FINAL

Lower Duwamish Waterway Group

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

PRE-DESIGN INVESTIGATION WORK PLAN FOR THE LOWER DUWAMISH WATERWAY UPPER REACH

FINAL

For submittal to

The Lower Duwamish Waterway Group
Seattle, WA

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ABBREVIATIONS

abbreviation	definition
95UCL	95% upper confidence limit (on the mean)
AC	activated carbon
AOC	Administrative Order on Consent
AOC3	Third Amendment to the Administrative Order on Consent
AOC4	Fourth Amendment to the Administrative Order on Consent
ARAR	applicable or relevant and appropriate requirement
BaP	benzo(a)pyrene
BDC	Boeing Developmental Center
Boeing	The Boeing Company
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm	centimeter
COC	contaminant of concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CQAP	construction quality assurance plan
DMMP	Dredged Material Management Program
DMMU	dredged material management unit
DQO	data quality objective
dw	dry weight
EAA	early action area
Ecology	Washington Department of Ecology
EIM	Environmental Information Management
ENR	enhanced natural recovery
EPA	U.S. Environmental Protection Agency
ESD	explanation of significant differences
FNC	federal navigation channel
LAET	lowest apparent effects threshold
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
LTMMP	Long-Term Maintenance and Monitoring Plan
mg/kg	milligrams per kilogram
MLLW	mean lower low water
MNR	monitored natural recovery
MTCA	Model Toxics Control Act

μg/kg	micrograms per kilogram
ng/kg	nanograms per kilogram
OC	organic carbon
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCUL	preliminary cleanup level
PDI	pre-design investigation
PDIWP	pre-design investigation work plan
QAPP	Quality Assurance Project Plan
RAL	remedial action level
RAO	remedial action objective
RD	remedial design
RDWP	Remedial Design Work Plan
RI/FS	remedial investigation/feasibility study
RM	river mile
ROD	Record of Decision
SCO	sediment cleanup objective
SMS	Washington State Sediment Management Standards
SOW	statement of work
STM	sediment transport model
T-117	Terminal 117
TEQ	toxic equivalent
TOC	total organic carbon
USACE	U.S. Army Corps of Engineers
WQMP	water quality monitoring plan
ww	wet weight

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1 Introduction

This work plan presents the approach for the pre-design investigation (PDI) of the upper reach of the Lower Duwamish Waterway (LDW) to address the scope outlined in the Fourth Amendment to the Administrative Order on Consent (AOC4) for the LDW (EPA 2018). This investigation is being conducted as an integral part of the remedial design (RD) of the upper reach, as described in the Remedial Design Work Plan (RDWP) to which this work plan is an appendix.

In 2000, the City of Seattle, King County, the Port of Seattle, and The Boeing Company (Boeing), working collectively as the Lower Duwamish Waterway Group (LDWG), agreed in an Administrative Order on Consent (AOC) to conduct a remedial investigation/feasibility study (RI/FS) for the LDW, with oversight by the U.S. Environmental Protection Agency (EPA) and the Washington Department of Ecology (Ecology). In September 2001, the LDW was formally listed as a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund) site; in February 2002, the LDW was formally added to the National Priorities List as a Washington Model Toxics Control Act (MTCA) site. The RI was completed in 2010 (Windward 2010a) and the FS was completed in 2012 (AECOM 2012a). A record of decision (ROD) was issued by EPA in 2014 (EPA 2014b).

Four amendments to the AOC have been signed. The first amendment resulted in the fishers study (completed in 2016); the second amendment involves an ongoing pilot study to assess the effectiveness of activated carbon (AC) amendments to sand layer placement as a remedial technology. The third amendment (AOC3) specified pre-design studies, including collecting baseline data following early actions but before implementation of the full remedial action, surveying waterway users to update information on uses of the waterway, and preparing a design strategy report (Integral and Windward 2019) to help EPA ensure that all RD data needs are addressed in the appropriate sequence. AOC4—addressed through this pre-design investigation work plan (PDIWP) and the RDWP—involves the RD for the upper reach of the LDW (river mile [RM] 3.0 to RM 5.0).

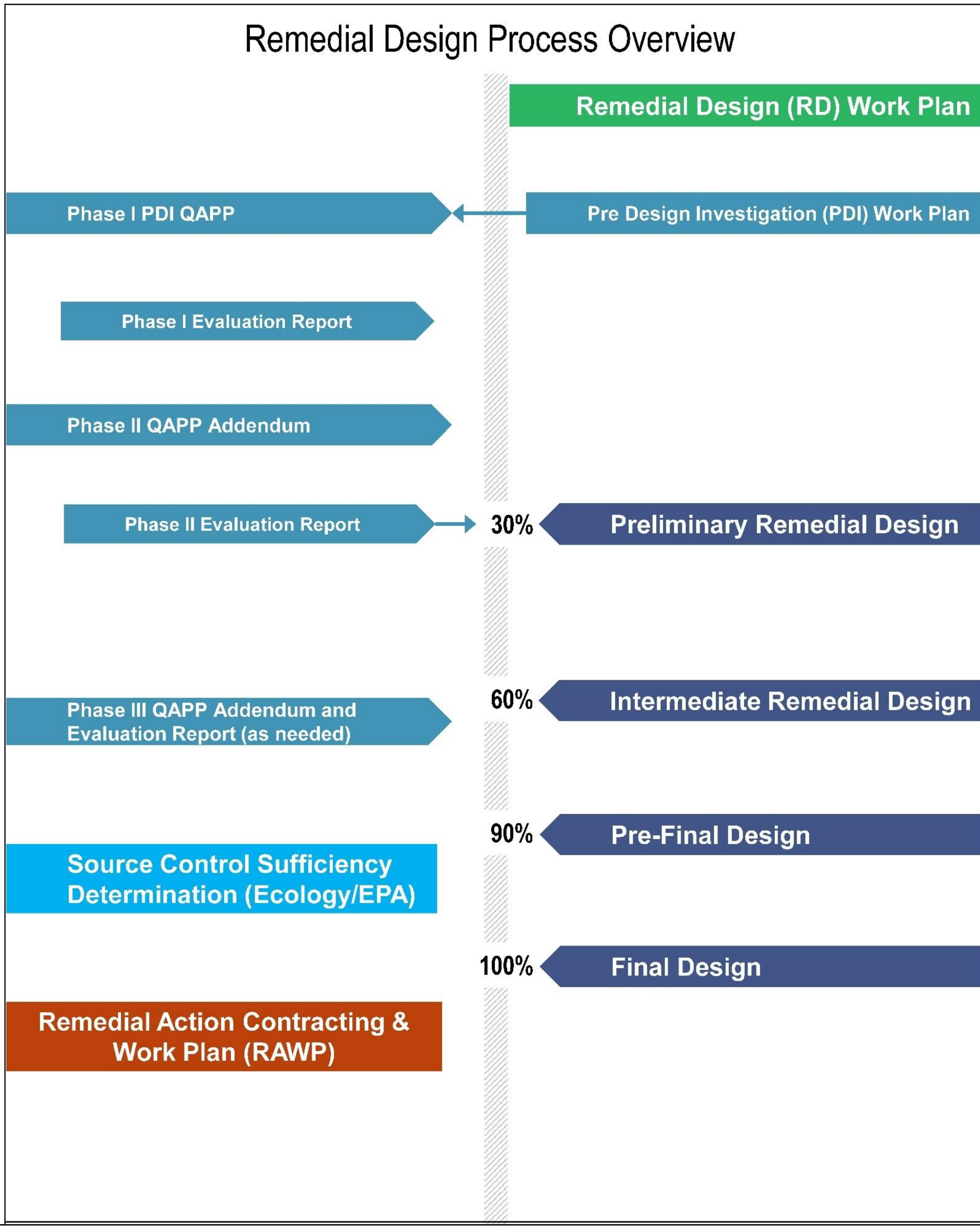
1.1 Pre-Design Investigation Work Plan Objectives

The primary objective of this PDIWP is to describe the process to be used to collect the data needed to support detailed engineering designs for the selected remedy for the upper reach of the LDW, as set forth in the ROD (EPA 2014b) and AOC4 (EPA 2018). Consistent with Section 5.4 of the AOC4 statement of work (SOW), this PDIWP includes an evaluation and summary of existing data, a description of data gaps, a strategy for data gathering, a conceptual design sampling plan including clearly stated rationales for tiering and phasing, and a schedule.

The objective of the PDI is to address data needs through field investigations for completion of the upper reach RD. There will be at least two phases of the PDI, each including a field sampling event and a data evaluation report (Figure 1). The data obtained through field sampling in PDI Phases I and II will be used to develop the 30% RD. If, after the completion of PDI Phases I and II, data gaps[1] remain to complete the RD, these will be filled by a third PDI phase.

[1] The approach to addressing data gaps that are not addressed through field sampling investigations is discussed in the RDWP.

Figure 1
Remedial Design Conceptual Strategy



1.2 Work Plan Organization

The PDIWP is organized into six sections, including this introduction. Section 2 presents a PDI strategy, Section 3 provides an existing data evaluation, and Section 4 presents a phased conceptual design sampling plan. The schedule and deliverables for the PDI tasks are presented in Section 5, and references are provided in Section 6.

