative 5C). In some cases, ENR may be applicable depending on the contaminant and its subsurface concentration (see Attachment 1 for remedial technology assignment details).

3.1.5 Applying Intertidal Subsurface Sediment RALs for Total PCBs

For intertidal areas, FS Alternative 5C has two sets of RALs that apply: the first applies to the upper 10 cm of sediment (referred to as site-wide RALs) and the second applies to the upper 45 cm of sediment based on human health direct contact exposure concerns (referred to as intertidal RALs) (see FS Table 8-1). Site-wide RALs were developed for 41 SMS COCs (which include two of the human health risk drivers, PCBs and arsenic) and two other human health risk drivers (dioxins/furans and cPAHs). Intertidal RALs were developed for three of the human health risk drivers (arsenic, dioxins/furans, and cPAHs). The site-wide PCB RAL for FS Alternative 5C is 12 milligrams per kilogram organic carbon (mg/kg oc) (the dry weight equivalent of this RAL is 240 micrograms per kilogram dry weight [µg/kg dw] assuming 2% total organic carbon) applied to the upper 10 cm of sediment throughout the site.[16]

For FS Alternative 5C, an intertidal RAL for PCBs in the upper 45 cm of sediment was not developed because the preliminary remediation goals (PRGs) for direct contact scenarios are achieved after remediation of the EAAs and other hot-spot areas (using Alternative 2 RALs). By achieving a total PCB concentration of 12 mg/kg oc in the surface sediment (upper 10 cm), the PCB PRGs for direct contact[17] would also be achieved (see Attachment 2 for details). Therefore, a human health PCB RAL was not developed to protect human health through direct contact with sediment because the PRGs for direct contact (the lowest being 500 µg/kg dw for tribal clamming) will be achieved by implementing the Alternative 5C RALs. However, there is concern that clamming, beach play, or other physical disturbance processes have the potential to expose contaminated subsurface sediments in intertidal areas in sufficient quantities to cause an increase in fish and shellfish tissue concentrations and thus affect the human health seafood consumption pathway. Therefore, a range of PCB intertidal RALs (applied to the top 45 cm of sediment) was developed for the Alternative 5C Plus scenarios (Table 4).

For the Alternative 5C Plus Base and Scenarios 1 through 3, the PCB intertidal RAL is 12 mg/kg oc, which is the same RAL that is applied to the top 10 cm of surface sediment. For this intertidal PCB RAL, the upper limit (UL) for ENR is reduced to 18 mg/kg oc (1.5 x SQS). Scenarios 4 and 5b use an intertidal PCB RAL of 195 mg/kg oc (3 x CSL). Scenario 5a uses an intertidal RAL of 65 mg/kg oc (CSL) for PCBs and the UL ENR is 97 mg/kg oc (1.5 x CSL). Note that all of these scenarios also keep the surface sediment PCB RAL of 12 mg/kg oc in the upper 10 cm of sediment for the protection of the benthic invertebrate community.

3.2 Alternative 5C Plus Element for Addressing Surface Sediment SMS Contaminants

Based on model predictions and empirical trends at many locations in the LDW, use of higher RALs (i.e., 2 times the SQS; Table 5) for ecological risk-driver COCs could still result in achieving the SQS in surface sediments less than 10 years after remedy construction. This higher RAL (2xSQS) for surface sediments would only be used for

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[16] In the FS, the upper limit for ENR (UL ENR) for Alternative 5C is three times the PCB surface sediment RAL, 36 mg/kg oc (which is approximately 720 µg/kg dw assuming a 2% total organic carbon content) in the upper 10 cm of sediment (in subtidal and intertidal areas).

[17] For 0- to 45-cm and 0- to 60-cm intervals, sediment COC concentrations will be averaged across the interval (i.e., it is not a point value but an average of values for the interval).

39 of the 41 SMS COCs, and would not be used for PCBs or arsenic; the two human health risk drivers with SMS numerical criteria. Additionally, this higher RAL (2xSQS) would apply only to surface sediments in Recovery Category 2 and 3 areas, which are predicted to recover, and would not apply to surface sediments in Recovery Category 1 areas, which are not predicted to recover. For the human health risk drivers, the Alternative 5C RALs[18] would be retained to address seafood consumption and direct contact risks, and would apply to all surface sediments in the LDW.

Using 2xSQS for the ecological risk-driver COCs (while applying the site-wide RALs for the human health risk drivers) provides a measureable threshold that can be applied during implementation of the remedy, while allowing MNR to achieve the SQS for the non-human health risk-driver COCs. The cleanup objective for all remedial alternatives for RAO 3 (protection of benthic invertebrates) is still based on achieving SQS in surface sediments, as required by the SMS, and these areas also include provisions for contingency actions (e.g., active remediation) if MNR is not effective.

The FS uses a model prediction of "SQS10"[19] to determine the areas of sediments amenable to natural recovery (the basis for FS Alternative 4C). In this memorandum, Scenarios 5a and 5b use a numeric value of 2 times the SQS to best approximate the exceedance concentrations that are predicted to recover to the SQS within 10 years by MNR.[20]

3.3 Development of Alternative 5C Plus Scenarios

The supplemental scenarios were developed through a two-step screening process over the course of several meetings with EPA and Ecology. In the first step, 13

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[18] These FS Alternative 5C site-wide RALs were: 12 mg/kg oc for PCBs, 57 mg/kg dw for arsenic, 1,000 µg TEQ/kg dw for cPAHs, and 25 ng TEQ/kg dw for dioxins/furans.

[19] SQS10 refers to areas where the model predicts sediments are expected to achieve the SQS within 10 years.

[20] In this Technical Memorandum, Scenarios 1 through 4 include only active remediation (i.e., no MNR) for all areas with RAL exceedances. Scenarios 5a and 5b do consider MNR as a remedial action for low-level exceedances of benthic risk drivers. The SMS allow for a 10-year natural recovery period following construction to achieve the SQS (WAC 173-204-570). Under Scenarios 5a and 5b, areas where natural recovery is likely (i.e., those areas with low-level or isolated exceedances of the SQS by non-human health risk drivers [i.e., the SMS contaminants]) would be designated for MNR. These MNR areas include increased surface sediment monitoring frequency (at a density of 4 samples/acre when sediments are above the SQS), with sampling occurring after construction at 2, 3, 5, 7, and 10 years and every five years thereafter (maximum of 30 years total used for cost estimating purposes). This sampling frequency is the same as used for MNR areas that were selected for other alternatives in the FS. Contingency actions (consisting of active remediation) would be required in these MNR areas if they have not recovered to the SQS within 10 years.

supplemental scenarios were proposed by EPA, Ecology, or LDWG. Several parameters were varied in the screening step, including subsurface sediment RAL concentrations, spatial areas, and the contaminant groupings. After reviewing the preliminary results with EPA and Ecology, five scenarios were retained for further evaluation in this memorandum to allow an assessment and comparison relative to FS Alternative 5C. These scenarios include Alternative 5C Plus base elements (dredging in shoaled areas, increasing long-term sediment monitoring, and increasing cap thickness in intertidal clamming areas), surface sediment RALs that incorporate MNR for a subset of scenarios, as well as the following subsurface and intertidal RALs added to Alternative 5C RALs (see Table 4 for scenario details):

- **Scenario 1:** A subsurface RAL of 3xAlt 5C RALs for PCBs and dioxins/furans (human health risk drivers[21]) and an intertidal PCB RAL of SQS
- **Scenario 2:** A subsurface RAL of the CSL (applied to all SMS contaminants), 3 times the Alt 5C RAL for dioxins/furans, and an intertidal PCB RAL of SQS
- **Scenario 3:** A subsurface RAL of 3 times the CSL (all SMS contaminants) and an intertidal PCB RAL of SQS
- **Scenario 4:** A subsurface RAL of 3 times the CSL only for PCBs and an intertidal PCB RAL of 3 times the CSL
- **Scenario 5:** A subsurface RAL of 3 times the CSL only for PCBs plus a surface RAL of 2 times SQS for 39 non-human health risk drivers in Recovery Category 2 and 3 areas. The sediment RALs for the four human health risk drivers (site-wide and intertidal) and for all risk-driver COCs in Recovery Category 1 areas remain the same as for Alternative 5C.[22] Scenario 5 also includes options 5a and 5b, which differ in the application of the PCB intertidal RAL. Scenario 5a applies an intertidal PCB RAL of CSL and 5b applies an intertidal PCB RAL of 3 times the CSL.

In addition, an intertidal PCB RAL of the SQS was also added to the Alternative 5C Plus base elements for evaluation (note this evaluation does not include a subsurface RAL).

[21] These two risk drivers have PRGs for seafood consumption pathway; PRGs for the other two risk drivers (arsenic and cPAHs) were not developed because clam tissue-to-sediment relationships based on the RI data for both were too uncertain (see Section 3 of the FS).

[22] In Recovery Category 1 areas, the site-wide RALs are applied to an evaluation depth of the upper 2 ft of sediment, which essentially is applying these as subsurface RALs in these areas.

Attachment 1 provides more details about the technology assignment assumptions made for these scenarios. If the average COC concentration in the upper 2 ft of a sediment core exceeds the subsurface sediment RAL, then the remedial technology assignment is either dredging, partial dredging/capping, or capping based on the technology assignment assumptions in the FS. ENR is not a candidate technology for these areas because the UL ENR is exceeded in all scenarios. More innovative technology assignments such as carbon amendments or ENR with scour mitigation were not considered in this analysis, but could be considered on a location-specific basis during remedial design. Areas with COC concentrations above the surface RALs follow the same FS technology assignments used for Alternative 5C (see FS Table 8-2, or FS Flow Chart Figures 8-1 and 8-2).

Figure 6 provides the locations of cores, Thiessen polygons associated with each core, and the exceedance status of each polygon in the upper 2 ft. This information was used to determine subsurface RAL exceedance areas for the scenarios. As discussed in Section 4.3, the low density of core stations is a key uncertainty in this analysis.

3.3.1 Spatial Extent of Application of the Subsurface Sediment RALs

The spatial extent of the subsurface sediment RAL application includes three considerations:

- **2-ft Depth of Predicted Scour.** The FS vessel scour model predicted scour depths from maneuvering vessels to be limited to about 25 cm (~1 ft) (Table 2). Evaluation of subsurface contamination within the upper 60 cm (2 ft) provides a significant safety factor to address this exposure concern, matches the resolution of core data, and accounts for deeper disturbance and scour events.
- **Potential Tug Scour Areas.** One factor that influences the extent of scour effects from maneuvering vessels is water depth. The energy generated by a propeller decreases exponentially away from the source and with water depth. In the LDW, the authorized depth in the navigation channel is -30 ft MLLW downstream of the 1st Ave South Bridge (RM 2.1), -20 ft MLLW upstream of the 1st Ave South Bridge to RM 2.8, and -15 ft MLLW upstream of RM 2.8 to the turning basin.[23] In the LDW, depths greater than -24 ft MLLW downstream of the 1st Ave South Bridge and depths greater than -18 ft MLLW upstream of the 1st Ave South Bridge are considered to have less potential for deep disturbance

[23] While these definitions using the 1st Ave South Bridge are descriptive, the actual boundary where the navigation channel transitions from -30 ft MLLW authorized dredge depth to -20 ft MLLW authorized dredge depth will be used during remedial design/remedial action. The actual boundary is located downstream of the bridge, and according to the USACE Seattle District Navigation Section, the coordinates are 201502.9575 and 1269582.2789 (NAD83/91). The station offsets (in ft) used by dredgers are 134+00,0.

effects. The -24 ft MLLW contour represents the deepest depth where scour could occur from the *Sea Valiant* (navigates only in Reach 1) during low tide (0 ft MLLW). The -18 ft MLLW represents the deepest depth where scour could occur from the *J.T. Quigg* (which navigates all reaches) during low tide (0 ft MLLW). Also, the shallowest depth that scour can occur is influenced by the draft of the vessels. In the LDW, depths shallower than about -4 ft MLLW are considered to have less potential for deep disturbance effects (although the intertidal areas may be subject to other forms of disturbance such as barge groundings during an ebbing tide or human use activity). For example, the *J.T. Quigg* has a vessel draft depth of 12.3 ft (navigates all LDW reaches), therefore, depths of about -1 to -4 ft MLLW represent the shallowest depth the tug could access during high tide. These factors were used to limit the extent of areas susceptible to deep disturbance. Figure 5 shows potential tug scour areas based on bathymetric elevation assumptions. All subsurface RALs considered in the scenarios above apply to subtidal sediments in potential tug scour areas.

- **Elevation of -4 ft MLLW Delineates Subtidal vs. Intertidal Areas.** The intertidal area has been defined in the FS as the area between +11.3 ft MLLW[24] down to -4 ft MLLW; subtidal areas are those areas deeper than -4 ft MLLW. Intertidal sediment RALs apply only to the areas above the -4 ft MLLW elevation.

3.3.2 Evaluation Depths and Points of Compliance

There are two points of compliance, expressed as depth below mudline, described in the FS and this memorandum: 1) the 0- to 10-cm depth or biologically active zone, applicable site-wide for human health seafood consumption pathway and for ecological receptors; and 2) the 0- to 45-cm depth applicable in intertidal areas for protection of human health direct contact. These points of compliance refer to the exposure interval that will be used to determine long-term compliance.

In intertidal areas, the point of compliance of 45 cm for direct contact with sediment is a health protective depth to ensure protection of human health in the intertidal clamming and beach play areas. This depth accounts for the potential exposure of children and of people clamming who may come into direct contact with sediment when digging in the intertidal area at low tide (FS Section 3). Also, this interval is a reasonable depth to address concerns about the potential exposure of contaminated

[24] In the HHRA, the intertidal areas, where clamming activities would likely occur, were limited to +6 ft MLLW because no evidence of clams were found above this elevation. Also note that +11.3 ft MLLW is the elevation to the top of the bank (see Section 4.3.5 of this memorandum).

subsurface sediments in the intertidal area due to physical disturbance from digging clams, playing in sediment, or from vessel operations in the LDW (EPA 2012b).

The other depth evaluated in the FS and this memorandum is the 0- to 60-cm (0 to 2 ft) "evaluation depth" interval, and is related to scour potential. Sediment concentrations in subtidal areas are averaged over a 0- to 60-cm depth interval and compared to the sediment RALs to determine if remedial actions are needed. An "evaluation interval" refers to any depth interval over which average COC concentrations are compared to RALs for the purpose of assigning remedial technologies.

For subtidal areas, the 0- to 2-ft interval is a reasonable evaluation depth for protectiveness from exposure to subsurface sediment contamination. As evaluated in the FS, the maximum depth of predicted scour was set at 2 ft based on model predictions of 25 cm maximum scour from maneuvering vessels (Table 3) plus a safety factor to address exposure concerns related to uncertainties in model predictions and empirical data. This depth matches the resolution of existing core data and accounts for potential deeper disturbance of contaminated subsurface sediments based on what is known about vessels operating under high-power and emergency conditions (see FS Appendix C Part 7, Appendix M Part 5 and EPA 2012b). As noted earlier, active remediation is already designated for all areas with subsurface RAL exceedances in the upper 2 ft of sediments in model-identified potential scour areas and where visible scars from scouring could be seen in bathymetric surveys (i.e., Recovery Category 1 areas). While imperfect in that the model assumptions used to estimate the depth of scour potential is highly uncertain (and therefore the error of model estimations is high for evaluating scour depth), and it is known that greater scour depths are possible during non-standard vessel operation, existing data and modeling output suggest that 2 ft is sufficient for protectiveness from exposure to subsurface sediment contamination (EPA 2012b). As a final note, based on the sediment data set from the RI/FS, the most highly contaminated sediments at deeper depths (e.g., greater than 2 feet, and often greater than 4 ft) are already being remediated in the EAAs or are proposed for dredging or capping in Alternative 5C.

3.3.3 Additional Refinements for Scenarios 3, 4, and 5

Additional refinements were developed to evaluate the differences in volume, costs, and benefits of the scenarios. These included:

- **Only PCBs (Rationale for Scenarios 4 and 5a/b).** Total PCBs are the dominant risk driver in the LDW. PCBs are of concern throughout the LDW for a number of exposure pathways and receptors. In addition, because the key concern is protection of human health for the seafood consumption pathway, the focus should be on how such disturbances affect the human health risk drivers, especially PCBs (expressed in long-term SWACs). Of over 500 sediment cores in the FS baseline dataset, only 15 cores with subsurface concentrations above the CSL for any SMS contaminant (in the upper 2 ft) are not remediated (dredged or capped) under Alternative 5C; 10 of these cores have exceedances of the CSL for total PCBs. PCBs are a good indicator contaminant to track in sediments and monitor recovery, recontamination, and potential for exposure of subsurface contamination over time. Because the primary long-term concern after remediation will be achievement of RAO 1 (human health seafood consumption), a subsurface RAL designed to protect against future disturbance and exposure of subsurface contamination that could elevate surface sediment SWACs focuses on the human health risk drivers, specifically PCBs. A subsurface sediment RAL based only on PCBs would achieve protectiveness for the other human health risk drivers with PRGs for the seafood consumption pathway (i.e., dioxins/furans).

- **Subsurface RAL of 3 times the CSL in Recovery Categories 2 and 3 (Rationale for Scenarios 3, 4, and 5a/b).** The purpose of a subsurface sediment RAL is to reduce the potential for buried contamination being exposed in areas subject to disturbances. As noted above, all scenarios (and all alternatives in the FS) already have subsurface RALs (called RALs in the FS) in areas with evidence of scour (Recovery Category 1 areas). In Recovery Category 2 and 3 areas, a higher subsurface RAL is reasonable because long-term natural recovery trends have been empirically observed in many areas (See FS Appendix F), consistent with the conceptual site model suggesting that recovery for benthic invertebrates would occur. These empirical trends indicate that deposition and burial are active processes in many areas of the LDW and the sediment bed is relatively stable. For the rationale for these scenarios, areas with more stable sediment (i.e., Recovery Category 2 and 3 areas) would be remediated primarily based on surface sediment concentrations, with a higher RAL in the subsurface (i.e., 3xCSL) only for additional protectiveness in case of emergency disturbance events.

- **Surface RAL of 2 times the SQS (Rationale for Scenario 5 a/b).** Scenarios 5a and 5b include a modification to Alternative 5C that assumes higher surface sediment RALs for non-human health risk-driver COCs in Recovery Category 2 and 3 areas. This modification allows MNR to be used where SMS contaminants are at moderate concentrations, and allows for the focused removal of the most persistent contaminants in the waterway (e.g., PCBs) while capitalizing on natural sedimentation processes to optimize the natural recovery within the waterway. MNR was not applied in Recovery Category 1 areas; the RAL of the SQS was used in these areas because these areas are more prone to scour and less likely to recover naturally. MNR was applied only to areas in Recovery Categories 2 and 3 where sediments are below 2 times the SQS for non-human health risk-driver COCs.

4.0 Evaluation of the Alternative 5C Plus Scenarios

This section presents results of the evaluation of the Alternative 5C Plus Scenarios. All the Alternative 5C Plus Scenarios start with FS Alternative 5C as a base, then add in the 5C Plus elements. Remedial technology assignments, volumes, construction time frames, and costs were all calculated using the same methodology as the FS, with modifications for the Plus elements. Attachment 1 describes the methods used to develop the scenarios in detail. Figures 8a through 8g map the remedial technology assignments for Alternative 5C Plus and Scenarios 1 through 5 respectively. Tables 6a through 6h summarize the subsurface statistics for remaining contamination. Figure 9 presents PCB summary statistics for contamination remaining in the subsurface sediments after remediation. Figure 10 presents the PCB SWAC, assuming some portion of the LDW is continually disturbed. The evaluation results are discussed below.

4.1 Estimated Acres, Volumes, Cost, and Construction Time

Alternative 5C, as represented in the FS, actively remediates[25] 157 acres out of 441 acres of the LDW in-water study area and includes a combination of dredging, capping, ENR, institutional controls, and long-term monitoring (including verification monitoring[26]). Construction is estimated to take 7 years at a present value cost of $290 million.[27] Supplemental Scenarios 1 through 4 are estimated to actively remediate up to approximately 24 percent more area (up to a total of 195 acres) with estimates of additional costs ranging up to $67 million (Table 5). Scenario 5b, which includes 28 acres of MNR, actively remediates slightly fewer acres (139 acres) than FS Alternative 5C but costs are similar ($289 million). This is because Scenario 5b dredges or caps more areas with subsurface contamination while allowing for natural recovery for low level SQS surface sediment exceedances, resulting in slightly less dredge volume compared to Alternative 5C. Scenario 5a also includes MNR, but assumes a lower PCB RAL (the CSL) in the intertidal areas compared to Scenario 5b. Scenarios 5a and 5b target more dredging and capping for PCB subsurface contamination than FS Alternative 5C and have higher performance contingency volumes compared to the other scenarios because they use MNR to achieve the SQS in some areas. Fifteen percent of the MNR footprint (same assumption as used in the FS) under Scenarios 5a and 5b is assumed to require contingency actions to meet the SQS because natural

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[25] "Active remediation" refers to ENR, capping, or dredging.

[26] "Verification monitoring" refers to areas above the SQS in surface sediment in the FS baseline dataset, but are predicted to be below the SQS at the time of remedial design sampling.

[27] The $95 million to clean up the in-water portion of the five EAAs is not included in this cost estimate.

recovery is not occurring at the rate required to achieve the SQS within 10 years (dredging is assumed for costing purposes, but a range of contingency actions are possible). In addition, Scenarios 5a and 5b have higher monitoring costs than the other scenarios because areas labeled as "MNR" have higher monitoring density (4 samples/acre) than areas labeled as "site-wide monitoring" or the "rest of the LDW" which had a monitoring density of verification monitoring 1 sample/acre.

Table 8 shows the contribution of each Alternative 5C Plus element to the estimated cost increase over that for the FS Alternative 5C. Applying a PCB intertidal RAL of the SQS to a 45-cm point of compliance incrementally adds about $16 million to the estimated cost of Alternative 5C. However, the uncertainty around this value is quite large, because of the limited data for PCBs at depth in intertidal areas and the spatial techniques used to determine the horizontal extent of contamination (see uncertainty discussion). The cost for this element alone could range up to $40 million if more conservative assumptions are applied. Other elements contributing to large portions of the incremental cost increases are the dredging of navigation channel shoaling areas exceeding the SQS ($17 million) and applying the subsurface sediment RAL (up $42 million).

4.2 Comparative Evaluation of the Scenarios

4.2.1 Threshold Criteria

The two threshold criteria are: 1) overall protection of human health and the environment and 2) compliance with applicable or relevant and appropriate requirements (ARARs). Like FS Alternative 5C, the Alternative 5C plus scenarios are each predicted to achieve the threshold criterion of overall protection of human health and the environment through varying combinations of engineering controls, natural recovery, and institutional controls. Institutional controls are required to provide additional protectiveness for people who consume resident seafood, although the effectiveness of these controls is unknown.

Like FS Alternative 5C, it is unlikely that any of the Alternative 5C Plus scenarios would fully comply with MTCA's requirement of natural background PRGs when risk-based goals are below natural background[28] and water quality ARARs. CERCLA requires that all ARARs be met or waived on any one or more of six bases upon completion of remedial actions. By far, the most common waiver has historically been for technical impracticability. The goal in all instances where predictions are that ARARs may not be achieved is to get as close as technically practicable to the ARAR,

[28] PRGs set to natural background are unlikely to be met in the urban environment of the LDW under any remedial alternative or scenario.

and apply a waiver only to the extent necessary. Because future conditions are difficult to predict, actual data available upon completion of the remedial action will underlie the basis for any such waivers, which are formally documented and issued by EPA.

4.2.2 Balancing Criteria

The scenarios represent incremental changes to FS Alternative 5C. To evaluate the cost and benefits of these changes among the scenarios, several analyses were completed using the CERCLA balancing criteria. The evaluation criteria are the same as used in the FS (see Table 10-1 of the FS) and the scenarios as well as 5C Plus base elements are evaluated relative to FS Alternative 5C with reference to other FS alternatives for context. The same criteria are used to compare the supplemental scenarios as were used in the FS (Section 10). To compare the supplemental scenarios with the FS Alternatives, Table 11 can be compared to FS Table 10-1.

The BCM was used to predict future surface sediment SWACs for the scenarios. The BCM predicts that all the scenarios achieve similar SWACs for the four human health risk drivers (PCBs, arsenic, cPAH, and dioxins/furans) in varying time frames with varying degrees of uncertainty (Table 9). As discussed in the FS, BCM inputs are dominated by the incoming sediment from the Green/Duwamish River, and do not consider the potential for subsurface sediments to become exposed at the surface by unanticipated disturbance events. Thus, predicted average concentrations of COCs in the long term are more sensitive to the concentration of incoming upstream sediment than to the area remediated, and are insensitive to the depth or COC concentration in subsurface sediments. For these reasons, the predicted future concentrations of COCs in surface sediments tend to converge.

Table 10 shows two predicted model results for the SMS COCs: the percentage of FS dataset stations and the percentage of the LDW surface sediment area predicted to comply with either the SQS or CSL, are calculated as area-based metrics and are charted as a function of time. Results show that all scenarios, including Scenarios 5a/b that allow for MNR, are predicted to be reduced to a level at or below the SQS within 5 years after the start of cleanup. FS Alternative 5C and Scenarios 1 through 4 have no point exceedances in surface sediments after active remediation because the RAL is the SQS. Scenarios 5a and 5b have a few predicted point exceedances but they are for phthalates located near outfalls. Sediment recontamination is predicted for these contaminants in localized areas because of the ongoing contributions from lateral loads (e.g., sediment coming into the LDW from stormwater and combined sewer overflow discharges).[29]

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[29] Scenarios 5a and 5b exhibit an increase in the estimated number of SQS/CSL exceedance stations from year 5 to year 10, but the other scenarios do not. This is primarily due to the way those exceedances were

A metric for evaluating the potential for exposure of subsurface sediment contamination is the amount of contamination remaining in the subsurface sediments after remediation, expressed in this memorandum as: 1) the number of cores remaining in the subsurface sediments, 2) number of acres of sediments available for disturbance, and 3) PCB concentration statistics in the upper 2 ft of sediments, grouped by recovery category. Tables 6a through 6h provide summary statistics for these three metrics for Alternative 5C, Alternative 5C Plus Base and Scenarios 1 through 5, respectively. The average concentrations and number of sediment cores remaining in Recovery Category 1 areas do not change significantly for the scenarios because FS Alternative 5C already targets those areas for cleanup. In Recovery Categories 2 and 3 areas, the post-construction average PCB concentrations range from 238 µg/kg dw (Scenario 1) up to 373 µg/kg dw (Scenario 5), and all average concentrations are below the Alternative 5C average concentration of 399 µg/kg dw for PCBs. Figure 10 provides a side-by-side comparison of sediment core statistics across the entire waterway for the scenarios. The figure indicates small differences in the average concentrations of contaminants across the range of scenarios.

Table 11 summarizes the CERCLA threshold and balancing criteria for Alternative 5C, Alternative 5C Plus Base, and all the scenarios, based on the analyses completed as part of this memorandum. For the threshold criteria of Overall Protectiveness and Compliance with ARARs, all the scenarios are similar to FS Alternative 5C.

4.2.2.1 Long-Term Effectiveness and Permanence

While Scenarios 1 through 5 differ somewhat in the degree to which they rely on dredging, capping, ENR, and MNR to reduce surface sediment concentrations and associated risks, they are all predicted to achieve human health and ecological risks similar to Alterative 5C. They do differ in their long-term effectiveness and permanence based on the areas with remaining subsurface contamination. The relative magnitude and type of residual risk that would remain in the LDW after implementation of each alternative is dependent on the potential for future exposure of subsurface contamination. Therefore, alternatives that remove or cap more contamination will rank higher for long-term effectiveness and will have a lower potential for subsurface sediment to be exposed than alternatives emphasizing ENR and MNR.

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calculated. If a station location is actively remediated, then it is assumed to be below the SQS for the duration of the 30-year model period. If a station is not actively remediated, then the BCM model is used to predict future surface sediment concentrations and exceedances. All scenarios are predicted to have localized recontamination above the SQS as a result of ongoing contaminant inputs from lateral sources (see FS Appendix J). However, SQS exceedances predicted after remediation (via recontamination) were not included in the station counts.

As discussed in the FS, Alternatives 4R, 4C, 5C, and 6C rank the same (4 out of 5 stars) for long-term effectiveness relative to the other FS alternatives because they have similar areas managed by ENR and MNR (and thus more subsurface sediment contamination), and similar monitoring and maintenance requirements. Alternative 5C removes approximately 750,000 cy of contaminated sediment and the scenarios remove 740,000 cy (Scenario 5b) up to 960,000 cy (Scenario 2) of sediment. Scenarios with larger dredge volumes are expected to leave less contaminated sediment in place relative to FS Alternative 5C and therefore have a lower potential for subsurface contaminated sediment to be exposed from potential disturbance events. However, the increments are relatively small among the scenarios and rank the same as FS Alternative 5C relative to the array of FS alternatives. For comparison purposes, FS Alternative 4C removes 690,000 cy, Alternative 4R removes 1,200,000 cy, and Alternative 6C removes 1,600,000 cy.

All the scenarios have similar relative rankings for monitoring and maintenance because they all require long-term monitoring of a large area, ranging from 100 to 114 acres, which is approximately 25 percent of the entire site. Similar seafood consumption advisories, public outreach, and education programs are required for Alternative 5C and all the Alternative 5C Plus scenarios.

To evaluate possible differences in the magnitude of the residual risk (expressed as SWAC values for the four human health risk drivers) between the scenarios and Alternative 5C, an additional analysis was conducted to address the potential for vessels maneuvering under emergency and high-power operations to expose subsurface sediment contamination. In the long term, exposure of subsurface contamination by mechanical disturbances (e.g., propeller scour) may occur as a series of localized events. Localized risks to benthic organisms could occur in these instances both from the physical disturbance and the exposed subsurface contamination. The overall impact of multiple events on residual risks that are based on SWACs (e.g., seafood consumption risks) is difficult to predict but could result in differences among the alternatives that are not made evident by the BCM, which predicts similar long-term outcomes for all alternatives. Although the degree and duration of this type of disturbance is not known, the potential magnitude of effects from these disturbance mechanisms increases with increasing COC concentrations, with larger areas of subsurface contamination, and with decrease in depths to contamination below the mudline. The impacts were assumed to be proportional to the total area disturbed and the subsurface sediment concentrations.

The scenarios assumed that the total area that could be accessed by large draft vessels is approximately 200 acres. Figure 10 plots the long-term model-predicted PCB SWAC as a function of area continually disturbed. Figure 10 shows small incremental decreases in the predicted long-term SWAC based on Scenarios 1 through 5 relative to FS Alternative 5C, with those differences increasing if larger areas of the waterway are assumed to be frequently disturbed. These small changes in SWAC are unlikely to decrease the seafood consumption risks for PCBs predicted for Alternative 5C.

In summary, Scenarios 1 and 2 remove the most subsurface contamination among the supplemental scenarios presented in this memorandum and therefore would rank highest in long-term effectiveness and permanence relative to Scenario 5b and Alternative 5C. All other scenarios remove an intermediate amount of sediment.

4.2.2.2 Reduction in Mobility, Toxicity, and Volume

The scenarios are also similar to Alternative 5C for reductions in mobility, toxicity, and volume because the scenarios do not include any *ex situ* treatment and have only minor differences from Alternative 5C (3 acres or less) in the areas using *in situ* treatment as a component of ENR.

4.2.2.3 Short-term Effectiveness

Scenarios 1 through 5 differ in their short-term effectiveness because the dredging volumes for the scenarios vary by up to 30% from Alternative 5C. Dredging volumes are a surrogate for short-term impacts and construction times. Scenario 5b has the shortest construction time (6 years). Scenarios 5a and 5b impact the least amount of ecological habitat and have relatively fewer air quality impacts compared to the other scenarios. Scenarios 5a and 5b focus additional dredging on the human health risk drivers while allowing natural recovery to protect benthic organisms in areas where non-human health risk drivers are within 2 times the SQS. Scenarios 1 through 3, increase the construction time by 50% over Scenario 5b (three additional years), creating more short-term impacts by extending the construction period while providing no significant additional long-term reduction in average contamination concentrations or risks to people and wildlife. The extended construction period is predicted to result in elevated fish tissue concentrations and risks related to seafood consumption during this period. The time to achieve the cleanup objectives is similar among the scenarios with Scenarios 5a and 5b predicted to achieve some cleanup objectives a year or two sooner than the other scenarios. The time to achieve cleanup objectives for RAO 1 is predicted to be the same for each scenario.

4.2.2.4 Implementability

In general, the potential for technical problems and schedule delays increases in direct proportion to the duration, complexity, and amount of active remediation. Scenarios 1 and 2 have the most stringent (i.e., lower) subsurface and intertidal sediment RALs and require more dredging and capping than Scenarios 4 and 5. Scenarios 1 and 2 are therefore more complex, have longer construction periods, and require more administrative coordination than Scenarios 4 and 5 (and Alternative 5C).

The reliability of the remedial technology and the relative ease of undertaking additional remedial actions after construction of the remedial alternatives are also important to consider in the comparative evaluation of alternatives. Alternatives that rely less on dredging and capping (i.e., Scenario 5) to achieve cleanup objectives have a higher potential for requiring contingency actions in the future because they include more MNR where future active remediation may be required if recovery does not occur. Scenarios 3 and 4 have the lowest area of monitoring and maintenance of all the scenarios.

4.2.2.5 Costs

FS Alternative 5C has an estimated net present value cost of $290 million. Scenarios 1 and 3 are the most expensive with estimated net present value costs of $357 and $358 million. Scenario 5b has the lowest net present value cost ($289 million). Table 7 presents costs for all the Alternative 5C Plus scenarios both as net present value and nondiscounted costs. Scenarios 1 through 3 assume an intertidal RAL of the SQS and therefore have a higher cost uncertainty than Scenarios 4 and 5.

4.3 Uncertainty of Assumptions

All of the results presented in this memorandum have some uncertainty. The assumptions used in this analysis may require further adjustment for consideration in the Proposed Plan, especially for mapping the extent of contamination and technology assignments. Attachment 1 provides detailed information on the methods used to estimate areas, volumes, construction time frames, and costs. Some of the larger sources of uncertainty are discussed below.

4.3.1 Estimated Extent of Subsurface Contamination

The estimated extent of subsurface contamination is the largest area of uncertainty in this analysis. While the surface sediment dataset is comprehensive, the subsurface sediment dataset (i.e., cores) does not have the spatial resolution to discern fine details. In particular, a significant area of uncertainty is the cost related to the intertidal PCB RAL (see Table 6). Costs were estimated at $16 million for the lower RAL and $2 million for the higher RAL; however, costs for the lower RAL could range up to approximately $40 million because of uncertainty associated with low core density in intertidal areas.

Several simplifying assumptions were made for this analysis to develop reasonable estimates of dredge volumes and costs. The extent of subsurface contamination was represented by Thiessen polygons for each core in the FS baseline dataset, extending over the entire 441 acres of the LDW. Although the Thiessen polygons were used to estimate subsurface concentrations across the entire LDW, subsurface RAL exceedances triggered active remediation only in applicable areas (e.g., outside of EAAs). The maximum concentrations in the upper 2 ft of cores were compared to subsurface RALs. Alternative 5C Plus Scenarios 1 and 2 used the full polygons to delineate the extent of subsurface contamination. See Figures 6 and 7 to see how the spatial extent of Thiessen polygons was limited by area of potential concern (AOPC) 1. For Scenarios 3 through 5, where the subsurface RAL is higher, the polygons were limited to the AOPC 1 footprint.[30] This step was applied to limit the area of influence associated with very high subsurface concentrations. Based on the existing dataset, the areas outside of AOPC 1 are less likely to have very high concentrations at depth. See Figure 11 for an example of how this was performed. While this is a reasonable assumption for evaluation purposes, it is possible that this "limiting" step is actually under-representing the extent of contamination given the limits of the core dataset.

This same concept was applied to the intertidal RAL for PCBs, except that even fewer cores have been collected in intertidal areas. The extent of subsurface contamination in intertidal areas is more uncertain. The spatial extent of Thiessen polygons (based on sediment cores) were limited to areas with surface sediment concentrations of total PCBs greater than 100 µg/kg dw (approximately the AOPC 2 footprint), then compared to the intertidal RALs in intertidal areas. This adjustment reduces the size of the subsurface intertidal exceedance footprint by over 50%. Since the spatial extent of subsurface contamination is more uncertain (as a result of fewer cores), it is important to note that the cost of remediation in these areas could range up to $40 million (if using an intertidal RAL of SQS) if the surface sediment concentrations were not limited and if the subsurface core polygons adequately represent PCB subsurface contamination in intertidal areas.

4.3.2 GIS Mapping of Technology Assignments

A geographic information system (GIS) mapping process was used for assigning remedial technologies and mapping remedial areas; however, the GIS output includes slivers and patches of contamination that do not represent realistic cleanup footprints.[31] The FS managed this uncertainty by applying best professional judgment (BPJ) to refine these areas and apply a minimum cleanup footprint size of about 100 ft by 100 ft. The Alternative 5C Plus scenarios presented in this memorandum have not had the BPJ refinement step. This refinement step could change the active acres by about ±10% based on previous FS experience.

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[30] AOPC 1 is delineated in the FS by surface sediment concentrations >FS Alternative 5C RALs.