The PDIWP has two attachments: Attachment A contains details regarding benzyl alcohol, and Attachment B contains a brief summary of monitoring data from within the early action areas (EAAs) in the upper reach. Key tables and figures from the ROD that are referenced in this PDIWP are contained in Appendix A to the RDWP.

2 PDI Strategy

This section presents the overall approach to the PDI, including the phases of the field data collection efforts. To put the PDI strategy into context, an overview of monitoring is provided, key elements of the ROD are presented, and the PDI sampling strategy and reporting are summarized.

2.1 Roles of PDI Sampling, Construction Sampling, and Long-term Monitoring

The PDI investigations (design sampling) in this work plan are intended to provide the information needed to complete the RD for the upper reach. The PDI will augment the existing information developed for the LDW, including RI/FS data, AC pilot study data, baseline sampling data, and other post-RI/FS data. Design sampling is part of a larger plan for data collection that will continue during and following construction.

Additional data will be collected during construction (as described in the construction quality assurance plan [CQAP] and water quality monitoring plan [WQMP]). The CQAP and WQMP sampling data will document compliance with plans, specifications, and applicable or relevant and appropriate requirements (ARARs) during construction, and will inform any corrective measures needed during construction.

Following construction, the LDW will be monitored as described in the Long-Term Maintenance and Monitoring Plan [LTMMP]). The purpose of the LTMMP is to ascertain attainment of cleanup levels and compliance with ARARs, to protect the integrity of the remedial actions, and to aid in the evaluation of source control effectiveness. The LTMMP will include both LDW-wide monitoring elements and elements specific to the remedy in the upper reach, such as specific monitoring requirements for caps, enhanced natural recovery (ENR), and MNR areas. It is expected that the LTMMP will be amended to include specific requirements for the middle and lower reaches following construction.

These various types of sampling and monitoring are discussed in general in Section 1.5.3 of the RDWP and will be discussed in detail in the CQAP, WQMP, and LTMMP outline to be prepared as part of the 60 and 90% design deliverables. The full LTMMP with all monitoring details will be prepared following construction.

2.2 ROD Elements

This section describes the key ROD elements that apply to the delineation of cleanup areas and the assignment of remedial technologies that are required to design the remedy. These elements require design sampling, as described in this PDIWP, to determine where contaminant-specific remedial action levels (RALs) (ROD Table 28[2]) are exceeded in sediment and to collect the information needed to assign the appropriate remedial technology to a given area (based on the decision flowcharts in ROD Figures 19, 20, and 21).

2.2.1 RALs and Recovery Categories

RALs are contaminant concentrations in sediment that are used to delineate areas that require active remediation. RALs apply to sediment in specific locations and depths on a point-by-point basis (EPA 2014b). RALs have been established for contaminants of concern (COCs) based on location type (intertidal vs. subtidal), recovery category, and depth interval in the sediment (e.g., 0 to 10 centimeters [cm]). In the intertidal areas, RALs apply to depth intervals of 0 to 10 cm and 0 to 45 cm (Figure 2). In the subtidal areas, RALs apply to depth intervals of 0 to 10 cm and 0 to 60 cm.[3] Shoal areas[4] within the federal navigation channel also have their own set of RALs. ROD Table 28 (Figure 3 of this PDIWP and included in the RDWP Appendix A) summarizes the RALs for each of the COCs.

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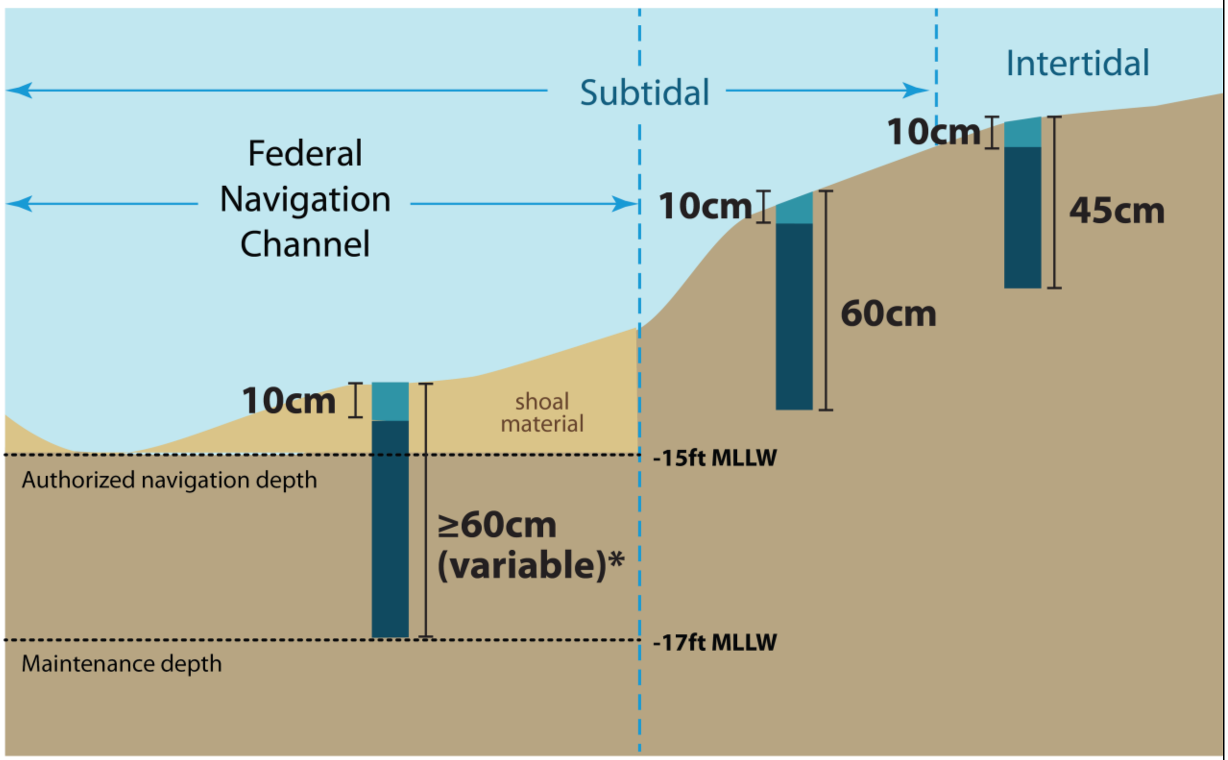
[2] ROD Table 28 is titled *Remedial Action Levels, ENR Upper Limits, and Areas and Depths of Application.*

[3] Subtidal RALs applicable to 0- to 60-cm depth are dependent on recovery category designation and potential tug scour areas.

[4] Shoaled areas are defined as areas within the federal navigation channel with sediment accumulations above the authorized navigation depth.

Figure 2
Depth Intervals where RALs Apply



* only applicable within Federal Navigation Channel

Figure 3
Record of Decision Table 28 (EPA 2014)

Table 28. Remedial Action Levels, ENR Upper Limits, and Areas and Depths of Application

			Intertidal Sediments (+11.3 ft MLLW to -4 ft MLLW)				Subtidal Sediments (-4 ft MLLW and Deeper)				
			Recovery Category 1 RALs, ENR ULs, and Application Depths		Recovery Category 2 and 3 RALs, ENR ULs, and Application Depths		Recovery Category 1 RALs, ENR ULs, and Application Depths		Recovery Category 2 and 3 RALs, ENR ULs, and Application Depths		Shoaled Areas[b] in Federal Navigation Channel
Risk Driver COC	**Units**	**Action Levels**	Top 10 cm (4 in)	Top 45 cm (1.5 ft)	Top 10 cm (4 in)	Top 45 cm (1.5 ft)	Top 10 cm (4 in)	Top 60 cm (2 ft)	Top 10 cm (4 in)	Top 60 cm (2 ft)[c]	Top to Authorized Navigation Depth Plus 2 ft
Human Health Based RALs											
PCBs (Total)	mg/kg OC	RAL	12	12	12	65	12	12	12	195	12
		UL[a] for ENR	--	--	36	97	--	--	36	195	--
Arsenic (Total)	mg/kg dw	RAL	57	28	57	28	57	57	57	--	57
		UL[a] for ENR	--	--	171	42	--	--	171	--	--
cPAH	µg TEQ/kg dw	RAL	1000	900	1000	900	1000	1000	1000	--	1000
		UL[a] for ENR	--	--	3000	1350	--	--	3000	--	--
Dioxins/Furans	ng TEQ/kg dw	RAL	25	28	25	28	25	25	25	--	25
		UL[a] for ENR	--	--	75	42	--	--	75	--	--
Benthic Protection RALs											
39 SMS COCs [d]	Contaminant-specific	RAL	Benthic SCO	Benthic SCO	2x Benthic SCO	--	Benthic SCO	Benthic SCO	2x Benthic SCO	--	Benthic SCO
		UL[a] for ENR	--	--	3x RAL	--	--	--	3x RAL	--	--

a. The ENR Upper Limit (UL) is the highest concentration that would allow for application of ENR in the areas described. For areas with no ENR limit listed, ENR is not a currently designated technology (see Section 13.2.1.2 for further discussion).

b. Shoaled areas are those areas in federal navigation channel with sediment accumulation above the authorized depth including a 2 ft over-dredge depth that USACE uses to maintain the channel for navigation purposes. The authorized channel depths are (1) from RM 0 to 2 (from Harbor Island to the First Avenue South Bridge), 30 ft below MLLW; (2) from RM 2 to RM 2.8 (from the First Avenue South Bridge to Slip 4), 20 ft below MLLW; and (3) from RM 2.8 to 4.7 (Slip 4 to the Upper Turning Basin), 15 ft below MLLW. For shoaled areas, the compliance intervals will be determined during Remedial Design; these are typically 2-4 ft core intervals. For areas in the channel that are not shoaled, Recovery Categories 1 or 2 & 3 RALs apply as indicated in the other subtidal columns.

c. Applied only in potential vessel scour areas. These are defined as subtidal areas (i.e., below -4 ft MLLW) that are above -24 ft MLLW north of the 1st Ave South Bridge, and above -18 ft MLLW south of the 1st Ave South Bridge (see Figure 17).

d. There are 41 SMS COCs, but total PCBs and arsenic ENR ULs are based upon human health based RALs only (see Table 20).

ROD Figure 12[5] outlines the spatial extent of the recovery category areas referred to in ROD Table 28 based on the FS.[6] Recovery categories are "based on information about the potential for sediment contaminant concentrations to be reduced through natural recovery or for subsurface contamination to be exposed at the surface due to erosion or scour" (EPA 2014b). Recovery Category 1 areas have less potential for natural recovery, whereas Recovery Category 2 and 3 areas have a greater likelihood for recovery and less likelihood of disturbance.

With respect to RALs, EPA is considering potential changes to the carcinogenic polycyclic aromatic hydrocarbon (cPAH) RALs presented in ROD Table 28 (Figure 3). In 2017, three years after the ROD was finalized in 2014, EPA published an updated slope factor for the toxicity of benzo(a)pyrene (BaP), which is used to estimate excess lifetime cancer risk from exposures to cPAHs. EPA also published a reference dose for BaP for non-cancer health effects based on the developmental endpoint (i.e., neurobehavioral changes). Both of these toxicity values are available on EPA's Integrated Risk Information System website (EPA 2019). The process for updating these values involved more than five years of research, the results of which showed that BaP is less toxic than previously thought for people who contact or ingest the chemical. The process for BaP included four draft documents released for agency or public comment from 2011 to 2016.[7]

EPA is currently determining when it will issue an explanation of significant differences (ESD) for the LDW and what changes will be made to the ROD involving cPAH RALs, sediment cleanup levels, and target tissue levels in clams. These decisions will affect the remedy, and thus design sampling, through changes in cPAH sediment cleanup levels and RALs (Windward 2019a). As EPA determines its course of action, this PDIWP will acknowledge both ROD and current recommendations for updated cPAH cleanup levels and RALs. All maps will show comparisons of data to ROD-based RALs. A final EPA decision on cPAH RAL updates before the analysis of Phase I archive samples (see Section 4.1) would enable design sampling to be consistent with the updated BaP toxicity information.

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[5] ROD Figure 12 is titled *Recovery Category Areas*.

[6] Based on the waterway users survey conducted under AOC3, a preliminary recommendation was made to change the recovery category of six berthing areas from Recovery Category 3 to Recovery Category 2 (Integral et al. 2018).

[7] Details regarding the BaP review process can be found here: https://cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?substance_nmbr=136#tab-3.

2.2.2 *Technology Assignments*

The flow charts in ROD Figures 19, 20, and 21[8] will be used to determine technology assignments for delineated active remedial areas (EPA 2014b). As stated in the ROD, "the use of Recovery Categories allows for more aggressive remedial technologies (such as capping and dredging) in areas with less potential for natural recovery and a higher likelihood of scour or other disturbance, and less aggressive remedial technologies (such as ENR and MNR) in areas where recovery is predicted to occur more readily and disturbance is less likely." The active remedial technologies listed in the ROD include removal through dredging/excavation, partial dredging and capping, capping, or ENR. Use of ENR includes the consideration of contaminant upper limits as specified in ROD Table 28.

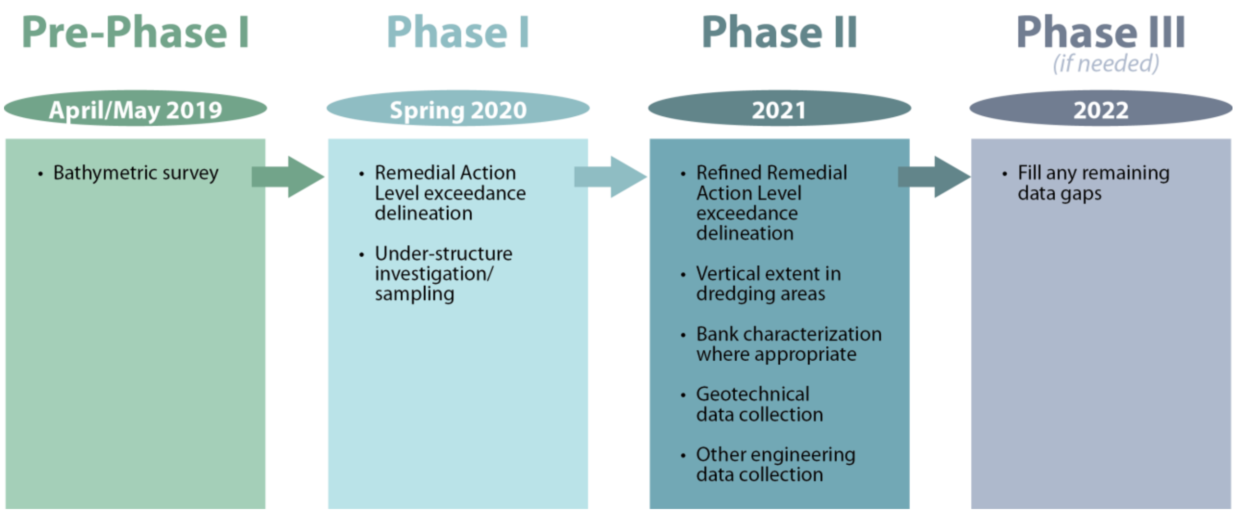
Outside of active remedial action areas, more intensive long-term monitoring will be conducted in Recovery Category 2/3 areas where contaminant concentrations are less than RALs but greater than the benthic sediment cleanup objective (SCO); these areas are referred to as MNR to benthic SCO in the ROD. If MNR does not achieve the benthic SCO or show sufficient progress toward achieving it in 10 years post-construction, additional cleanup will be implemented as a part of the remedy. Less intensive monitoring will be conducted in areas where contaminant concentrations are below the benthic SCO but above the sediment cleanup levels (based on Puget Sound natural background) for the protection of human health for polychlorinated biphenyls (PCBs), dioxin/furans, and arsenic. PDI data will be used in delineating these areas (see Section 4.1).

2.3 Design Sampling Strategy

Design sampling will be done in phases (Figure 4). Phase I will focus on defining the extent of RAL exceedances in order to identify initial remedial action areas and make initial technology assignments. Phase II will involve the collection of additional RAL delineation data (as needed), vertical contamination data in dredge/cap areas, and area-specific data needed for design. Phase III will be conducted if data gaps remain after Phase II. Section 4.1 lays out the DQOs for each phase and describes details of each design sampling phase.

[8] Figure 19 is titled *Intertidal Areas – Remedial Technology Applications,* Figure 20 is titled *Subtidal Areas – Remedial Technology Application*, and Figure 21 is titled *Intertidal and Subtidal Areas – Natural Recovery Application*.

Figure 4
Design Sampling Phases



As described in the RDWP and the RI/FS (Windward 2010a; AECOM 2012a), much is known about where RAL exceedances are expected (and where RAL exceedances are not expected) to occur within the upper reach based on existing sediment data, sediment transport model (STM) results, and the locations of potential sources along the LDW. Given this existing information, the approach to sample collection varies spatially and is designed to address location-specific questions. While additional design sampling is required to define remedial action areas, it is generally assumed that sediment concentrations in the upper reach are declining overall relative to RI/FS data for the following reasons:

- The baseline composite data in the upper reach show declines in risk driver concentrations relative to those in the RI/FS, in line with modeled predictions.
- The Green River continues to deliver approximately 220,000 metric tons of upstream sediment to the LDW annually (see Section 2.1.4 in the RDWP), approximately 50% of which is deposited in the LDW with 80% of the deposition in the vicinity of the Turning Basin (RM 4.0 to RM 4.9) (AECOM 2012a). Section 8.2 of the draft Pre-Design Studies data evaluation report (Windward 2018b) summarizes concentrations of total PCBs, cPAHs, arsenic, and dioxins/furans representative of upstream sediments, which are lower than average concentrations in the LDW.[9]
- The EAAs in the LDW have been remediated.

[9] Upstream concentrations and baseline site-wide spatially weighted average concentrations were as follows, as summarized in the draft Pre-Design Studies data evaluation report: 20 and 172 µg/kg dry weight (dw) total PCBs, 55 and 147 µg/kg dw cPAH TEQ, 4 and 8.33 ng/kg dw dioxin/furan TEQ, and 10 and 11.6 mg/kg dw arsenic.