[31] Very small areas are unlikely to be dredged because of the effort involved in mobilizing equipment. The average barge size operating in Puget Sound is about 80 ft long and 40 to 50 ft wide for dredge equipment and material handling. Based on these barge sizes, the FS assumed a minimum cleanup footprint size of about 100-by-100 ft.

4.3.3 Vertical Averaging of Concentrations

In the remedial design phase, the average concentration of a contaminant over the applicable evaluation depth interval (60 cm in subtidal areas, and 45 cm in intertidal areas) in a sediment core would be compared to the subsurface sediment RAL. For this analysis, the maximum concentrations of contaminants over the nominal 2-ft interval were used instead because of how the data are organized. When only a 60 cm sample interval was available, the maximum concentration would be the same as the average for the interval, but when 6-inch or 1-ft intervals were available, the maximum concentration within the upper 60 cm was used. This assumption could be over-estimating the area required for cleanup. In practice, future sediment data would be collected over the 0- to 10-cm interval for surface RAL evaluations throughout the entire site, over the 0- to 45-cm interval for subsurface RAL evaluation in the intertidal area, and over the 0- to 60-cm interval for subsurface RAL evaluation in the subtidal area.

4.3.4 Disturbance Areas

Two types of uncertainty in the subsurface sediment disturbance analysis (Figure 10) may affect surface sediment predictions: 1) the available cores in AOPCs 1 and 2 may not be representative of subsurface sediment conditions over these broad areas and therefore contribute to uncertainty in the mean subsurface sediment concentrations used in the analysis, and 2) a lack of information on how much of the LDW might be affected by disturbances caused by vessels maneuvering under emergency and high-power conditions or by earthquakes. FS Appendix M Part 5 provides the assumptions used and the limitations of this analysis. Several relevant factors were not included in this analysis that could mitigate the increases in SWAC, including the spatial distribution of potential disturbance events, the deposition of material from natural sedimentation or sand from ENR/*in situ* material placement, repeated events over the same area, or adaptive management.

4.3.5 Extent of Intertidal and Clamming Areas

For human health direct contact, the exposure areas of concern in the nearshore areas (accessed on foot) are the clamming areas (105 acres; 91 acres excluding EAAs) and the eight beach play areas (44 acres; 39 acres excluding EAAs) in the intertidal area. The FS assumed people might access any intertidal area in the future and included RALs to protect for direct contact in all intertidal areas. For mapping purposes, the FS also extended these areas to the top of bank at +11.3 ft MLLW. Intertidal RALs are applied to areas between +11.3 ft down to -4 ft MLLW. It is possible that these scenarios overestimated the amount of contamination requiring remediation in the intertidal areas because the intertidal area was simply extended up to the top of bank, without delineating areas with riprap or other structural foundations or areas without accumulations of fine-grained sediment. However, at the same time, limited sediment data for the 0- to 45-cm depth interval in the intertidal areas might also lead to an underestimate of the active remedial areas based on the intertidal RALs.

4.3.6 Additional Technology Considerations

The FS and this memorandum use dredging, capping, ENR, and MNR as the array of remedial technologies to clean up contaminated sediment in the LDW, reduce the potential for disturbance and exposure of subsurface contamination, and reduce future surface sediment concentrations. However, during remedial design and potentially in the Proposed Plan, other cost-effective remedial technologies could be considered that would achieve the same cleanup objectives. Many of these technologies, such as scour mitigation, carbon amendments or other *in situ* treatment for ENR or sediment caps, and thicker sediment caps have been effective at other sediment cleanup sites. These technologies could reduce the bioavailability of contaminants in targeted areas of concern (the biologically active zone and intertidal direct contact exposure areas) for the same cost-benefit.

This memorandum provides a range of potential refinements to Alternative 5C that attempt to address key uncertainties and limitations identified by EPA, Ecology, and LDWG. The refinements provide an added level of conservatism over FS Alternative 5C, while maintaining a certain degree of flexibility in the selection of remedial strategies to address subsurface contamination that will remain in place following implementation of the cleanup. These refinements also optimize an efficient cleanup of the LDW by considering MNR for non-human health risk-driver SMS contaminants where applicable to achieve the SQS within 10 years following construction and balance potential short-term impacts to the gains in long-term protectiveness.

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Tables

Table 1 Areal Extent of Intertidal, Clamming, and Beach Play Areas Used in the FS

Area	Size of Area Used in FS (excludes EAAs) (acres)	Elevation Range (MLLW)	Original Source of GIS Layer
Total Intertidal	113	+11.3 ft to -4 ft	n/a
Clamming	91	~ +11.3 ft to -4 ft (FS)	HHRA Map B.3-2
Beach Play (eight beaches combined)	39	n/a (based on assessment of public access and use)	HHRA Map B.3-1

Notes:

1. The top of bank is +11.3 ft MLLW
2. Clamming access was visually mapped in the field but generally extends down to -4 ft MLLW. Some mapped clamming areas may extend into deeper areas based on inconsistencies between bathymetric data and observations made during the clam surveys.
3. The public use survey conducted during the RI did not observe clams in all of the intertidal areas (e.g., upper reaches where the salinity is too low to support clams) and the presence of clams were limited to the +6 ft MLLW elevation. The elevation range for clams is approximately +6 ft to -4 ft MLLW.
4. The FS Alternatives apply to 113 acres of intertidal areas, which excludes the 15 acres of intertidal area in the early action areas. There are 128 acres of intertidal areas in the LDW: 15 acres in early action areas, 11 acres in Recovery Category 1 areas, and 102 acres in Recovery Category 2 and 3 areas.

EAA = early action area; FS = feasibility study; GIS = geographic information system; HHRA = Human Health Risk Assessment (Windward 2007); LDW = Lower Duwamish Waterway; MLLW = mean lower low water; n/a = not applicable; RI = remedial investigation

Table 2 Potential Mechanisms for Exposure of Subsurface Sediment Contamination

Exposure Mechanism	LDW-Specific and Location-Specific Considerations	How Addressed in FS Alternative 5C	Potential Ways Exposure Concerns Could be Addressed Beyond FS Alternative 5C
General Exposures	Unspecified	a) High surface sediment contaminant concentrations are dredged or capped. Because high subsurface sediment contaminant concentrations are often co-located with high surface sediment contaminant concentrations, this results in high subsurface sediment contaminant concentrations also being dredged or capped (e.g., see Figure 3). b) RALs applied to the upper 2 ft of sediment in Recovery Category 1 areas (77 acres LDW-wide) which include potential vessel scour based on bathymetric evidence, proximity to berths, and model-predicted high-flow scour area. c) Monitoring of surface sediment contaminant concentrations in ENR areas is 4 samples/ acre; therefore, a maximum single-event scour footprint sufficient to substantially increase surface sediment contaminant concentrations (that would not be detected) is about ¼ acre. d) Periodic bathymetric surveys can identify large changes in mudline elevations (ridges and furrows).	a) Intertidal: Implement a subsurface RAL for PCBs and/or SMS contaminants and reduce the associated upper limit for ENR. b) Subtidal: implement a subsurface RAL in addition to the RALs applied in Recovery Category 1. c) Increase monitoring in all areas with subsurface sediment contamination.
Intertidal Areas: +13 ft to -4 ft MLLW (113 acres)			
Boat Activity – Vessel Scour	In shallow areas, limited to prop scour from small vessels.	45-cm point of compliance depth for RALs based on direct contact (arsenic, cPAHs, and dioxins/furans).[a] Reduced upper limit for ENR to 1.5 x RAL for RALs based on direct contact (arsenic, cPAHs, and dioxins/furans) See "General Exposures" above.	Same as "General Exposures" above.
Boat Activity – Barge Grounding	Compression of intertidal sediments.	Same as above.	Same as "General Exposures" above.
Children/Adults Playing/ Digging on Beach	Only beach play areas.	Same as above.	Risk pathway is sufficiently addressed in the FS. Potential disturbance concerns – same as "General Exposures" above.
Clamming	Only clamming areas.	Same as above.	a) Same as "General Exposures" above. b) Increase cap thickness in clamming areas to ensure that cap effectiveness is not compromised during clamming.
Maintenance Activities (e.g., pulling piles, facilities repairs, USACE permit activities)	More likely to occur near established overwater structures in nearshore areas.	Partially addressed by permitting, BMPs, and ICs, but requires interagency cooperation. Partially addressed by "General Exposures" above.	Increase sediment removal in areas with potential maintenance activities. Develop an interagency coordination position.
Bank Erosion	Nearshore	Bank stability assumed to be addressed during remedial design.	Assumed to be adequately addressed by FS Alternative 5C.

Table 2 Potential Mechanisms for Exposure of Subsurface Sediment Contamination (continued)

Exposure Mechanism	LDW-Specific and Location-Specific Considerations	How Addressed in FS Alternative 5C	Potential Ways Exposure Concerns Could be Addressed Beyond FS Alternative 5C
Erosion from Outfall Discharges	Nearshore	a) Ongoing erosion is already expressed by baseline surface sediment concentrations. b) Cap armoring assumed where necessary.	Assumed to be adequately addressed by FS Alternative 5C.
Anchor Drag	Limited by size of anchor – large vessels do not anchor in the LDW, they typically tie-up to fixed structures or spud. Small vessels could create anchor penetration of up to ~45 cm deep for a fully engaged anchor. Anchor drag would be created by unengaged anchors and be significantly shallower. In intertidal areas, this would be limited to small boats anchoring during high tide with small anchors or anchoring of gillnets during tribal fishing activities.	Same as "Boat activity – vessel scour" above. See "General Exposures" above.	Same as "General Exposures" above.
Boat/Barge Activity – Spudding	Could occur LDW-wide, but more likely to occur near berthing areas. Spudding is when steel pipes are pushed into sediment.	When pulled, sediment tends to collapse on itself. In practice, not a large source of disturbance. Partially addressed by "General Exposures" above.	Same as "General Exposures" above.
Earthquake/ Tsunami	Potentially LDW-wide, the environmental damage due to a large event is highly unpredictable and event specific. Low likelihood of occurrence but large potential effects, including new contaminant inputs from upland sources.	a) Partially addressed by "general exposures" above. b) Slope stability will be considered during design in capping areas. c) Incorporates provisions that areas of disturbance resulting from large events will be repaired post-event.	Same as "General Exposures" above.
Subtidal Areas: deeper than -4 ft MLLW			
Boat Activity – Vessel Scour	Propeller scour from large vessels. Not likely to occur in deep areas (e.g., deeper than -24 ft MLLW north of the 1st Ave South Bridge and -18 ft MLLW south of the 1st Ave South Bridge). Below these water depths, the scour depth is predicted by the Maynord model to be less than 1 ft during extreme emergency operations, and significantly less than 1 ft during routine operations. Most likely to occur near berthing areas and identified scour areas.	a) Dredging and/or capping applied in areas prone to scour (Recovery Category 1 areas). RALs applied to upper 2 ft (also considered a subsurface RAL). No ENR in these areas. b) Estimated scour depths from maneuvering vessels is about 25 cm depth; a safety factor was applied down to 60 cm (2 ft). c) Cap armoring, where appropriate, as determined during remedial design.	a) Same as "General Exposures" above, b) Implement a subsurface RAL (in addition to the one used in Recovery Category 1 areas) at elevations that are more likely to have scour effects reach the mudline and cause disturbance.

Table 2 Potential Mechanisms for Exposure of Subsurface Sediment Contamination (continued)

Exposure Mechanism	LDW-Specific and Location-Specific Considerations	How Addressed in FS Alternative 5C	Potential Ways Exposure Concerns Could be Addressed Beyond FS Alternative 5C
High-flow Scour	High-flow scour areas.	Same as "boat activity – vessel scour" above.	Same as "boat activity – vessel scour" above.
Maintenance Dredging	In and near navigation channel and berthing areas.	Clearance requirements for ENR and capping, assuming appropriate side-slopes and dredge tolerance. Technology assignments incorporate consideration of shoaling in navigational areas.	Add a provision that subsurface contamination in shoaling areas (areas where the bathymetric elevation is above the authorized navigation depth) will be environmentally dredged.
Maintenance Activities	Same as intertidal areas.	Same as intertidal areas.	Same as intertidal areas.
Anchor Drag	Limited by size of anchor – large vessels do not anchor in the LDW, they typically tie-up to fixed structures or spud. Small vessels could create anchor penetration at depth for a fully engaged anchor. Anchor drag would be created by unengaged anchors and be significantly shallower.	a) In Recovery Category 1 areas (recovery limited): RALs are applied to upper 2 ft. b) In Recovery Categories 2 & 3 (recovery predicted to occur): partially addressed by "General Exposures" above.	Very small potential exposure areas because of the small size of anchors of vessels that anchor in the LDW, and the shallow depth of an unengaged anchor.
Boat/Barge Activity – Spudding	Could occur LDW-wide, but more likely to occur near berthing areas. Spudding is when steel pipes are pushed into sediment.	When pulled, sediment tends to collapse on itself. In practice, not a large source of disturbance. Partially addressed by "General Exposures" above.	Assumed to be adequately addressed by FS Alternative 5C.
Earthquake/Tsunami	Same as intertidal area.	Same as intertidal area.	Same as intertidal area.

Source: Table based on EPA 2012a.

Notes:

a. The 45-cm point of compliance in intertidal areas was applied in the FS only to human health direct contact (RAO 2) risk drivers and cleanup objectives. Intertidal RALs were only developed in the FS for RAO 2 cleanup objectives for arsenic, cPAHs, and dioxins/furans. A RAL for PCBs was not developed because the RAO 2 cleanup objectives for PCBs were achieved through conducting cleanups in the EAAs and hot spot removal actions as represented by FS Alternative 2.

b. The 10^{-6} RBTCs for human health direct sediment contact RME exposure scenarios for risk drivers are:
   a. Arsenic (mg/kg dw): 3.7 (netfishing); 2.8 (beach play); 1.3 (tribal clamming)
   b. cPAHs (µg/kg dw): 380 (netfishing); 90 (beach play); 150 (tribal clamming)
   c. Dioxin/furans (ng/kg dw): 37 (netfishing); 28 (beach play); 13 (tribal clamming)
   d. Total PCBs (µg/kg dw): 1,300 (netfishing); 1,700 (beach play); 500 (tribal clamming)

   Note: natural background estimates for arsenic are above the RBTCs for all direct contact RME exposure scenarios.

AOPC = area of potential concern; BMPs = best management practices; C = combined technology; CAD = contained aquatic disposal; cm = centimeter; cPAH = carcinogenic polycyclic aromatic hydrocarbon; cy = cubic yards; EAA = early action area; ENR = enhanced natural recovery; IC = institutional control; LDW = Lower Duwamish Waterway; MLLW = mean lower low water; MM = million; MNR = monitored natural recovery; n/a = not applicable; R = removal emphasis; RAL= remediation action level; RBTC = risk based threshold concentration; RME = reasonable maximum exposure; SMS = Sediment Management Standards; SQS = sediment quality standard; UL = upper limit; USACE = U.S. Army Corps of Engineers; VM = verification monitoring

Table 3 Estimated Depths of Scour from Vessel Operations

Tug	Applicability	Water Depth	Approximate Maximum Scour Depth (cm/inches)		
			Average Conditions 15% of Applied Power 15 minutes	Maneuvering 35% of Applied Power 5 minutes	Emergency Operations 100% of Applied Power 5 minutes
Sea Valiant	Downstream of 1st Ave Bridge (RM 0 to 2)	7 m (23 ft)	20/8	20/8	>25/>10
		9 m (30 ft)	6/3	15/6	20/8
J.T. Quigg	Upstream of 1st Ave Bridge (RM 2 to 4.8)	5 m (16 ft)	10/4	12/5	>25/>10
		7 m (23 ft)	5/2	5/2	10/4

Notes:

1. Data from FS Appendix C, Part 7, Figures 5 through 8. Results are based on the Maynord Model applied to Sedflume data collected in the LDW. No precise methods are available to relate propeller-induced shear stress (and vessel scour) to sediment erosion. However, rough estimates of the scour magnitude were developed.
2. Maximum vessel scour depth from maneuvering vessels was calculated to be > 25 cm depth, but greater scour depths are possible during emergency operations with long durations. The subsurface RALs in Recovery Category 1 areas and potential tug scour areas are applied to 2 ft of depth.
3. Maximum high-flow event scour is estimated to be about 25 cm, in limited areas of the river.
4. The Maynord Model was also used to calculate the minimum water depth that would result in less than 30 cm of scour during emergency operations (100% power for 5 minutes). For the *Sea Valiant*, this was calculated to be 24 ft of water depth (or 11 ft of clearance from the base of the propeller to the sediment surface). For the *J.T. Quigg*, this was calculated to be 18 ft of water depth (or 7 ft of clearance from the base of the propeller to the sediment surface). Note that Sedflume cores were only 25 cm in depth; for this calculation, the properties of the 20- to 25-cm depth interval were assumed to extend into the 25- to 30-cm interval. Note that the Agencies believe that for excessive and emergency operating conditions for vessels, the model assumptions and calculated scour depths have a large degree of uncertainty. The impact of this uncertainty is that infrequent events may scour deeper than the model predictions.

cm = centimeter; ft = foot; FS = feasibility study; LDW = Lower Duwamish Waterway; RAL= remedial action level; RM = river mile

Table 4 Alternative 5C Plus Scenarios – Remedial Action Levels and Concentration Upper Limits for ENR

Remedial Action Level (RAL)	Evaluation Depth or Point of Compliance ("Depth Interval")[b]	FS Alt 5C	Supplemental 5C Plus Scenarios[a]						
			5C Plus Base (plus PCB intertidal RAL at SQS)[c]	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5: Subsurface RAL of 3xCSL(only PCBs and only in potential tug scour areas in Category 2 and 3) and Surface RAL of 2xSQS for non-HH COCs (only in Category 2 and 3 areas)	
				Subsurface RAL of 3x Human Heath RALs for PCBs and D/F	Subsurface RAL of CSL (all SMS) and 3x Alt. 5C RALs for D/F	Subsurface RAL of 3x CSL (all SMS)	Subsurface RAL of 3xCSL (only PCBs)	5a: Intertidal Subsurface RAL of CSL for PCBs	5b: Intertidal Subsurface RAL of 3xCSL for PCBs
Surface and Subsurface RAL (UL ENR) for PCBs (mg/kg oc) in intertidal areas	10 cm	RAL: 12 (UL ENR: 36)	RAL: 12 (UL ENR: 18)	RAL: 12 (UL ENR: 18)	RAL: 12 (UL ENR: 18)	RAL: 12 (UL ENR: 18)	RAL: 12 (UL ENR: 65)	RAL: 12 (UL ENR: 65)	RAL: 12 (UL ENR: 65)
	45 cm	---	RAL: 12 (UL ENR: 18)	RAL: 12 (UL ENR: 18)	RAL: 12 (UL ENR: 18)	RAL: 12 (UL ENR: 18)	RAL: 195 (UL ENR: 195)	RAL: 65 (UL ENR: 97)[d]	RAL: 195 (UL ENR: 195)
RAL and UL ENR for chemicals other than PCBs in intertidal areas	10 cm and 45 cm	Same as FS Alt. 5C							
Subsurface RAL in Recovery Category 1 intertidal and subtidal areas [e]	2 ft	Same as FS Alt. 5C surface RALs							
Subsurface RAL in subtidal areas [f]	2 ft	---	---	36 mg/kg oc (PCB) 75 ng TEQ/kg dw (D/F)	CSL (all SMS) 75 ng TEQ/kg dw (D/F)	3x CSL (all SMS)	195 mg/kg oc (PCB)	195 mg/kg oc (PCB)	195 mg/kg oc (PCB)
Surface RAL (UL ENR) for SMS COCs [g]	10 cm	RAL: SQS (UL ENR: 3xSQS)	Same as FS Alt. 5C; except UL ENR reduced from 3xSQS to 1.5xSQS for PCBs in intertidal areas.				Same as FS Alt. 5C	Same as FS Alt. 5C, except for non-HH COCs: [h] RAL: 2xSQS (UL ENR: 3xRAL)	

Notes:

a. Assume all RALs are the same as Alt 5C unless otherwise specified.

b. The rationale for evaluation depths (to which RALs are applied) or points of compliance for which PRGs are compared against is provided in EPA 2012b.

c. Alt 5C Plus base elements include dredging of navigation channel shoaling areas exceeding Alt. 5C RALs, increased surface sediment monitoring in areas not actively remediated, and increased cap thickness in clamming areas plus an intertidal RAL for PCBs to the SQS at a 45 cm depth.

d. An intertidal UL ENR for PCBs of 65 mg/kg oc was used for mapping purposes.

e. Recovery Category 1 is 77 acres (66 subtidal acres and 11 intertidal acres); applies to the upper 60 cm of sediment for cost estimating purposes.

Table 4 Alternative 5C Plus Scenarios – Remedial Action Levels and Concentration Upper Limits for ENR (continued)

f. Applicable to the upper 60 cm of sediment in potential tug scour areas in Recovery Categories 2 and 3 only (estimate of 128 acres). Potential tug scour areas are shown in Figure 5 of this technical memorandum, and this RAL only applies to subtidal sediments in -4 to -24 ft MLLW in Reach 1 (estimate of 62 acres) and -4 to -18 ft MLLW of Reaches 2 and 3 (estimate of 66 acres). For those areas remaining areas in Recovery Categories 2 and 3 where potential tug scour is not expected to occur (estimate of 105 acres), there is no subsurface RAL.

g. Applicable to top 10 cm for 41 SMS COCs. The 2xSQS RAL applies for 39 SMS COCs (PCBs and arsenic RALs are same as Alternative 5C; the SQS)).

h. Applicable in Recovery Categories 2 and 3 only. In Recovery Category 1, the surface RAL is the same as Alt 5C (i.e., SQS).

--- = no RAL; COC = contaminant of concern; CSL= cleanup screening level; D/F = dioxins/furans; ENR= enhanced natural recovery; PCBs = polychlorinated biphenyls; RAL = remedial action level; SMS = Sediment Management Standards; SQS = sediment quality standard; UL = upper limit

Table 5a Statistical Summaries for Risk-Driver Contaminants - LDW-wide

	With EAAs											
	Summary Statistics for Surface Sediments			Total Number of Surface Sediment Samples in FS Baseline Dataset						Percent of Surface Sediment Samples in FS Baseline Dataset		
Risk-Driver Contaminant	Minimum Detect	Maximum Detect	Mean[a]	Total	With Detected Values	Detection Frequency	> CSL, detected[b]	> SQS, detected[b]	>2xSQS, detected[b]	> CSL, detected[b]	> SQS, detected[b]	>2xSQS, detected[b]
Metals (mg/kg dw)												
Arsenic	1.2	1,100	17	916	857	94%	9	14	9	1.0%	1.5%	1.0%
Cadmium	0.03	120	1.03	894	632	71%	12	14	10	1.3%	1.6%	1.1%
Chromium	4.80	1,680	42	906	906	100%	10	11	7	1.1%	1.2%	0.8%
Copper	5.0	12,000	106	908	908	100%	13	13	10	1.4%	1.4%	1.1%
Lead	2.0	23,000	139	908	908	100%	23	25	11	2.5%	2.8%	1.2%
Mercury	0.015	247	0.53058	927	813	88%	30	50	18	3.2%	5.4%	1.9%
Silver	0.018	270	1.03	875	537	61%	10	10	5	1.1%	1.1%	0.6%
Zinc	16	9,700	194	905	905	100%	19	45	24	2.1%	5.0%	2.7%
PAHs (µg/kg dw)												
2-Methylnaphthalene	0.38	3,300	42	882	169	19%	4	5	3	0.5%	0.6%	0.3%
Acenaphthene	1.0	5,200	65	891	352	40%	4	20	6	0.4%	2.2%	0.7%
Anthracene	1.30	10,000	134	891	647	73%	0	2	0	0.0%	0.2%	0.0%
Benzo(a)anthracene	7.3	8,400	322	891	821	92%	6	16	3	0.7%	1.8%	0.3%
Benzo(a)pyrene	6.5	7,900	309	886	819	92%	5	12	5	0.6%	1.4%	0.6%
Benzo(g,h,i)perylene	6.1	3,800	165	891	763	86%	12	22	7	1.3%	2.5%	0.8%
Total benzofluoranthenes	6.6	17,000	732	885	829	94%	6	12	3	0.7%	1.4%	0.3%
Chrysene	12.0	7,700	474	891	846	95%	3	32	10	0.3%	3.6%	1.1%
Dibenzo(a,h)anthracene	1.6	1,500	63	891	498	56%	6	24	9	0.7%	2.7%	1.0%
Dibenzofuran	1.0	4,200	54	889	276	31%	3	10	3	0.3%	1.1%	0.3%
Fluoranthene	18	24,000	889	891	868	97%	12	47	22	1.3%	5.3%	2.5%
Fluorene	0.68	6,800	78	891	431	48%	3	14	5	0.3%	1.6%	0.6%
Indeno(1,2,3-cd)pyrene	6.4	4,300	180	891	801	90%	13	29	7	1.5%	3.3%	0.8%
Naphthalene	3.0	5,300	49	882	183	21%	2	2	1	0.2%	0.2%	0.1%
Phenanthrene	7.1	28,000	430	891	832	93%	3	30	8	0.3%	3.4%	0.9%
Pyrene	19.0	16,000	725	891	860	97%	6	8	1	0.7%	0.9%	0.1%
Total HPAHs	23	85,000	3,818	891	873	98%	6	31	8	0.7%	3.5%	0.9%
Total LPAHs	9.1	44,000	698	891	835	94%	3	7	3	0.3%	0.8%	0.3%
Phthalates (µg/kg dw)												
Bis(2-ethylhexyl)phthalate	5.4	17,000	590	886	704	79%	58	104	40	6.5%	11.7%	4.5%
Butyl benzyl phthalate	2.0	7,100	87	878	478	54%	10	90	42	1.1%	10.3%	4.8%
Dimethyl phthalate	2.0	440	25	878	186	21%	2	2	2	0.2%	0.2%	0.2%
Chlorobenzenes (µg/kg dw)												
1,2,4-Trichlorobenzene	1.6	940	19	871	6	1%	2	2	2	0.2%	0.2%	0.2%
1,2-Dichlorobenzene	1.3	670	19	871	19	2%	4	4	3	0.5%	0.5%	0.3%
1,4-Dichlorobenzene	1.5	1,600	23	871	50	6%	4	4	4	0.5%	0.5%	0.5%
Hexachlorobenzene	0.4	95	17	874	46	5%	2	6	3	0.2%	0.7%	0.3%
Other SVOCs and COCs (µg/kg dw, unless otherwise noted)												
2,4-Dimethylphenol	6.1	290	44	869	29	3%	25	25	8	2.9%	2.9%	0.9%
4-Methylphenol	4.8	4,600	44	883	116	13%	4	4	2	0.5%	0.5%	0.2%
Benzoic acid	54	4,500	238	876	111	13%	9	9	4	1.0%	1.0%	0.5%
Benzyl alcohol	8.2	670	49	867	30	3%	7	16	3	0.8%	1.8%	0.3%
n-Nitrosodiphenylamine	6.5	230	27	871	24	3%	2	2	2	0.2%	0.2%	0.2%
Pentachlorophenol	14.0	14,000	122	840	30	4%	1	2	1	0.1%	0.2%	0.1%
Phenol	10.0	2,800	91	886	282	32%	6	25	11	0.7%	2.8%	1.2%
Total PCBs (µg/kg dw)												
Total PCBs	2.2	223,000	1,136	1390	1309	94%	179	515	344	12.9%	37.1%	24.7%
cPAHs and D/F (ug TEQ/kg dw and ng TEQ/kg dw respectively)												
cPAHs - mammal - half DL	9.7	11,000	459	891	852	96%	n/a	n/a	n/a	n/a	n/a	n/a
Dioxin/furan TEQ - mammal (half DL)	0.25	2,100	42	119	119	100%	n/a	n/a	n/a	n/a	n/a	n/a

Notes

a. Calculated mean concentration is the average of detected concentrations and one-half the reporting limit for non-detected results.

b. SMS exceedances are based on SMS criteria, even if concentrations are shown in a different unit. For example, SMS exceedances for total PCBs are based on mg/kg oc concentrations as opposed toµg/kg dw concentrations.

cPAH = carcinogenic polycyclic aromatic hydrocarbons; COC = contaminants of concern; CSL = cleanup screening level; DL = detection limit; dw = dry weight; EAA = early action area; FS = feasibility study; kg = kilograms; µg = micrograms; mg = milligrams; ng = nanograms; oc = organic carbon; PCB = polychlorinated biphenyls; SMS = Sediment Management Standards; SQS = sediment quality standard; SVOC = semivolatile organic compounds; TEQ = toxic equivalent

Table 5b Statistical Summaries for Risk-Driver Contaminants - Excluding EAAs

	Without EAAs											
	Summary Statistics for Surface Sediments			Total Number of Surface Sediment Samples in FS Baseline Dataset						Percent of Surface Sediment Samples in FS Baseline Dataset		
Risk-Driver Contaminant	Minimum Detect	Maximum Detect	Mean[a]	Total	With Detected Values	Detection Frequency	> CSL, detected[b]	> SQS, detected[b]	>2xSQS, detected[b]	> CSL, detected[b]	> SQS, detected[b]	>2xSQS, detected[b]
Metals (mg/kg dw)												
Arsenic	1.2	1,100	18	719	703	98%	9	14	9	1.3%	1.9%	1.3%
Cadmium	0.03	36	0.50	698	467	67%	2	3	1	0.3%	0.4%	0.1%
Chromium	4.80	1,680	33	710	710	100%	2	2	1	0.3%	0.3%	0.1%
Copper	5.0	1,420	70	712	712	100%	6	6	4	0.8%	0.8%	0.6%
Lead	2.0	12,300	88	712	712	100%	8	8	3	1.1%	1.1%	0.4%
Mercury	0.015	247	0.60905	721	627	87%	19	29	9	2.6%	4.0%	1.2%
Silver	0.018	19	0.43	679	417	61%	1	1	1	0.1%	0.1%	0.1%
Zinc	16	4,580	145	711	711	100%	7	18	8	1.0%	2.5%	1.1%
PAHs (µg/kg dw)												
2-Methylnaphthalene	0.38	3,300	37	702	127	18%	2	3	2	0.3%	0.4%	0.3%
Acenaphthene	1.0	5,200	59	711	275	39%	3	13	4	0.4%	1.8%	0.6%
Anthracene	1.30	10,000	126	711	534	75%	0	1	0	0.0%	0.1%	0.0%
Benzo(a)anthracene	7.3	4,200	290	711	671	94%	4	12	2	0.6%	1.7%	0.3%
Benzo(a)pyrene	6.5	4,500	267	709	667	94%	3	8	3	0.4%	1.1%	0.4%
Benzo(g,h,i)perylene	6.1	3,100	150	711	619	87%	8	15	6	1.1%	2.1%	0.8%
Total benzofluoranthenes	6.6	8,800	627	705	670	95%	4	8	2	0.6%	1.1%	0.3%
Chrysene	12.0	5,700	438	711	681	96%	3	26	8	0.4%	3.7%	1.1%
Dibenzo(a,h)anthracene	1.6	1,200	57	711	418	59%	4	18	7	0.6%	2.5%	1.0%
Dibenzofuran	1.0	4,000	49	710	226	32%	2	6	2	0.3%	0.8%	0.3%
Fluoranthene	18	23,000	838	711	695	98%	8	39	19	1.1%	5.5%	2.7%
Fluorene	0.68	6,800	69	711	348	49%	2	8	3	0.3%	1.1%	0.4%
Indeno(1,2,3-cd)pyrene	6.4	3,200	161	711	658	93%	8	19	5	1.1%	2.7%	0.7%
Naphthalene	3.0	5,300	41	702	142	20%	1	1	1	0.1%	0.1%	0.1%
Phenanthrene	7.1	22,000	374	711	676	95%	2	21	6	0.3%	3.0%	0.8%
Pyrene	19.0	16,000	667	711	690	97%	5	6	1	0.7%	0.8%	0.1%
Total HPAHs	23	51,000	3,454	711	698	98%	5	23	6	0.7%	3.2%	0.8%
Total LPAHs	9.1	44,000	615	711	676	95%	2	4	2	0.3%	0.6%	0.3%
Phthalates (µg/kg dw)												
Bis(2-ethylhexyl)phthalate	5.4	17,000	378	704	539	77%	21	51	10	3.0%	7.2%	1.4%
Butyl benzyl phthalate	2.0	3,300	48	696	383	55%	2	45	18	0.3%	6.5%	2.6%
Dimethyl phthalate	2.0	440	23	696	146	21%	1	1	1	0.1%	0.1%	0.1%
Chlorobenzenes (µg/kg dw)												
1,2,4-Trichlorobenzene	1.6	940	16	694	2	0%	1	1	1	0.1%	0.1%	0.1%
1,2-Dichlorobenzene	1.5	670	16	694	13	2%	1	1	1	0.1%	0.1%	0.1%
1,4-Dichlorobenzene	1.5	1,300	19	694	36	5%	3	3	3	0.4%	0.4%	0.4%
Hexachlorobenzene	0.4	95	15	695	43	6%	2	6	3	0.3%	0.9%	0.4%
Other SVOCs and COCs (µg/kg dw, unless otherwise noted)												
2,4-Dimethylphenol	6.1	77	36	693	26	4%	22	22	5	3.2%	3.2%	0.7%
4-Methylphenol	4.8	1,400	36	706	91	13%	3	3	1	0.4%	0.4%	0.1%
Benzoic acid	54	4,500	221	697	95	14%	9	9	4	1.3%	1.3%	0.6%
Benzyl alcohol	8.2	670	33	688	26	4%	5	13	3	0.7%	1.9%	0.4%
n-Nitrosodiphenylamine	6.5	179	26	692	19	3%	1	1	1	0.1%	0.1%	0.1%
Pentachlorophenol	14.0	14,000	118	662	27	4%	1	2	1	0.2%	0.3%	0.2%
Phenol	10.0	1,400	72	707	239	34%	2	14	4	0.3%	2.0%	0.6%
Total PCBs (µg/kg dw)												
Total PCBs	2.2	223,000	439	1024	950	93%	28	215	99	2.7%	21.0%	9.7%
cPAHs and D/F (ug TEQ/kg dw and ng TEQ/kg dw respectively)												
cPAHs - mammal - half DL	9.7	6,600	400	711	686	96%	n/a	n/a	n/a	n/a	n/a	n/a
Dioxin/furan TEQ - mammal (half DL)	0.25	2,100	44	107	107	100%	n/a	n/a	n/a	n/a	n/a	n/a

Notes

a. Calculated mean concentration is the average of detected concentrations and one-half the reporting limit for non-detected results.

b. SMS exceedances are based on SMS criteria, even if concentrations are shown in a different unit. For example, SMS exceedances for total PCBs are based on mg/kg OC concentrations as opposed toµg/kg dw concentrations.