- Source control efforts have been on-going to reduce inputs to the LDW; it is assumed that there are no new sources contributing contamination in this reach of the waterway.

Thus, areas that have not had RAL exceedances based on the RI/FS or post-FS datasets are not expected to have RAL exceedances now or in the future. Since the RI/FS sampling included both focused sampling near sources and areas with higher concentrations and sampling for overall spatial coverage, that dataset represents a fairly comprehensive analysis of where RAL exceedances can be expected. In addition, source-related data collected as part of AOC3 (i.e., near-outfall sediment, bank, and seep samples) did not reveal new source areas of concern in the upper reach (see Section 3). If Ecology identifies new source areas, or if additional new data are collected, these data will be considered in design.

Design sampling will focus on areas with existing RAL exceedances and with concentrations just below RALs.[10] In areas with existing RAL exceedances, samples will be collected from locations that either reoccupy RAL exceedance sampling locations or that bound an area where existing information indicates active sediment remediation would occur. The decision to reoccupy or bound will be based on the age of the data, the RAL exceedance factor, and potential source proximity; see Section 4 for more details.

Sediment remediation has been conducted at the four EAAs in the upper reach (Boeing Plant 2, Jorgensen Forge, Terminal 117 [T-117], and Norfolk), which involved dredging of contaminated sediment and backfill with clean sediment (Map 1). At Boeing Plant 2 and T-117, construction was completed within the last few years.[11] Design sampling is not planned within the boundaries of these EAAs, and EAA monitoring is ongoing (Attachment B). The removal action at Norfolk was completed in 1999 and monitoring of the backfill was completed in 2008. A remedial action was also completed in 2003 near Boeing (at the Boeing Developmental Center [BDC] south storm drain outfall, adjacent to Norfolk EAA); monitoring was last conducted in this area in 2017. Additional surface samples will be collected in this area as part of RD to confirm the earlier monitoring data for the backfill.

2.4 PDI Reporting

Details regarding Phase I design sampling and analysis will be described in the upcoming PDI Quality Assurance Project Plan (QAPP). Phase II and Phase III (if needed) design sampling and analysis details will be presented in QAPP addenda. In addition to standard elements, the QAPP

[10] Of the 12 locations with a RAL exceedance factor between 0.9 and 1.0, all but two locations are near locations with RAL exceedances.

[11] Remediation work at the Jorgensen Forge EAA is not considered complete; see Section 3.3.2.1.

and its addenda will include maps and coordinates for specific design sampling locations, as well as a table with rationale for the placement of each sample (i.e., which specific data needs will be addressed by each sample).

The AOC4 2019 bathymetry data collected per the survey QAPP (Anchor and Windward 2019) and the sun-illuminated digital terrain maps[12] based on the 2019 survey will be included in the PDI QAPP. This information will be used in making recommendations for adjustments to Recovery Category 1 areas based on observed vessel scour and updates to potential vessel scour areas based on bathymetry. Recommendations will be made in consultation with EPA. Recovery categories from RM 3.0 to RM 5.0 will be finalized in the Phase II data evaluation report after consideration of Phase I and II data for chemical trends.

The updated bathymetry data will guide the PDI for the upper reach in several ways, including:

- Identification of shoals in the federal navigation channel (FNC)
- Refinement of Recovery Category 1 areas based on evidence of vessel scour areas identified in the FS and in the 2019 survey
- Refinement of areas in the elevation range denoting "potential vessel scour" (areas between -4 and -18 feet mean lower low water [MLLW] as defined in the ROD (EPA 2014b))

Data evaluation reports will be submitted following each phase of design sampling. Initial technology assignments will be made in the Phase I data evaluation report following the first phase of design sampling. These assignments will be used to determine which data are needed in Phase II (e.g., vertical information in dredging/capping areas, bank data, geotechnical data, etc.). Technology assignment modifications based on Phase II data will be documented in the Phase II data evaluation report.

[12] Sun-illuminated digital terrain maps are maps with shading to enhance the appearance of bathymetric features.

3 Existing Data Evaluation

AOC4 requires a summary of existing sediment data in this PDIWP in order to identify data gaps for design sampling. Existing sediment data include those collected for the RI/FS (1990 to 2010) (Windward 2010a; AECOM 2012a) and those collected post-FS (2010 to 2018). The RI/FS dataset was submitted to EPA as part of the FS (AECOM 2012a), and post-FS data were summarized in the *Compilation of Existing Data* (Windward and Integral 2018) and the Pre-Design Studies sediment data report (Windward 2019b).

In addition to existing data, Ecology's Environmental Information Management (EIM) system was searched for this evaluation to determine if any further sediment data are available from within RM 3.0 to RM 5.0 following the AOC3 data compilation cutoff date of June 2018. No additional data were identified as of March 2019. If new data become available that are directly relevant (e.g., additional data from the ENR/AC pilot study), they will also be considered in the design.

This section presents an evaluation of existing sediment data, describes data management rules, and provides a summary of sediment and potential source information for the upper reach.

3.1 Data Management

The RI/FS and post-FS sediment data were merged into one dataset[13] using a consistent set of data rules (Windward and Integral 2017) to make data comparable. Data from dredged areas (including EAAs and FNC) were excluded if they were collected prior to dredging. Also, if a location was re-sampled regularly, as is common in monitoring datasets, only the most recent result was selected to represent that location.

The following criteria were used to define the sediment intervals included in the data evaluation dataset:

- The 0- to 10-cm samples include all samples collected from surface intervals from 0 to 5 cm to 0 to 15 cm.
- The 0- to 60-cm samples include all samples collected from intervals from 0 to 45 cm (0 to 1.5 feet) to 0 to 75 cm (0 to 2.5 feet). In cases where two 1-foot intervals were collected, the 0- to 60-cm results were calculated as the mean of the results for the two intervals.

[13] The merged dataset will be available on ldwg.org in 2020.

- In shoal areas within the FNC, the subsurface sediment interval is variable depending on the depth of the shoaled material (see Section 4.2.2.1). For the purposes of this PDIWP, all available subsurface data for the shoal areas were compared to the 0- to 60-cm RAL.

Many of the sediment RALs (e.g., PCBs, benthic risk drivers such as polycyclic aromatic hydrocarbons [PAHs] and phthalates) are total organic carbon (TOC)-normalized values. The ROD does not provide direction regarding the TOC range that is appropriate for TOC normalization (EPA 2014b). Thus, the range for TOC normalization will be 0.5 to 3.5%, based on Ecology's *Sediment Cleanup User's Manual II* (Ecology 2019). Concentrations in samples with TOC values outside of this range were compared to dry weight lowest apparent effects threshold (LAET) values listed in Table 8-1 of Ecology's *Sediment Cleanup User's Manual II*.

3.2 Existing Sediment Data

This section presents a comparison of existing sediment data with RALs. This comparison is important because the delineation of areas with RAL exceedances in the upper reach is one of the primary objectives of the PDI sampling. This section also presents a summary of benzyl alcohol chemistry and toxicity information, with details provided in Attachment A.

The existing surface and subsurface sediment sampling locations from RM 3.0 to RM 5.0 of the LDW are shown on Maps 2 and 3, respectively. Data collected from these locations are divided into two datasets, RI/FS data and post-FS data (including baseline) based on age. The large surface and subsurface RI/FS dataset and a 2012 subsurface U.S. Army Corps of Engineers (USACE) dataset[14] were used in the ROD (EPA 2014b) to estimate remedial action areas, shown on ROD Figure 18,[15] based on rules defined in ROD Figures 19, 20, and 21. The RI/FS and post-FS datasets are discussed further as follows:

- **RI/FS dataset** – The surface and subsurface RI/FS dataset includes data collected from 1990 to January 2010. This dataset provides a valuable foundation regarding the nature and extent of contamination within the LDW. However, consistent with the conceptual site model in the FS, surface sediment conditions have likely changed since the RI/FS data were evaluated in the ROD.

- **Post-FS dataset** – The post-FS dataset includes data collected from March 2010 to March 2019 and provides an updated assessment of the nature and extent of contamination. Sediment investigations included in the dataset, which were conducted for a variety of purposes, often did not collect all the sediment intervals required for RAL

[14] The USACE 2012 dataset is included in the post-FS dataset (Windward and Integral 2018).
[15] ROD Figure 18 is titled *Selected Remedy*.

delineation. In addition, much of the sediment data collected to characterize baseline conditions in 2017/2018 were from composite samples, which cannot be used to define remedial action area boundaries. The baseline composite samples included 24 composites, each created from 7 grab samples collected from the 0- to 10-cm sediment interval; 8 of these composites were from the upper reach. There were also baseline composite samples collected from beach play areas from the 0-45 cm sediment interval; 3 of these composites were from the upper reach.[16] Although not appropriate for identifying remedial action area boundaries, these composites are useful in making general inferences regarding sediment quality within a given area and help determine design sampling strategy in those areas.

Table 1 presents a summary of the available data by depth interval and sample type. The depth interval is important because it determines which RAL is applicable for each sample (see Figure 3).

Table 1
Available Sediment Data for the Upper Reach of the LDW for use in the PDI

Sediment Sample Interval	Sample Type	Number of Sampling Locations by Dataset	
		RI/FS (1990–2010)	Post-FS (2010–2019)
0–10 cm	Discrete	410	197
	Composite	0	8 surface sediment composites (each consisting of 7 individual samples)
0–45 cm (intertidal)	Discrete	0	0
	Composite	1 (located in Duwamish Waterway Park, RM 3.05W)	3 beach play area composites from each of the 3 beach play areas (each composite consisting of 6 to 9 individual samples)
0–60 cm (subtidal)	Discrete	14	7[1]
Deeper cores[2]	Discrete	30	54[2]

Notes:

[1] Total includes 0–60 cm interval locations and shoaling area locations with intervals greater than 0–60 cm (e.g., USACE 2012 cores).

[2] Includes intertidal and subtidal core locations with sample intervals that characterize sediment deeper than 60 cm (e.g., 3- to 4-ft or 4- to 6-ft intervals). Some cores in this category are also included in the 0–60-cm count.

cm: centimeter

[16] In addition to the beach play composites, 3 site-wide composites were created from 16 potential clamming areas from the 0- to 45-cm sediment interval; 5 of these intertidal areas were within or partially within the upper reach. These data are not summarized herein because these composite samples include sediment from the entire LDW and thus are not helpful in assessing sediment quality in the upper reach.

EAA: early action area
EIM: Environmental Information Management
FS: feasibility study
PDIWP: pre-design investigation work plan
RI: remedial investigation
RM: river mile
USACE: US Army Corps of Engineers

The number of samples for each of the risk driver chemicals and the number of RAL exceedances in specific depth intervals are summarized in Table 2. The 0- to 10-cm interval had the greatest number of samples available for all analytes. There are no existing discrete 0- to 45-cm samples in the intertidal. The only 0- to 45-cm samples collected to characterize specific upper reach areas are composite samples collected in intertidal beach play areas. PCBs were analyzed in the greatest number of samples (548 of the 0- to 10-cm samples); dioxins/furans were analyzed in the fewest samples (72 of the 0- to 10-cm samples). The spatial distribution of the existing sediment samples and associated RAL exceedances for specific risk drivers are presented on Maps 4 through 8.

Table 2
Summary of Upper Reach Sediment Data and RAL Exceedances by Chemical

Risk Driver Chemical	Sediment Interval	Number of Samples and Number of RAL Exceedances			
		Sediment Samples[1]		RAL Exceedances[2]	
		RI/FS	Post-FS[3]	RI/FS	Post-FS[3]
Total PCBs (Map 4)	0–10 cm[4]	365	183	52	24
	0–45 cm (intertidal)	no data[4]	no data[4]	no data	no data
	0–60 cm (subtidal)	14	16	1	3
cPAH TEQ (Map 5)	0–10 cm[4]	243	123	14	2
	0–45 cm (intertidal)	no data[4]	no data[4]	no data	no data
	0–60 cm (subtidal)	5	14	1	0
Dioxin/Furan TEQ (Map 6)	0–10 cm[4]	35	37	0	0
	0–45 cm (intertidal)	no data[5]	no data[5]	no data	no data
	0–60 cm (subtidal)	2	14	0	0
Arsenic (Map 7)	0–10 cm[4]	255	177	3	3
	0–45 cm (intertidal)	no data[5]	no data[5]	no data	no data
	0–60 cm (subtidal)	5	14	0	0

Risk Driver Chemical	Sediment Interval	Number of Samples and Number of RAL Exceedances			
		Sediment Samples[1]		RAL Exceedances[2]	
		RI/FS	Post-FS[3]	RI/FS	Post-FS[3]
Benthic Risk Drivers[6] (Map 8)	0–10 cm[4]	275	177	24 (23) [7]	41 (4)[7]
	0–45 cm (intertidal)[8]	no data	no data	no data	no data
	0–60 cm (subtidal)[8]	5	6	1 (0)[7]	6 (0)[7]

Notes:

[1] The number of samples includes only samples with a RAL for that risk driver in that interval. For example, there are two 0- to 60-cm samples with dioxin/furan data in Recovery Category 3 areas, which do not have a 0- to 60-cm RAL for dioxin/furan. Therefore, these two samples are not included in the number of dioxin/furan samples for that interval.

[2] RAL exceedances include detected COC concentrations greater than the RAL.

[3] At post-FS monitoring locations, counts include only the most recent sampling event.

[4] Includes intertidal and subtidal areas.

[5] No discrete locations exist for the 0- to 45-cm interval. However, there is one composite sample in the RI/FS dataset (in the Duwamish Waterway Park area) and nine beach play area composites in the post-FS dataset.

[6] Includes all benthic risk drivers except PCBs and arsenic, which are summed separately because they are human health risk drivers.

[7] The number in parentheses indicates the number of locations with RAL exceedances if benzyl alcohol exceedances were excluded from the dataset.

[8] Benthic RALs for these sediment intervals only apply in Recovery Category 1 and shoal areas.

cm: centimeter

COC: contaminant of concern

cPAH: carcinogenic polycyclic aromatic hydrocarbon

FS: feasibility study

PCB: polychlorinated biphenyl

RAL: remedial action level

RI: remedial investigation

TEQ: toxic equivalent

Map 8 presents the distribution of RAL exceedances of benthic risk drivers with and without PCB and arsenic benthic RAL exceedances. This distinction is made because:

- PCBs and arsenic are both human health and benthic risk drivers and in many instances the human health and benthic RALs are the same for each of these risk drivers (Figure 3)
- Locations with PCB and arsenic RAL exceedances are shown separately (Maps 4 and 7)
- Toxicity testing cannot be used to override RAL exceedances at locations with both human health and benthic RAL exceedances

Locations that exceed the RAL for only benzyl alcohol are shown separately on Map 8. A recent review of the available sediment toxicity data for benzyl alcohol conducted by USACE suggests that the benthic toxicity threshold for benzyl alcohol is higher than the current benthic SCO (Fourie and Fox 2016). Attachment A summarizes available benzyl alcohol data and associated toxicity data for samples collected to date in the LDW. A toxicity testing approach will be outlined in the PDI QAPP or QAPP addendum.

Also, as indicated in Table 3, some of the post-FS surface sediment data for the upper reach are from monitoring studies conducted outside of the EAA boundaries where the same location was repeatedly re-occupied.[17] In these cases, the most recent result for each monitoring location has been shown on the maps in this PDIWP. The largest monitoring study involved pre- and post-construction season monitoring associated with the early action cleanup at Boeing Plant 2 (Map 9). All of the Boeing perimeter monitoring samples are 0- to 10-cm surface sediment samples. These data represent PCB concentrations in sediments near three active dredging operations collected just before and just after each construction season (Boeing Plant 2 [2012–2015], Jorgensen [2014–2015] and T-117 [2013–2015]). The PCB concentrations for these locations fluctuate with time during the three-year construction period (Table 3). Therefore, samples collected just following construction along the perimeter may not be representative of sediment conditions in 2019, several years after construction.

Table 3
Boeing Plant 2 Perimeter Monitoring Data within the Upper Reach

Location	Unit	Total PCB Concentration[1,2]						
		Construction Season 1		Construction Season 2		Construction Season 3		
		Pre (2012)	Post (2013)	Pre (2013)	Post (2014)	Pre (2014) (July)[3]	Pre (2014) (Sept)	Post (2015)
PER205	mg/kg OC	5.6	**19**	7.7	**18**	na	11.7	**21.4**
PER207	mg/kg OC	2.7	2.9	7.7	6.5	na	8.6	10.8
PER208	mg/kg OC	6.9	5.8	**12.1**	**12.5**	na	**12.8**	**39.3**
PER209	mg/kg OC	2.8	na	8.2	7.2	na	6.9	nc
	µg/kg dw[4]	31	3.5	101	88	na	45	**143**
PER210	mg/kg OC	4.7	5.5	5.6	8.7	na	10	6.7
PER211	mg/kg OC	8.1	**25.5**	**1,150**	7.1	na	**36.1**	11.1
PER212	mg/kg OC	5.5	**16.1**	nc	11.5	na	7.9	**22.8**
	µg/kg dw[3]	76	**220**	66	125	na	55.1	124
PER213	mg/kg OC	5.5	9.4	4.4	**13.6**	na	**12.2**	6.1
PER301	mg/kg OC	2.8	na	7.4	2.5	4.3	8	5
PER302	mg/kg OC	1.6	na	2.4	4.5	2.8	11.9	8

[17] The monitoring studies include Boeing Plant 2 (27 locations), Jorgensen Forge (13 locations), T-117 Cleanup Action (5 locations), Boeing Developmental Center (2 locations), and T-117 Outfall Construction (1 location).