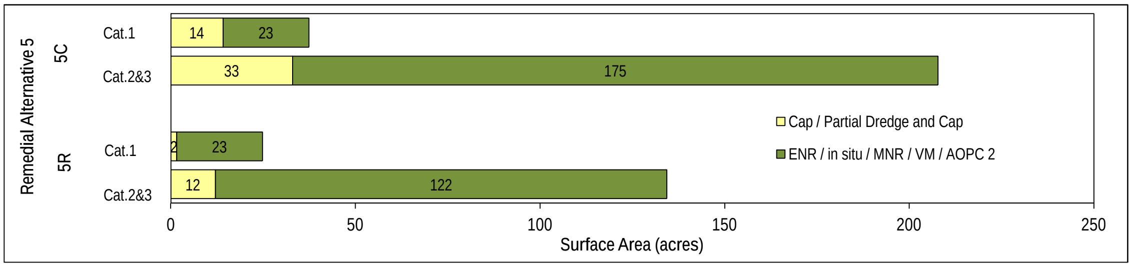
cPAH = carcinogenic polycyclic aromatic hydrocarbons; COC = contaminants of concern; CSL = cleanup screening level; DL = detection limit; dw = dry weight; EAA = early action area; FS = feasibility study; kg = kilograms; µg = micrograms; mg = milligrams; ng = nanograms; oc = organic carbon; PCB = polychlorinated biphenyls; SMS = Sediment Management Standards; SQS = sediment quality standard; SVOC = semivolatile organic compounds; TEQ = toxic equivalent

Table 6a Post-Construction Sediment Conditions for Alternative 5 (from Final FS)

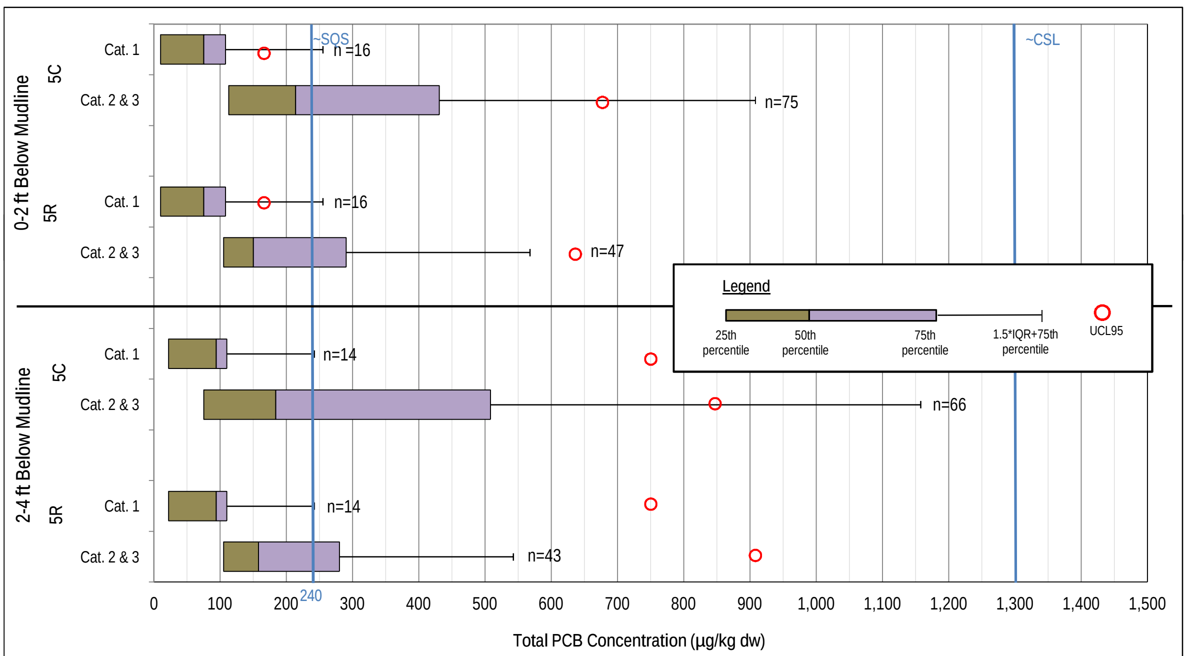
Number of Core Stations with SMS Chemistry Exceedances and Total PCB Concentration in Areas Outside the EAA and Dredge Footprint for Alternative 5

Remedial Alternative 5	Recovery Category	Located within AOPC 1 and AOPC 2 Outside Dredge and Cap Footprint: Core Station Counts > CSL	Core Station Counts < CSL, > SQS	Total PCB Concentration (µg/kg dw) 0 to 2 ft depth n	0 to 2 ft depth Mean	0 to 2 ft depth UCL95	2 to 4 ft depth n	2 to 4 ft depth Mean	2 to 4 ft depth UCL95	Cap / Partial Dredge and Cap: Core Station Counts > CSL	Core Station Counts < CSL, > SQS	Total PCB Concentration (µg/kg dw) 0 to 4 ft depth n	0 to 4 ft depth Mean
Combined	1	0	2	16	80	166	14	133	750				
	2 and 3	22	22	75	399	677	66	451	847	20	4	31	610
	All	22	24	91	343	579	80	395	730				
Removal	1	0	2	16	80	166	14	133	750				
	2 and 3	5	16	47	313	636	43	363	908	1	0	1	240
	All	5	18	63	253	501	57	306	606				

Surface Areas Outside the EAA and Dredge Footprint Corresponding to Technology Assignment Groups for Alternative 5



Summary Statistics of Subsurface Total PCB Concentrations Remaining in AOPC 1 and AOPC 2 and Outside the EAA, Dredge and Cap Footprint for Alternative 5



Notes:

1. Recovery Category 1, 2, and 3 designations were assigned to any area of the LDW, regardless of AOPC or RAL status, and based on a specific recovery assessment (see FS Section 6). Recovery in Category 1 areas is presumed to be limited. Recovery in Category 2 areas is less certain. Category 3 areas are predicted to recover.
2. Core counts may be conservative because some of the material at these locations may have been previously dredged. In such cases, it is unconfirmed whether all contamination was removed and, in some instances, whether dredging actually occurred at these locations. Therefore, all remaining cores were included in the core counts.
3. Dredged areas are not shown in the center panel, which are 57 and 143 acres for 5C and 5R, respectively. The AOPC 1 and 2 footprints are approximately 180 and 122 acres, respectively.
4. Summary statistics for the 0- to 2-ft and 2- to 4-ft intervals (top table and lower panel) are for the vertically averaged total PCB concentrations in each remaining core station. Summary statistics were calculated with ProUCL 4.1 software; the ProUCL-recommended UCL was used as the UCL95 in all cases, with the exception of the H-Statistic UCL, use of which was avoided (per ProUCL warning) and overridden by a non-parametric 95% Chebyshev (Mean, SD) UCL. No data greater than the 1.5*IQR+75th percentile are shown in the lower panel.
5. The mean PCB concentration for capped and partially dredged/capped areas in the 0- to 4-ft interval (shown in top table) is the vertical average of the combination of clean capping material (0 to 2 ft [with an assumed total PCB concentration of 40 µg/kg dw]), and the native sediment (0 to 2 ft in areas to be capped, and 2 to 4 ft in areas to be partially dredged/capped [with the total PCB concentration from those intervals in the subsurface FS baseline dataset]). However, the sediment cap is designed to be 3 ft thick.
6. The mean and UCL95 total PCB concentrations in the 0- to 4-ft interval in the rest of the waterway (110 acres outside of AOPC 2; 52 cores) are 68 and 120 µg/kg dw, respectively.

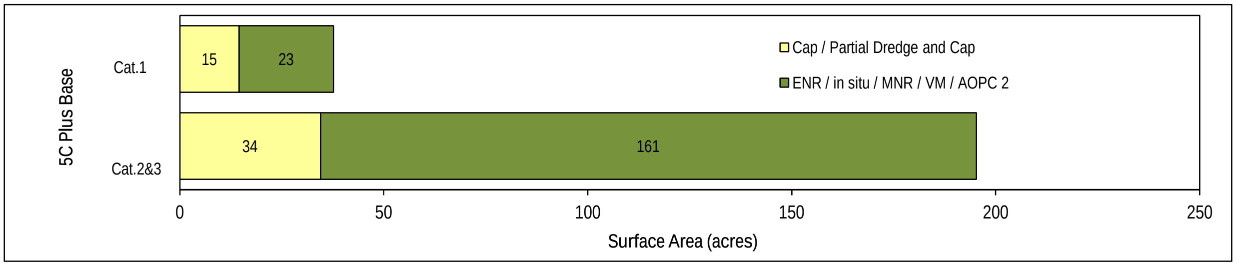
AOPC = area of potential concern; C = combined; Cat. = recovery category; CSL = cleanup screening level; EAA = early action area; ENR = enhanced natural recovery; FS = feasibility study; ft = foot; IQR = interquartile range; LDW = Lower Duwamish Waterway; µg/kg dw = microgram per kilogram dry weight; MNR = monitored natural recovery; n = number of cores; PCB = polychlorinated biphenyl; R = removal; R-T = removal with treatment; RAL = remedial action level; SD = standard deviation; SMS = Sediment Management Standards; SQS = sediment quality standard; UCL95 = 95% upper confidence limit on the mean; VM = verification monitoring

Table 6b Post-Construction Sediment Conditions for 5C Plus Base[a]

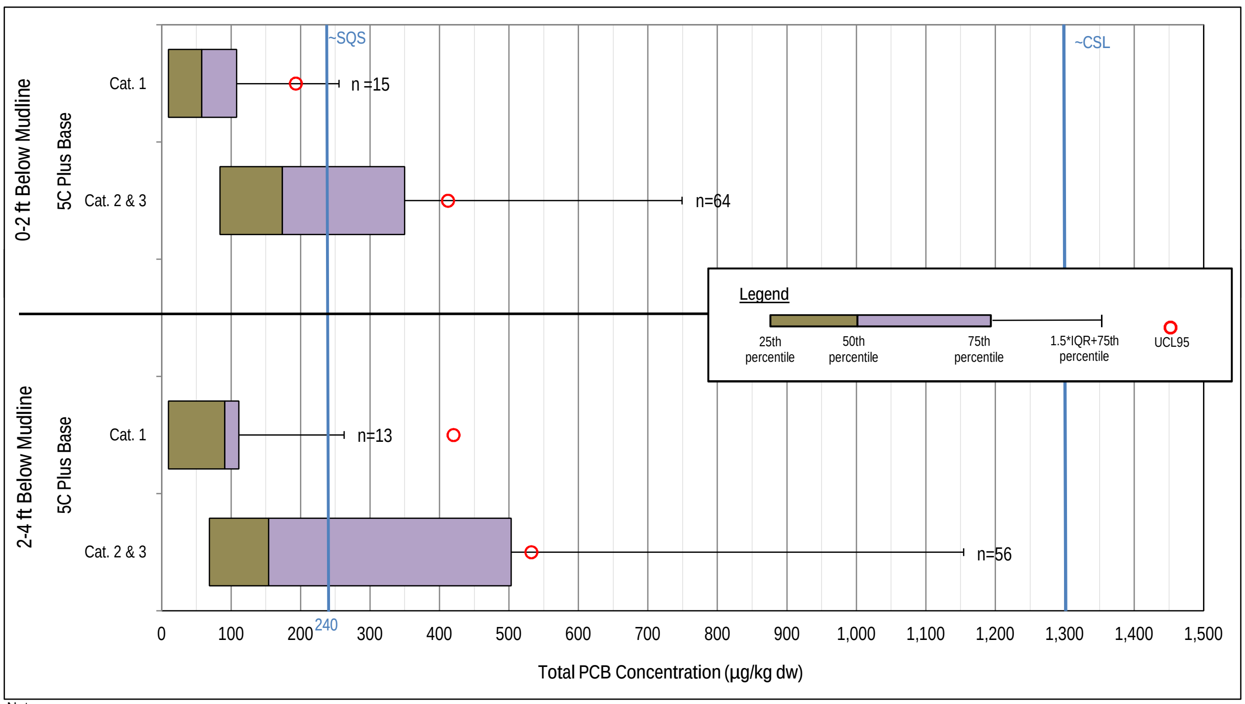
Number of Core Stations with SMS Chemistry Exceedances and Total PCB Concentration in Areas Outside the EAA and Dredge Footprint for 5C Plus Base

Scenario	Recovery Category	Located within AOPC 1 and AOPC 2 Outside Dredge and Cap Footprint								Cap / Partial Dredge and Cap			
		Core Station Counts		Total PCB Concentration (µg/kg dw)						Core Station Counts		Total PCB Concentration (µg/kg dw)	
				0 to 2 ft depth			2 to 4 ft depth					0 to 4 ft depth	
		> CSL	< CSL, > SQS	n	Mean	UCL95	n	Mean	UCL95	> CSL	< CSL, > SQS	n	Mean
5C Plus Base (plus PCBs intertidal RAL)	1	0	2	15	79	193	13	136	420	21	4	32	592
	2 and 3	17	17	64	328	412	56	379	532				
	All	17	19	79	281	356	69	333	461				

Surface Areas Outside the EAA and Dredge Footprint Corresponding to Technology Assignment Groups for 5C Plus Base



Summary Statistics of Subsurface Total PCB Concentrations Remaining in AOPC 1 and AOPC 2 and Outside the EAA, Dredge and Cap Footprint for 5C Plus Base



Notes:

1. Recovery Category 1, 2, and 3 designations were assigned to any area of the LDW, regardless of AOPC or RAL status, and based on a specific recovery assessment (see FS Section 6). Recovery in Category 1 areas is presumed to be limited. Recovery in Category 2 areas is less certain. Category 3 areas are predicted to recover.

2. Core counts may be conservative because some of the material at these locations may have been previously dredged. In such cases, it is unconfirmed whether all contamination was removed and, in some instances, whether dredging actually occurred at these locations. Therefore, all remaining cores were included in the core counts.

3. Scenario 5C Plus Base includes 72 acres of dredged areas, not shown in center panel. The AOPC 1 and 2 footprints are approximately 180 and 122 acres, respectively.

4. Summary statistics for the 0- to 2-ft and 2- to 4-ft intervals (top table and lower panel) are for the vertically averaged total PCB concentrations in each remaining core station. Summary statistics were calculated with ProUCL 4.1 software; the ProUCL-recommended UCL was used as the UCL95 in all cases, with the exception of the H-Statistic UCL, use of which was avoided (per ProUCL warning) and overridden by a non-parametric 95% Chebyshev (Mean, SD) UCL. No data greater than the 1.5*IQR+75th percentile are shown in the lower panel.

5. The mean PCB concentration for capped and partially dredged/capped areas in the 0- to 4-ft interval (shown in top table) is the vertical average of the combination of clean capping material (0 to 2 ft [with an assumed total PCB concentration of 40 µg/kg dw]), and the native sediment (0 to 2 ft in areas to be capped, and 2 to 4 ft in areas to be partially dredged/capped [with the total PCB concentration from those intervals in the subsurface FS baseline dataset]). However, the sediment cap is designed to be 3 ft thick.

6. The mean and UCL95 total PCB concentrations in the 0- to 4-ft interval in the rest of the waterway (110 acres outside of AOPC 2; 52 cores) are 68 and 120µg/kg dw, respectively.

Footnote:

a. Alternative 5C Plus Base includes the common base elements and PCB intertidal RAL of the SQS.

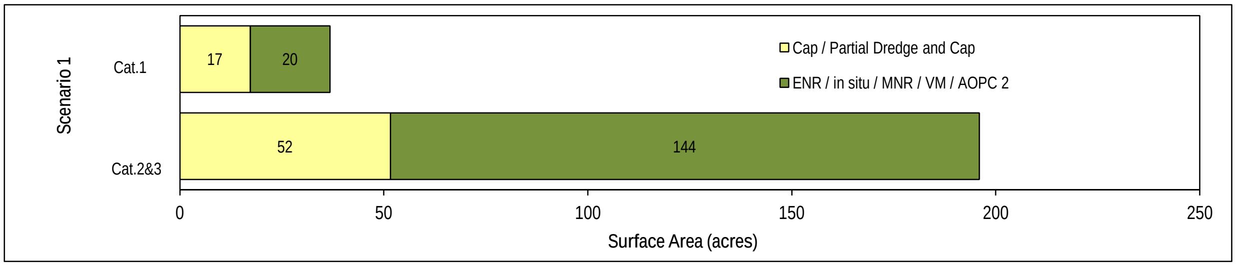
AOPC = area of potential concern; Cat. = recovery category; CSL = cleanup screening level; EAA = early action area; ENR = enhanced natural recovery; FS = feasibility study; ft = foot; IQR = interquartile range; LDW = Lower Duwamish Waterway; µg/kg dw = microgram per kilogram dry weight; MNR = monitored natural recovery; n = number of cores; PCB = polychlorinated biphenyl; RAL = remedial action level; SD = standard deviation; SMS = Sediment Management Standards; SQS = sediment quality standard; UCL95 = 95% upper confidence limit on the mean; VM = verification monitoring

Table 6c Post-Construction Sediment Conditions for Scenario 1 - Subsurface RAL of 3 x HH RAL for PCBs and Dioxins/Furans

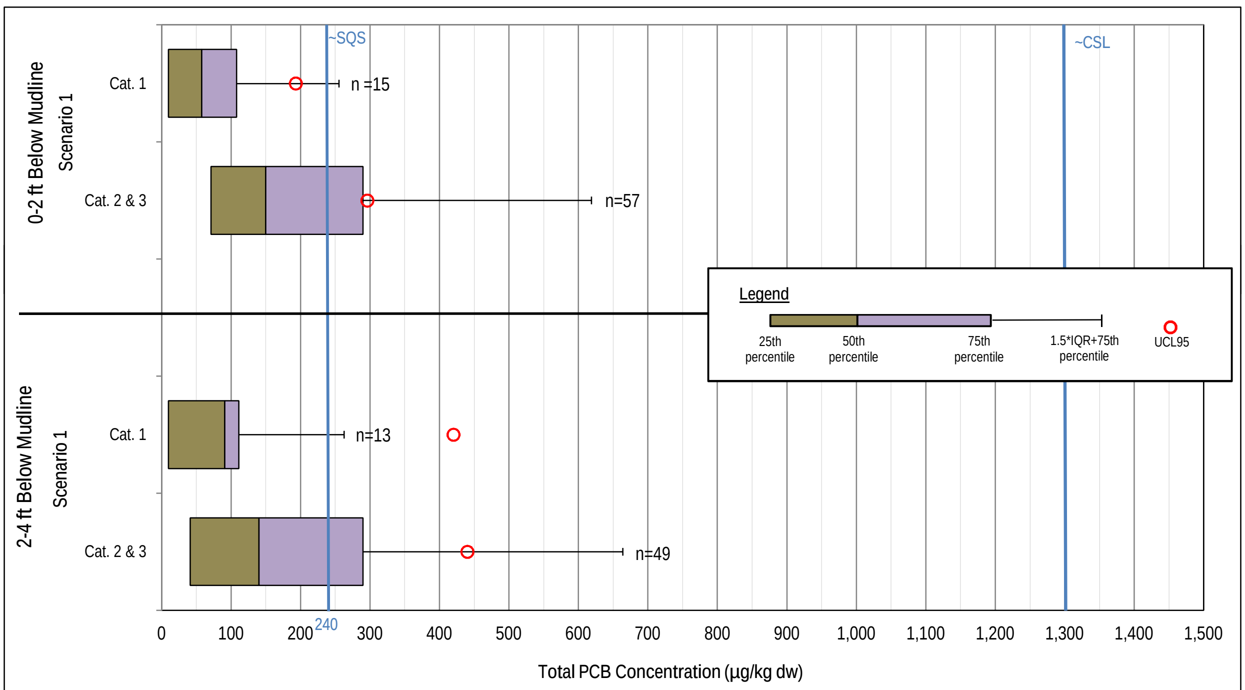
Number of Core Stations with SMS Chemistry Exceedances and Total PCB Concentration in Areas Outside the EAA and Dredge Footprint for Scenario 1

		Located within AOPC 1 and AOPC 2 Outside Dredge and Cap Footprint								Cap / Partial Dredge and Cap			
		Core Station Counts		Total PCB Concentration (µg/kg dw)						Core Station Counts		Total PCB Concentration (µg/kg dw)	
				0 to 2 ft depth			2 to 4 ft depth					0 to 4 ft depth	
Scenario	Recovery Category	> CSL	< CSL, > SQS	n	Mean	UCL95	n	Mean	UCL95	> CSL	< CSL, > SQS	n	Mean
1	1	0	2	15	79	193	13	136	420	25	5	38	585
	2 and 3	13	15	57	238	296	49	304	440				
	All	13	17	72	205	259	62	269	380				

Surface Areas Outside the EAA and Dredge Footprint Corresponding to Technology Assignment Groups for Scenario 1



Summary Statistics of Subsurface Total PCB Concentrations Remaining in AOPC 1 and AOPC 2 and Outside the EAA, Dredge and Cap Footprint for Scenario 1



Notes:

1. Recovery Category 1, 2, and 3 designations were assigned to any area of the LDW, regardless of AOPC or RAL status, and based on a specific recovery assessment (see FS Section 6). Recovery in Category 1 areas is presumed to be limited. Recovery in Category 2 areas is less certain. Category 3 areas are predicted to recover.

2. Core counts may be conservative because some of the material at these locations may have been previously dredged. In such cases, it is unconfirmed whether all contamination was removed and, in some instances, whether dredging actually occurred at these locations. Therefore, all remaining cores were included in the core counts.

3. Scenario 1 includes 80 acres of dredged areas, not shown in center panel. The AOPC 1 and 2 footprints are approximately 180 and 122 acres, respectively

4. Summary statistics for the 0- to 2-ft and 2- to 4-ft intervals (top table and lower panel) are for the vertically averaged total PCB concentrations in each remaining core station. Summary statistics were calculated with ProUCL 4.1 software; the ProUCL-recommended UCL was used as the UCL95 in all cases, with the exception of the H-Statistic UCL, use of which was avoided (per ProUCL warning) and overridden by a non-parametric 95% Chebyshev (Mean, SD) UCL. No data greater than the 1.5*IQR+75th percentile are shown in the lower panel.

5. The mean PCB concentration for capped and partially dredged/capped areas in the 0- to 4-ft interval (shown in top table) is the vertical average of the combination of clean capping material (0 to 2 ft [with an assumec total PCB concentration of 40 µg/kg dw]), and the native sediment (0 to 2 ft in areas to be capped, and 2 to 4 ft in areas to be partially dredged/capped [with the total PCB concentration from those intervals in the subsurface FS baseline dataset]). However, the sediment cap is designed to be 3 ft thick.

6. The mean and UCL95 total PCB concentrations in the 0- to 4-ft interval in the rest of the waterway (110 acres outside of AOPC 2; 52 cores) are 68 and 120µg/kg dw, respectively.

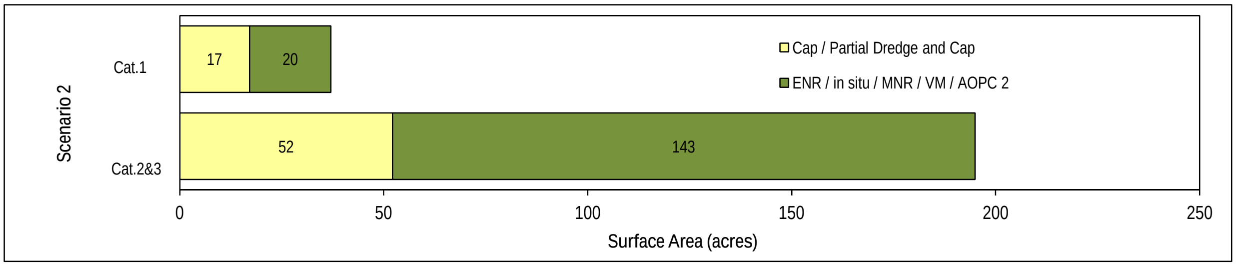
AOPC = area of potential concern; Cat. = recovery category; CSL = cleanup screening level; EAA = early action area; ENR = enhanced natural recovery; FS = feasibility study; ft = foot; HH = human health; IQR = interquartile range; LDW = Lower Duwamish Waterway; µg/kg dw = microgram per kilogram dry weight; MNR = monitored natural recovery; n = number of cores; PCB = polychlorinated biphenyl; R = removal; RAL = remedial action level; SD = standard deviation; SMS = Sediment Management Standards; SQS = sediment quality standard; UCL95 = 95% upper confidence limit on the mean; VM = verification monitoring

Table 6d Post-Construction Sediment Conditions for Scenario 2 - Subsurface RAL of CSL for all SMS and 3 x Alt.5C RAL for Dioxins/Furans

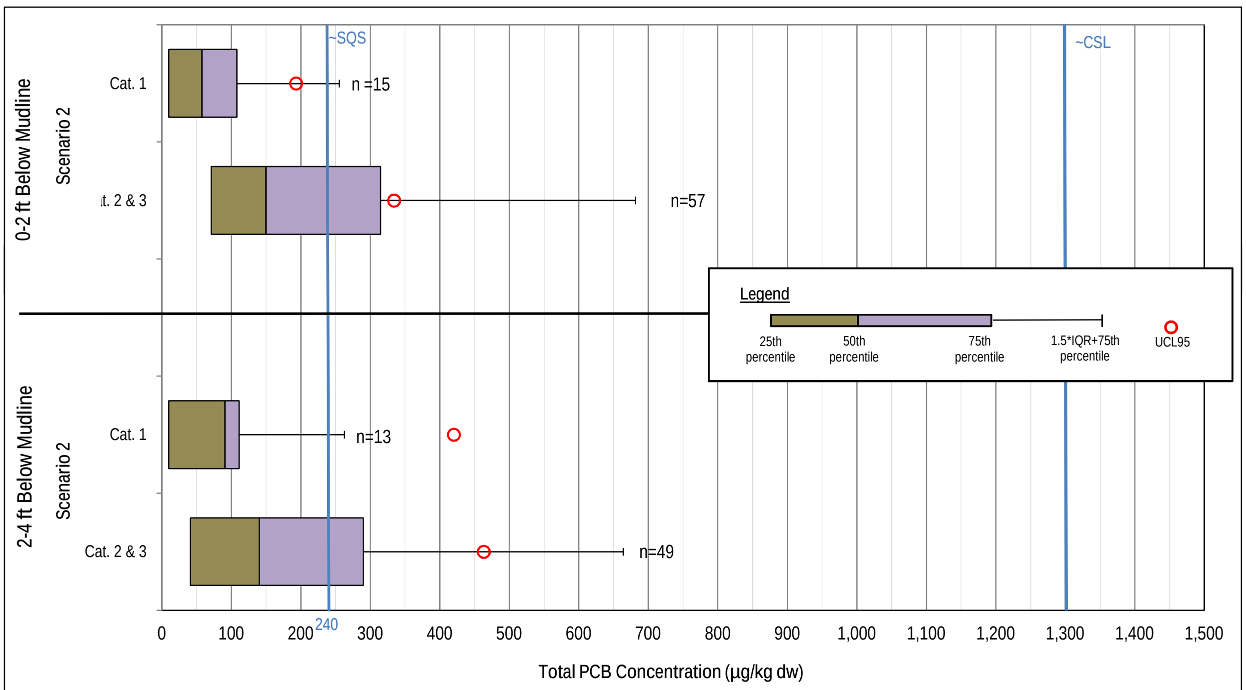
Number of Core Stations with SMS Chemistry Exceedances and Total PCB Concentration in Areas Outside the EAA and Dredge Footprint for Scenario 2

		Located within AOPC 1 and AOPC 2 Outside Dredge and Cap Footprint									Cap / Partial Dredge and Cap			
		Core Station Counts		Total PCB Concentration (µg/kg dw)							Core Station Counts		Total PCB Concentration (µg/kg dw)	
				0 to 2 ft depth			2 to 4 ft depth						0 to 4 ft depth	
Scenario	Recovery Category	> CSL	< CSL, > SQS	n	Mean	UCL95	n	Mean	UCL95		> CSL	< CSL, > SQS	n	Mean
2	1	0	2	15	79	193	13	136	420		27	4	39	563
	2 and 3	11	17	57	266	334	49	319	463					
	All	11	19	72	227	289	62	281	398					

Surface Areas Outside the EAA and Dredge Footprint Corresponding to Technology Assignment Groups for Scenario 2



Summary Statistics of Subsurface Total PCB Concentrations Remaining in AOPC 1 and AOPC 2 and Outside the EAA, Dredge and Cap Footprint for Scenario 2



Notes:

1. Recovery Category 1, 2, and 3 designations were assigned to any area of the LDW, regardless of AOPC or RAL status, and based on a specific recovery assessment (see FS Section 6). Recovery in Category 1 areas is presumed to be limited. Recovery in Category 2 areas is less certain. Category 3 areas are predicted to recover.
2. Core counts may be conservative because some of the material at these locations may have been previously dredged. In such cases, it is unconfirmed whether all contamination was removed and, in some instances, whether dredging actually occurred at these locations. Therefore, all remaining cores were included in the core counts.
3. Scenario 2 includes 82 acres of dredged areas, not shown in center panel. The AOPC 1 and 2 footprints are approximately 180 and 122 acres, respectively
4. Summary statistics for the 0- to 2-ft and 2- to 4-ft intervals (top table and lower panel) are for the vertically averaged total PCB concentrations in each remaining core station. Summary statistics were calculated with ProUCL 4.1 software; the ProUCL-recommended UCL was used as the UCL95 in all cases, with the exception of the H-Statistic UCL, use of which was avoided (per ProUCL warning) and overridden by a non-parametric 95% Chebyshev (Mean, SD) UCL. No data greater than the 1.5*IQR+75th percentile are shown in the lower panel.
5. The mean PCB concentration for capped and partially dredged/capped areas in the 0- to 4-ft interval (shown in top table) is the vertical average of the combination of clean capping material (0 to 2 ft [with an assumed total PCB concentration of 40 µg/kg dw]), and the native sediment (0 to 2 ft in areas to be capped, and 2 to 4 ft in areas to be partially dredged/capped [with the total PCB concentration from those intervals in the subsurface FS baseline dataset]). However, the sediment cap is designed to be 3 ft thick.
6. The mean and UCL95 total PCB concentrations in the 0- to 4-ft interval in the rest of the waterway (110 acres outside of AOPC 2; 52 cores) are 68 and 120µg/kg dw, respectively.

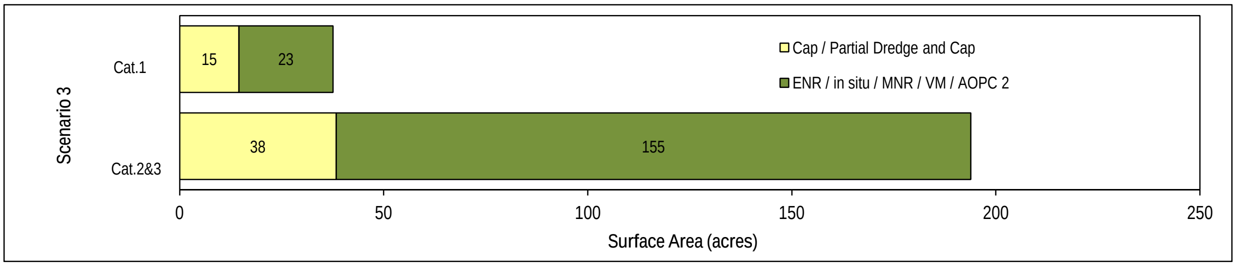
AOPC = area of potential concern; Cat. = recovery category; CSL = cleanup screening level; EAA = early action area; ENR = enhanced natural recovery; FS = feasibility study; ft = foot; IQR = interquartile range; LDW = Lower Duwamish Waterway; µg/kg dw = microgram per kilogram dry weight; MNR = monitored natural recovery; n = number of cores; PCB = polychlorinated biphenyl; RAL = remedial action level; SD = standard deviation; SMS = Sediment Management Standards; SQS = sediment quality standard; UCL95 = 95% upper confidence limit on the mean; VM = verification monitoring

Table 6e Post-Construction Sediment Conditions for Scenario 3 - Subsurface RAL of 3 x CSL for all SMS

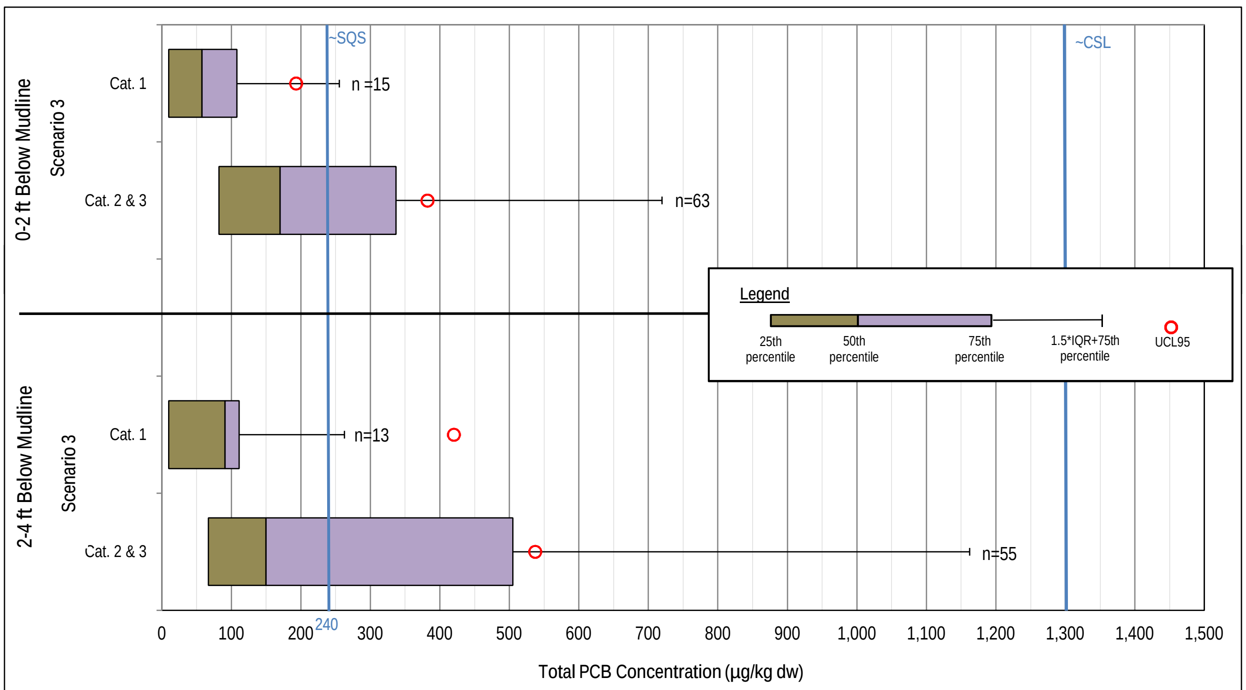
Number of Core Stations with SMS Chemistry Exceedances and Total PCB Concentration in Areas Outside the EAA and Dredge Footprint for Scenario 3

		Located within AOPC 1 and AOPC 2 Outside Dredge and Cap Footprint								Cap / Partial Dredge and Cap			
		Core Station Counts		Total PCB Concentration (µg/kg dw)						Core Station Counts		Total PCB Concentration (µg/kg dw)	
				0 to 2 ft depth			2 to 4 ft depth					0 to 4 ft depth	
Scenario	Recovery Category	> CSL	< CSL, > SQS	n	Mean	UCL95	n	Mean	UCL95	> CSL	< CSL, > SQS	n	Mean
3	1	0	2	15	79	193	13	136	420				
	2 and 3	16	17	63	306	382	55	380	537	22	4	33	601
	All	16	19	78	262	332	68	334	464				

Surface Areas Outside the EAA and Dredge Footprint Corresponding to Technology Assignment Groups for Scenario 3



Summary Statistics of Subsurface Total PCB Concentrations Remaining in AOPC 1 and AOPC 2 and Outside the EAA, Dredge and Cap Footprint for Scenario 3



Notes:

1. Recovery Category 1, 2, and 3 designations were assigned to any area of the LDW, regardless of AOPC or RAL status, and based on a specific recovery assessment (see FS Section 6). Recovery in Category 1 areas is presumed to be limited. Recovery in Category 2 areas is less certain. Category 3 areas are predicted to recover.
2. Core counts may be conservative because some of the material at these locations may have been previously dredged. In such cases, it is unconfirmed whether all contamination was removed and, in some instances, whether dredging actually occurred at these locations. Therefore, all remaining cores were included in the core counts.
3. Scenario 3 includes 73 acres of dredged areas, not shown in center panel. The AOPC 1 and 2 footprints are approximately 180 and 122 acres, respectively
4. Summary statistics for the 0- to 2-ft and 2- to 4-ft intervals (top table and lower panel) are for the vertically averaged total PCB concentrations in each remaining core station. Summary statistics were calculated with ProUCL 4.1 software; the ProUCL-recommended UCL was used as the UCL95 in all cases, with the exception of the H-Statistic UCL, use of which was avoided (per ProUCL warning) and overridden by a non-parametric 95% Chebyshev (Mean, SD) UCL. No data greater than the 1.5*IQR+75th percentile are shown in the lower panel.
5. The mean PCB concentration for capped and partially dredged/capped areas in the 0- to 4-ft interval (shown in top table) is the vertical average of the combination of clean capping material (0 to 2 ft [with an assumed total PCB concentration of 40 µg/kg dw]), and the native sediment (0 to 2 ft in areas to be capped, and 2 to 4 ft in areas to be partially dredged/capped [with the total PCB concentration from those intervals in the subsurface FS baseline dataset]). However, the sediment cap is designed to be 3 ft thick.
6. The mean and UCL95 total PCB concentrations in the 0- to 4-ft interval in the rest of the waterway (110 acres outside of AOPC 2; 52 cores) are 68 and 120µg/kg dw, respectively.