Location	Unit	Total PCB Concentration[1,2]						
		Construction Season 1		Construction Season 2		Construction Season 3		
		Pre (2012)	Post (2013)	Pre (2013)	Post (2014)	Pre (2014) (July)[3]	Pre (2014) (Sept)	Post (2015)
PER303	mg/kg OC	2.1	na	7.8	5.7	6.8	9.2	4.2
PER304	mg/kg OC	2.3	na	11.9	6.3	nc	**12.2**	6.3
	µg/kg dw[4]	32	na	**161**	94	28.2	79	**144**
PER305	mg/kg OC	2.1	na	4.9	2.8	5.6	5.8	6.1
PER306	mg/kg OC	2.6	na	8.6	10.8	**16.3**	9.1	7.2
PER308	mg/kg OC	2.8	na	7.5	9.3	11.8	6.8	**20.8**
PER309	mg/kg OC	1.8	na	3.7	3.3	2.2	4	3.4
PER310	mg/kg OC	7.1	na	11.6	7.6	ns	11.9	7.9
PER311	mg/kg OC	3.3	na	7.3	3.2	4.5	7.1	4.2
PER312	mg/kg OC	2.5	na	2.4	6	4	5	6.6
PER313	mg/kg OC	2.5	na	4.4	5.6	8.3	5.4	2.9
PER401	mg/kg OC	5.1	6.8	7.4	9.7	11.4	**25.1**	8.2
PER402	mg/kg OC	3.1	2	2	2.9	4.7	3.2	3.5
PER403	mg/kg OC	1.9	3.3	3.4	4.8	7.2	5.3	5.1
PER404	mg/kg OC	6	6.9	7.7	5.3	5.4	4.2	8.1
PER405	mg/kg OC	4.9	2.3	3.9	5	6.3	10	2.7
PER406	mg/kg OC	3.6	8.4	4.6	10.8	8.8	**22.9**	8.4

Notes:

[1] Data presented as reported in (AMEC Foster Wheeler et al. 2016).

[2] **Bold font** denotes concentrations above the surface sediment PCB RAL (12 mg/kg OC) or the dry weight LAET (130 µg/kg dw), depending on sample-specific TOC values.

[3] Samples were collected in July 2014 in a portion of the EAA (Areas 300 and 400) prior to the implementation of the southwest bank re-excavation and prior to the initiation of Jorgensen Forge dredging).

[4] Dry weight total PCB concentrations are provided for samples with TOC values outside the range for TOC normalization in Ecology's *Sediment Cleanup User's Manual II* (Ecology 2017) for applying benthic cleanup values (0.5 to 3.5%).

dw: dry weight

EAA: early action area

Ecology: Washington Department of Ecology

LAET: lowest apparent effects threshold

na: not applicable

nc: not calculated because TOC is outside TOC normalization range

OC: organic carbon

PCB: polychlorinated biphenyl

RAL: remedial action level

TOC: total organic carbon

3.3 Segment-specific Data Evaluations and Data Gaps

The upper reach (RM 3.0 to RM 5.0) was divided into four design sampling segments in order to assess the upper reach in manageable pieces, evaluate where design sampling should be focused, and facilitate identification of design data needs on a smaller scale. The segments were delineated based on locations of intertidal beach areas, landmarks and property lines, EAAs, and STM modeling extent (i.e., sediment transport related to scour and deposition was not assessed from RM 4.75 to RM 5.0 in the STM). Important factors to evaluate within each segment include existing sediment data (Maps 10 through 14), upland sources (Map 15), sedimentation and scour (Map 16), and dredging and other in-water activities (Map 17). This section presents information for the four segments relevant to identifying design data needs.

Maps 10 through 14 have two panels. The right panel presents sediment chemistry results compared to RALs to indicate which COCs have RAL exceedances and to what extent (exceedance factor). The right panel also includes Recovery Category 1 areas, structures, and the locations of ROD Figure 18 remedial action areas and technology assignments. The left panel presents RAL exceedance locations and intertidal areas, tug scour areas, and shoaling areas.

Potential sources and associated COCs are also discussed for each segment. Observations about data gaps related to potential sources and associated COCs are preliminary. Ecology will review all relevant data and make source control recommendations.

3.3.1 Segment 1 (RM 3.0 to RM 3.5)

Segment 1 extends from RM 3.0 to RM 3.5 (Map 10) and includes areas of intertidal sediment on the west side of the waterway[18] (a portion of beach play Area 5). Based on RAL exceedances in sediment data, PCBs are the primary COC in Segment 1.

3.3.1.1 Potential Sources and Associated COCs

There are three listed upland cleanup sites adjacent to Segment 1: 1) Boeing Plant 2, which is currently in the Corrective Measures Study phase; 2) the King County South Rose St. Heating Oil MTCA site, which has been remediated and has no potential pathway of contamination to the LDW (Ecology and Leidos 2018); and 3) the South Park Marina, which has an Agreed Order that was finalized in April 2019.

A portion of the Boeing Plant 2 EAA is within Segment 1, and the T-117 EAA (discussed in Section 3.3.2 [Segment 2]) is adjacent to Segment 1 to the south. These upland properties were historical sources of PCBs and other COCs to the LDW (Map 15). The early actions at Boeing

[18] The intertidal area on the east side of the waterway is within the Boeing Plant 2 EAA.

Plant 2 involved dredging and backfill. Dredging was completed in 2015 (Ecology and Leidos 2018). Boeing Plant 2 is currently being monitored.

Source samples (i.e., seep and bank samples) collected in Segment 1 did not have concentrations in seeps greater than preliminary cleanup levels (PCULs) (based on Ecology's screening tool for groundwater applied to seep samples) or concentrations in bank samples that were greater than the lowest RAL (for bank samples) for any chemical. Seep and bank locations are shown on Map 10.

3.3.1.2 Sediment Transport

As characterized in the FS (AECOM 2012a), results from the STM presented in the FS indicate that Segment 1 is generally net depositional, with sedimentation rates ranging from ≤ 0.5 to > 3 cm/year (Map 16). There is some potential for scour during high flow, generally in and adjacent to the FNC; there is also one small area with evidence of propeller wash scour in the FNC at RM 3.0[19] and one area near RM 3.1/3.2 characterized by net erosion (Map 16). These areas have been identified as Recovery Category 1 (Map 10).

3.3.1.3 Dredging

Prior to navigation or berth maintenance dredging, sediment is characterized under the Dredged Material Management Program (DMMP) criteria. Sediment to be dredged is typically characterized using composite samples made up of cores from variable sediment depths, depending on the amount of material to be dredged. Each composite represents a dredged material management unit (DMMU). In addition, Z-samples are collected that represent the 0- to 1-feet or 0- to 2-feet interval that will remain after dredging. The DMMP criteria used to evaluate the dredged sediment and Z-samples are generally[20] less than or equal to the most conservative sediment RALs. Therefore, sediment determined to suitable for open-water disposal is indicative of an area where RAL exceedances would not be expected.

The most recent dredge events in Segment 1 are shown on Map 17 and summarized as follows:

- **FNC (RM 3.0 to RM 3.5)** – There are no records of dredging between RM 3.0 and RM 3.3 since 1990. The FNC between RM 3.3 and RM 3.5 was last dredged as part of a larger dredging event in 1992 that extended to the Turning Basin. Dredging was conducted to an authorized depth of -15 feet MLLW with 2 feet of allowable overdredge. All of the material dredged between RM 3.3 and RM 3.5 was suitable for open-water disposal.

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[19] Propeller wash scour was based on review of the 2003 bathymetry survey sun illumination maps in the FS. Updated sun illumination maps based on the 2019 bathymetry survey will be presented in the QAPP.

[20] The DMMP criteria are dry weight for all chemicals, whereas many of the RALs are OC normalized; therefore, in situations with unusually high or low TOC, this comparison could have different results.

Dioxins/furans were not analyzed because the DMMP did not begin requiring their analysis until 2010.

Based on 2003 bathymetry, shoaling exists on the western side of the FNC between RM 3.3 and RM 3.5. The 2019 bathymetry data will be used in the QAPP to update the extent of shoaling.

- **South Park Marina** – The northern half of South Park Marina was last dredged in 1993 to an authorized depth of -8 feet MLLW with 1 feet of allowable overdredge. All dredged material was suitable for open-water disposal (USACE et al. 1991). No dioxin/furan data were collected.
- **Boeing Plant 2** –Sediment cleanup adjacent to Boeing Plant 2 was conducted over three construction seasons beginning in 2012 and ending in 2015; cleanup involved dredging approximately 163,000 CY of sediment, placing approximately 160,000 CY of backfill in dredging areas, excavating approximately 46,200 CY of material along the south bank, and placing approximately 31,300 CY of backfill material along the south bank (Ecology and Leidos 2018). Post-construction monitoring is ongoing; year 1 and year 3 sediment monitoring data are available and are summarized in Attachment B.
- **South Park Bridge** – King County replaced the South Park Bridge between 2010 and 2014, relocating the bridge slightly to the north in the process (i.e., the new bridge was built next to the footprint of the old bridge) (King County 2017).[21] A total of 23,250 CY of underlying material was determined to be suitable for open-water disposal (USACE et al. 2010). Approximately 3,100 CY of overlying material was not suitable for open-water disposal due to concentrations of PCBs, PAHs, and metals above the DMMP criteria (Wilbur Consulting 2004). Material that was not suitable for open-water disposal was disposed upland.

3.3.1.4 Available Sediment Data and RAL Exceedances

Sediment sampling locations and RAL exceedances in Segment 1 are shown on Map 10. Segment 1 includes a total of 103 surface sediment locations from the 0- to 10-cm interval and a total of 7 subsurface sediment locations.

RAL exceedances in Segment 1 were primarily for total PCBs: 70% of the 0- to 10-cm sediment samples with concentrations that exceeded RALs only exceeded the PCB RAL. However, many of

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[21] All maps in the RDWP and the PDIWP that show the South Park Bridge show the new location of the bridge. Map 2-4 in the RDWP has an insert that shows both the old and new locations.

the post-FS samples were Boeing Plant 2 perimeter monitoring samples and thus may reflect transient conditions. Three other benthic risk driver chemicals were detected at concentrations above the RAL: Hexachlorobenzene and 4-methyl phenol were limited to a single location per chemical, and benzyl alcohol exceeded the RAL at three locations (Map 10).

With respect to subsurface sediment, one core from Segment 1 had a RAL exceedance (other than for benzyl alcohol, see Section 3.2). This core was collected in a shoaling area, and PCB concentrations in the 6.5- to 8.5-feet sediment interval (-15 to -17 feet MLLW) exceeded the RAL.

3.3.1.5 Segment 1 Data Gaps

Information regarding potential sources in Segment 1 and available sediment data confirm that PCBs are the primary COC in this segment of the upper reach; further design sampling is needed to confirm the extent of this contamination.

A couple of areas with significant historical PCB contamination exist in this part of the waterway. The majority of the PCB contamination has been remediated as part of the EAA cleanups. However, PCBs may remain at concentrations above the RAL in some areas (Map 10). For example, in the southwestern corner of the South Park Marina at RM 3.5W, both historical and more recent data indicate 0- to 10-cm RAL exceedances; the boundaries of this area will need to be defined. In addition, individual PCB RAL exceedances exist to the west and within the FNC (including one in a shoal area), although there is uncertainty associated with the Boeing Plant 2 perimeter 0- to 10-cm monitoring data, as discussed above.

In the intertidal area, beach composite 0- to 45-cm data indicate that concentrations of the human health risk driver chemicals are below the remedial action objective (RAO) 2 direct contact cleanup level and RALs in both the Duwamish Waterway Park area and southern Beach 5 areas for total PCBs, and dioxin/furan TEQ (Maps 4 and 6). For arsenic and cPAHs (Maps 5 and 7), concentrations in the Duwamish Waterway Park are below the cleanup levels, but concentrations are above the cleanup levels (but below the RALs) in the southern Beach 5 areas.[22] Since these samples are composite samples, discrete 0- to 45-cm samples are needed from this segment to confirm that concentrations are less than RALs in this intertidal area.

Additional subsurface characterization will be needed within and near the FNC where data have not been collected.

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[22] The 95UCL reported in the FS for Beach 5 south (RM 2.75 to RM 3.4) was 110 μg/kg for cPAH TEQ and 8.5 mg/kg for arsenic (as compared with 95UCLs of 3,900 ug/kg and 16 mg/kg for the northern area, respectively).

3.3.2 Segment 2 (RM 3.5 to RM 4.05)

Segment 2 extends from RM 3.5 to RM 4.05 and includes intertidal sediment on both sides of the waterway. The ENR/AC pilot study intertidal plots are located between RM 3.83 and RM 3.95E. Based on existing data, PCBs are the primary COC in this segment. In addition, there are RAL exceedances for arsenic, metals (lead, mercury and zinc), cPAHs and butyl benzyl phthalate (primarily on the east side of the waterway between RM 3.7 to RM 3.9E area) (Map 11).

3.3.2.1 Potential Sources and Associated COCs

There are five upland sites located in Segment 2. Three are associated with EAAs: Boeing Plant 2, Jorgensen Forge and T-117, properties that were historical sources of PCBs and other COCs to the LDW. The other two listed upland sites from RM 3.7 to RM 4.05 along the east side are Boeing Isaacson Thompson and PACCAR-Kenworth (Map 15). The COCs listed for these sites are shown on Map 15. In addition, the area near RM 3.8E was listed as candidate area 6 for early action in 2003 (Windward 2003) because of elevated concentrations of arsenic, PCBs, PAHs, and phthalates. RM 3.8 is in area of the former Slip 5, which was filled with slag waste and soil in the 1950s and 1960s (SAIC 2008).

The southern portion of the Boeing Plant 2 EAA, the Jorgensen Forge EAA, and the T-117 EAA are in the northern part of Segment 2 along both sides of the waterway from RM 3.5 to RM 3.7 (Map 11). The Boeing Plant 2 and T-117 EAAs have been remediated and are now being monitored. Some remediation work has been completed at the Jorgensen Forge EAA; additional samples have been collected and a supplemental engineering evaluation/cost analysis will be produced to determine the need for additional remedial action. There is a new Agreed Order for the Jorgensen Forge upland area that will require an RI/FS and a cleanup action plan (Ecology and Leidos 2018). An underground pipe identified as releasing PCBs to the LDW is being excavated and removed in phases at Jorgensen Forge (Ecology and Leidos 2018). In addition, groundwater discharges from Jorgensen Forge may present an ongoing pathway of concern for cadmium, chromium, acenaphthene, and naphthalene (Ecology and Leidos 2018).

On the western side of Segment 2, the T-117 EAA includes upland facilities historically operated by Duwamish Manufacturing and Malarkey Asphalt Company. Other than in the T-117 EAA, facilities along the western side of Segment 2 have not been listed in this segment. Ecology has identified source control actions, many of which have been completed (Ecology and Leidos 2018).

The 14 seep samples collected in Segment 2 did not have concentrations greater than PCULs (see Map 11 for seep locations). None of the six bank samples collected between RM 3.9 and RM 4.05W had COC concentrations above the lowest RAL (Map 11).

3.3.2.2 Sediment Transport

Segment 2 is characterized in the FS as net depositional (AECOM 2012a). The STM identified areas with the potential for scour greater than 10 cm in the FNC during periods of high flow (Map 16). In addition, there is one area between RM 3.9 and RM 4.05W with evidence of propeller wash scour. These areas have been identified as Recovery Category 1 (Map 11).

3.3.2.3 Dredging

The most recent dredge events in Segment 2 are shown on Map 17 and summarized as follows (except for Boeing Plant 2, which was covered in Section 3.3.1.3):

- **FNC (RM 3.5 to RM 4.05)** – The FNC within Segment 2 was last dredged in 1999, as part of a project that included dredging approximately 165,000 CY of material from the FNC between RM 3.5 and the south end of the Turning Basin. The analysis of dioxins/furans was not required when this dredge characterization was conducted. Dredged material within this segment was all suitable for open-water disposal (USACE 1999). Approximately 156,000 CY of this material was disposed at the Elliott Bay open-water disposal site, and approximately 9,000 CY from the Turning Basin was used as backfill material at the Norfolk EAA (USACE 1999; King County 1999).

  Based on 2003 bathymetry, shoaling exists throughout much of the FNC between RM 3.5 and RM 4.05.

- **Jorgensen Forge –** Sediment cleanup adjacent to Jorgensen Forge was conducted in 2014 and involved the removal of contaminated sediment and bank soils (Ecology and Leidos 2018). Following dredging, backfill material was placed. EPA may require additional sediment remediation within or near this EAA (Ecology and Leidos 2018).

- **T-117 –** Cleanup, including removal of approximately 14,000 CY of contaminated sediment, was completed at T-117 in 2015. The dredge footprint was backfilled with clean sand and crushed stone to pre-construction grades, except near South Park Marina, where deeper elevations were left for marina access (AECOM 2018). Monitoring began in 2018 and is ongoing (Integral and AECOM 2018); the first round of sediment sampling occurred in 2019. Monitoring data will be summarized in Attachment B when they are available.

3.3.2.4 Available Data and RAL Exceedances

Sediment sampling locations and RAL exceedances in Segment 2 are shown on Map 11. Segment 2 includes a total of 169 surface sediment locations in the 0- to 10-cm interval and 16 subsurface data locations. Of all the RAL exceedances in the 0- to 10-cm interval, 50% were for PCBs (41 samples). In addition, there are RAL exceedances for arsenic (6 samples), metals (lead, mercury and zinc, 3 samples), cPAHs (8 samples), and butyl benzyl phthalate (6 samples) (primarily in the RM 3.7 to RM 3.9E area). Most sediment RAL exceedances in Segment 2 are located on the east side of the waterway between RM 3.7 and RM 4.05. On the west side of the waterway, there are six RAL exceedances for PCBs, and a single RAL exceedance each for zinc and hexachlorobenzene.

The USACE collected five cores from shoal areas within the FNC in this segment. Two cores (LDW 14 at RM 3.55 and LDW 17 at RM 3.87) had PCB RAL exceedances in the sediment interval collected from -15 to -17 feet MLLW.

3.3.2.5 Segment 2 Data Gaps

The area from RM 3.7 to RM 4.05, south of the Jorgensen Forge EAA along the eastern bank, has historical and more recent data indicating RAL exceedances. Further design sampling is needed to confirm the extent of this contamination, including whether it extends into the FNC, as well as its depth.

Additional sampling is needed within the FNC in the 0- to 10-cm and 0- to 60-cm intervals, particularly within the shoaling and Recovery Category 1 areas.

RAL exceedances (primarily PCBs) exist west of the FNC. Confirmation and information regarding the extent of PCB exceedances are needed in this intertidal area, as well as spatial coverage data for the 0- to 45-cm interval.