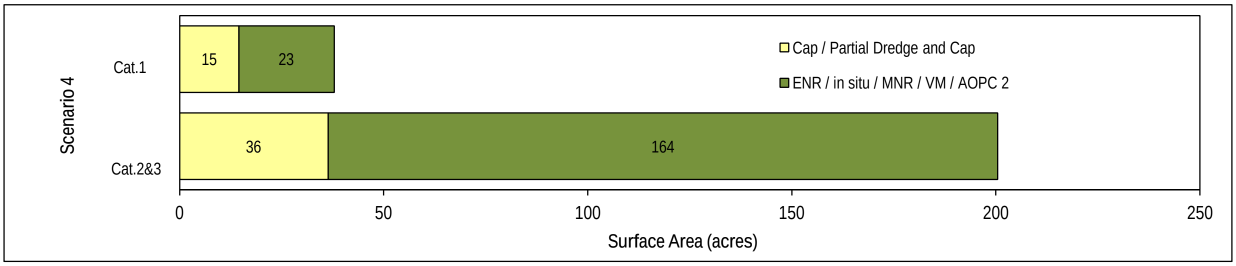
AOPC = area of potential concern; Cat. = recovery category; CSL = cleanup screening level; EAA = early action area; ENR = enhanced natural recovery; FS = feasibility study; ft = foot; IQR = interquartile range; LDW = Lower Duwamish Waterway; µg/kg dw = microgram per kilogram dry weight; MNR = monitored natural recovery; n = number of cores; PCB = polychlorinated biphenyl; RAL = remedial action level; SD = standard deviation; SMS = Sediment Management Standards; SQS = sediment quality standard; UCL95 = 95% upper confidence limit on the mean; VM = verification monitoring

Table 6f Post-Construction Sediment Conditions for Scenario 4 - Subsurface RAL of 3 x CSL for PCBs

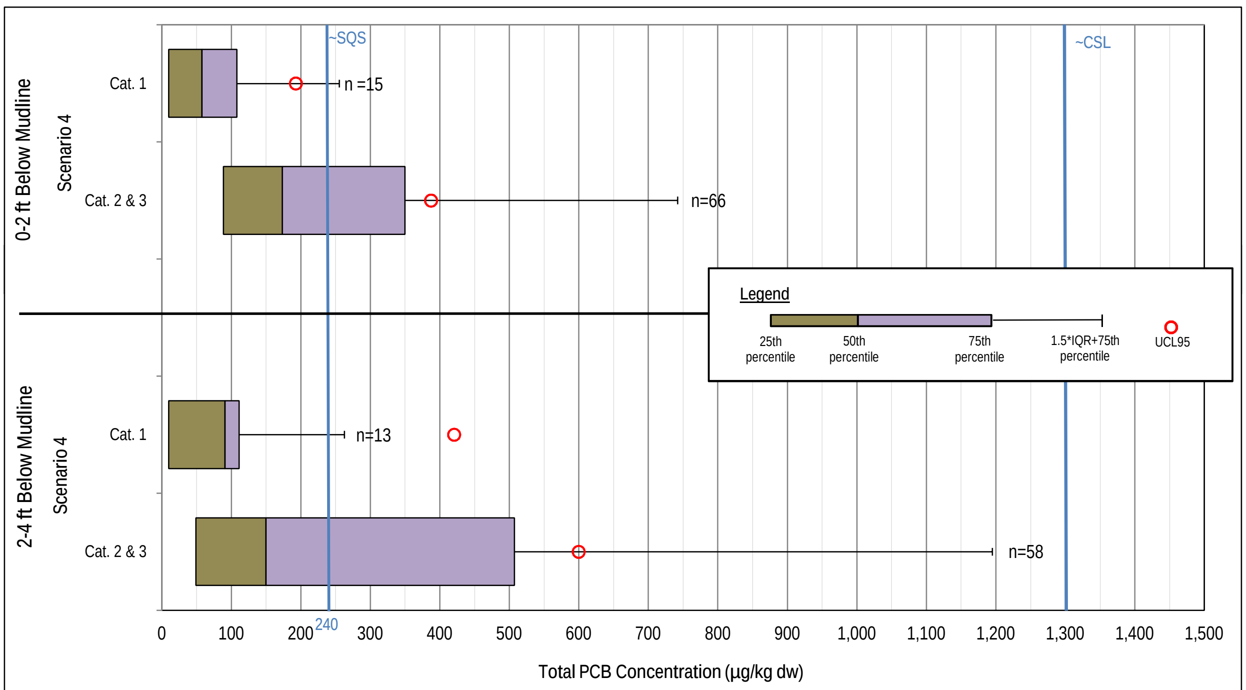
Number of Core Stations with SMS Chemistry Exceedances and Total PCB Concentration in Areas Outside the EAA and Dredge Footprint for Scenario 4

Scenario	Recovery Category	Located within AOPC 1 and AOPC 2 Outside Dredge and Cap Footprint: Core Station Counts > CSL	Core Station Counts < CSL, > SQS	Total PCB Concentration (µg/kg dw) 0 to 2 ft depth n	0 to 2 ft Mean	0 to 2 ft UCL95	2 to 4 ft depth n	2 to 4 ft Mean	2 to 4 ft UCL95	Cap / Partial Dredge and Cap: Core Station Counts > CSL	Core Station Counts < CSL, > SQS	Total PCB Concentration (µg/kg dw) 0 to 4 ft depth n	0 to 4 ft Mean
4	1	0	2	15	79	193	13	136	420	22	4	33	601
	2 and 3	19	17	66	312	387	58	420	600				
	All	19	19	81	269	338	71	368	513				

Surface Areas Outside the EAA and Dredge Footprint Corresponding to Technology Assignment Groups for Scenario 4



Summary Statistics of Subsurface Total PCB Concentrations Remaining in AOPC 1 and AOPC 2 and Outside the EAA, Dredge and Cap Footprint for Scenario 4



Notes:

1. Recovery Category 1, 2, and 3 designations were assigned to any area of the LDW, regardless of AOPC or RAL status, and based on a specific recovery assessment (see FS Section 6). Recovery in Category 1 areas is presumed to be limited. Recovery in Category 2 areas is less certain. Category 3 areas are predicted to recover.

2. Core counts may be conservative because some of the material at these locations may have been previously dredged. In such cases, it is unconfirmed whether all contamination was removed and, in some instances, whether dredging actually occurred at these locations. Therefore, all remaining cores were included in the core counts.

3. Scenario 4 includes 66 acres of dredged areas, not shown in center panel. The AOPC 1 and 2 footprints are approximately 180 and 122 acres, respectively

4. Summary statistics for the 0- to 2-ft and 2- to 4-ft intervals (top table and lower panel) are for the vertically averaged total PCB concentrations in each remaining core station. Summary statistics were calculated with ProUCL 4.1 software; the ProUCL-recommended UCL was used as the UCL95 in all cases, with the exception of the H-Statistic UCL, use of which was avoided (per ProUCL warning) and overridden by a non-parametric 95% Chebyshev (Mean, SD) UCL. No data greater than the 1.5*IQR+75th percentile are shown in the lower panel.

5. The mean PCB concentration for capped and partially dredged/capped areas in the 0- to 4-ft interval (shown in top table) is the vertical average of the combination of clean capping material (0 to 2 ft [with an assumed total PCB concentration of 40 µg/kg dw]), and the native sediment (0 to 2 ft in areas to be capped, and 2 to 4 ft in areas to be partially dredged/capped [with the total PCB concentration from those intervals in the subsurface FS baseline dataset]). However, the sediment cap is designed to be 3 ft thick.

6. The mean and UCL95 total PCB concentrations in the 0- to 4-ft interval in the rest of the waterway (110 acres outside of AOPC 2; 52 cores) are 68 and 120µg/kg dw, respectively.

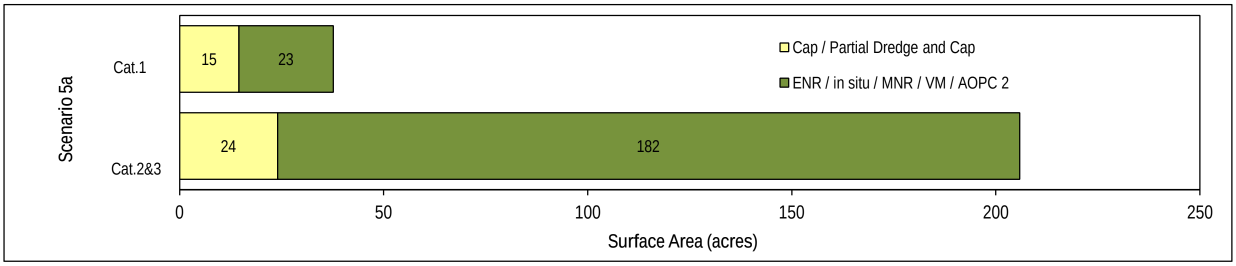
AOPC = area of potential concern; Cat. = recovery category; CSL = cleanup screening level; EAA = early action area; ENR = enhanced natural recovery; FS = feasibility study; ft = foot; IQR = interquartile range; LDW = Lower Duwamish Waterway; µg/kg dw = microgram per kilogram dry weight; MNR = monitored natural recovery; n = number of cores; PCB = polychlorinated biphenyl; RAL = remedial action level; SD = standard deviation; SMS = Sediment Management Standards; SQS = sediment quality standard; UCL95 = 95% upper confidence limit on the mean; VM = verification monitoring

Table 6g Post-Construction Sediment Conditions for Scenario 5a -Subsurface RAL of 3 x CSL for PCBs; Surface RALs of Alt. 5C RALs (for PCBs, Arsenic, cPAHs, and Dioxins/Furans) and 2 x SQS for other COCs; Intertidal Subsurface RAL of CSL for PCBs

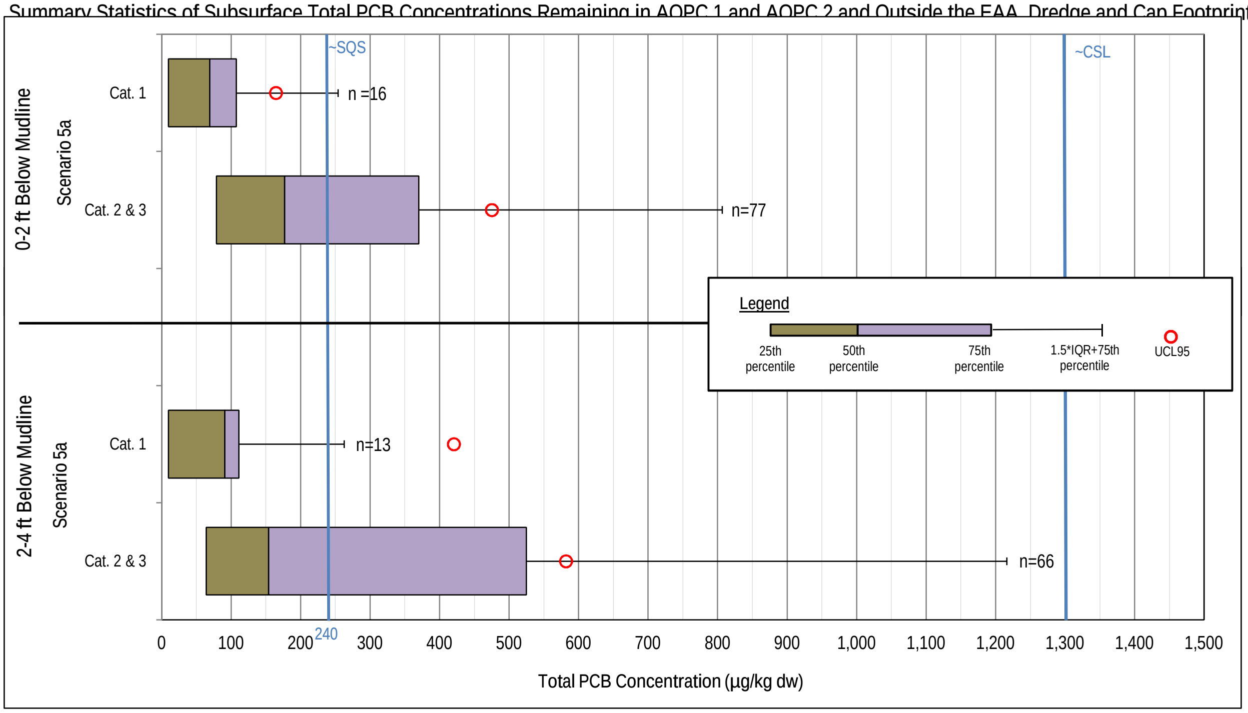
Number of Core Stations with SMS Chemistry Exceedances and Total PCB Concentration in Areas Outside the EAA and Dredge Footprint for Scenario 5a

Scenario	Recovery Category	Located within AOPC 1 and AOPC 2 Outside Dredge and Cap Footprint								Cap / Partial Dredge and Cap			
		Core Station Counts		Total PCB Concentration (µg/kg dw)						Core Station Counts		Total PCB Concentration (µg/kg dw)	
				0 to 2 ft depth			2 to 4 ft depth					0 to 4 ft depth	
		> CSL	< CSL, > SQS	n	Mean	UCL95	n	Mean	UCL95	> CSL	< CSL, > SQS	n	Mean
5a	1	0	3	16	79	164	13	136	420	19	4	27	639
	2 and 3	22	20	77	373	475	66	424	582				
	All	22	23	93	322	409	79	377	682				

Surface Areas Outside the EAA and Dredge Footprint Corresponding to Technology Assignment Groups for Scenario 5a



Summary Statistics of Subsurface Total PCB Concentrations Remaining in AOPC 1 and AOPC 2 and Outside the EAA, Dredge and Cap Footprint for Scenario 5a



Notes:

1. Recovery Category 1, 2, and 3 designations were assigned to any area of the LDW, regardless of AOPC or RAL status, and based on a specific recovery assessment (see FS Section 6). Recovery in Category 1 areas is presumed to be limited. Recovery in Category 2 areas is less certain. Category 3 areas are predicted to recover.
2. Core counts may be conservative because some of the material at these locations may have been previously dredged. In such cases, it is unconfirmed whether all contamination was removed and, in some instances, whether dredging actually occurred at these locations. Therefore, all remaining cores were included in the core counts.
3. Scenario 5a includes 62 acres of dredged areas, not shown in center panel. The AOPC 1 and 2 footprints are approximately 180 and 122 acres, respectively.
4. Summary statistics for the 0- to 2-ft and 2- to 4-ft intervals (top table and lower panel) are for the vertically averaged total PCB concentrations in each remaining core station. Summary statistics were calculated with ProUCL 4.1 software; the ProUCL-recommended UCL was used as the UCL95 in all cases, with the exception of the H-Statistic UCL, use of which was avoided (per ProUCL warning) and overridden by a non-parametric 95% Chebyshev (Mean, SD) UCL. No data greater than the 1.5*IQR+75th percentile are shown in the lower panel.
5. The mean PCB concentration for capped and partially dredged/capped areas in the 0- to 4-ft interval (shown in top table) is the vertical average of the combination of clean capping material (0 to 2 ft [with an assumed total PCB concentration of 40 µg/kg dw]), and the native sediment (0 to 2 ft in areas to be capped, and 2 to 4 ft in areas to be partially dredged/capped [with the total PCB concentration from those intervals in the subsurface FS baseline dataset]). However, the sediment cap is designed to be 3 ft thick.
6. The mean and UCL95 total PCB concentrations in the 0- to 4-ft interval in the rest of the waterway (110 acres outside of AOPC 2; 52 cores) are 68 and 120µg/kg dw, respectively.

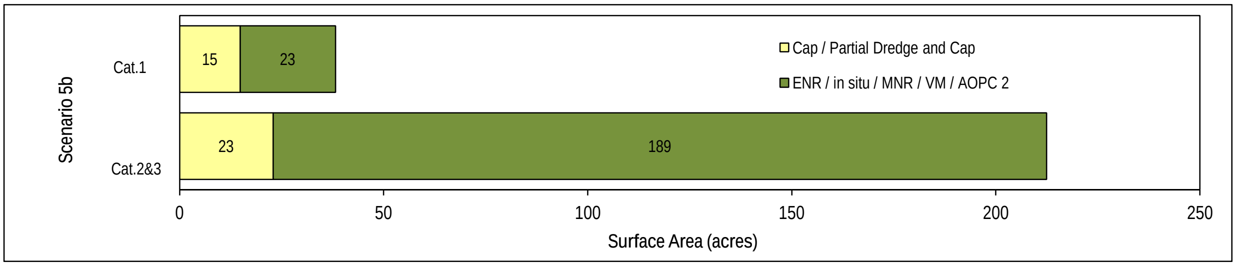
AOPC = area of potential concern; Cat. = recovery category; CSL = cleanup screening level; EAA = early action area; ENR = enhanced natural recovery; FS = feasibility study; ft = foot; IQR = interquartile range; LDW = Lower Duwamish Waterway; µg/kg dw = microgram per kilogram dry weight; MNR = monitored natural recovery; n = number of cores; PCB = polychlorinated biphenyl; RAL = remedial action level; SD = standard deviation; SMS = Sediment Management Standards; SQS = sediment quality standard; UCL95 = 95% upper confidence limit on the mean; VM = verification monitoring

Table 6h Post-Construction Sediment Conditions for Scenario 5b - Subsurface RAL of 3 x CSL for PCBs; Surface RALs of Alt. 5C RALs (for PCBs, Arsenic, cPAHs, and Dioxins/Furans) and 2 x SQS for other COCs; Intertidal Subsurface RAL of 3 x CSL (PCBs)

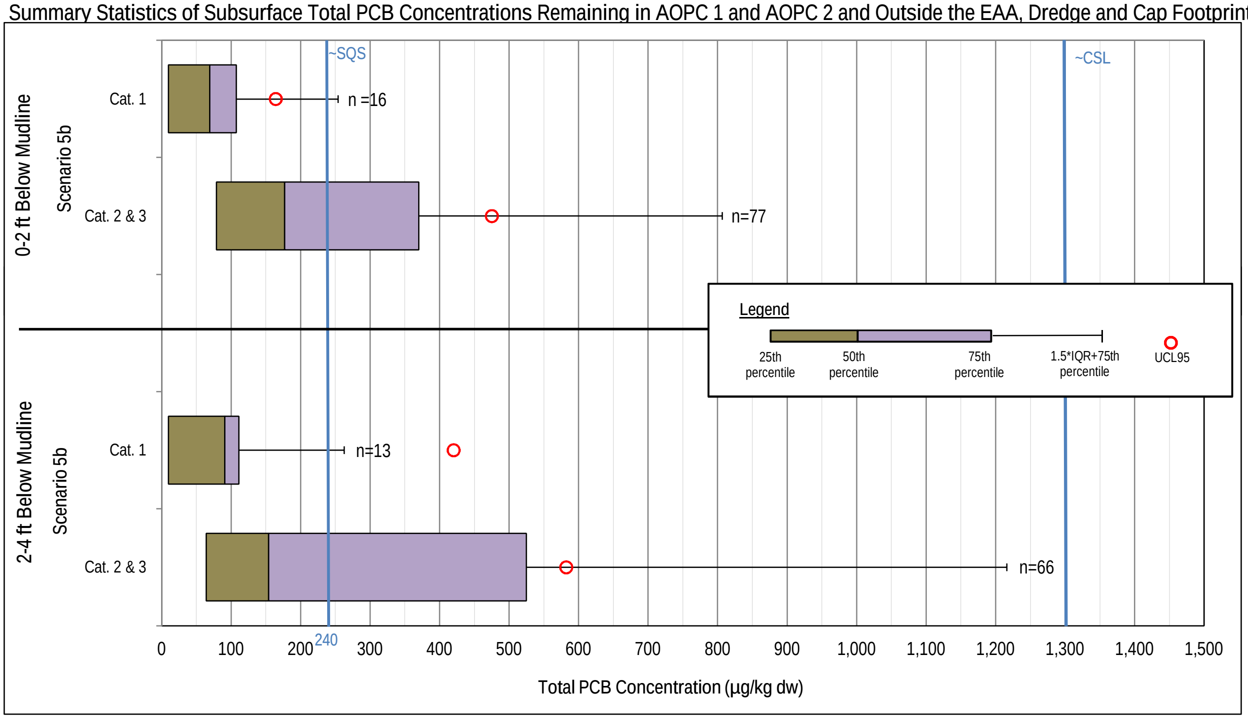
Number of Core Stations with SMS Chemistry Exceedances and Total PCB Concentration in Areas Outside the EAA and Dredge Footprint for Scenario 5b

Scenario	Recovery Category	Located within AOPC 1 and AOPC 2 Outside Dredge and Cap Footprint								Cap / Partial Dredge and Cap			
		Core Station Counts		Total PCB Concentration (µg/kg dw)						Core Station Counts		Total PCB Concentration (µg/kg dw)	
				0 to 2 ft depth			2 to 4 ft depth					0 to 4 ft depth	
		> CSL	< CSL, > SQS	n	Mean	UCL95	n	Mean	UCL95	> CSL	< CSL, > SQS	n	Mean
5b	1	0	3	16	79	164	13	136	420	19	4	27	639
	2 and 3	22	20	77	373	475	66	424	582				
	All	22	23	93	322	409	79	377	682				

Surface Areas Outside the EAA and Dredge Footprint Corresponding to Technology Assignment Groups for Scenario 5b



Summary Statistics of Subsurface Total PCB Concentrations Remaining in AOPC 1 and AOPC 2 and Outside the EAA, Dredge and Cap Footprint for Scenario 5b



Notes:

1. Recovery Category 1, 2, and 3 designations were assigned to any area of the LDW, regardless of AOPC or RAL status, and based on a specific recovery assessment (see FS Section 6). Recovery in Category 1 areas is presumed to be limited. Recovery in Category 2 areas is less certain. Category 3 areas are predicted to recover.

2. Core counts may be conservative because some of the material at these locations may have been previously dredged. In such cases, it is unconfirmed whether all contamination was removed and, in some instances, whether dredging actually occurred at these locations. Therefore, all remaining cores were included in the core counts.

3. Scenario 5a includes 55 acres of dredged areas, not shown in center panel. The AOPC 1 and 2 footprints are approximately 180 and 122 acres, respectively

4. Summary statistics for the 0- to 2-ft and 2- to 4-ft intervals (top table and lower panel) are for the vertically averaged total PCB concentrations in each remaining core station. Summary statistics were calculated with ProUCL 4.1 software; the ProUCL-recommended UCL was used as the UCL95 in all cases, with the exception of the H-Statistic UCL, use of which was avoided (per ProUCL warning) and overridden by a non-parametric 95% Chebyshev (Mean, SD) UCL. No data greater than the 1.5*IQR+75th percentile are shown in the lower panel.

5. The mean PCB concentration for capped and partially dredged/capped areas in the 0- to 4-ft interval (shown in top table) is the vertical average of the combination of clean capping material (0 to 2 ft [with an assumed total PCB concentration of 40 µg/kg dw]), and the native sediment (0 to 2 ft in areas to be capped, and 2 to 4 ft in areas to be partially dredged/capped [with the total PCB concentration from those intervals in the subsurface FS baseline dataset]). However, the sediment cap is designed to be 3 ft thick.

6. The mean and UCL95 total PCB concentrations in the 0- to 4-ft interval in the rest of the waterway (110 acres outside of AOPC 2; 52 cores) are 68 and 120µg/kg dw, respectively.

AOPC = area of potential concern; Cat. = recovery category; CSL = cleanup screening level; EAA = early action area; ENR = enhanced natural recovery; FS = feasibility study;
ft = foot; IQR = interquartile range; LDW = Lower Duwamish Waterway; µg/kg dw = microgram per kilogram dry weight; MNR = monitored natural recovery; n = number of cores; PCB = polychlorinated biphenyl;
RAL = remedial action level; SD = standard deviation; SMS = Sediment Management Standards; SQS = sediment quality standard; UCL95 = 95% upper confidence limit on the mean; VM = verification monitoring

Table 7 FS Alternatives 4C and 5C and Supplemental Alternative 5C Plus Scenarios: Areas, Volumes, Construction Times, and Costs

#	Remedial Scenario	Remedial Technology and Areas											Dredge-cut Prism Volume (cy)[b]	Performance Contingency Volume (cy)[c]	Total Dredge Volume (cy)[d]	Total Placement Volume (Capping, ENR/*in situ*, Dredge Residuals, Habitat) (cy)	Construction Time Frame (years)[e]	Cost ($MM Net Present Value)[f]	Cost ($MM undiscounted)
			Actively Remediated				Areas without Active Remediation												
		EAAs (acres)	Dredge (acres)	Partial Dredge and Cap (acres)	Cap (acres)	ENR/ *in situ* (acres)	MNR[a] (acres)	VM (acres)	Institutional Controls, Site-wide Monitoring, & Natural Recovery (AOPC 2 and Rest of LDW) (acres)	Total Active (acres)	Total not actively remediated (acres)	Total Study Area (acres)							
	FS Alternative 4C	29	50	18	23	16	50	23	232	107	305	441	560,000	130,000	690,000	470,000	6	$260	$300
	FS Alternative 5C	29	57	23	24	53	0	23	232	157	255	441	640,000	110,000	750,000	580,000	7	$290	$330
	5CPlus Base (plus PCB intertidal RAL)[g]	29	72	25	24	51	0	20	220	172	240	441	780,000	100,000	880,000	650,000	8	$331	$380
1	Scenario 1[h,i,j] Subsurface 3xHuman Health RAL for PCBs and Dioxins/Furans	29	80	29	40	45	0	17	203	193	219	441	860,000	89,000	950,000	800,000	9	$357	$410
2	Scenario 2[h,i,j] Subsurface CSL RAL (all SMS) and 3x Alt 5C RAL for Dioxins/Furans	29	82	28	41	44	0	17	200	195	217	441	870,000	88,000	960,000	810,000	9	$358	$411
3	Scenario 3[h,i,j] Subsurface RAL of 3xCSL (all SMS)	29	73	25	28	48	0	17	220	175	237	441	790,000	95,000	890,000	680,000	9	$333	$382
4	Scenario 4[h,i,j] Subsurface RAL of 3xCSL only for PCBs	29	66	24	27	50	0	20	225	167	245	441	740,000	100,000	840,000	620,000	8	$319	$366
5a	Scenario 5a[h,i,j] Subsurface RAL of CSL/ 3xCSL only for PCBs (intertidal/subtidal), and surface RAL of 2xSQS for non-HH risk drivers	29	62	16	23	48	27	17	220	148	264	441	650,000	130,000	790,000	560,000	7	$303	$345
5b	Scenario 5b[h,i,j] Subsurface RAL of 3xCSL only for PCBs (intertidal and subtidal areas) and surface RAL of 2xSQS for non-HH risk drivers	29	55	15	23	47	28	20	225	139	273	441	600,000	140,000	740,000	490,000	6	$289	$329

Notes:

1. Areas are rounded to the nearest acre as shown. Acres for all remedial alternatives add up to the total study area of 441.3 acres; apparent discrepancies in total areas are due only to rounding. Volumes are rounded to two significant figures. Volumes are calculated in a spreadsheet prior to rounding; apparent discrepancies in total volumes are due only to rounding. Volumes and costs do not include the EAAs.

a. MNR is monitoring to achieve the SQS within 10 years following construction.

b. The dredge-cut prism volume estimate is the neat-line volume to the maximum depth of SQS exceedances plus an additional 50% to account for overdredging, additional sediment characterization, cleanup passes for residuals management, and additional volumes for constructability (e.g., stable side slopes).

c. Performance contingency volumes account for changes in technology assignment and performance-based contingency assumptions (e.g., 15% of ENR/*in situ*, MNR, and VM areas are assumed to require dredging based on long-term monitoring results). There are no contingency actions assumed in the areas identified with institutional control and natural recovery.

d. Total dredge volume equals dredge-cut prism volume plus the performance contingency volume. Rounded values are shown in the table. Cost calculations are performed on unrounded values.

e. Construction time frame estimated based on open water dredge-cut prism volumes.

f. Net present value costs are calculated assuming a discount rate of 2.3% on both capital and monitoring costs starting at the beginning of construction. Best estimate cost assumptions are considered accurate to +50% and -30%.

g. Changes to FS Alternative 5C for the 5CPlus include the three base elements: dredging of navigation channel shoaling areas exceeding Alt. 5C RALs, 1 sample/acre for monitoring in AOPC 2 and the Rest of LDW, and 4-ft cap thickness in intertidal areas. Additional remediation also added a 45-cm point of compliance and an intertidal RAL of the SQS for PCBs. Volumes were estimated using the maximum concentrations in the upper 45 cm of cores, delimited horizontally using core polygons restricted to areas with surface sediment PCB concentrations >100 µg/kg dw (i.e., ~clipped to AOPC 2 boundary). The additional remediation due to subsurface concentrations in navigation channel shoaling areas was estimated using the maximum concentrations in the upper 2 ft of cores, delimited horizontally using core polygons restricted to areas where the existing bathymetric elevations above the authorized navigation channel depth. Concentrations >Alternative 5C RALs were assigned to partial dredging/capping or dredging based on the technology assignment assumptions in the FS.

h. All scenarios include the three base elements. Scenarios 1, 2, and 3 include intertidal RALs of the SQS for PCBs to 45-cm depth. Scenarios 4 and 5b include subsurface RAL of 3 x CSL for PCBs applied to intertidal areas. Scenario 5a includes an intertidal RAL of the CSL for PCBs to 45-cm depth. Scenarios 5a and 5b only apply to Recovery Category 2 and 3 areas (RALs for Recovery Category 1 areas remain the same as for FS Alternative 5C).

i. Subsurface RAL applies in potential tug scour water depths, defined as -24 ft MLLW to -4 ft MLLW in Reach 1 (i.e., north of 1st Ave Bridge), and -18 ft MLLW to -4 ft MLLW in Reaches 2 and 3 (i.e., south of 1st Ave Bridge).

j. Additional remediation from the subsurface RAL exceedances was estimated using the maximum concentrations in the upper 2 ft of cores, delimited horizontally using core polygons. Scenarios 3 through 5 restrict the core polygons to AOPC 1 (i.e., ~areas with surface sediment concentrations >Alt. 5C RALs); Scenarios 1 and 2 do not restrict the extent of core polygons.

AOPC = area of potential concern; C = combined technology; CAD = contained aquatic disposal; cy = cubic yards; EAA = early action area; ENR = enhanced natural recovery; HH = human health; LDW = Lower Duwamish Waterway; MM = million; MNR = monitored natural recovery; n/a = not applicable; R = removal emphasis; RAL = remediation action level; SQS = sediment quality standard; UL = upper limit; VM = verification monitoring

Table 8 Incremental Cost Change for Supplemental Alternative 5C Plus Scenarios from FS Alternative 5C ($MM net present value)

	Plus Elements	FS Alt. 5C	5C Plus Base (plus PCB intertidal RAL)[a]	Scenario 1 Subsurface 3xHuman Health RAL for PCBs and Dioxins/Furans	Scenario 2 Subsurface CSL RAL (all SMS) and 3x Alt 5C RAL for Dioxins/Furans	Scenario 3 Subsurface RAL of 3xCSL (all SMS)	Scenario 4 Subsurface RAL of 3xCSL only for PCBs	Scenario 5 — 5a: Subsurface RAL of CSL/ 3xCSL only for PCBs (intertidal/subtidal), and surface RAL of 2xSQS for non-HH risk drivers	Scenario 5 — 5b: Subsurface RAL of 3xCSL only for PCBs (intertidal and subtidal areas) and surface RAL of 2xSQS for non-HH risk drivers
Base Elements Common to All Scenarios	Dredging contaminated shoaling areas of the navigation channel with subsurface concentrations >RALs[b]	—	$17	$17	$17	$17	$17	$17	$17
	Increasing sediment monitoring in areas not actively remediated (AOPC 2 and the rest of the LDW)[c]	—	$7	$7	$7	$7	$7	$7	$7
	Increasing cap thickness in intertidal clamming areas	—	$2	$2	$2	$2	$2	$2	$2
Elements Varied by Scenario	Subsurface RAL[d,e]	—	—	$25	$26	$2	$1	$1	$1
	45-cm point of compliance for PCBs in intertidal areas[f]	—	$16	$16	$16	$16	$2	$16	$2
	SMS surface RAL[g]	—	—	—	—	—	—	-$30	-$30
Incremental Total Cost (Above Alt 5C)		—	$42	$67	$68	$44	$29	$13	-$1
Total Estimated Cost ($MM net present value)[h]		$290	$332	$357	$358	$334	$319	$303	$289
Total Estimated Cost ($MM non-discounted)[h]		$330	$380	$410	$411	$382	$366	$345	$329
Construction Time Frame (years)		7	8	9	9	9	8	7	6

Notes:

a. The 5C Plus Base scenario includes the three base elements and an intertidal RAL of SQS for total PCBs.

b. Additional remediation from subsurface concentrations in navigation channel shoaling areas was estimated using the maximum concentrations in the upper 2 ft of cores, in areas where the existing bathymetric elevations are above the authorized navigation channel depth.

c. Monitoring frequency changed to 1 sample/acre in natural recovery areas and ICs and long-term monitoring areas (AOPC 2 and “rest of LDW”). No contingency actions are assumed in these areas for cost estimating purposes.

d. Subsurface RALs apply in potential tug scour elevations defined as -24 ft MLLW to -4 ft MLLW in Reach 1 (i.e., north of 1st Ave Bridge) and -18 ft MLLW to -4 ft MLLW in Reaches 2 and 3 (i.e., south of 1st Ave Bridge).

e. Subsurface RAL exceedances were estimated using the maximum concentrations in the upper 2 ft of cores, delimited horizontally using core polygons. Scenarios 3 through 5 restrict the core polygons to AOPC 1 (i.e., ~areas with surface sediment concentrations >Alt. 5C RALs); Scenarios 1 and 2 do not restrict the extent of core polygons.

f. For intertidal RALs, Scenarios 1, 2, and 3 assume the surface RAL of the SQS for PCBs extends down to 45 cm depth. Scenarios 4 and 5b assume a subsurface RAL of 3xCSL for PCBs in the intertidal areas and retain the 10 cm SQS point of compliance for PCBs in Alt 5C. Scenario 5a assumes an intertidal RAL of the CSL for PCBs. Costs were estimated at $16MM for the lower RALs and $2MM for the higher RAL; however, costs could range up to approximately $40MM because of uncertainty associated with low core density in intertidal areas.

g. Assume Alternative 5C RALs unless otherwise specified. Scenario 5 has surface sediment RALs of SQS in Recovery Category 1 areas and 2xSQS in Recovery Categories 2 and 3 areas for non-human health risk drivers.

h. Net present value costs were calculated assuming a discount rate of 2.3% on both capital and monitoring costs starting at the beginning of construction. Feasibility study-level cost estimates are considered accurate to +50% and -30%. Non-discounted incremental costs for individual plus elements were not calculated, although non-discounted costs are about 15% higher than net present value costs for the 5C Plus Scenarios.

AOPC = area of potential concern; C = combined technology; cm = centimeters; CSL = cleanup screening level; FS = feasibility study; IC = institutional controls; LDW = Lower Duwamish Waterway; MLLW = mean lower low water; MM = million; RAL= remediation action level; SMS = Sediment Management Standards; SQS = sediment quality standard

Table 9 Effectiveness Evaluation of Alternative 5C and Supplemental 5C Plus Scenarios – Predicted Post-Construction Arsenic, Total PCB, cPAH, and Dioxin/Furan Concentrations (SWACs)

Arsenic (mg/kg dw) (RAO 2)

Scenario	Active Area in FS Study Area (acres)	Construc-tion Period (years)	Netfishing Direct Contact Baseline = 16 10^{-6} RBTC = 3.7 PRG = Background = 7.0										Tribal Clamming Direct Contact Baseline = 13 10^{-6} RBTC = 1.3 PRG = Background = 7.0										Beach Play Direct Contact Baseline = 9.1 10^{-6} RBTC = 2.8 PRG = Background = 7.0									
			Time from Beginning of Construction (years)										*Time from Beginning of Construction (years)*										*Time from Beginning of Construction (years)*									
			0 [a]	*5*	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*	*0* [a]	*5*	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*	*0* [a]	*5*	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*
Alternative 5C	157	7	16	10	9.6	9	9	9	9	9	9	9	13	9.6	9.4	9.3	9.2	9.2	9.2	9.2	9.2	9.2	9.1	9.6	9.4	9.3	9.2	9.2	9.2	9.2	9.2	9.2
5C Plus Base[b]	172	8	16	10	9.5	9.3	9.2	9.2	9.2	9.1	9.1	9.1	13	9.6	9.3	9.3	9.2	9.2	9.2	9.2	9.2	9.1	9.1	9.6	9.4	9.3	9.2	9.2	9.2	9.2	9.2	9.2
Scenario 1	193	9	16	10	9.5	9.3	9.2	9.2	9.2	9.1	9.1	9.1	13	9.6	9.3	9.3	9.2	9.2	9.2	9.2	9.2	9.1	9.1	9.6	9.4	9.3	9.2	9.2	9.2	9.2	9.2	9.2
Scenario 2	195	9	16	10	9.5	9.3	9.2	9.2	9.2	9.1	9.1	9.1	13	9.6	9.3	9.3	9.2	9.2	9.2	9.2	9.2	9.1	9.1	9.6	9.4	9.3	9.2	9.2	9.2	9.2	9.2	9.2
Scenario 3	175	9	16	10	9.5	9.3	9.2	9.2	9.2	9.1	9.1	9.1	13	9.6	9.3	9.3	9.2	9.2	9.2	9.2	9.2	9.1	9.1	9.6	9.4	9.3	9.2	9.2	9.2	9.2	9.2	9.2
Scenario 4	167	8	16	10	9.6	9.4	9.2	9.2	9.2	9.1	9.1	9.1	13	9.6	9.4	9.3	9.2	9.2	9.2	9.2	9.2	9.2	9.1	9.6	9.4	9.3	9.2	9.2	9.2	9.2	9.2	9.2
Scenario 5a	148	7	16	10	9.6	9.4	9.2	9.2	9.2	9.1	9.1	9.1	13	9.5	9.3	9.3	9.2	9.2	9.2	9.2	9.2	9.1	9.1	9.5	9.3	9.3	9.2	9.2	9.2	9.2	9.2	9.2
Scenario 5b	139	6	16	10	9.6	9.4	9.2	9.2	9.2	9.1	9.1	9.1	13	9.5	9.4	9.3	9.2	9.2	9.2	9.2	9.2	9.2	9.1	9.5	9.3	9.3	9.2	9.2	9.2	9.2	9.2	9.2

Total PCBs (µg/kg dw) (RAOs 1, 2, and 4)

Scenario	Active Area in FS Study Area (acres)	Construc-tion Period (years)	Site-wide Baseline = 346 Netfishing Direct Contact: PRG = 10^{-6} RBTC = 1,300 Seafood Consumption - Human: PRG = Background = 2 Seafood Consumption - Ecological (otter): PRG = 128 - 159										Tribal Clamming Direct Contact Baseline = 540 10^{-6} RBTC = 500 PRG = 500										Beach Play Direct Contact Baseline = 286 10^{-6} RBTC = 1,700 PRG = 1,700									
			Time from Beginning of Construction (years)										*Time from Beginning of Construction (years)*										*Time from Beginning of Construction (years)*									
			0 [a]	*5*	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*	*0* [a]	*5*	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*	*0* [a]	*5*	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*
Alternative 5C	157	7	178	70	56	48	46	44	44	43	43	41	195	59	52	48	46	45	45	44	44	43	275	54	49	45	44	44	45	44	44	42
5C Plus Base[b]	172	8	178	70	53	47	45	44	44	43	42	41	195	59	48	46	44	44	44	43	43	42	275	54	47	45	44	44	45	44	44	42
Scenario 1	193	9	178	70	52	47	45	43	43	42	42	41	195	59	48	46	44	44	44	43	43	42	275	54	47	45	44	44	45	44	44	42
Scenario 2	195	9	178	70	51	47	45	44	43	42	42	41	195	59	48	46	44	44	44	43	43	42	275	54	47	45	44	44	45	44	44	42
Scenario 3	175	9	178	70	53	47	45	44	44	43	42	41	195	59	48	46	44	44	44	43	43	42	275	54	47	45	44	44	45	44	44	42
Scenario 4	167	8	178	70	54	48	46	44	44	43	43	41	195	59	51	48	46	45	45	44	44	43	275	54	49	45	44	44	45	44	44	42
Scenario 5a	148	7	178	70	55	48	46	44	44	43	42	41	195	59	49	46	45	44	44	43	43	42	275	54	48	45	44	44	45	44	44	42
Scenario 5b	139	6	178	70	55	48	46	44	44	43	43	41	195	59	52	48	46	45	45	44	44	43	275	54	49	45	44	44	45	44	44	42

cPAHs (µg TEQ/kg dw) (RAO 2)

Scenario	Active Area in FS Study Area (acres)	Construc-tion Period (years)	Netfishing Direct Contact Baseline = 390 10^{-6} RBTC = 380 PRG = 380										Tribal Clamming Direct Contact Baseline = 380 10^{-6} RBTC = 150 PRG = 150										Beach Play Direct Contact Baseline = 331 10^{-6} RBTC = 90 PRG = 90									
			Time from Beginning of Construction (years)										*Time from Beginning of Construction (years)*										*Time from Beginning of Construction (years)*									
			0 [a]	*5*	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*	*0* [a]	*5*	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*	*0* [a]	*5*	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*
Alternative 5C	157	7	358	156	129	110	105	103	105	103	103	96	296	131	118	107	106	105	107	104	105	99	308	140	129	116	118	118	124	117	119	109
5C Plus Base[b]	172	8	358	156	127	109	104	102	105	103	103	96	296	131	116	106	106	105	107	103	105	99	308	140	128	116	118	118	124	117	119	109
Scenario 1	193	9	358	156	126	108	104	102	105	103	103	96	296	131	116	106	106	105	107	103	105	99	308	140	128	116	118	118	124	117	119	109
Scenario 2	195	9	358	156	126	108	104	102	105	103	103	96	296	131	116	106	106	105	107	103	105	99	308	140	128	116	118	118	124	117	119	109
Scenario 3	175	9	358	156	127	109	104	102	105	103	103	96	296	131	116	106	106	105	107	103	105	99	308	140	128	116	118	118	124	117	119	109
Scenario 4	167	8	358	156	128	109	105	103	105	103	103	96	296	131	117	107	106	105	107	104	105	99	308	140	128	116	118	118	124	117	119	109
Scenario 5a	148	7	358	158	130	110	105	103	105	103	103	96	296	130	117	107	106	105	106	103	105	99	308	139	129	116	118	118	124	117	119	109
Scenario 5b	139	6	358	160	131	111	105	103	105	103	103	96	296	130	118	107	106	105	106	103	105	99	308	139	129	116	118	118	123	117	119	109

Table 9 Effectiveness Evaluation of Alternative 5C and Supplemental 5C Plus Scenarios – Predicted Post-Construction Arsenic, Total PCB, cPAH, and Dioxin/Furan Concentrations (SWACs)

Dioxins/Furans (ng TEQ/kg dw) (RAOs 1 and 2)

Scenario	Active Area in FS Study Area (acres)	Construction Period (years)	Site-wide Baseline = 26 Netfishing Direct Contact: PRG = 10^{-6} RBTC = 37 Seafood Consumption - Human: PRG = 2										Tribal Clamming Direct Contact Baseline = 32 10^{-6} RBTC = 13 PRG = 13										Beach Play Direct Contact Baseline = 18 10^{-6} RBTC = 28 PRG = 28									
			Time from Beginning of Construction (years)										*Time from Beginning of Construction (years)*										*Time from Beginning of Construction (years)*									
			0[a]	*5*	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*	*0*[a]	*5*	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*	*0*[a]	*5*	*10*	*15*	*20*	*25*	*30*	*35*	*40*	*45*
Alternative 5C	157	7	24	4.9	4.7	4.4	4.4	4.4	4.4	4.4	4.4	4.3	30	4.9	4.7	4.4	4.4	4.4	4.4	4.3	4.4	4.3	14	4.7	4.7	4.5	4.5	4.5	4.6	4.6	4.6	4.5
5C Plus Base[b]	172	8	24	4.9	4.6	4.4	4.4	4.3	4.4	4.4	4.4	4.3	30	4.9	4.6	4.4	4.4	4.3	4.3	4.3	4.3	4.3	14	4.7	4.6	4.5	4.5	4.5	4.6	4.6	4.6	4.5
Scenario 1	193	9	24	4.9	4.5	4.3	4.3	4.3	4.4	4.4	4.4	4.3	30	4.9	4.6	4.4	4.3	4.3	4.3	4.3	4.3	4.3	14	4.7	4.6	4.5	4.5	4.5	4.6	4.6	4.6	4.5
Scenario 2	195	9	24	4.9	4.5	4.3	4.3	4.3	4.4	4.4	4.4	4.3	30	4.9	4.6	4.4	4.3	4.3	4.3	4.3	4.3	4.3	14	4.7	4.6	4.5	4.5	4.5	4.6	4.6	4.6	4.5
Scenario 3	175	9	24	4.9	4.6	4.4	4.4	4.3	4.4	4.4	4.4	4.3	30	4.9	4.6	4.4	4.4	4.3	4.3	4.3	4.3	4.3	14	4.7	4.6	4.5	4.5	4.5	4.6	4.6	4.6	4.5
Scenario 4	167	8	24	4.9	4.6	4.4	4.4	4.4	4.4	4.4	4.4	4.3	30	4.9	4.7	4.4	4.4	4.4	4.4	4.3	4.4	4.3	14	4.7	4.7	4.5	4.5	4.5	4.6	4.6	4.6	4.5
Scenario 5a	148	7	24	5.0	4.7	4.4	4.4	4.4	4.4	4.4	4.4	4.3	30	4.9	4.7	4.4	4.4	4.3	4.4	4.3	4.3	4.3	14	4.7	4.7	4.5	4.5	4.5	4.6	4.6	4.6	4.5
Scenario 5b	139	6	24	5.0	4.7	4.4	4.4	4.4	4.4	4.4	4.4	4.3	30	5.0	4.8	4.5	4.4	4.4	4.4	4.3	4.4	4.3	14	4.8	4.7	4.5	4.6	4.6	4.6	4.6	4.6	4.5

Notes:

1. BCM predictions use base case STM outputs revised June 2010 (Appendix C) and FS dataset.
2. Arsenic BCM inputs (mg/kg dw): upstream 9, lateral 13, and post-remedy bed sediment replacement value 10 (AOPC 1) and 9 (AOPC 2).
3. Total PCB BCM inputs (µg/kg dw): upstream 35, lateral 300, and post-remedy bed sediment replacement value 60 (AOPC 1) and 20 (AOPC 2).
4. cPAH BCM inputs (µg TEQ/kg dw): upstream 70, lateral 1,400, and post-remedy bed sediment replacement value 140 (AOPC 1) and 100 (AOPC 2).
5. Dioxin/furan BCM inputs (ng TEQ/kg dw): upstream 4, lateral 20, and post-remedy bed sediment replacement value 4 (AOPC 1).
6. BCM model area = 430 acres and FS study area = 441 acres

a. The 5-year model-predicted intervals associated with the BCM SWAC output are indexed to the start of construction for Alternative 5C and all scenarios.
b. Alternative 5C Plus Base includes the common base elements and PCB intertidal RAL of the SQS.

(shaded) BCM output used as approximation (estimate) of concentrations after construction.

AOPC = area of potential concern
BCM = bed composition model
cPAH = carcinogenic polycyclic aromatic hydrocarbon
dw = dry weight
EAA = early action area
FS = feasibility study
kg = kilogram
µg = microgram
mg = milligram
ng = nanogram

PCB = polychlorinated biphenyl
PRG = preliminary remediation goal
RAL = remedial action level
RAO = remedial action objective
RBTC = risk-based threshold concentration
SQS = sediment quality standard
STM = sediment transport model
SWAC = spatially-weighted average concentration
TEQ = toxic equivalent

Table 10 Effectiveness Evaluation of Alternative 5C and Supplemental 5C Plus Scenarios – Predicted Post-Construction Exceedances of SMS Criteria (CSL and SQS) (Addresses RAO 3)

Remaining CSL Chemistry Station Counts; Total Baseline Station Count = 1,395

			Time from Beginning of Construction: 0 yr [a]			5 yr			10 yr			15 yr			20 yr			25 yr			30 yr			10 Years Following End of Construction		
Scenario	Active Area in FS Study Area (acres)	Construc-tion Period (years)	Number of Stations	% of Stations < CSL	% of Area < CSL	Number of Stations	% of Stations < CSL	% of Area < CSL	Number of Stations	% of Stations < CSL	% of Area < CSL	Number of Stations	% of Stations < CSL	% of Area < CSL	Number of Stations	% of Stations < CSL	% of Area < CSL	Number of Stations	% of Stations < CSL	% of Area < CSL	Number of Stations	% of Stations < CSL	% of Area < CSL	Number of Stations	% of Stations < CSL	% of Area < CSL
Alternative 4C	107	6	63	95%	96%	6	>99%	>99%	3	>99%	>99%	2	>99%	>99%	1	>99%	>99%	1	>99%	>99%	2	>99%	>99%	2	>99%	>99%
Alternative 5C	157	7	63	95%	96%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%
5C Plus Base[b]	172	8	63	95%	96%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%
Scenario 1	193	9	63	95%	96%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%
Scenario 2	195	9	63	95%	96%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%
Scenario 3	175	9	63	95%	96%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%
Scenario 4	167	8	63	95%	96%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%
Scenario 5a	148	7	63	95%	96%	1	>99%	>99%	1	>99%	>99%	1	>99%	>99%	1	>99%	>99%	1	>99%	>99%	1	>99%	>99%	1	>99%	>99%
Scenario 5b	139	6	63	95%	96%	1	>99%	>99%	1	>99%	>99%	1	>99%	>99%	1	>99%	>99%	1	>99%	>99%	1	>99%	>99%	1	>99%	>99%

Remaining SQS Chemistry Station Counts; PRG = compliance with SQS; Total Baseline Station Count = 1,395

			Time from Beginning of Construction: 0 yr [a]			5 yr			10 yr			15 yr			20 yr			25 yr			30 yr			10 Years Following End of Construction		
Scenario	Active Area in FS Study Area (acres)	Construc-tion Period (years)	Number of Stations	% of Stations < SQS	% of Area < SQS	Number of Stations	% of Stations < SQS	% of Area < SQS	Number of Stations	% of Stations < SQS	% of Area < SQS	Number of Stations	% of Stations < SQS	% of Area < SQS	Number of Stations	% of Stations < SQS	% of Area < SQS	Number of Stations	% of Stations < SQS	% of Area < SQS	Number of Stations	% of Stations < SQS	% of Area < SQS	Number of Stations	% of Stations < SQS	% of Area < SQS
Alternative 4C	107	6	224	84%	82%	24	98%	98%	15	99%	99%	13	99%	99%	8	99%	>99%	5	>99%	>99%	6	>99%	>99%	13	99%	99%
Alternative 5C	157	7	224	84%	82%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%
5C Plus Base[b]	172	8	224	84%	82%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%
Scenario 1	193	9	224	84%	82%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%
Scenario 2	195	9	224	84%	82%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%
Scenario 3	175	9	224	84%	82%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%
Scenario 4	167	8	224	84%	82%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%	0	>99%	>99%
Scenario 5a	148	7	224	84%	82%	2	>99%	>99%	3	>99%	>99%	3	>99%	>99%	3	>99%	>99%	3	>99%	>99%	3	>99%	>99%	3	>99%	>99%
Scenario 5b	139	6	224	84%	82%	2	>99%	>99%	3	>99%	>99%	3	>99%	>99%	3	>99%	>99%	3	>99%	>99%	3	>99%	>99%	3	>99%	>99%

[green shading] = Predicted percentage of baseline stations or LDW surface area below CSL or SQS is ≥ 98%

Notes:

1. FS study area = 441 acres. BCM model area = 430 acres.
2. Contaminant concentration predictions use BCM input parameters for SMS contaminants as described in Section 5 of the FS.
3. Stations falling within the actively remediated footprint of each remedial scenario are not counted after construction is completed for that scenario. However, recontamination potential analysis shows that 23 STM grid cells (out of >700) have the potential to recontaminate above the SQS for bis 2-ethylhexyl phthalate (BEHP) 10 years after remedy completion. These counts do not factor into the recontamination potential.
4. In some locations, the BCM predicts point concentrations above the SQS, but recent chemical data and trend analysis suggest sediment concentrations are below the SQS. Therefore, the assignment of remedial technologies may not be consistent with BCM point-counts. This apparent discrepancy will be resolved during remedy implementation through design sampling, monitoring, and adaptive management.
5. Many of the predicted SQS exceedances remaining are located on the edges of areas to be actively remediated and will likely be recharacterized during remedial design sampling. Other locations are in areas expected to recover (based on other factors used to define the recovery categories) and were assigned to MNR using best professional judgment.
6. The percent of LDW area below SMS criteria is calculated by dividing the polygon-derived areas associated with predicted exceedances by the total area of the LDW (441 acres).
7. The percent of stations below SMS criteria is calculated by dividing the predicted number of station exceedances by the number of FS baseline stations (n = 1,395 points).
8. Station-specific TOC values were used to oc-normalize dry weight concentrations for non-polar organic compounds, with TOC values between 0.5 and 4%. For samples with a TOC outside this range, oc-normalization was not performed, and the dry weight concentration was compared to the LAET and 2LAET criteria.
9. The convention of 98% stations or LDW surface area below the SMS criteria is used in the FS for point count and area estimation purposes only. It does not represent a standard to be applied to compliance monitoring.

a. The 5-year model-predicted intervals associated with the BCM output are indexed to the start of construction for Alternatives 4C and 5C and all the scenarios.
b. Alternative 5C Plus Base includes the common base elements and PCB intertidal RAL of the SQS.

2LAET = second lowest appearent effects threshold
BCM = bed composition model
CSL = cleanup screening level
D/F = dioxins and furans
EAA = early action area
FS = feasibility study
LAET = lowest apparent effect threshold
LDW = Lower Duwamish Waterway
MNR = monitored natural recovery
oc = organic carbon
PRG = preliminary remediation goal
RAL = remedial action level
RAO = remedial action objective
SMS = Sediment Management Standards
SQS = sediment quality standard
STM = sediment transport model
TOC = total organic carbon
yr = year

Table 11 Comparative Evaluation and Relative Ranking of Alternative 5C and Supplemental 5C Plus Scenarios

Evaluation Criteria			Remedial Scenario							
			Alternative 5C	5C Plus Base (and PCB Intertidal RAL)	Scenario 1:	Scenario 2:	Scenario 3:	Scenario 4:	Scenario 5a:	Scenario 5b:
Overall Protection of Human Health and the Environment		*Summary of Overall Protection of Human Health and the Environment*	Alternative 5C and all the scenarios achieve overall protection of human health and the environment in varying time frames and with varying degrees of certainty. All require institutional controls to fully achieve protectiveness. Longer construction periods result in proportionately greater short-term impacts. Dredging or capping a larger surface area has a lower potential for subsurface contamination to be exposed by natural or mechanical disturbances (e.g., scour, earthquakes). The potential for subsurface contaminated sediment to be exposed diminishes as more contaminated sediment is dredged.							
Comply with ARARs		*Summary of ARARs*	Alternative 5C and the scenarios are not expected to comply with all surface water quality standards, or with all natural background sediment standards required under MTCA (for risk-based RBTCs below background). Surface water quality and MTCA ARAR waivers, the need for which varies among scenarios, will be required at or before completion of the remedial action.							
Achieve Threshold Requirements			Scenarios likely require one or more ARAR waivers to meet threshold criteria.							
Long-term Effectiveness and Permanence	Magnitude of Residual Risk (Contaminated sediment remaining in the subsurface)	Total dredge area outside of EAAs (acres)	57	72	80	82	73	66	62	55
		Total cap, partial dredge/cap	47	49	69	69	53	51	39	38
		Total ENR/*in situ* area (in Category 1/Categories 2 & 3 combined; acres) [a, b]	0/53	0/51	0/45	0/44	0/48	0/50	0/48	0/47
		MNR area (in Category 1/Categories 2 & 3 combined; acres) [b]	0/0	0/0	0/0	0/0	0/0	0/0	0/27	0/28
		Total VM and AOPC 2 area (in Category 1/Categories 2 & 3 combined; acres) [b]	23/122	23/110	19/100	19/100	23/108	23/115	23/114	23/115
		Post-construction number of core stations remaining >CSL at any depth in the FS dataset (under caps/ all other locations)[c]	20/22	21/17	25/13	27/11	22/16	22/19	19/22	19/22
		Potential for Exposing Remaining Subsurface Contamination	Alternative 5C and all the scenarios have a low potential for exposure due to unanticipated disturbance effects. Modeling results range from 22 acres disturbed (FS Alternative 5C) up to 49 acres disturbed (Scenario 1) needed to produce a 25% increase in the long term SWAC.							
	Adequacy and Reliability of Controls [d]	Relative amount of monitoring and maintenance required (based on total cap, ENR/*in situ* and MNR area).	Large area (100 acres)	Large area (100 acres)	Large area (114 acres)	Large area (113 acres)	Large area (101 acres)	Large area (101 acres)	Large area (114 acres)	Large area (113 acres)
	Adequacy and Reliability of Controls [d] – Magnitude and Duration of Institutional Controls	Monitoring and notification of waterway users (based on total cap, ENR, and MNR area; acres)	Similar requirements for monitoring and maintenance as Alternative 5C.							
		Seafood consumption advisories, public outreach, and education	Similar seafood consumption advisories, public outreach, and education are required for Alternative 5C and all the scenarios.							
		Summary	Scenarios 1 and 2 leave the least areas with subsurface contaminated sediments and therefore rank higher in long-term effectiveness and permanence than 5C and 5b. All others leave an intermediate amount of sediments. For comparison purposes, Alternative 4R dredges 93 acres, Alternative 6C dredges 108 acres and Alternative 5R dredges 143 acres The scenarios also have similar monitoring and maintenance requirements to Alternative 5C.							

Table 11 Comparative Evaluation and Relative Ranking of Alternative 5C and Supplemental 5C Plus Scenarios (continued)

Evaluation Criteria			Remedial Scenario							
			Alternative 5C	5C Plus Base (and PCB Intertidal RAL)	Scenario 1:	Scenario 2:	Scenario 3:	Scenario 4:	Scenario 5a:	Scenario 5b:
Reduction of Toxicity, Mobility, or Volume through Treatment		*Ex situ* treatment of dredged material	None	None	None	None	None	None	None	None
		In situ treatment (Area in acres potentially treated *in situ* is assumed to be 50% of total ENR and *in situ* treatment area)	26.5	25.5	22.5	22	24	25	24	23.5
Short-term Effectiveness	Protection during Construction	Period of community exposure (including noise), worker exposure, ecological disturbance and resuspension of contaminated material from dredging (years of construction)[e]	7	8	9	9	9	8	7	6
		Dredge-cut prism volume/ Performance contingency (cy)	640,000/ 750,00	780,000/ 880,000	860,000/ 950,000	870,000/ 960,000	790,000/ 890,000	740,000/ 840,000	650,000/ 790,000	600,000/ 740,000
		Air quality impacts (normalized to Alt 5C[divided by Alt. 5C impacts for a relative score])	1	1.17	1.27	1.28	1.19	1.12	1.05	0.99
		Ecological – Habitat area shallower than -10 ft MLLW disturbed (dredging and capping)	39	48	56	58	50	42	36	33
	Time to achieve RAOs or important risk reduction milestones (years) [f]	RAO 1: 10^{-4} magnitude PCB risk (Adult Tribal RME)[g]	7	8	9	9	9	8	7	6
		RAO 1: Predicted time for total PCBs and dioxins/furans to reach long-term model-predicted concentration range in surface sediment[g]	15	15	15	15	15	15	15	15
		RAO 2: Total risk $\leq 1 \times 10^{-5}$ (All exposure scenarios)[h]	3	3	3	3	3	3	3	3
		RAO 2: Individual risk from cPAHs $\leq 1 \times 10^{-6}$ in all areas except Beach 3	3	3	3	3	3	3	3	3
		RAO 3: Benthic invertebrates (SQS)[i]	6	6	6	6	6	6	6	6
		RAO 4: Ecological – river otters (HQ<1)[j]	7	8	9	9	9	8	7	6
		Summary of short-term effectiveness	Impacts from construction similar to Alt 3R and higher than Alt 2, 3C, and 4C and lower than Alt 5R, 6C and 6R. Construction time of 7 yrs to reduce contaminant concentrations. Very low uncertainty (no MNR).	Impacts are 20% higher than Alt 5C. Construction time of 9 years. No MNR.	Impacts are 30% higher than Alt 5C. Construction time of 9 years. No MNR.	Impacts are 30% higher than Alt 5C. Construction time of 9 years. No MNR.	Impacts are 20% higher than Alt 5C. Construction time of 9 years. No MNR.	Impacts are 10% higher than Alt 5C. Construction time of 8 years. No MNR.	Impacts are similar to Alt 5C. Construction time of 7 years. 27 acres MNR.	Impacts are similar to Alt 5C. Construction time of 6 years. 28 acres MNR.

Table 11 Comparative Evaluation and Relative Ranking of Alternative 5C and Supplemental 5C Plus Scenarios (continued)

Evaluation Criteria		Remedial Scenario							
		Alternative 5C	5C Plus Base (and PCB Intertidal RAL)	Scenario 1:	Scenario 2:	Scenario 3:	Scenario 4:	Scenario 5a:	Scenario 5b:
Implementability	Technical and administrative implementability during construction	Construction period longer than Alt 2, 3 and 4C, and shorter than Alt 4R, 5R and 6. Low potential for difficulties and delays.	Longer construction period than 5C. Greater potential for construction delays.	Longer construction period than 5C. Greater potential for construction delays.	Longer construction period than 5C. Greater potential for construction delays.	Longer construction period than 5C. Greater potential for construction delays.	Longer construction period than 5C. Greater potential for construction delays.	Same construction period than 5C.	Lower construction period than 5C.
	Technical and administrative implementability after construction	Additional actions may be needed after dredging to meet low RALs. Low potential for additional actions in ENR areas.	Additional actions may be needed after dredging to meet low RALs. Low potential for additional actions in ENR areas.	Additional actions may be needed after dredging to meet low RALs. Low potential for additional actions in ENR areas.	Additional actions may be needed after dredging to meet low RALs. Low potential for additional actions in ENR areas.	Additional actions may be needed after dredging to meet low RALs. Low potential for additional actions in ENR areas.	Additional actions may be needed after dredging to meet low RALs. Low potential for additional actions in ENR areas.	Less need for additional actions after dredging because of higher surface RALs. Higher potential for additional actions than Alternative 5C due to MNR areas.	Less need for additional actions after dredging because of higher surface RALs. Higher potential for additional actions than Alternative 5C due to MNR areas.
Costs	Total (MM$)[k]	290	331	357	358	333	319	303	289

Notes:

a. The proportion of ENR with or without *in situ* treatment is assumed to be 50%/50% for Alternative 5C and all the scenarios.

b. Recovery categories: Category 1 – presumed to be limited; Category 2 – less certain than Category 3; Category 3 – predicted to occur. The acres shown in Recovery Category 1 are “verification monitoring” acres, which are predicted to be below the Alt 5C RALS when remedial design data area collected.

c. Remaining cores grouped by those located under caps and those located anywhere else within the LDW after construction.

d. This analysis evaluates the reliability of controls after RAOs are achieved. The construction periods differ (see Short-term Effectiveness) and various controls will also be required during construction.

e. Construction period rounded to nearest year. Additional time beyond construction would be required for ecologically sensitive areas to recover. Also, fish and shellfish tissue contaminant concentrations may require additional time after construction to recover.

f. The predicted time to achieve cleanup objectives is calculated from the start of construction.

g. No remedial alternative or scenario achieves RAO 1 PRGs. Alternative 5C and all scenarios achieve protectiveness with some combination of active and passive remediation and ICs. Two time frames are provided for purposes of comparing the scenarios: 1) the point at which the scenario reduces the Adult Tribal RME seafood consumption risk to 10^{-4}, and 2) the predicted time for risk-driver concentrations to achieve long-term model-predicted concentration ranges. The latter are based on achieving a site-wide total PCB SWAC within 25% (≤ 49 µg/kg dw) of the 45-yr FS Alternative 6R total PCB SWAC of 39 µg/kg dw, and a site-wide dioxin/furan SWAC within 25% (≤ 5.4 ng TEQ/kg dw) of the 45-yr FS Alternative 6R dioxin/furan SWAC of 4.3 ng TEQ/kg dw. The time is from the beginning of construction (see Table 7). Fish and shellfish tissue concentrations are expected to remain elevated during construction as a result of resuspension and release of total PCBs into the water column.

h. Alternative 3C of the FS specifically addresses direct contact risks and achieves the total and individual direct contact risk metrics defined in FS Section 9.1.2.3 at the end of construction for all direct contact exposure scenarios. FS Alternative 5C, 5C Plus, and the supplemental scenarios are expected to have similar risk results.

i. The FS assumes the time to achieve cleanup objectives for RAO 3 to be when at least 98% of FS surface sediment dataset stations are predicted to comply with the SMS and more than 98% of the LDW surface area is predicted to comply with the SMS. This is not intended as a compliance metric. EPA and Ecology will determine the appropriate metric for SMS compliance.

j. The time to achieve cleanup objectives for RAO 4 is when wildlife seafood consumption HQ <1 is achieved based on the site-wide total PCB SWAC at the end of construction.

k. The cost for 5C Plus Base and Scenarios 1 through 3 have the highest uncertainties because of uncertainties in subsurface sediment above PCB intertidal RALs of the SQS (cost estimated at $16 M but could be as high as $40 M).

AOPC = area of potential concern; ARAR = applicable or relevant and appropriate requirement; C = combined-technology alternative; cPAH = carcinogenic polycyclic aromatic hydrocarbons; CSL = cleanup screening level; cy = cubic yards; dw = dry weight; ENR = enhanced natural recovery; FS = feasibility study; HQ = hazard quotient; IC = institutional control; kg = kilograms; µg = micrograms; mg = milligrams; MLLW = mean lower low water; MM = million; MNR = monitored natural recovery; n/a = not applicable; ng = nanograms; O&M = operation and monitoring; PCB = polychlorinated biphenyls; PRG = preliminary remediation goal; R = removal-emphasis alternative; RAL = remedial action level; RAO = remedial action objective; RME = reasonable maximum exposure; SMS = Sediment Management Standards; SQS = sediment quality standard; SWAC = spatially-weighted average concentration; TEQ = toxic equivalent; UCL95 = 95 percent upper confidence; VM = verification monitoring

Figures

Legend

Recovery Category

- Category 1: Recovery Presumed to be Limited (77 acres)
- Category 2: Recovery Less Certain (44 acres)
- Category 3: Predicted to Recover (281 acres)
- Early Action Area (29 acres)
- Outfall Location
- River Mile Marker
- Navigation Channel

Feet
0 200 400 800

Notes:
1. See FS Table 6-3 for recovery category criteria.
2. The entire FS study area downstream of RM 4.75, except the EAAs, is grouped into recovery categories (402 acres).
3. Surface sediment concentrations are evaluated separately (during technology assignments).
   An area may be remediated because of elevated COCs regardless of the recovery category.

EAA= early action area

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Lower Duwamish Waterway
Supplemental Scenarios
60150279-9.9

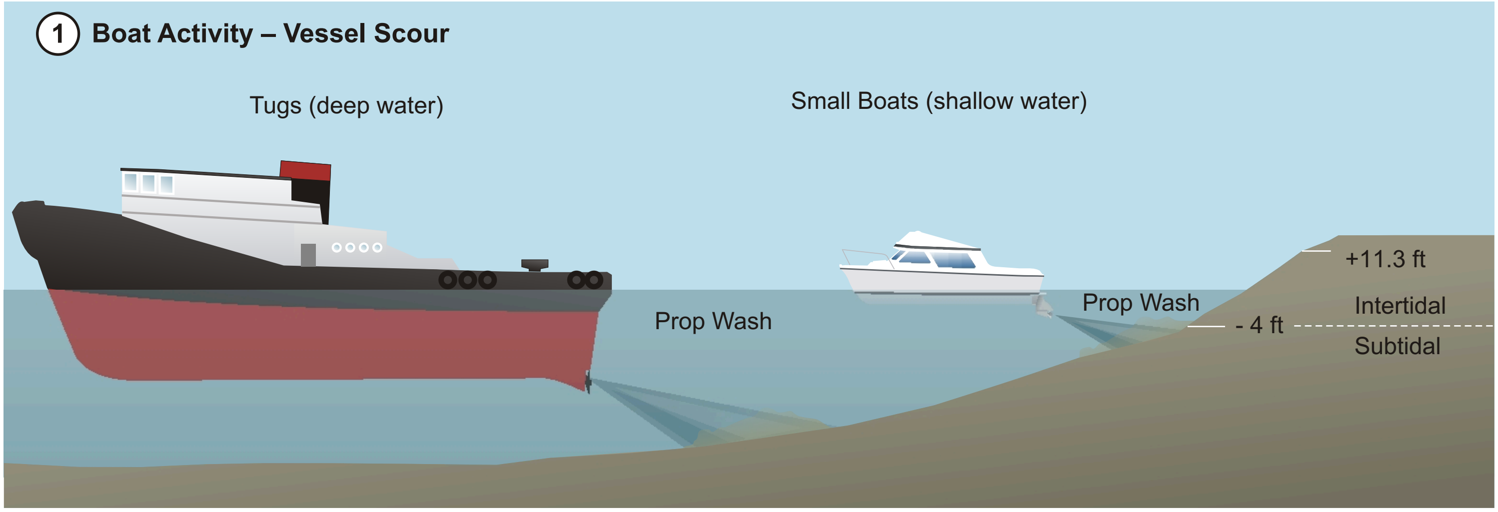
Recovery Categories

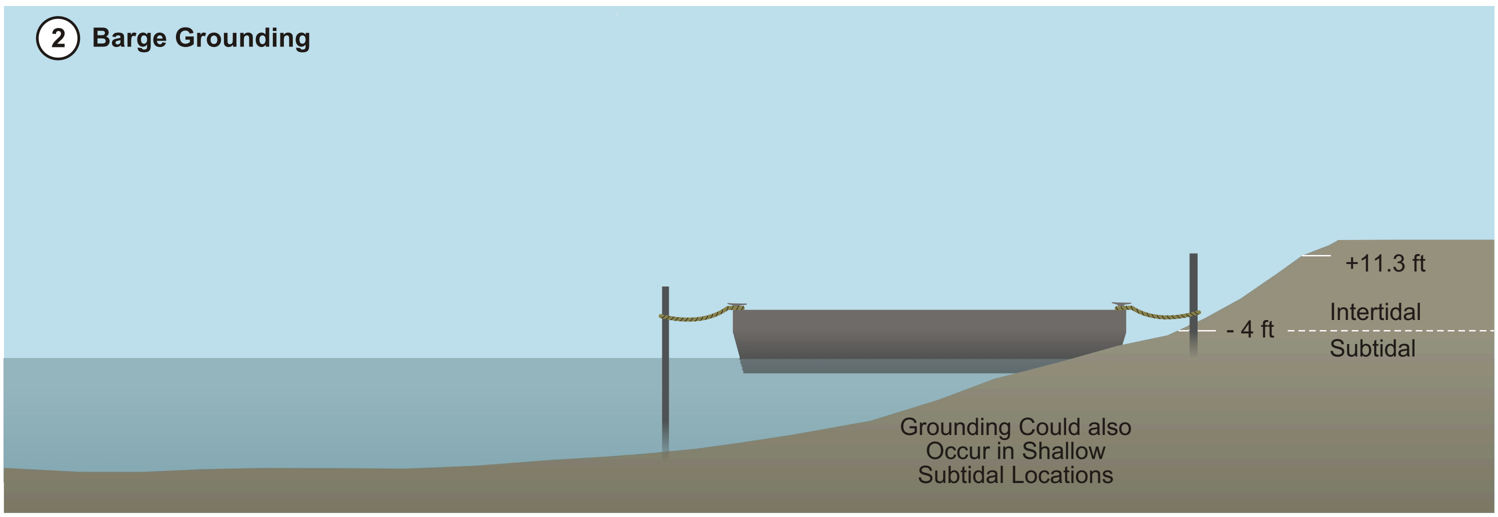
DATE: 12/05/12 | DWRN:de/SEA | Revision: 0

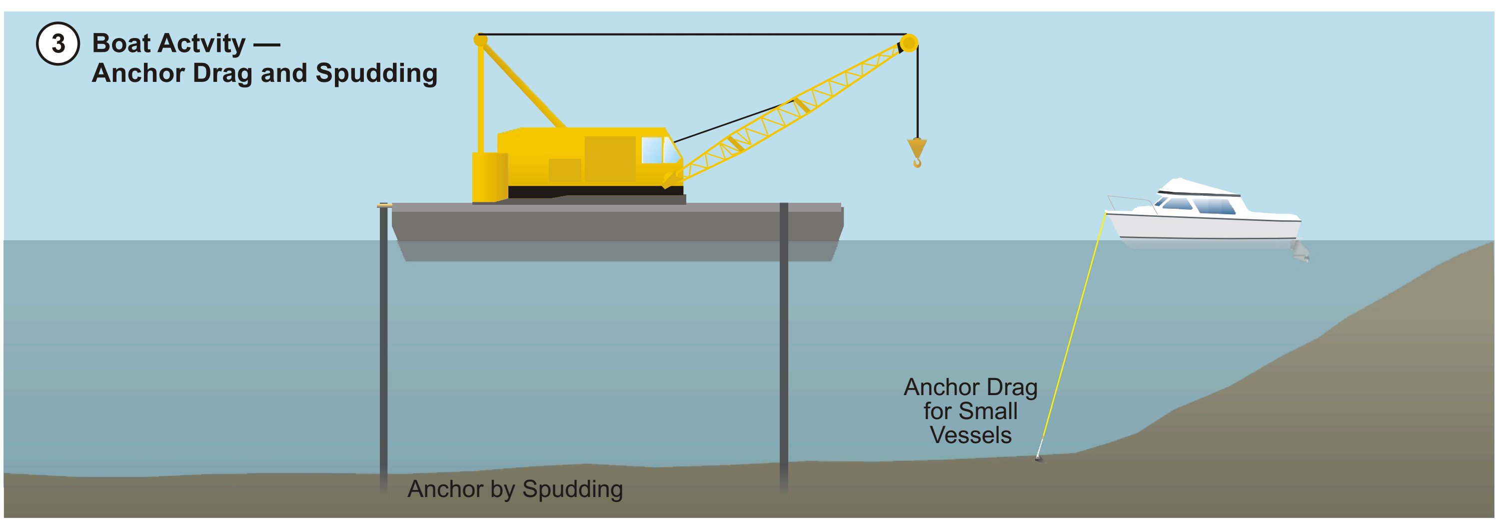
FIGURE 1

Path: Q:\GIS_ENV\Lower Duwamish FS\Prefered Alternative\MXDs\Suplemental Scenarios Post FS_112012\Memo Figures\Figure1_RecoveryCats.mxd

Figure 2 Potential Mechanisms for Exposure of Subsurface Sediment Contamination







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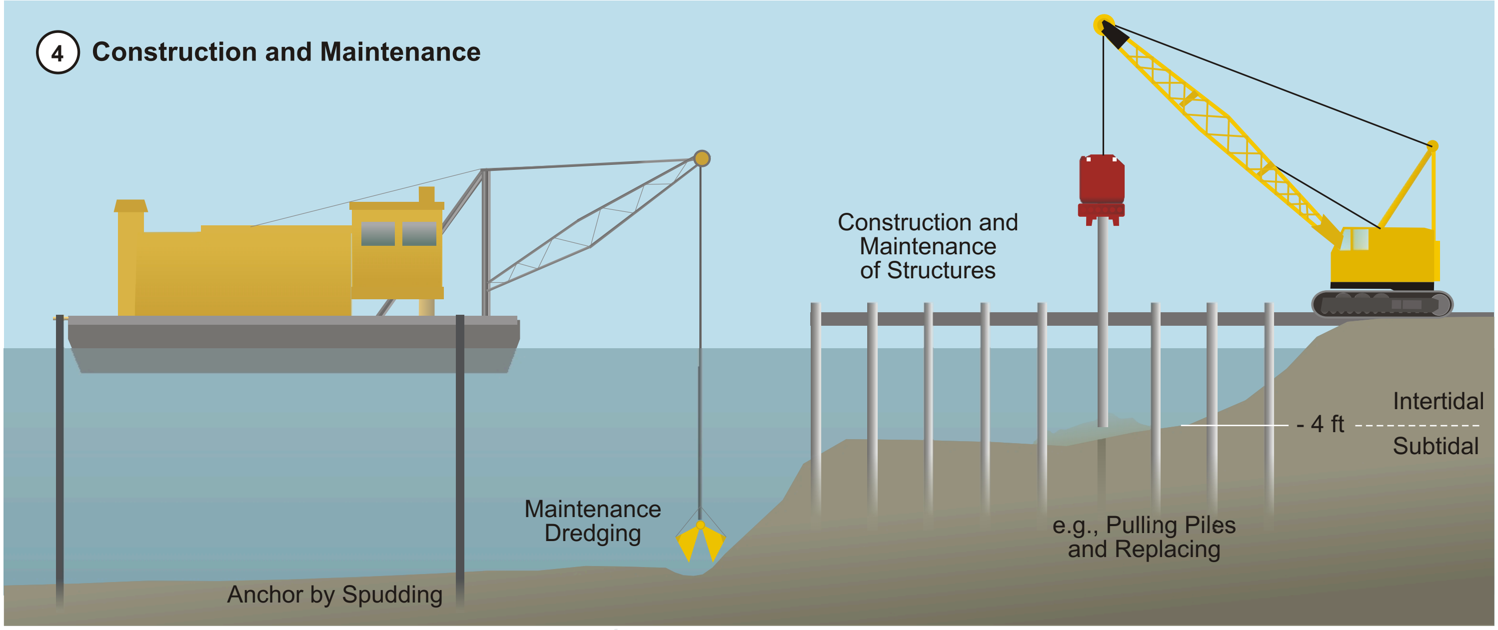
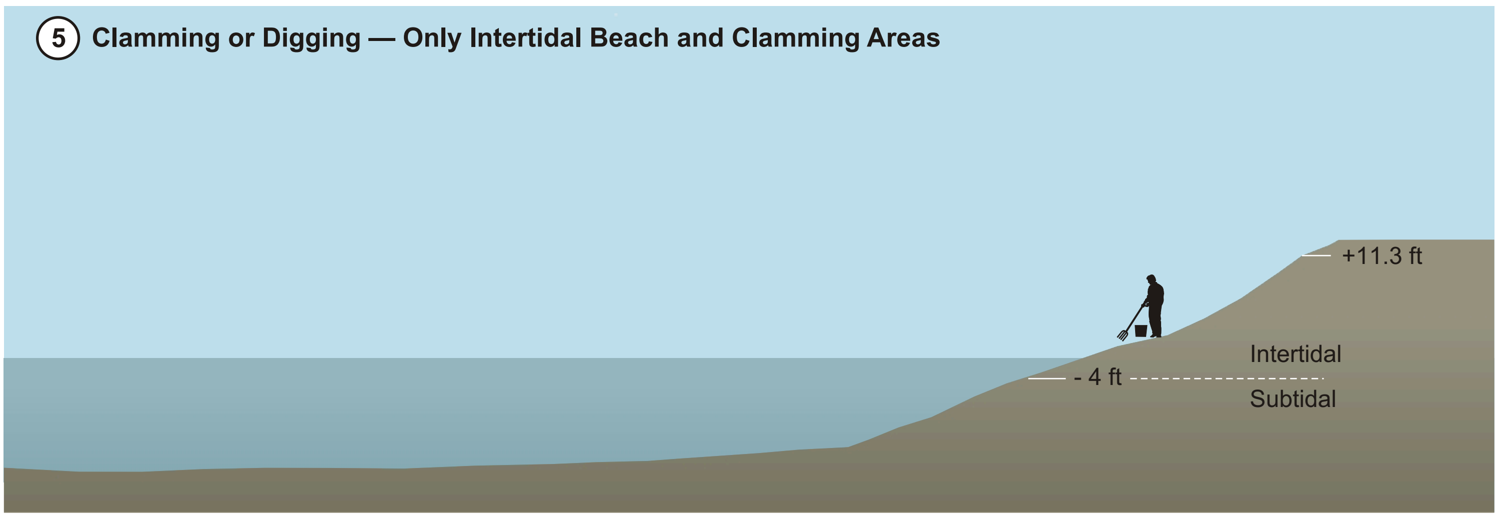
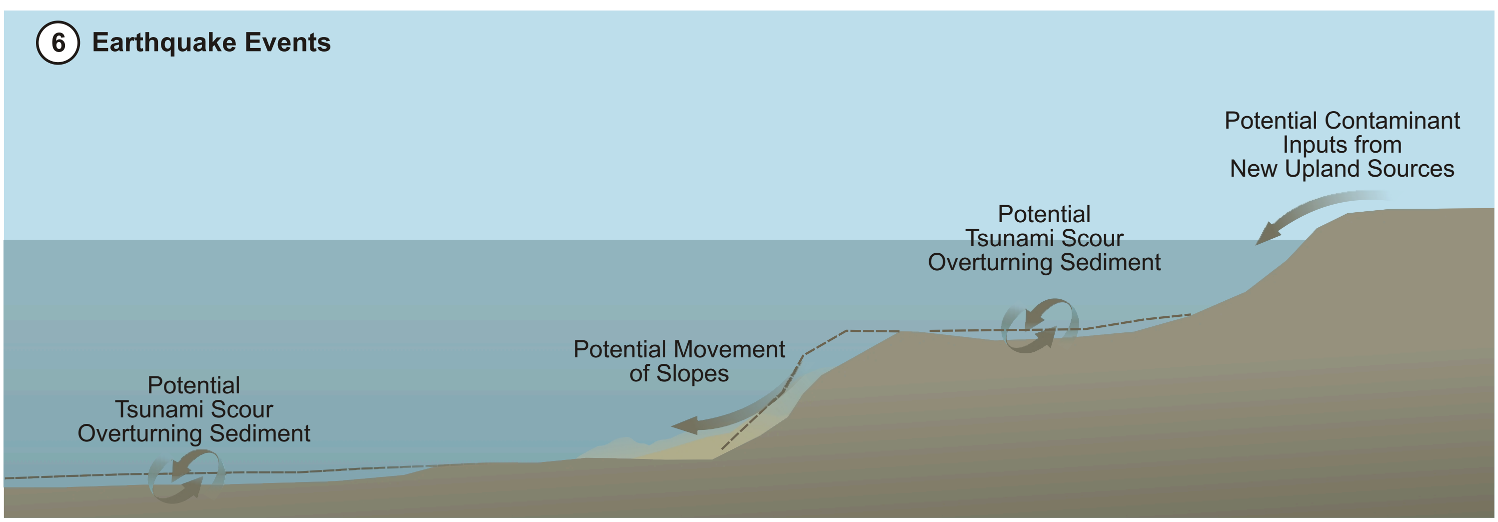
4 Construction and Maintenance

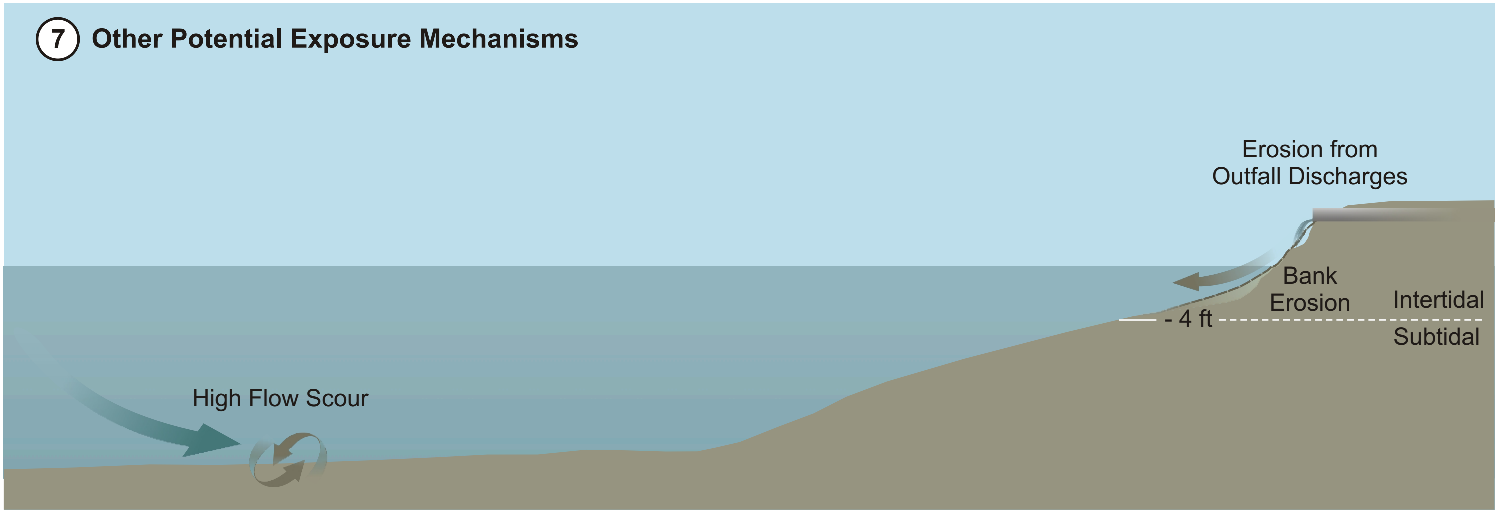


5 Clamming or Digging — Only Intertidal Beach and Clamming Areas



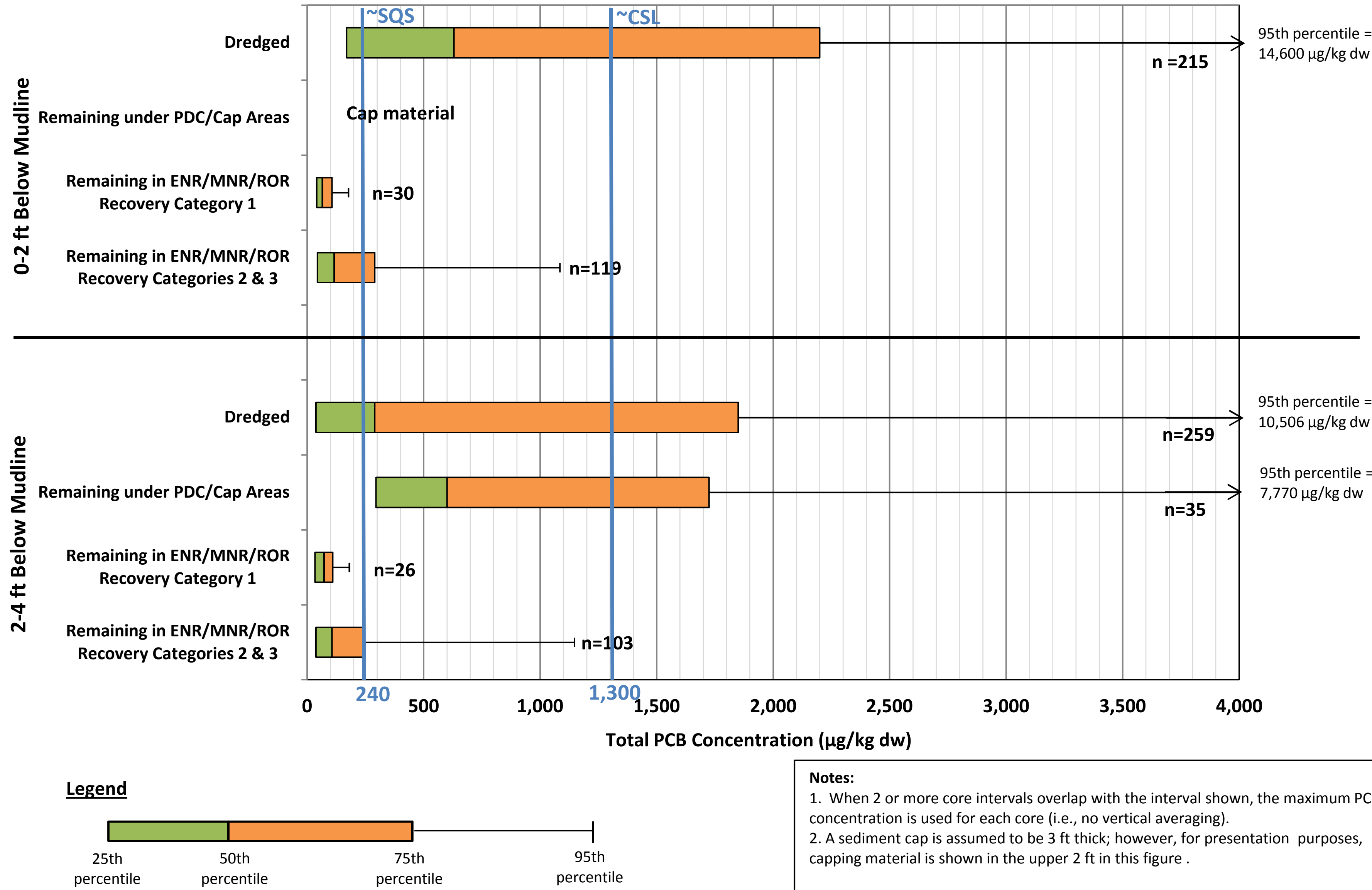
6 Earthquake Events





7 Other Potential Exposure Mechanisms
Erosion from
Outfall Discharges
Bank
Erosion
Intertidal
- 4 ft
Subtidal
High Flow Scour

Figure 3. Total PCB Concentrations in Sediments Removed and Remaining by Depth Intervals Post-FS Alternative 5C



Notes:

1. When 2 or more core intervals overlap with the interval shown, the maximum PCB concentration is used for each core (i.e., no vertical averaging).
2. A sediment cap is assumed to be 3 ft thick; however, for presentation purposes, capping material is shown in the upper 2 ft in this figure .

EAA=early action area; ENR=enhanced natural recovery; MNR=monitored natural recovery; n = number of cores; PDC = partial dredge and cap; ROR=rest of LDW

Figure 4. Temporal Trends of Selected Organic Contaminants at Duwamish/Diagonal EAA (2004-2011)

Figure 4a. Benzyl Alcohol Concentration in Surface Sediment at Duwamish/Diagonal Station 1A (2004-2011)

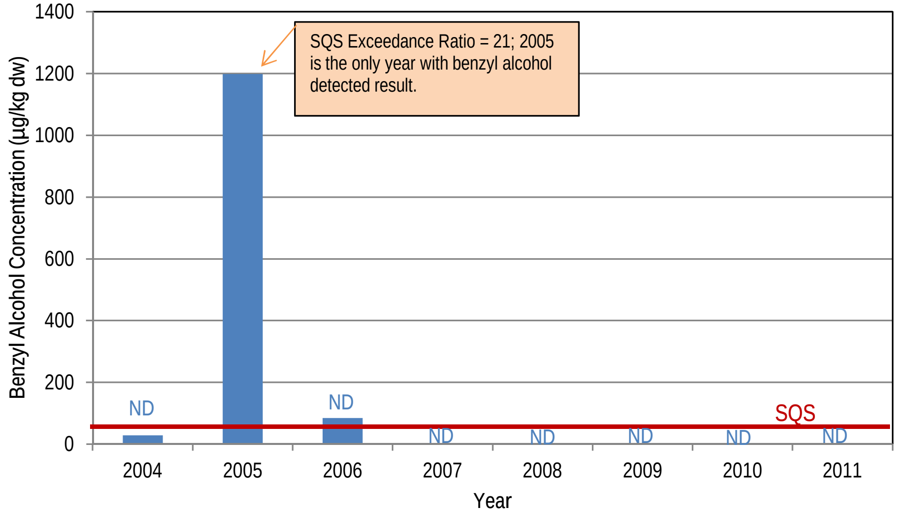


Figure 4b. Benzoic Acid Concentration in Surface Sediment at Duwamish/Diagonal Station 1A (2004-2011)

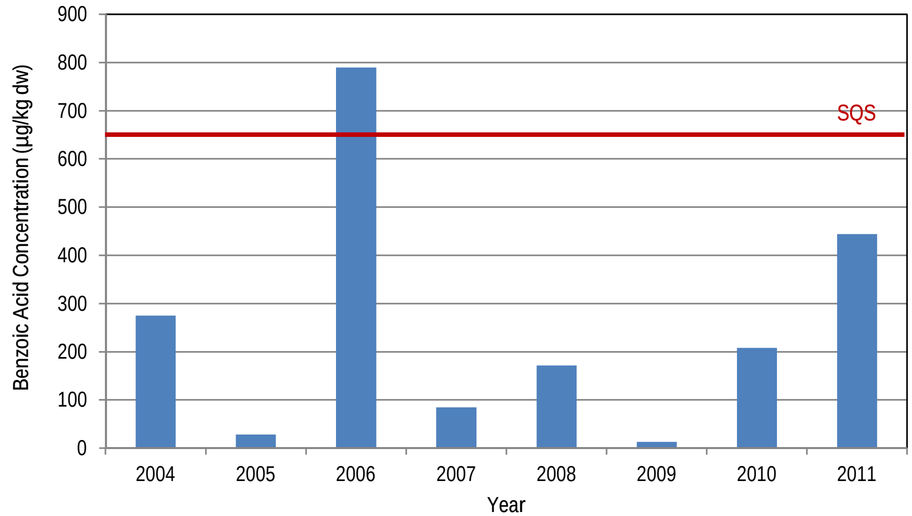
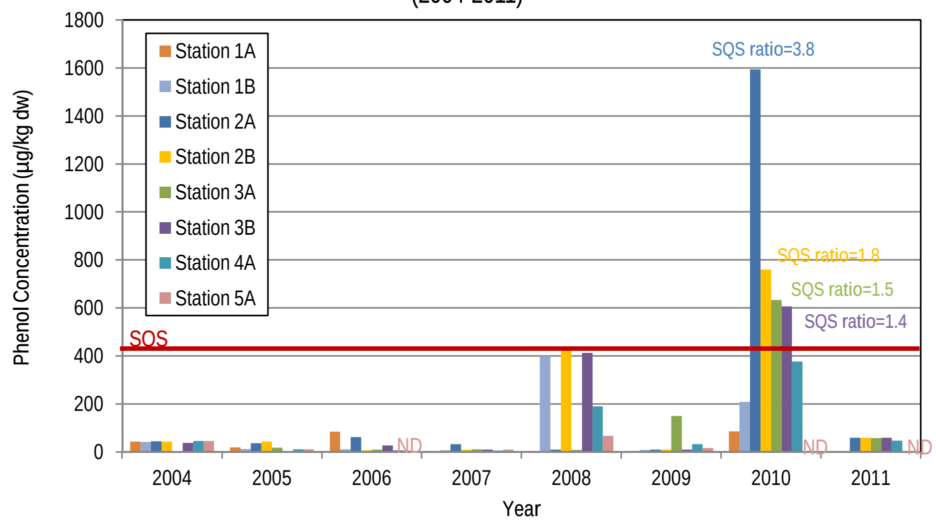
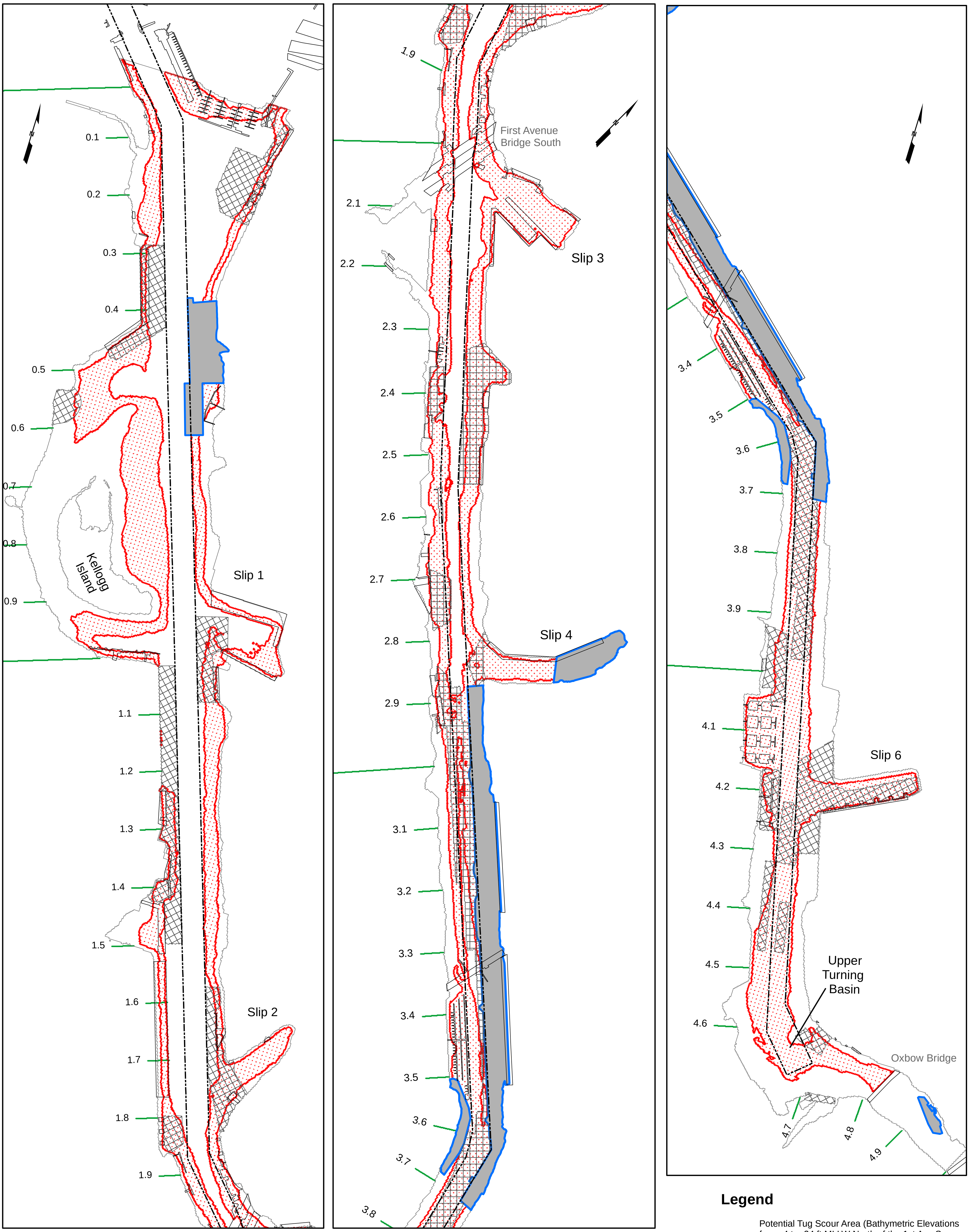


Figure 4c. Phenol Concentration in Surface Sediment at Duwamish/Diagonal (2004-2011)



Notes:
All stations are from Duwamish/ Diagonal Early Action Area, which was dredged and capped in 2003-2004. All data shown are post-remediation.

EAA = early action area; SQS = sediment quality standard; ND = non-detect



Notes:
1. Potential tug scour area is assumed not to extend upstream of Oxbow Bridge at River Mile 4.8.
MLLW= mean lower low water.

Legend

- Potential Tug Scour Area (Bathymetric Elevations from -4 to -24 ft MLLW North of the 1st Ave S Bridge and -4 to -18 ft MLLW South of the 1st Ave S Bridge) (184 acres, 128 acres in Recovery Categories 2 or 3)
- Recovery Category 1: Recovery Presumed to be Limited
- Overwater Structure
- Early Action Area
- Navigation Channel
- River Mile Marker

Feet
0 200 400 800

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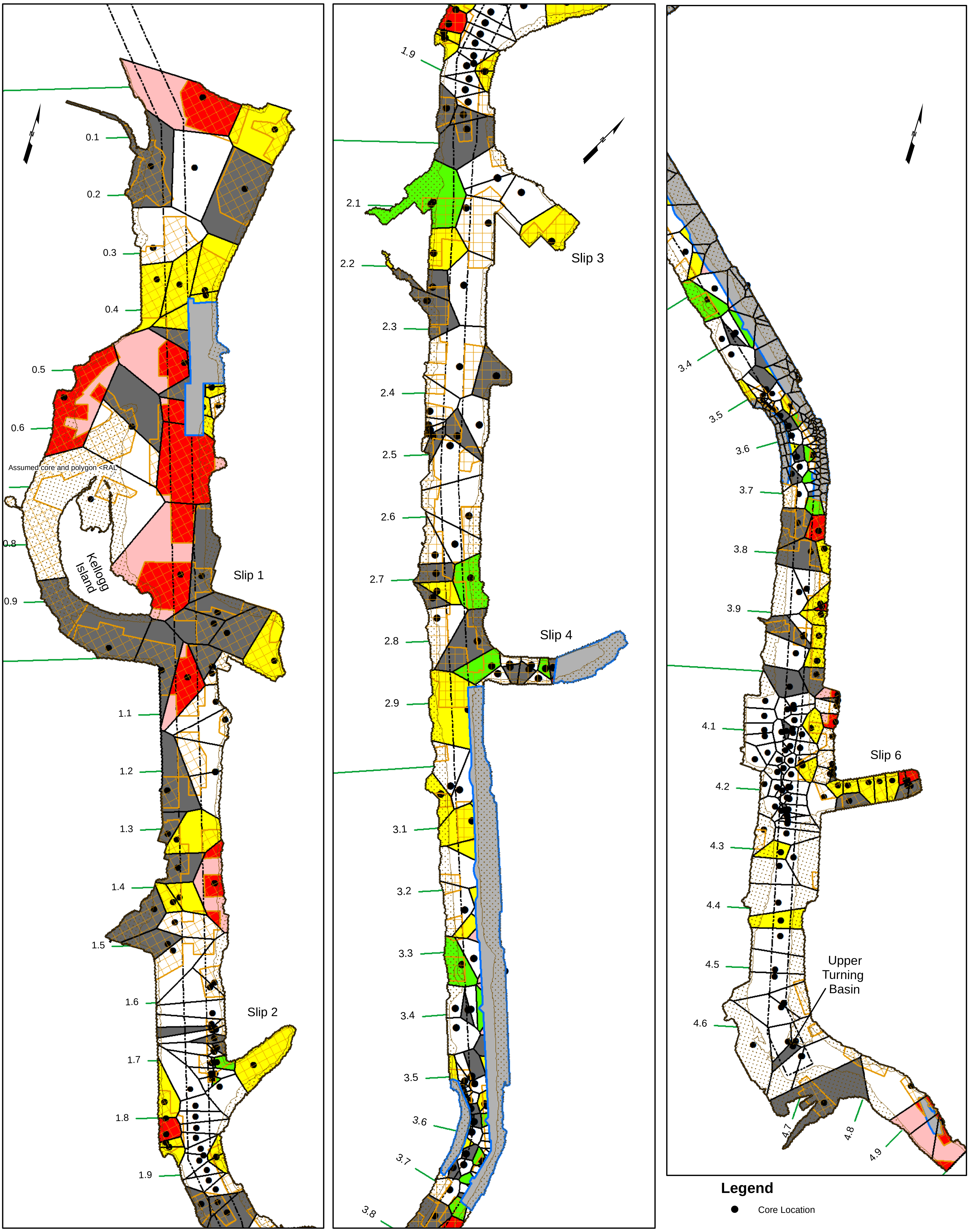
Lower Duwamish Waterway Supplemental Scenarios 60150279-9.9			**Potential Tug Scour Area Based on Bathymetric Elevation**
DATE: 12/04/12	DWRN:MVI/sea	Revision: 0	**FIGURE 5**



Notes:
1. The polygon exceedance footprints are not always incremental as shown. For example, several exceedance polygons for CSL are not exceedances for 3xHH.

AOPC= area of potential concern; CSL= cleanup screening level; D/F= dioxins and furans; HH= human health risk drivers; ND= non-detected exceedance; PCBs= polychlorinated biphenyl; SMS= Sediment Management Standards, SQS= sediment quality standards.

Legend

- Core Location

Incremental Core Polygon Exceedance Status

- > 3xCSL
- > 3xCSL Outside of AOPC 1
- > CSL with 3x D/F
- > 3xHH
- > SQS
- < SQS or ND
- Intertidal Area > -4 ft MLLW
- AOPC 1 Footprint
- Early Action Area

- Navigation Channel
- River Mile Marker

Feet
0 200 400 800

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Lower Duwamish Waterway Group
Port of Seattle / City of Seattle / King County / The Boeing Company

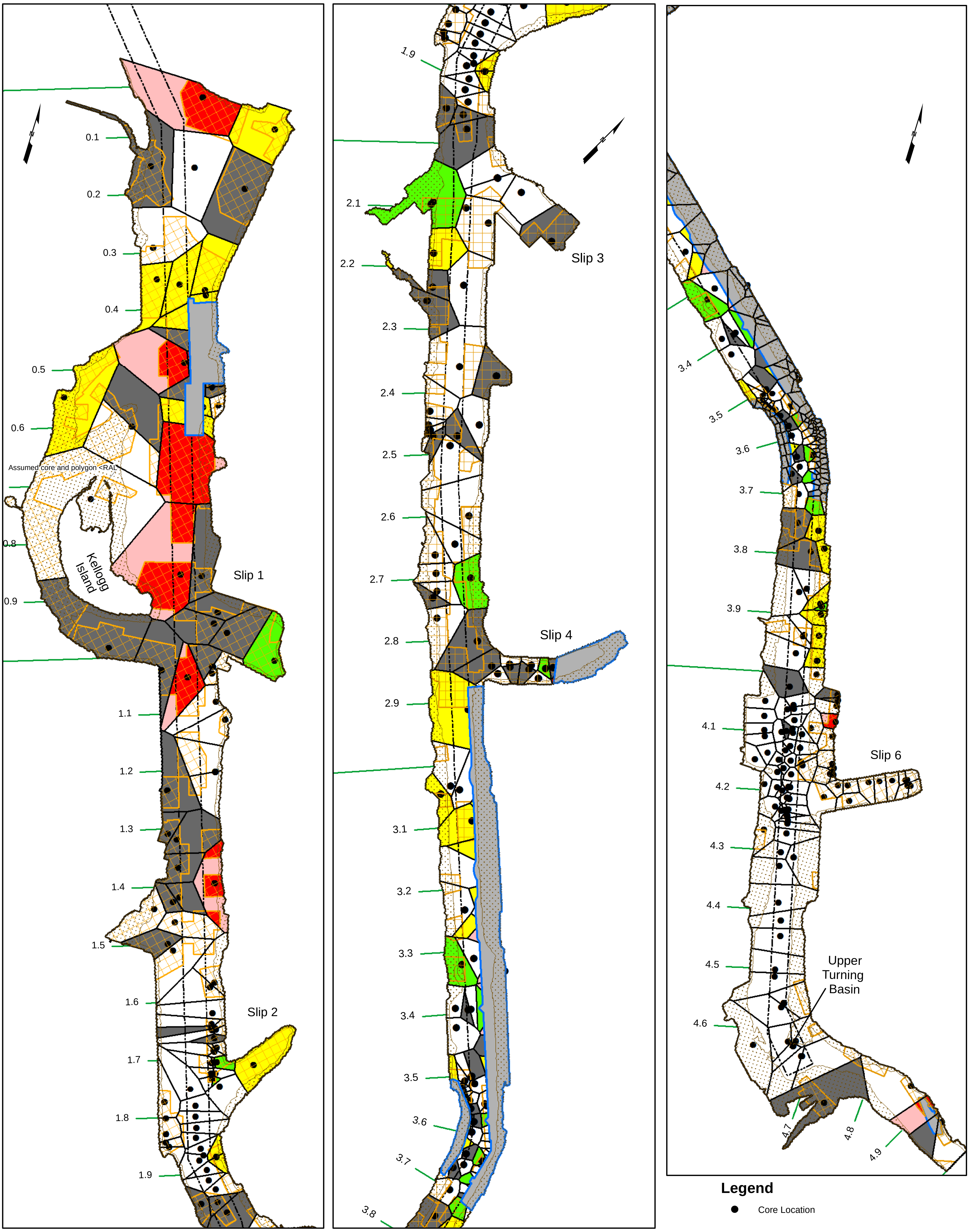
Lower Duwamish Waterway
Supplemental Scenarios
60150279-9.9

Subsurface Exceedance Polygons in the Upper 2 ft of Cores

DATE: 12/12/12 | DWRN:MVI/sea | Revision: 0

FIGURE 6

Path: Q:\GIS_ENV\Lower Duwamish FS\Prefered Alternative\MXDs\Suplemental Scenarios Post FS_112012\Memo Figures\Figure6Alt5RALSCombined.mxd



AOPC= area of potential concern; CSL= cleanup screening level; D/F= dioxins and furans;
HH= human health risk drivers; ND= non-detected exceedance; PCBs= polychlorinated biphenyl;
SMS= Sediment Management Standards, SQS= sediment quality standards.

Legend

- Core Location

Incremental Core Polygon Exceedance Status

- > 3xCSL
- > 3xCSL Outside of AOPC 1
- > CSL
- > 3xSQS
- > SQS
- < SQS or ND
- Intertidal Area > -4 ft MLLW
- AOPC 1 Footprint
- Early Action Area
- Navigation Channel
- River Mile Marker

0 200 400 800 Feet

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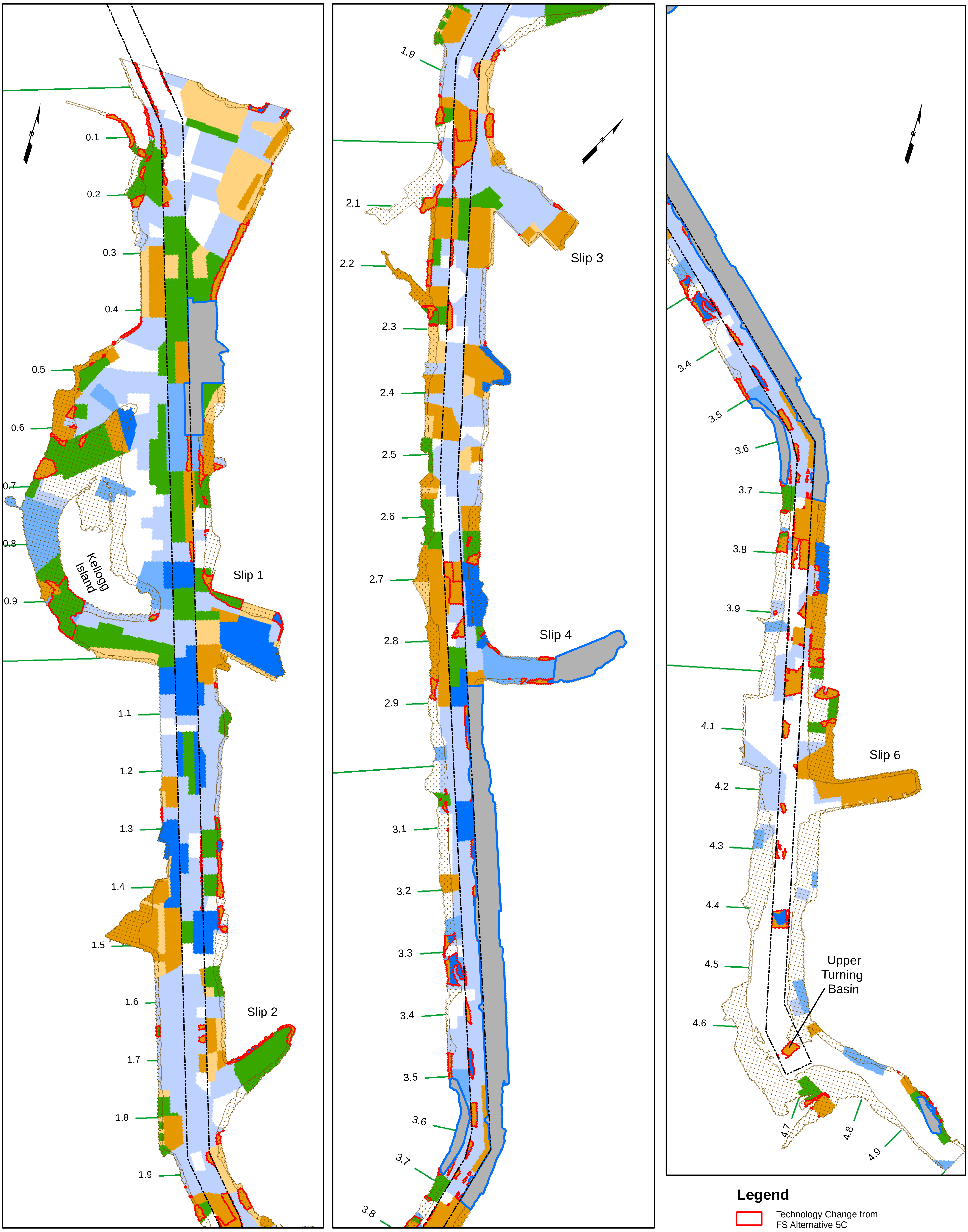
Lower Duwamish Waterway
Supplemental Scenarios
60150279-9.9

Subsurface Exceedance Polygons in the Upper 2 ft of Cores for PCBs Only

DATE: 12/12/12	DWRN:MVI/sea	Revision: 0	**FIGURE 7**

Path: Q:\GIS_ENV\Lower Duwamish FS\Prefered Alternative\MXDs\Suplemental Scenarios Post FS_112012\Memo Figures\Figure7PCBsOnly.mxd



Notes:
1. See Tables 4, 7, and 8 for remedial action levels (RALs), areas, volumes and costs. 5C Plus Base includes the "base elements" (additional dredging in shoaling areas, increased monitoring in passively remediated areas, and 4-ft cap thickness in intertidal areas) and an intertidal RAL of the SQS for total PCBs to 45 cm point of compliance.
2. Intertidal area is -4 ft MLLW to +11.3 ft MLLW.
3. New technology assignments are based on GIS output without best professional judgment modifications.

GIS= geographic information system; MLLW= mean lower low water; PCBs= polychlorinated biphenyl; RAL= remedial action level; SQS= sediment quality standards

Technology Assignment

- Dredge
- Partial Dredge and Cap
- Cap
- ENR/*in situ*
- Monitored Natural Recovery
- Verification Monitoring
- AOPC 2
- Early Action Area
- Remaining Study Area (Institutional Controls and Site-wide Monitoring)

Feet
0 200 400 800

Legend

- Technology Change from FS Alternative 5C
- Intertidal Area > -4 ft MLLW
- Navigation Channel
- River Mile Marker

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Lower Duwamish Waterway Group
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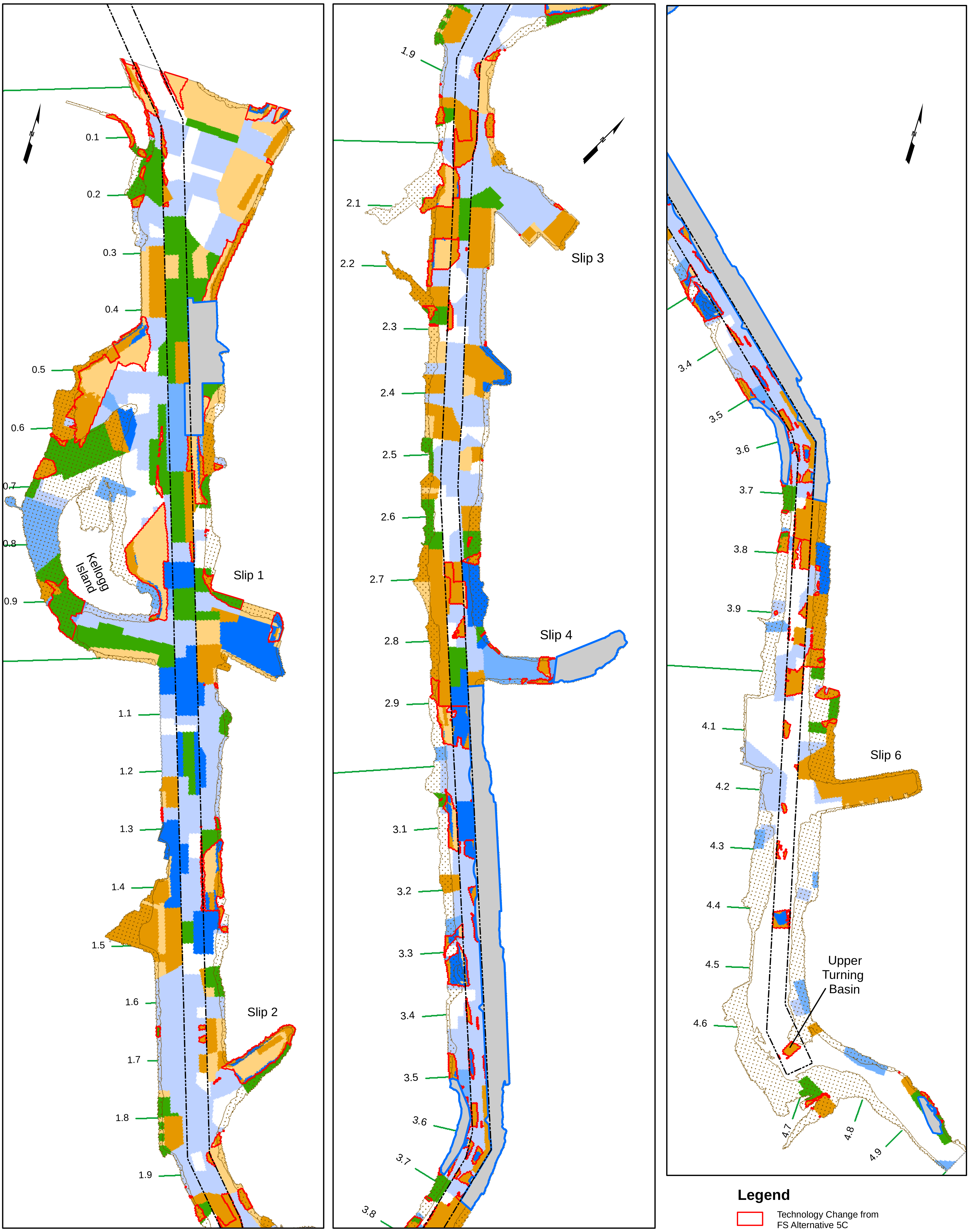
Lower Duwamish Waterway Supplemental Scenarios 60150279-9.9	**5C Plus Base (plus PCB intertidal RAL)**
DATE: 12/12/12 DWRN:MVI/sea Revision: 0	**FIGURE 8a**

Path: Q:\GIS_ENV\Lower Duwamish FS\Prefered Alternative\MXDs\Suplemental Scenarios Post FS_112012\Memo Figures\Figure8a-Alt5C+Base.mxd



Legend

- Technology Change from FS Alternative 5C
- Intertidal Area > -4 ft MLLW
- Navigation Channel
- River Mile Marker

Technology Assignment

- Dredge
- Partial Dredge and Cap
- Cap
- ENR/*in situ*
- Monitored Natural Recovery
- Verification Monitoring
- AOPC 2
- Early Action Area
- Remaining Study Area (Institutional Controls and Site-wide Monitoring)

0 200 400 800 Feet

Notes:

1. See Tables 4, 7, and 8 for remedial action levels (RALs), areas, volumes and costs. Scenario 1 includes the "base elements" (additional dredging in shoaling areas, increased monitoring in passively remediated areas, and 4-ft cap thickness in intertidal areas), an intertidal subsurface RAL of the SQS for total PCBs, and subsurface RALs of 3x Human Health RALs for PCBs and dioxins/furans.
2. Intertidal area is -4 ft MLLW to +11.3 ft MLLW.
3. New technology assignments are based on GIS output without best professional judgment modifications.

GIS= geographic information system; MLLW= mean lower low water; PCBs= polychlorinated biphenyl; RAL= remedial action level; SQS= sediment quality standards

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Lower Duwamish Waterway Group
Port of Seattle / City of Seattle / King County / The Boeing Company

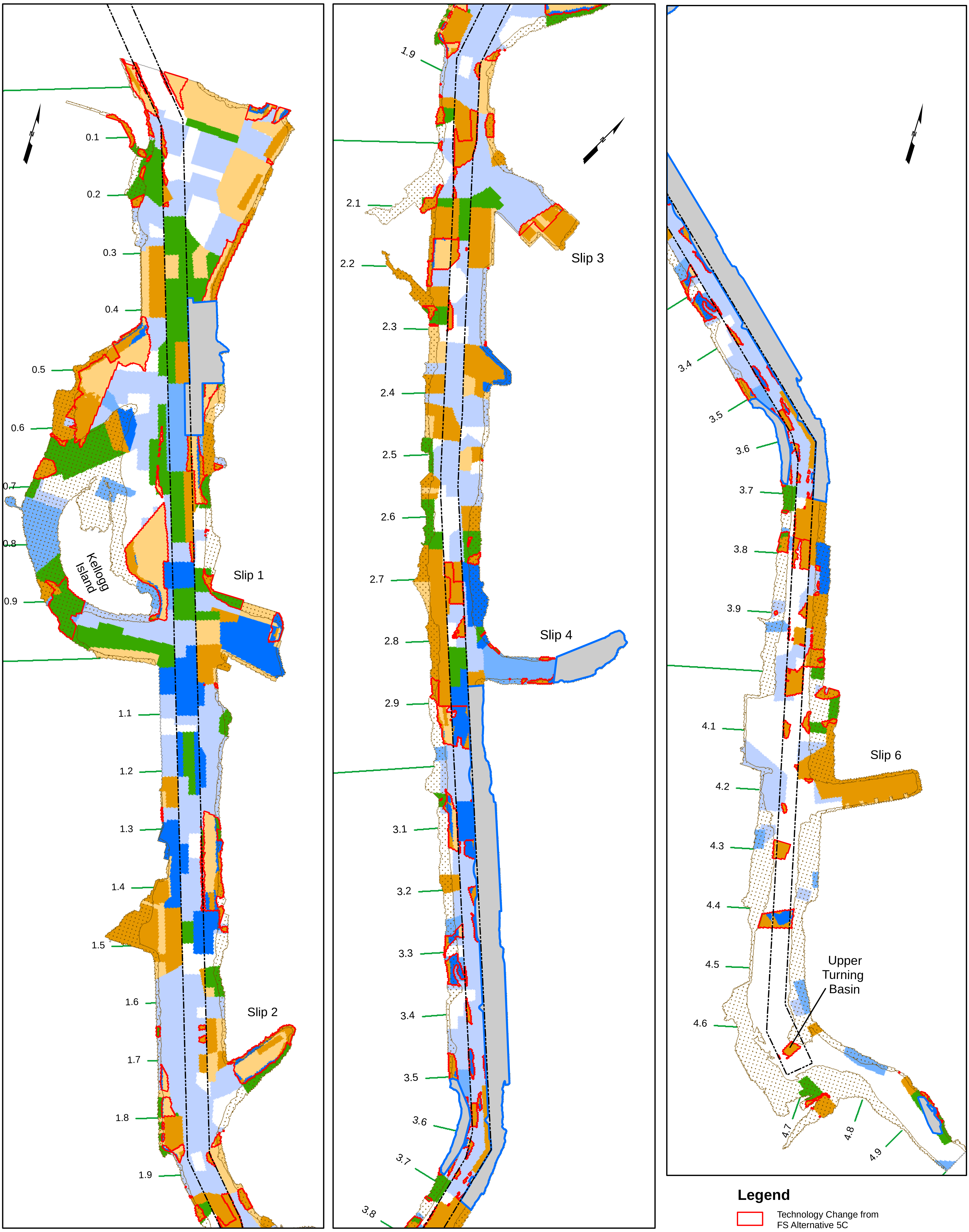
Lower Duwamish Waterway
Supplemental Scenarios
60150279-9.9

Scenario 1

DATE: 12/12/12 | DWRN:MVI/sea | Revision: 0

FIGURE 8b

Path: Q:\GIS_ENV\Lower Duwamish FS\Prefered Alternative\MXDs\Suplemental Scenarios Post FS_112012\Memo Figures\Figure8b-Alt5C3xHHTug.mxd



Notes:
1. See Tables 4, 7, and 8 for remedial action levels (RALs), areas, volumes and costs. Scenario 2 includes the "base elements" (additional dredging in shoaling areas, increased monitoring in passively remediated areas, and 4-ft cap thickness in intertidal areas), an intertidal subsurface RAL of the SQS for total PCBs, and subsurface RALs of CSL for all SMS contaminants and 3x Alt. 5C RAL for dioxins/furans.
2. Intertidal area is -4 ft MLLW to +11.3 ft MLLW.
3. New technology assignments are based on GIS output without best professional judgment modifications.

CSL= cleanup screening level; GIS= geographic information system; MLLW= mean lower low water; PCBs= polychlorinated biphenyl; RAL= remedial action level; SMS=Sediment Management Standards; SQS= sediment quality standards

Technology Assignment

- Dredge
- Partial Dredge and Cap
- Cap
- ENR/*in situ*
- Monitored Natural Recovery
- Verification Monitoring
- AOCP 2
- Early Action Area
- Remaining Study Area (Institutional Controls and Site-wide Monitoring)

Legend

- Technology Change from FS Alternative 5C
- Intertidal Area > -4 ft MLLW
- Navigation Channel
- River Mile Marker

Feet
0 200 400 800

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Lower Duwamish Waterway Group
Port of Seattle / City of Seattle / King County / The Boeing Company

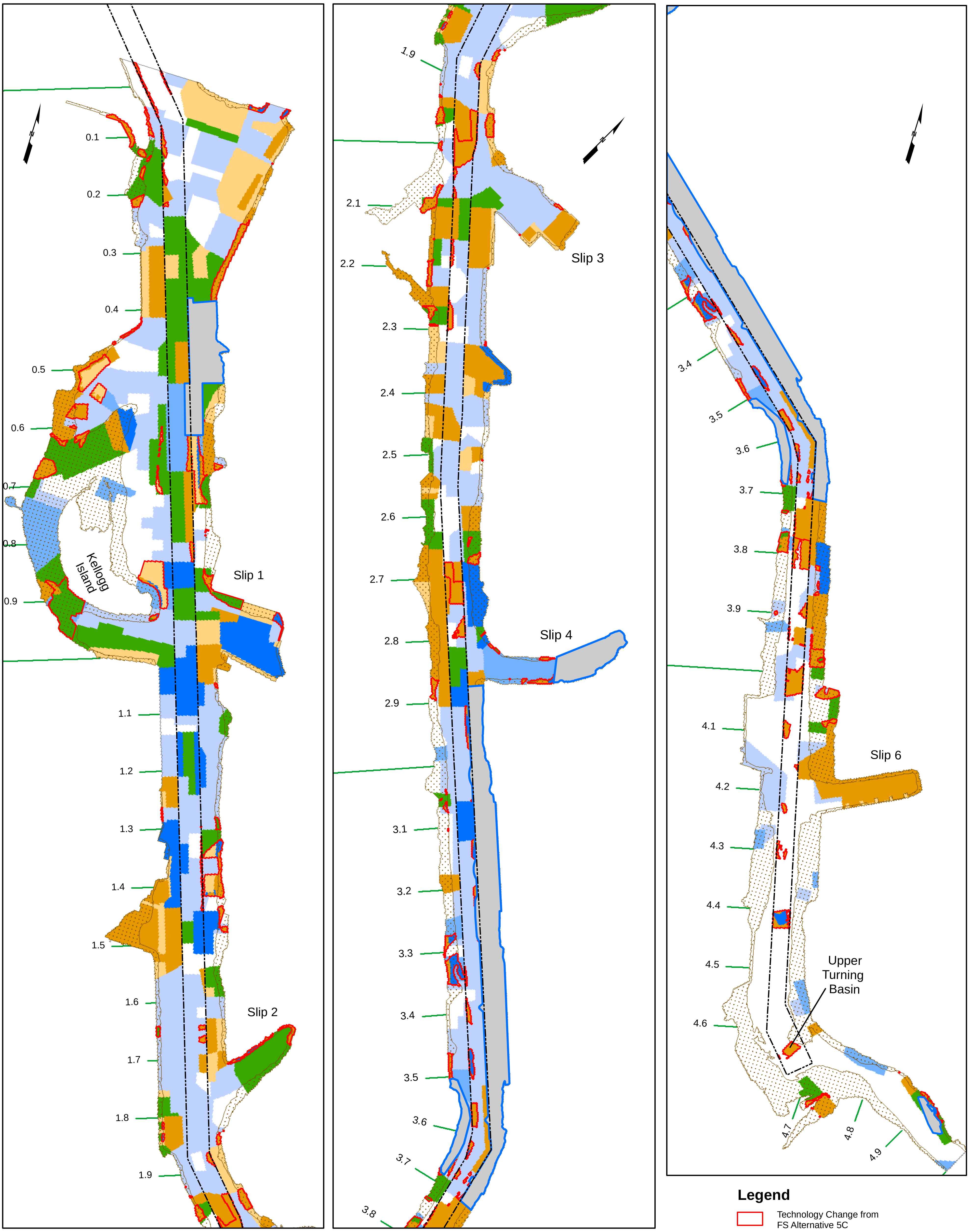
Lower Duwamish Waterway
Supplemental Scenarios
60150279-9.9

Scenario 2

DATE: 12/05/12 | DWRN:MVI/sea | Revision: 0

FIGURE 8c

Path: Q:\GIS_ENV\Lower Duwamish FS\Prefered Alternative\MXDs\Suplemental Scenarios Post FS_112012\Memo Figures\Figure8c-Alt5CCSLTug.mxd



Legend

- Technology Change from FS Alternative 5C
- Intertidal Area > -4 ft MLLW
- Navigation Channel
- River Mile Marker

Technology Assignment

- Dredge
- Partial Dredge and Cap
- Cap
- ENR/*in situ*
- Monitored Natural Recovery
- Verification Monitoring
- AOPC 2
- Early Action Area
- Remaining Study Area (Institutional Controls and Site-wide Monitoring)

0 200 400 800 Feet

Notes:

1. See Tables 4, 7, and 8 for remedial action levels (RALs), areas, volumes and costs. Scenario 3 includes the "base elements" (additional dredging in shoaling areas, increased monitoring in passively remediated areas, and 4-ft cap thickness in intertidal areas), an intertidal subsurface RAL of the SQS for total PCBs, and subsurface RALs of 3xCSL for all SMS.
2. Intertidal area is -4 ft MLLW to +11.3 ft MLLW.
3. New technology assignments are based on GIS output without best professional judgment modifications.

CSL= cleanup screening level; GIS= geographic information system; MLLW= mean lower low water; PCBs= polychlorinated biphenyl; RAL= remedial action level; SMS=Sediment Management Standards; SQS= sediment quality standards

Path: Q:\GIS_ENV\Lower Duwamish FS\Prefered Alternative\MXDs\Suplemental Scenarios Post FS_112012\Memo Figures\Figure8d-Alt5C3xCSLTug.mxd

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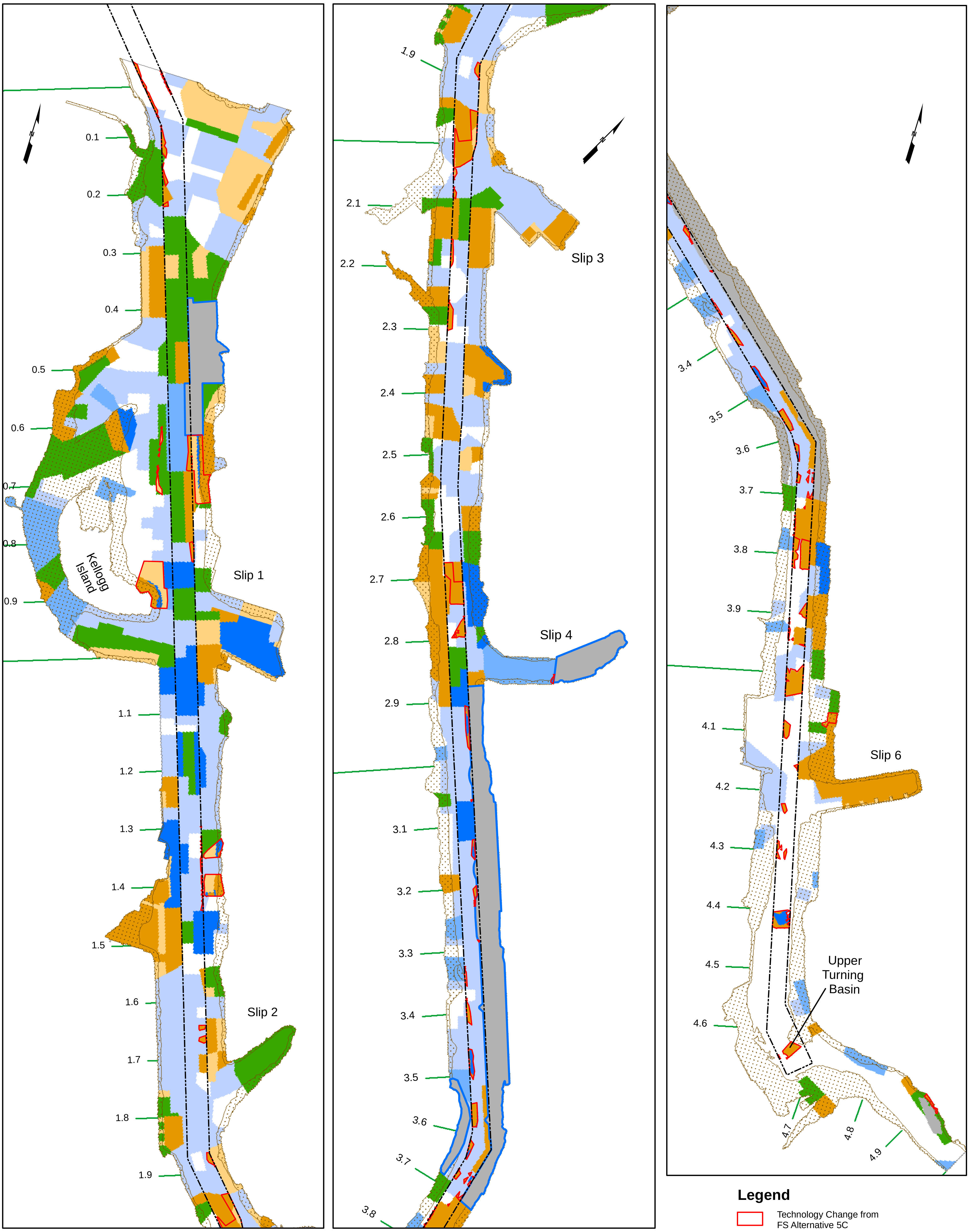
Lower Duwamish Waterway Supplemental Scenarios 60150279-9.9			Scenario 3
DATE: 12/12/12	DWRN:MVI/sea	Revision: 0	FIGURE 8d



Legend

- Technology Change from FS Alternative 5C
- Intertidal Area > -4 ft MLLW
- Navigation Channel
- River Mile Marker

Technology Assignment

- Dredge
- Partial Dredge and Cap
- Cap
- ENR/*in situ*
- Monitored Natural Recovery
- Verification Monitoring
- AOPC 2
- Early Action Area
- Remaining Study Area (Institutional Controls and Site-wide Monitoring)

0 200 400 800 Feet

Notes:

1. See Tables 4, 7, and 8 for remedial action levels (RALs), areas, volumes and costs. Scenario 4 includes the "base elements" (additional dredging in shoaling areas, increased monitoring in passively remediated areas, and 4-ft cap thickness in intertidal areas) and a subsurface RAL of the 3xCSL for total PCBs (both intertidal and subtidal).
2. Intertidal area is -4 ft MLLW to +11.3 ft MLLW.
3. New technology assignments are based on GIS output without best professional judgment modifications.

CSL= cleanup screening level; GIS= geographic information system; MLLW= mean lower low water; PCBs= polychlorinated biphenyl; RAL= remedial action level;

Path: Q:\GIS_ENV\Lower Duwamish FS\Prefered Alternative\MXDs\Suplemental Scenarios Post FS_112012\Memo Figures\Figure8e-Alt5C3xCSL PCBs.mxd

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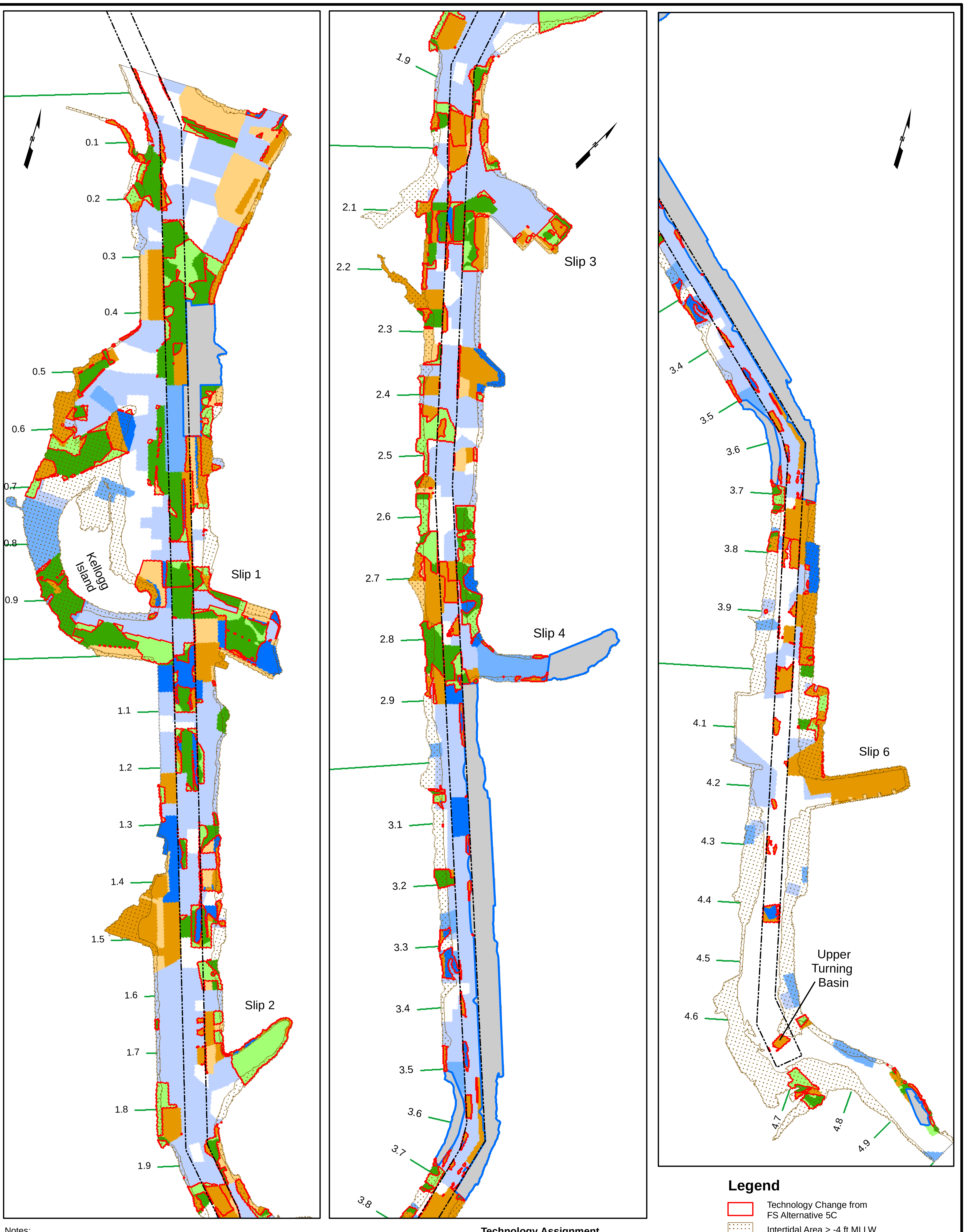
Lower Duwamish Waterway Supplemental Scenarios 60150279-9.9			Scenario 4
DATE: 12/12/12	DWRN:MVI/sea	Revision: 0	FIGURE 8e



Notes:
1. See Tables 4, 7, and 8 for remedial action levels (RALs), areas, volumes and costs. Scenario 5a includes the "base elements" (additional dredging in shoaling areas, increased monitoring in passively remediated areas, and 4-ft cap thickness in intertidal areas), an intertidal subsurface RAL of the CSL for total PCBs, a subsurface RAL of 3xCSL for total PCBs, and a surface sediment RAL of 2xSQS for all non-human health SMS contaminants (in Recovery Categories 2 and 3).
2. Intertidal area is -4 ft MLLW to +11.3 ft MLLW.
3 New technology assignments are based on GIS output without best professional judgment modifications.
CSL= cleanup screening level; GIS= geographic information system; MLLW= mean lower low water; PCBs= polychlorinated biphenyl; RAL= remedial action level; SMS=Sediment Management Standards; SQS= sediment quality standards

Technology Assignment

- Dredge
- Partial Dredge and Cap
- Cap
- ENR/*in situ*
- Monitored Natural Recovery
- Verification Monitoring
- AOPC 2
- Early Action Area
- Remaining Study Area (Institutional Controls and Site-wide Monitoring)

0 200 400 800 Feet

Legend

- Technology Change from FS Alternative 5C
- Intertidal Area > -4 ft MLLW
- Navigation Channel
- River Mile Marker

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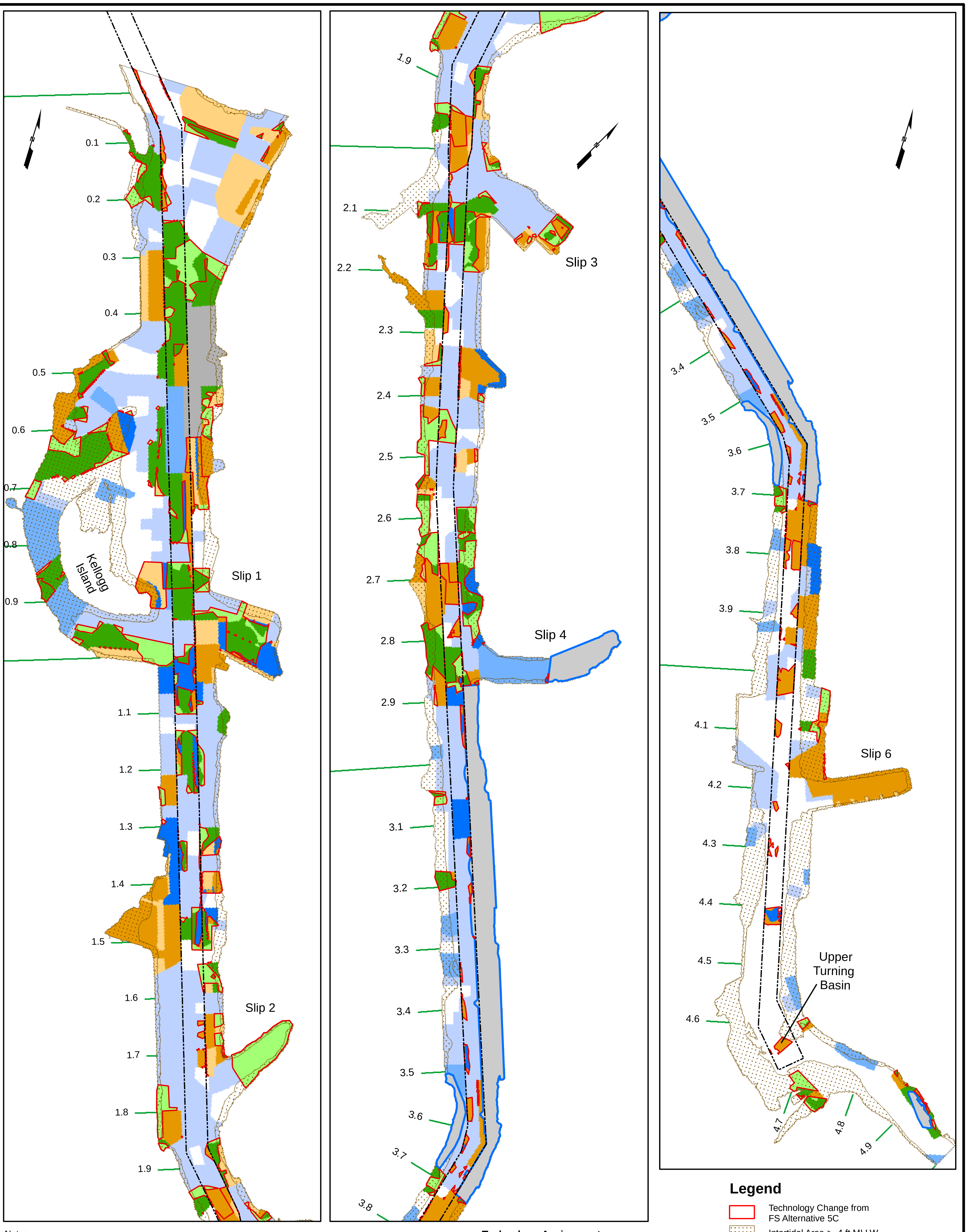
Lower Duwamish Waterway Supplemental Scenarios 60150279-9.9	**Scenario 5a**
DATE: 12/12/12 DWRN:MVI/sea Revision: 0	**FIGURE 8f**

Path: Q:\GIS_ENV\Lower Duwamish FS\Prefered Alternative\MXDs\Suplemental Scenarios Post FS_112012\Memo Figures\Figure8f-Alt5ALDWG.mxd



Notes:

1. See Tables 4, 7, and 8 for remedial action levels (RALs), areas, volumes and costs. Scenario 5b includes the "base elements" (additional dredging in shoaling areas, increased monitoring in passively remediated areas, and 4-ft cap thickness in intertidal areas), a subsurface RAL of the 3xCSL for total PCBs (both intertidal and subtidal), and a surface sediment RAL of 2xSQS for all non-human health SMS contaminants (in Recovery Categories 2 and 3).
2. Intertidal area is -4 ft MLLW to +11.3 ft MLLW.
3. New technology assignments are based on GIS output without best professional judgment modifications.

CSL= cleanup screening level; GIS= geographic information system; MLLW= mean lower low water; PCBs= polychlorinated biphenyl; RAL= remedial action level; SMS=Sediment Management Standards; SQS= sediment quality standards

Technology Assignment

- Dredge
- Partial Dredge and Cap
- Cap
- ENR/*in situ*
- Monitored Natural Recovery
- Verification Monitoring
- AOPC 2
- Early Action Area
- Remaining Study Area (Institutional Controls and Site-wide Monitoring)

0 200 400 800 Feet

Legend

- Technology Change from FS Alternative 5C
- Intertidal Area > -4 ft MLLW
- Navigation Channel
- River Mile Marker

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60150279-9.9

DATE: 12/12/12 | DWRN:MVI/sea | Revision: 0

Scenario 5b

FIGURE 8g

Path: Q:\GIS_ENV\Lower Duwamish FS\Prefered Alternative\MXDs\Suplemental Scenarios Post FS_112012\Memo Figures\Figure8g-Alt5CLDWG2.mxd

Figure 9. Summary Statistics of Subsurface Total PCB Concentrations Remaining in AOPC 1 and AOPC 2 (Outside of the EAAs, Dredge, and Cap Footprint) for All Categories in the 0- to 2-ft Depth Interval

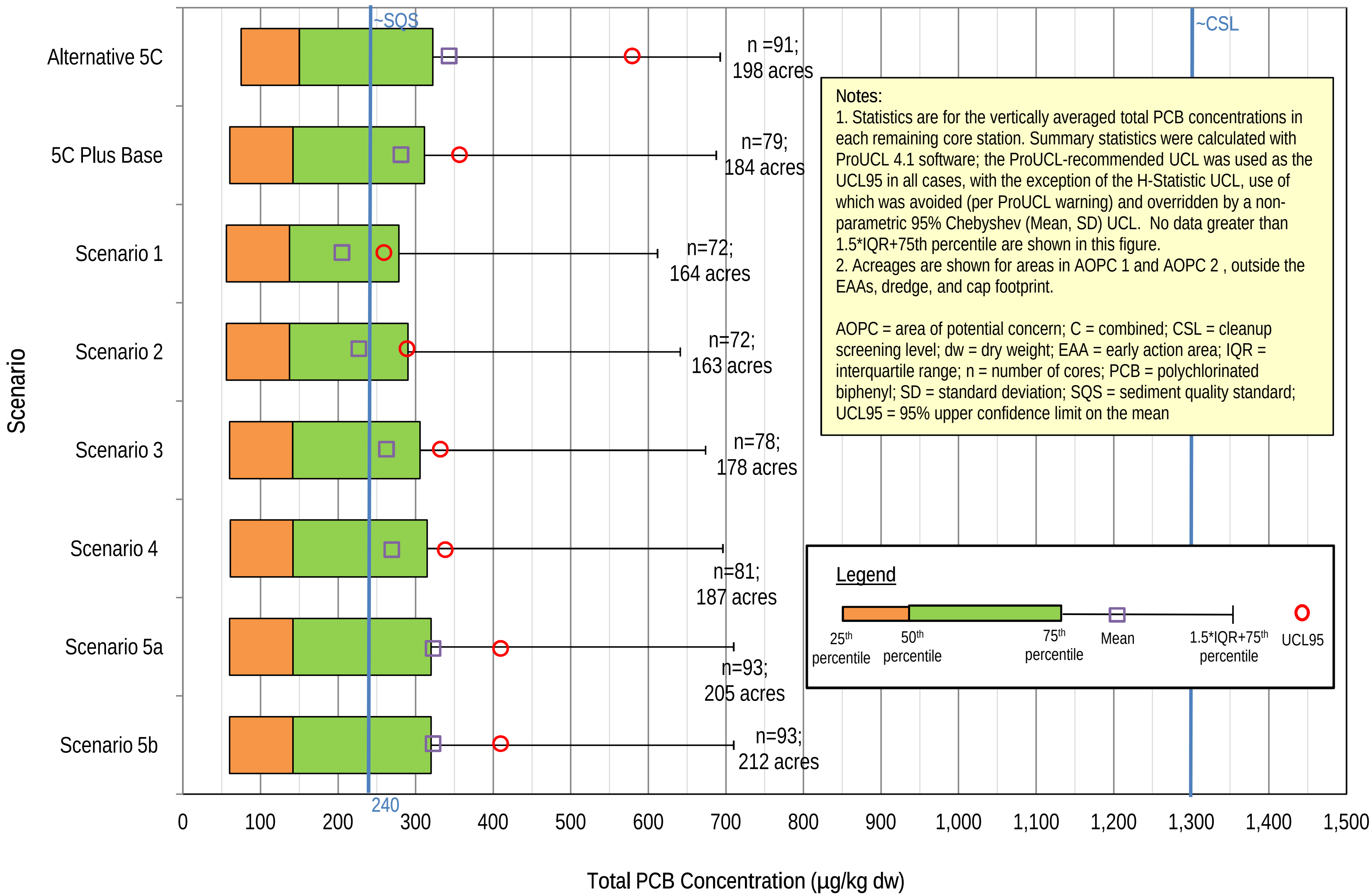
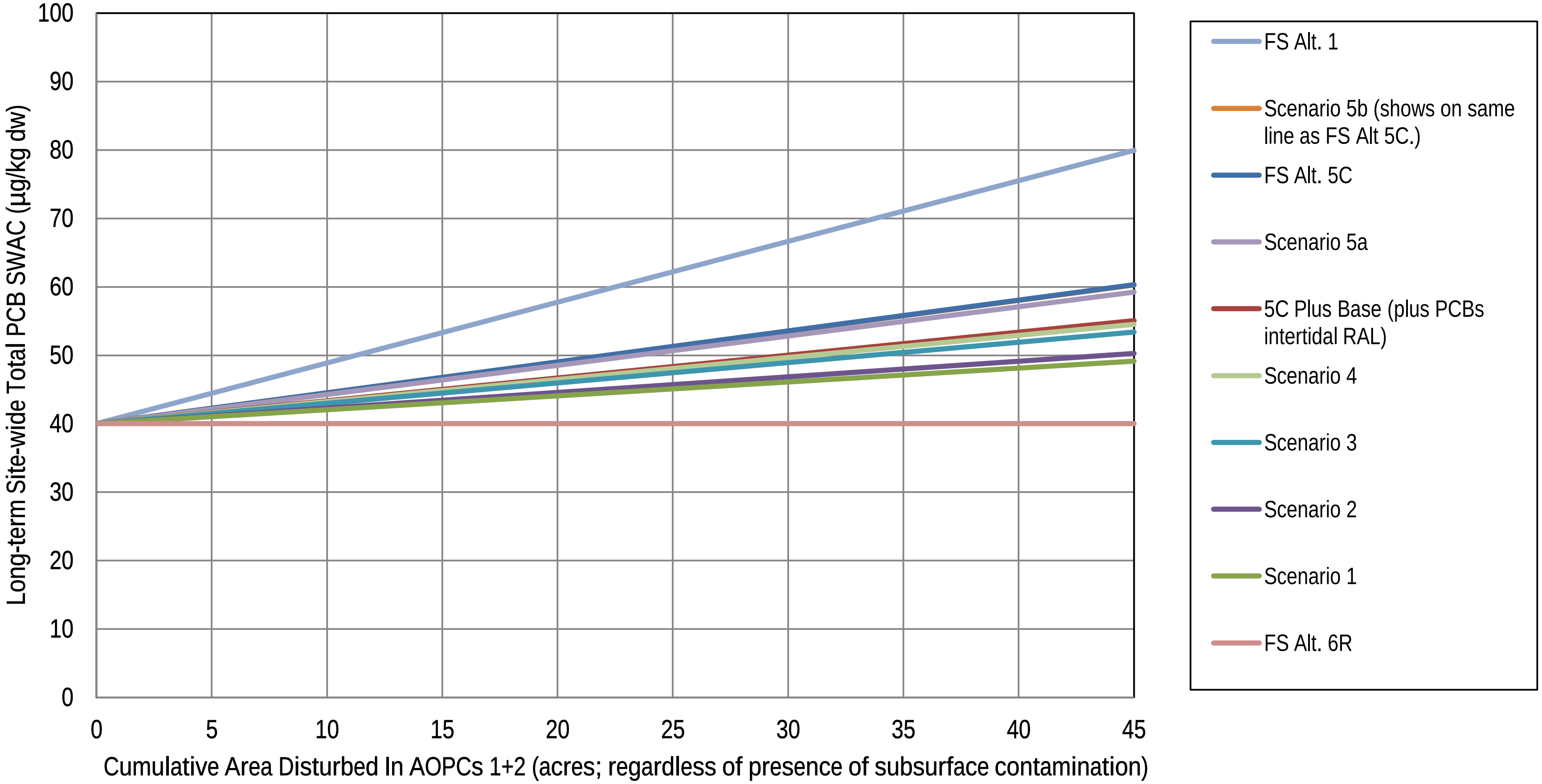


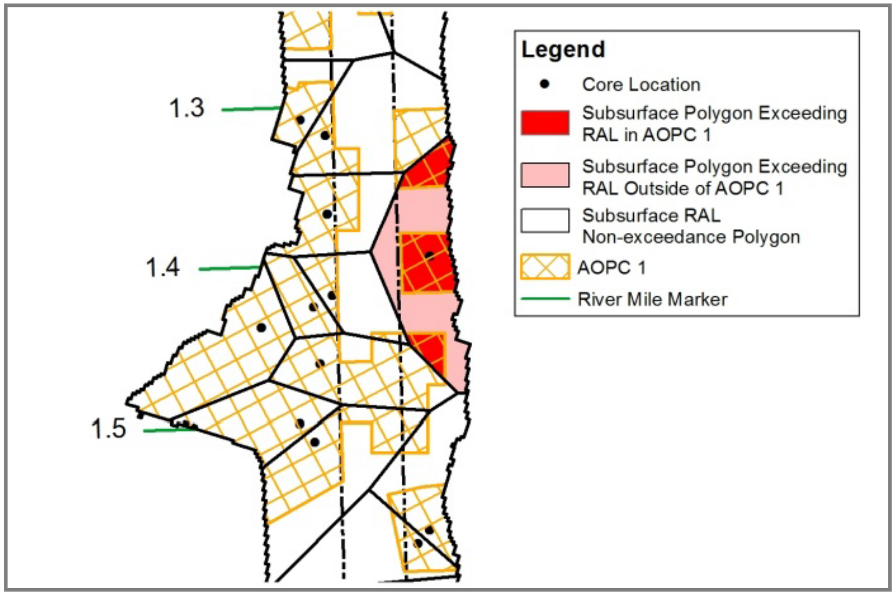
Figure 10. Estimates of Potential Change in the Site-wide Total PCB SWAC Resulting from Disturbance of Subsurface Sediments



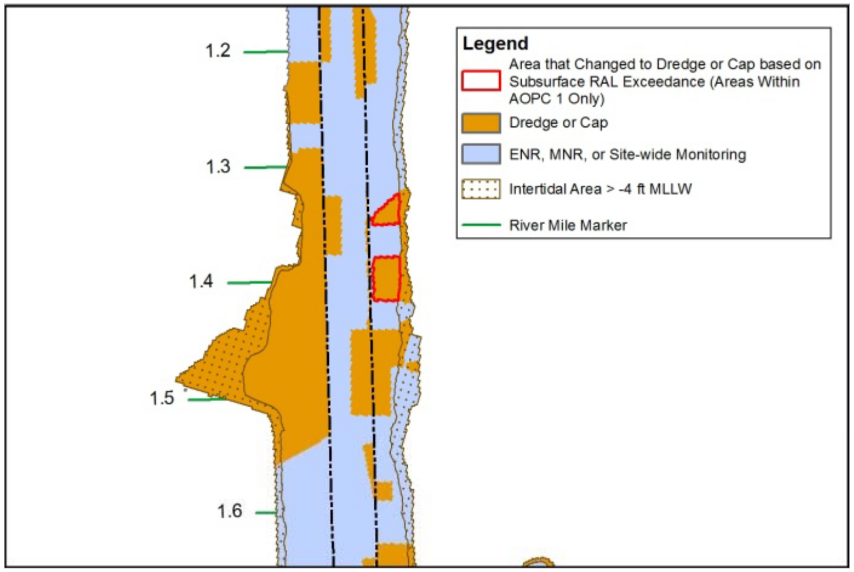
Notes:
1. For comparison, all alternatives and scenarios are assumed to have the same long-term SWAC without any disturbance (40 µg/kg dw).
2. See FS Appendix M, Part 5, for methods, results for FS alternatives not shown, and limitations of this analysis.

AOPC = area of potential concern; C = combined; CSL = cleanup screening levels; D/F = dioxins and furans; FS = feasibility study; HH = human health risk driver; PCB = polychlorinated biphenyl; R = removal; RAL = remedial action level; SWAC = spatially-weighted average concentration

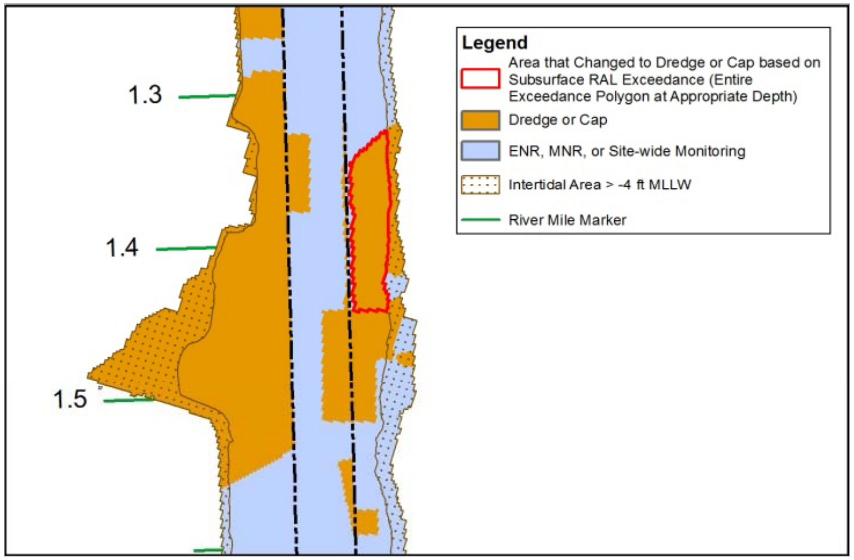
Figure 11. Example of Subsurface Exceedance Polygon and Resultant Technology Assignments



Subsurface Exceedance Polygons (from Figure 7)



Technology Assignments: Scenario 3 (from Figure 8d)



Technology Assignments: Scenario 1 (from Figure 8b)

Note: This figure demonstrates how the subsurface exceedance polygons (left) are limited to AOPC 1 for Scenarios 3 through 5 (e.g., Scenario 3, top right), but not for Scenarios 1 and 2 (e.g., Scenario 1, lower right.)

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Attachment 1 Remedial Technology Assignment Assumptions

Attachment 1: Remedial Technology Assignment Assumptions

Part 1: Methodology for Developing the Alternative 5C Plus Scenarios (Supplemental Scenarios)

The following text provides the steps used to perform the remedial technology assignments for the Alternative 5C Plus scenarios. All scenarios start with FS Alternative 5C and make additional modifications. The supplemental scenarios have six elements. Five elements were added to Alternative 5C to address concerns regarding potential exposure of subsurface sediment contamination. These five elements are: 1) dredging the shoaling areas in the navigation channel with subsurface contaminant concentrations above the Alternative 5C RALs, 2) increasing the sediment monitoring in AOPC 2 and rest of LDW, 3) increasing the cap thickness (to 4 ft) in intertidal clamming areas, 4) applying a sediment intertidal RAL for PCBs to the top 45-cm in intertidal areas; and 5) applying subsurface RALs in Recovery Category 2 and 3 areas. The sixth element was developed to address surface sediment SQS contamination, using a surface sediment RAL of 2xSQS for non-human health SMS contaminants in Recovery Category 2 and 3 areas. The first three elements are considered "base" elements and are applied to all scenarios. The last three elements vary among the scenarios[1]. These "Plus" elements change the active remediation (acres and volumes) and the costs of FS Alternative 5C.

In general, the sample flow chart/technology assignment rules from the FS were applied to these supplemental scenarios. Any exceptions are described below in the overall description of each element.

1. **Dredging the Contaminated Shoaled Areas in the Navigation Channel.**
   a. From the FS baseline subsurface sediment dataset (sediment cores), determine cores with contaminant concentrations at any sample depth in the upper 60 cm of cores (used as a proxy for subsurface contamination in the shoaled interval, although shoaling areas may be thicker or thinner than 60 cm) above the Alternative 5C RALs (used as a proxy for Dredged Material Management Program criteria that would be used to evaluate acceptability for open-water disposal).
   b. For spatial extent, generate core polygons and limit to the navigation channel.
   c. Identify shoaled areas based on bathymetric elevations above the authorized dredging depth (using 2003 bathymetric survey in the FS) with subsurface RAL exceedances.[2] These areas go to partial dredge and cap (PDC) or dredging and upland disposal based on the FS flow chart.
2. **Increasing the Long-term Sediment Monitoring Sampling Density and Frequency in Areas not Actively Remediated (referred to as AOPC 2 and Rest of LDW Areas in the FS).**
   a. Increase surface sediment sampling density from 1 sample/4 acres to 1 sample/acre in these areas.
   b. For clarification, the "AOPC 2 and Rest of LDW" areas are located outside of the active remediation footprint for FS Alternative 5C (157 acres) and outside of verification monitoring (VM) areas (23 acres). This is equivalent to saying all areas outside of AOPC 1 (180 acres out of 441 acres). For cost estimating purposes, this element was not applied to VM areas (23 acres in FS Alternative 5C). While this assumption is acceptable for cost estimating purposes, the actual implementation of this element in the selected alternative would specify increased density and frequency in <u>all</u> areas outside of the active remediation areas (active remediation is defined as dredge, cap, and enhanced natural recovery [ENR]).
   c. Increase sampling frequency to the same as the FS for MNR technology (with sampling occurring 2, 3, 5, 7, and 10 years following construction). After 10 years, the sampling frequency is every five years thereafter,

---

1 While these elements vary among the scenarios (e.g., the different scenarios implement different subsurface RALs), the evaluation depths (top 45 cm in intertidal areas and top 60 cm in subtidal areas in Recovery Categories 2 and 3) are the same for all scenarios.

2 The U.S. Army Corps of Engineers have conducted more recent bathymetric surveys since 2003. These new survey data will be considered during remedial design.

for a total of 30 years from the start of construction (similar to the site-wide monitoring program). Do not assume that additional monitoring will lead to additional contingency actions; no costs added for contingency actions.

3. **Increasing Cap Thickness to 4 ft in Intertidal Clamming Areas.**
   a. Increase both the partial dredging depth and the cap placement thickness in intertidal clamming areas. If contamination thickness was less than 5 ft, full dredging was assumed as opposed to partial dredge and cap (PDC).
4. **Applying a Sediment Intertidal RAL for PCBs to the Top 45 cm in Intertidal Areas.**
   a. Intertidal areas are defined from +11.3 ft to -4 ft mean lower low water (MLLW).
   b. From the FS baseline subsurface sediment dataset (sediment cores), determine the maximum total PCB concentration of sample intervals that occur within the upper 45 cm of cores. Note: During remedial design, RAL exceedances will likely be determined by the contaminant concentrations of composite samples vertically averaged over this interval.
   c. For estimates of spatial extent, generate core polygons and determine overlap with intertidal areas. Limit the subsurface sediment exceedance footprint to areas with surface sediment PCB concentrations of more than 100 µg/kg dw based on interpolated surface sediment concentrations (i.e., limit exceedance footprint to the AOPC 1+2 footprint).
   d. Intertidal locations with subsurface contaminant concentrations above the intertidal RALs are assigned to active remediation; active remediation is defined as ENR, capping, PDC, or full dredging. The intertidal RALs for the scenarios are in Table 4 of this memorandum. Assignment of ENR, PDC, or dredging and backfilling is based on the FS technology assignment rules described in Part 2.
   e. Intertidal locations with concentrations above the upper limit for ENR (UL ENR) are assigned to PDC or dredge and backfill. The upper limits for ENR in intertidal areas for each scenario are in Table 4 of this memorandum. PDC or dredging with backfilling is applied following FS technology assignment rules.
      i. For supplemental Scenarios 1 through 3 (and the 5C Plus Base) in which the surface sediment PCB UL for ENR has been lowered from FS Alternative 5C, identify ENR locations with PCB concentrations above 360 µg/kg dw (i.e., 1.5 x SQS assuming dry weight equivalent) based on the interpolated surface sediment concentrations.
      ii. For Scenarios 4 and 5, the surface RAL (12 mg/kg OC; SQS) and the upper limit for ENR (65 mg/kg OC; CSL) are applied to the upper 10 cm of sediment.
      iii. For Scenario 4 and 5b, the subsurface RAL and upper limit for ENR are both 195 mg/kg OC, applied to the upper 45 cm of sediment. For Scenario 5a, the subsurface RAL is 65 mg/kg OC and the subsurface upper limit for ENR is 97 mg/kg OC. An intertidal UL ENR for PCBs of 65 mg/kg oc was used for mapping purposes.
5. **Applying Subsurface RALs in Recovery Category 2 and 3 areas (applied to Subtidal Areas).**
   a. Subtidal areas are delineated as areas deeper than -4 ft MLLW.
   b. From the FS baseline subsurface dataset, determine the maximum contaminant concentration in sample intervals that overlap the upper 60 cm of cores. For contaminants with subsurface RALs, the RALs and the depths vary by scenario, as shown in Table 4 of this memorandum. During remedial design, RAL exceedance would be determined based on the vertically weighted average in the upper 60 cm of sediment.

Location (and Size) of Potential Disturbance Area (excluding EAAs)	Sample Depth Used in the Evaluation
Recovery Category 1 (77 acres)	60 cm (2 ft)
Potential Tug Scour Areas – Subtidal (128 acres excluding Recovery Category 1 areas)	60 cm (2 ft)
Intertidal Areas (113 acres)	45 cm (1.5 ft) (as described above)

c. For clarification, RALs were already applied to 60 cm depth in Recovery Category 1 (an estimated 77 acres) in the FS (essentially these are subsurface RALs). The RAL values are the same as FS Alternative 5C. No changes needed for this memo.

d. The subsurface RAL in Recovery Categories 2 and 3 applies to potential tug scour areas (see further information in Section 3.1.4 of the Technical Memorandum). Recovery Categories 2 and 3 where potential tug scour is estimated to occur is in 128 acres. [Note: No subsurface RAL is proposed for the remaining 105 acres in Recovery Categories 2 and 3 where tug scour is not a concern). Potential tug scour occurs at depths below -4 ft MLLW and above -24 ft MLLW in Reach 1 and above -18 ft MLLW in Reaches 2 and 3, based on the draft of tugs that enter those reaches of the Duwamish (only smaller tugs go south of the 1st Avenue South Bridge at RM 2.0) (see Figure 3 of the Technical Memorandum). The potential tug scour area was assumed not to extend upstream of Oxbow Bridge at RM 4.8.

e. For spatial extent, generate core polygons and determine overlap with potential tug scour areas. Note: during the core polygon generation, a “dummy core” was added to the north of Kellogg Island to help manage unrealistic polygon extrapolations through Kellogg Island. For Scenarios 1 and 2, use the entire core polygons that overlap in the potential tug scour area. For Scenarios 3 through 5, limit the exceedance footprint to AOPC 1 (i.e., above Alternative 5C RALs in surface sediment).

f. Areas with RAL exceedances are selected for capping, PDC, or full dredging based on the FS technology assignment rules described below. Subsurface RALs are also assumed to serve as upper limits for ENR (no ENR in an area with a subsurface RAL exceedance). Dredge and cap areas will increase based on subsurface RAL exceedances. ENR and MNR footprints (based on technology assignments for surface concentrations) will decrease based on subsurface RAL exceedances.

6. **Applying Surface Sediment RAL of 2xSQS for non-Human Health SMS Contaminants of Concern (Scenario 5).**

a. Start with FS Alternative 5C, then apply the appropriate Plus elements above.

b. Identify surface sediment sample locations that are less than RALs for Scenario 5 (2xSQS for non-human health risk drivers, which are 39 SMS COCs; all other surface sediment RALs are the same as for FS Alternative 5C: 12 mg/kg-oc for PCBs, 57 mg/kg dw for arsenic, 1,000 µg TEQ/kg dw for cPAHs, and 25 ng TEQ/kg dw for dioxins/furans).

c. For spatial extent of RAL exceedances (or non-exceedances), code the entire surface sediment SMS Thiessen polygon (e.g., FS Figure 2-21) based on RAL exceedance status, consistent with FS methodology.

d. Limit the areas potentially amenable to MNR to only the areas in Recovery Categories 2 and 3. MNR was not applied to Recovery Category 1 areas.

e. Identify areas with surface sediment contaminant concentrations less than the UL ENR, outside of Recovery Category 1, and less than the subsurface sediment RALs. These areas are assigned to ENR.

f. The upper limit for ENR is 3 x RAL for all SMS contaminants (excluding PCBs, which has an upper limit for ENR of the CSL) applied to the upper 10 cm. Use the FS technology assumptions for ENR, dredge, or cap assignments. If there is a RAL exceedance at both the 10-cm and 45-cm compliance depths, then the more restrictive upper limit for intertidal direct contact is applied.

g. Based on mapping, five small areas were unlikely to be amenable for MNR designations based on site knowledge. In these areas, the surface sediment RALs of 2xSQS were not applied; instead, the technology assignments were based on the FS Alternative 5C technology assignments.

Part 2: FS Remedial Technology Application

This section describes the remedial technology application used in the FS. For the Plus elements above, once an area is determined to need active remediation based on RAL exceedances, then the methodologies described below and in the FS are used to assign remedial technologies (ENR, capping, PDC, or dredging), and to determine which technology is most appropriate. The FS rules are presented in FS Table 8-2 and FS Figure 8-2.

a. **General Process.** The general process is to apply the remedial technologies from the least active (ENR) to the most active (full dredging) in a step-wise manner:
   i. ENR where feasible.
   ii. If ENR is not feasible, then cap if there is adequate vertical clearance.
   iii. If there is no room for a cap, then PDC if contaminated sediment is thick enough to warrant partial removal and leave some contamination behind (> 4 ft).
   iv. If contaminated sediment is less than 4 ft thick in habitat areas, then full dredge and backfill as necessary. If located in a habitat area (i.e., above -10 ft MLLW), cap or backfill to existing grade.

b. **Detailed Criteria.** Start with an area that is being actively remediated (i.e., above any surface sediment or subsurface sediment RAL):
   i. If located in an under-pier area, then assume cap, although location-specific analysis will be needed. Cap may be less than 3 ft depending upon access, pier and substrate conditions, etc.
   ii. If above the upper limit for ENR in surface or subsurface sediment, or in Recovery Category 1, or in a navigation channel or berthing area without adequate clearance, then assume cap (with or without partial dredging as determined below). If below the upper limit for ENR and not in Recovery Category 1 and adequate clearance is available, ENR is applicable.
      - The required pre-ENR clearance was assumed to be > 0.5 ft in berthing areas and > 2.5 ft in the navigation channel between the existing mudline elevation and navigational depth requirements;
      - No ENR in Category 1 areas; and
      - In intertidal areas, if there is a RAL exceedance at both the 10-cm and 45-cm point of compliance depths, then the more restrictive upper limit for intertidal direct contact is applied.
   iii. If ENR is not applicable, then assume capping. If location is in a habitat area (above -10 ft MLLW) or in the navigation channel without adequate clearance, or in a berthing area without adequate clearance, then assume partial dredging is needed. Capping is not applicable in these areas. If these conditions do not apply, capping is applicable.
      - The required pre-cap clearance was assumed to be > 5 ft in berthing areas and > 6 ft in the navigation channel between the existing mudline elevation and navigation depth requirements.
   iv. If capping and ENR are not applicable, then assume PDC. Calculate the partial dredging depth necessary to fit a cap. If <1 ft of contamination is left after doing so, then a cap would not be necessary, and full dredging is assumed. If >1 ft of contamination is left, then PDC is warranted. In general, if contamination is less than 4 ft thick, then full dredge; but navigation and berthing areas require location-specific assessments for shoaling.

c. In the FS, the technology assignments were performed in GIS and then areas with similar technology assignments were lumped together by hand into larger constructible units. In contrast, the technology assignments for the 5C Plus scenarios were performed only in GIS, without the additional step of modifying the remedial areas by hand. As a result, specific areas of the 5C Plus scenarios would be impractical to remediate (e.g., a dredging area smaller than 100 ft by 100 ft). However, this method is reasonable for approximating the areas, volumes, and costs on an LDW-wide level for comparative purposes.

d. Dredge volumes are calculated based on the method used in the FS. The dredge depth is calculated to the maximum depth in the sediments of SQS exceedances using the isopach developed in Appendix E of the FS. For PDC, the dredge depth is limited to the depth necessary to fit an isolation cap. The dredge depth assumptions were not varied among the supplemental scenarios.

e. Costs are calculated using the same cost assumptions and calculations as the FS, unless specified differently above.

Attachment 2 Clarification of Remedial Action Levels, Evaluation Depths of RALs, and Upper Limits for ENR in Intertidal Areas for the Lower Duwamish Waterway Feasibility Study Alternative 5C

Attachment 2: Clarification of Remedial Action Levels, Evaluation Depths for RALs, and Upper Limits for ENR in Intertidal Areas for the Lower Duwamish Waterway Feasibility Study Alternative 5C

This attachment clarifies assumptions used in the Lower Duwamish Waterway (LDW) Feasibility Study (FS) for remedial action levels (RALs), evaluation depths for RALs, and upper limits for enhanced natural recovery (UL ENR) in intertidal areas for Remedial Alternative 5C. The human health risk drivers are total polychlorinated biphenyls (PCBs), arsenic, carcinogenic polycyclic aromatic hydrocarbons (cPAHs), and dioxins/furans; and the three human health exposure areas evaluated in the FS are netfishing (applied site-wide), tribal clamming, and beach play. Understanding these assumptions is important to understanding the Alternative 5C Plus scenarios developed in this memorandum specifically to address concerns in intertidal areas.

Remedial Action Levels (RALs) in Intertidal Areas

RALs and to what depth they apply are shown in Tables 1 and 2. For FS Alternative 5C, the surface sediment RAL for total PCBs is applied throughout the LDW in the upper 10 cm of sediment; the RAL is 12 mg/kg oc (the dry weight equivalent of the RAL is 240 µg/kg dw PCB assuming 2% total organic carbon content; this dry weight concentration was used for mapping purposes in the FS).

Also, for Alternative 5C in the FS, a sediment RAL of 12 mg/kg oc PCBs (and RALs for arsenic, cPAHs, dioxins/furans, and SMS contaminants) is applied in Recovery Category 1 areas in the top 60 cm for protection from potential disturbance events. For the protection of human health, sediment RALs were established for arsenic, cPAHs, and dioxins/furans in intertidal areas and applied to 45 cm depths; an intertidal RAL was not proposed for PCBs. In the FS, subsurface sediment RALs were not established in subtidal areas designated as Recovery Categories 2 and 3.

As described above, RALs were established for arsenic, cPAHs, and dioxins/furans in the top 45 cm in intertidal areas (Table 1). For these three contaminants, the intertidal RALs were developed to address protectiveness for human health direct contact (skin contact and incidental ingestion) with sediments during tribal clamming and beach play scenarios (see remedial action objective [RAO] 2 in Table 1 and risk-based threshold concentrations for direct contact in Table 3 [1]). These intertidal, point-based RALs are based on sediment risk-based threshold concentrations at a target risk level[2] of 1×10^{-5} or lower (see Table 3). An intertidal sediment RAL was similarly calculated for PCBs, but the resulting values (5,000 µg/kg dw for tribal clamming and 17,000 µg/kg dw for beach play) were not selected as a RAL for the top 45 cm because they were significantly higher than the site-wide surface PCB RAL (240 µg/kg dw equivalent). Also, as described in the FS, it was determined that it was not necessary to establish a RAL for PCBs in the top 45 cm in intertidal areas because the direct contact preliminary remediation goals (PRGs) for PCBs (500 µg/kg for tribal clamming scenarios and 1,700 µg/kg for beach play scenarios) are predicted to be achieved in the top 45 cm after sediment remediation. In other words, applying the other RALs (including the Alternative 5C site-wide sediment PCB RAL of 12 mg/kg oc in top 10 cm) was predicted to result in concentrations less than the PCB PRGs (e.g., see FS Table 6-2). As shown in Table 1, the lowest PRG for PCBs for direct contact is 500 µg/kg (based on tribal clamming). This site-wide PRG is

[1] RAO 2 also addresses a third reasonable maximum exposure (RME) scenario (direct contact for tribal netfishing), but PRGs for this scenario apply to the top 10 cm (not the top 45 cm).

[2] This value is based on applying a 1×10^{-5} risk-based threshold concentration value to all sample locations, which results in achieving the 1×10^{-6} risk-based threshold value (the same as the PRG) as a spatially-weighted average concentration for the clamming exposure areas.

over two times higher than the site-wide PCB RAL of 240 µg/kg dw (the equivalent of 12 mg/kg-oc PCBs assuming 2% total organic carbon content); achieving the point concentration of 240 µg/kg dw in the upper 10 cm of sediment through active remediation is predicted to also achieve a spatially-weighted average concentration (SWAC) of 500 µg/kg dw in the upper 45 cm of sediment in clamming areas.

Upper Limit for ENR

Based on the methodology in FS Section 8, the UL ENR was assumed to be 3×RAL site-wide (for the 10-cm depth), and 1.5×RAL in intertidal areas (for 45 cm depth). Therefore, the UL ENR for PCBs in both intertidal and subtidal areas was assumed to be three times the RAL, or 36 mg/kg oc, because the evaluation depth is the upper 10 cm of sediment (Table 4).

For contaminants with a 45-cm evaluation depth in intertidal areas, the UL ENR was assumed to be 1.5 times the RAL for the protection of human health direct contact. Therefore, if an intertidal RAL for PCBs had been developed for the protection of human health direct contact (presumably 5,000 µg/kg dw) then the UL for ENR would be 1.5 times that value, or 7,500 µg/kg dw.

Table 1 FS Preliminary Remediation Goals and Alternative 5C RALs (adapted from FS Table 6-1)

Risk Driver	FS Alternative 5C Remedial Action Levels[a]	Preliminary Remediation Goals (PRGs)				
		RAO 1 (site-wide SWAC)	RAO 2 (site-wide netfishing)[b]	RAO 2 (beach play; clamming SWACs)[b]	RAO 3 (point)	RAO 4 (site-wide SWAC)
Point of Compliance (depth in cm)		0-10 cm	0-10 cm	0-45 cm (intertidal areas only)	0-10 cm	0-10 cm
Total PCBs (µg/kg dw)	12 mg/kg-oc[e] (site-wide)	bg: 2	1,300	1,700 500	12 mg/kg oc[e]	128-159
Arsenic (mg/kg dw)	57 (site-wide) 28 (intertidal)	n/c	bg: 7	bg: 7	57	n/a
cPAHs (µg TEQ/kg dw)	1,000 (site-wide) 900 (intertidal)	n/c	380	90; 150	n/a	n/a
Dioxins/furans (ng TEQ/kg dw)	25 (site-wide) 28 (intertidal)	bg: 2	37	28; 13	n/a	n/a
SMS contaminants	SQS (site-wide)	n/a	n/a	n/a	SQS	n/a

Notes: The evaluation depths are used for RAL application. Points of compliance are used for evaluating achievement of PRGs.

a. The depths used to evaluate site-wide RALs are the top 10 cm of sediment except in Recovery Category 1 areas, where the evaluation depth also includes the top 60 cm. In addition, arsenic, cPAHs, and dioxins/furans have intertidal RALs that apply to the top 45 cm.

b. PRGs for RAO 2 are based on the SWACs that achieve 10^{-6} risk for the individual risk drivers, except arsenic, where the PRG is based on natural background.

c. Because natural background PRG is unlikely to be achieved, this RAO is being evaluated by surface sediment reaching the long-term model-predicted concentrations. These concentrations are achieved with time after remediation of Alternative 5 and are achieved immediately after remediation of Alternative 6.

d. Although the combined beach play area cPAH SWAC is not below 90 µg TEQ/kg dw, this PRG is considered to be achieved because most of the individual beaches achieve this PRG or a 1 x 10^{-6} excess cancer risk threshold.

e. The dry weight equivalent of this RAL (240 µg/kg dw PCB assuming 2% organic carbon content) was used in the FS for mapping purposes.

bg = background; cPAH = carcinogenic polycyclic aromatic hydrocarbon; dw = dry weight; kg = kilograms; µg = micrograms; mg = milligrams; n/a = not applicable; n/c = not calculated; ng = nanograms; oc = organic carbon; PCB = polychlorinated biphenyl; PRG = preliminary remediation goal; RAL = remedial action level; RAO = remedial action objective; SMS = Sediment Management Standards; SQS = sediment quality standard; SWAC = spatially-weighted average concentration; TEQ = toxic equivalent.

Table 2 FS Remedial Action Levels for Alternative 5C – How Derived and How Applied (adapted from FS Table 6-2)

Risk-Driver Remedial Action Level[a]	Rationale	Depth Evaluated	Areal Extent
Total PCBs (µg/kg dw)			
12 mg/kg oc	• SQS[b;] achieved immediately after construction	10 cm	site-wide
Arsenic (mg/kg dw)			
57 (site-wide)	• Achieve SQS immediately after construction and part of a well-spaced range of RALs	10 cm	site-wide
28 (intertidal areas)	• 10^{-5} beach play RBTC (applied as point basis; 45-cm evaluation depth) and part of a well-spaced range of RALs	45 cm	intertidal
cPAHs (µg TEQ/kg dw)			
1,000 (site-wide)	• Site-wide SWAC within range of upstream values	10 cm	site-wide
900 (intertidal areas)	• Beach play 10^{-5} RBTC (applied as point basis; 45-cm evaluation depth)	45 cm	intertidal
Dioxins/Furans (ng TEQ/kg dw)			
28 (intertidal areas)	• 10^{-6} beach play RBTC (applied as point basis; 45-cm evaluation depth)	45 cm	intertidal
25 (site-wide)	• Provides a well-spaced range of RALs for evaluation	10 cm	site-wide
SMS Contaminants			
SQS at Year 0	• Achieve SQS immediately after completion of construction	10 cm	site-wide

Notes:

a. A remedial action level is a contaminant-specific sediment concentration that triggers the need for active remediation (i.e., dredging, capping, or ENR). It is a point-based concentration that can be targeted to achieve an area-based goal (SWAC). RALs labeled site-wide apply to top 10 cm in Recovery Categories 2 and 3 and to top 10 cm and top 60 cm in Recovery Category 1 areas.

b. Dry weight equivalents of the SMS criterion of the SQS (12 mg/kg oc) is 240 µg/kg dw, assuming 2% TOC (average site-wide TOC value).

cPAH = carcinogenic polycyclic aromatic hydrocarbon; CSL = cleanup screening level; dw = dry weight; kg = kilograms; µg = micrograms; mg = milligrams; n/a = not applicable to the RAO; ng = nanograms; oc = organic carbon; PCB = polychlorinated biphenyl; PRG = preliminary remediation goal; RAL = remedial action level; RAO = remedial action objective; RBTC = risk-based threshold concentration; SMS = Sediment Management Standards; SQS = sediment quality standard; SWAC = spatially-weighted average concentration; TEQ = toxic equivalent; TOC = total organic carbon.

Table 3 Sediment Risk-Based Threshold Concentrations (RBTCs) for Human Health Direct Sediment Contact RME Exposure Scenarios (same as FS Table 3-10)

Risk Driver	Target Risk	Sediment RBTC		
		Netfishing RME	Beach Play RME	Tribal Clamming RME
Arsenic (mg/kg dw)	1×10^{-6}	3.7	2.8	1.3
	1×10^{-5}	37	28	13
	1×10^{-4}	370	280	130
cPAH TEQ[a] (µg/kg dw)	1×10^{-6}	380	90	150
	1×10^{-5}	3,800	900	1,500
	1×10^{-4}	38,000	9,000	15,000
Dioxin/furan TEQ[b] (ng/kg dw)	1×10^{-6}	37	28	13
	1×10^{-5}	370	280	130
	1×10^{-4}	3,700	2,800	1,300
Total PCBs (µg/kg dw)	1×10^{-6}	1,300	1,700	500
	1×10^{-5}	13,000	17,000	5,000
	1×10^{-4}	130,000	170,000	50,000
	HQ = 1	n/a[c]	5,900	n/a[c]

Notes:

a. cPAHs are presented as benzo(a)pyrene TEQs.

b. Dioxins/furans are presented as 2,3,7,8-TCDD mammalian TEQs.

c. Sediment RBTCs were calculated for non-cancer risk (HQ of 1) only when HQs were greater than 1 for a given scenario-risk driver combination.

cPAH = carcinogenic polycyclic aromatic hydrocarbon; dw = dry weight; HQ = hazard quotient; n/a = not applicable; PCB = polychlorinated biphenyl; RBTC = risk-based threshold concentration; RME = reasonable maximum exposure; TCDD = tetrachlorodibenzo-p-dioxin; TEQ = toxic equivalent.

Table 4 Concentration Upper Limit for Enhanced Natural Recovery (With or Without *In Situ* Treatment) in Subtidal and Intertidal Areas for Alternative 5C (adapted from FS Table 8-3)

Risk Driver	Concentration Upper Limits for Enhanced Natural Recovery (With or Without *in situ* Treatment) for Alternative 5C [a, b, c]	
	Intertidal and Subtidal Areas (10 cm Evaluation Depth)	Intertidal (45 cm Evaluation Depth)
PCBs (µg/kg dw)	720	n/a
Arsenic (mg/kg dw)	171	42
cPAHs (µg TEQ/kg dw)	3,000	1,350
Dioxins/Furans (ng TEQ/kg dw)	75	42
SMS Contaminants	3 × SQS	n/a

Notes:

a. The upper limit for ENR/ *in situ* represents 3 times the RAL site-wide, and 1.5 times the intertidal RAL in intertidal areas (for arsenic, cPAHs and dioxins/furans). If an intertidal RAL exists, the higher RAL applies only to subtidal areas.

b. All concentration upper limits are site-wide unless two upper limits are presented for subtidal/intertidal areas.

c. The ENR upper limits apply only to areas assigned to Recovery Categories 2 and 3; this feasibility study assumes that no ENR (with or without *in situ* treatment) will be applied in areas assigned to Recovery Category 1. *In situ* treatment assumed viable in all ENR/*in situ* areas.

cPAH = carcinogenic polycyclic aromatic hydrocarbon; dw = dry weight; ENR = enhanced natural recovery; *in situ* = *in situ* treatment; kg = kilograms; µg = micrograms; mg = milligrams; ng = nanograms; PCB = polychlorinated biphenyl; RAL = remedial action level; SMS = Sediment Management Standards; SQS = sediment quality standard; TEQ = toxic equivalent