3.3.3 Segment 3 (RM 4.05 to RM 4.75)

Segment 3 extends from RM 4.05 to RM 4.8 and includes intertidal sediment on both the east and west sides of the LDW (the west side includes most of Beach Play Areas 7 and 8) (Maps 12 and 13). PCBs are the primary COC in Segment 3, but individual exceedances of PAHs, benzoic acid, phenol, and phthalates also exist, primarily near and within Slip 6 and in one area in the Turning Basin.

3.3.3.1 Potential Sources and Associated COCs

There are no EAAs in or adjacent to Segment 3, but there are three listed upland cleanup sites adjacent to Segment 3: Rhone-Poulenc and the BDC on the eastern side and Seattle City Light

Substation on the western side (Map 15). Investigations have been conducted at these three sites, and remedial actions have been completed at the Rhone-Poulenc and BDC properties (Ecology and Leidos 2018; Windward 2010b; Ecology 2018). Groundwater remediation has been conducted at both sites, and stormwater solids and stormwater monitoring are ongoing at BDC. The COCs for these sites are listed on Map 15.

There are six bank sampling locations within Segment 3 (Maps 12 and 13). One bank sample at RM 4.7W had a total PCB concentration of 130 mg/kg organic carbon (OC). The sediment sample collected adjacent to the bank did not have any RAL exceedances. There are 11 seep sampling locations within Segment 3. One seep sample from the southeast corner of Slip 6 had a cPAH TEQ greater than the PCUL (Map 12).

3.3.3.2 Sediment Transport

As characterized in the FS (AECOM 2012a), Segment 3 is net depositional, with high sedimentation rates (> 3 to ≤ 146 cm/year) in most of the segment (except Slip 6, which has > 1 to ≤ 2 cm/year) (Map 16). The STM predicts the potential for scour during high flow in some areas within this segment, and there is evidence of propeller wash scour in and near Slip 6 and across the waterway at Delta Marine; these areas have been identified as Recovery Category 1 (Maps 12 and 13).

3.3.3.3 Dredging

The most recent dredge events in Segment 3 are shown on Map 17 and summarized as follows:

- **FNC (RM 4.05 to Turning Basin) –** The downstream portion of the FNC in Segment 3 (RM 4.05 to RM 4.25) is dredged every 6 to 10 years, and the portion from RM 4.25 to the Turning Basin is dredged approximately every 2 years. Dredging the FNC in Segment 3 takes two dredge seasons; a portion of this area was dredged in the 2018/2019 dredge season, and the remainder will be dredged in the 2019/2020 dredge season.[23] All dredged material from the 2018/2019 season was suitable for open-water disposal (USACE et al. 2018).

  As a result of the high levels of sediment deposition from the Green River in the FNC and the Turning Basin in this segment, extensive shoaling regularly occurs between RM 4.05 and the Turning Basin.

[23] Samples collected from the Z-layer in the upstream portion (RM 4.05 to RM 4.25) had dioxin/furan TEQs between 3 and 11 ng/kg (i.e., below the lowest RAL of 25 ng/kg). To comply with Ecology's anti-degradation regulations, 1 ft of shoal was left in place.

- **Delta Marine –** The area around the Delta Marine pier at RM 4.2W was most recently dredged in 2008 and 2010. The dredged material was suitable for open-water disposal (USACE et al. 2007).
- **Duwamish Yacht Club –** The area near the Duwamish Yacht Club (RM 4.05 to RM 4.15W) was dredged in 1999. All dredged material was suitable for open-water disposal (USACE et al. 1999). A subsequent dredged material characterization study was conducted in 2012. The dioxin/furan TEQs in two out of six DMMUs were greater than the DMMP criterion of 10 ng/kg. Both DMMUs with exceedances were located in the southern end of the marina. The DMMU composite that characterized the 0- to 4-feet sediment interval in that area had a dioxin/furan TEQ of 20.94 ng/kg. The DMMU representing the 4- to 6-feet sediment interval in the southwestern corner of the marina had a dioxin/furan TEQ of 10.74 ng/kg (USACE 2013). Dredging was not conducted following this characterization.

3.3.3.4 Available Data and RAL Exceedances

Segment 3 includes a total of 270 surface sediment sampling locations from the 0- to 10-cm interval and 7 subsurface core locations from the 0- to 60-cm interval. Most of the RAL exceedances in Segment 3 are located within and downstream of Slip 6 on the east side of the LDW (Map 12). Within Slip 6, COCs that exceed RALs include PCBs, cPAHs, benzoic acid, phenol, dimethyl phthalate, and individual PAH compounds. North of Slip 6, PCBs, cPAHs, and individual PAHs exceed RALs. Slip 6 and the area to the north were intensively sampled in 2011 and 2012, and there are numerous benzyl alcohol exceedances associated with these datasets. Many of these samples were submitted for and passed bioassay testing, which is summarized in Attachment A.

Along the west side of this segment, other than benzyl alcohol exceedances in recent data (see Section 3.2 and Attachment A), only one low-level PCB RAL exceedance has been detected (in a 1997 sample at RM 4.28W) (Map 12). Dredge characterization composite samples collected in the southern portion of the Duwamish Yacht club had dioxin/furan TEQs that ranged from 6.43 to 20.94 ng/kg. Also, a nearby 0- to 10-cm sample collected at RM 4.17E had a dioxin/furan TEQ exceedance factor of 0.9.

With the exception of RAL exceedances in two areas in the southernmost part of the Turning Basin, no RAL exceedances have been detected in more than 70 samples in this area (Map 13). The RAL exceedances include a PCB exceedance in a bank sample and PCB, phenol, and PAH exceedances in one sediment sample each. Composite data are consistent with low concentrations in this area. Concentrations of the four human health risk driver chemicals in the

0- to 10-cm composite samples in Segment 3 were low relative to RAO 2 direct-contact cleanup levels (Maps 4 to 6), with the exception of arsenic (Map 7), which was detected at an average concentration of 9.02 mg/kg in the segment (relative to the Puget Sound natural background-based cleanup level of 7 mg/kg).

Along the eastern side of the LDW south of Slip 6, low-level PCB RAL exceedances exist in RI/FS samples at RM 4.5. However, newer data in this area have no exceedances (other than for benzyl alcohol). The single cPAH exceedance in this area would not exceed the RAL based on the updated BaP toxicity data (see Section 2.1.1).

With respect to the 0- to 45-cm data for Segment 3, Beaches 7 and 8 composite data were used to calculate 95% upper confidence limits (on the mean) (95UCLs) for both PCBs and dioxins/furans concentrations that were below the RAO 2 cleanup levels for both beaches. The 95UCL for cPAHs is greater than the RAO 2 cleanup level in the ROD for Beach 8, but it would be below the cleanup level based on the updated BaP slope factor (Section 2.1.1). The 95UCLs for arsenic are above natural background-based cleanup level for both beaches.

There are only seven locations with 0- to 60-cm data in Segment 3. There is one cPAH RAL exceedance in Slip 6 (which would not be a RAL exceedance using the updated BaP slope factor) (Maps 12). In addition, all dredged materials removed from the navigation channel during the 2018/2019 season met DMMP guidelines (i.e., were suitable for open-water disposal) (see Section 3.3.3.3).

3.3.3.5 Segment 3 Data Gaps

Most of the contamination in Segment 3 is located within and just downstream from Slip 6 along the east side of the waterway. Further design sampling is needed to confirm the extent of this contamination and to characterize sediment below the structures in Slip 6. South of Slip 6 on the eastern side, two PCB RAL exceedances, one cPAH RAL exceedance, and several benzyl alcohol exceedances exist that will be further investigated.

Along the west side of the waterway, the southern portion of the Duwamish Yacht Club basin requires further design sampling to verify that dioxin/furan TEQs are below the RAL and one PCB RAL exceedance exists at RM 4.3 that should be resampled. The southwestern portion of the Turning Basin also has two locations with RAL exceedances and a potential bank source that should be further investigated.

3.3.4 Segment 4 (RM 4.75 to RM 5.0)

Segment 4 is located between RM 4.75 and RM 5.0 and is the most upstream segment of the LDW (Map 14). This segment includes intertidal sediment on the west side of the LDW (which is part of Beach Play Area 8). Based on RAL exceedances in existing data, the primary COC in Segment 4 is PCBs.

3.3.4.1 Potential Sources and Associated COCs

The Norfolk EAA is located within Segment 4. The sediment in the Norfolk EAA area was dredged and backfilled during remediation in 1999 (King County 1999; Ecology and Leidos 2018) (Map 15). Four Norfolk monitoring locations (NFK501, NFK502, NFK503, and NFK504) were sampled on an annual basis by King County until 2004. These locations were also sampled in October 2006 as part of the RI (Windward 2010b). COC concentrations at these locations in 2006 and in the single sample analyzed in 2008 were less than RALs (see Attachment B).

PCB-contaminated sediments offshore of the BDC's south storm drain outfall (No. 2093), which is adjacent to the Norfolk EAA, were removed and backfilled by Boeing in 2003 (Figure 15). The BDC is a listed upland site in this segment. Three locations on the cap offshore of the south storm drain were monitored for PCBs from 2004 to 2007. Monitoring at locations S1 and S3, where PCBs have exceeded the RAL, has continued; the most recent monitoring event occurred in 2017 (Map 14), at which time PCB concentrations were greater than the RAL at both locations.

There were no samples collected as part of bank studies in Segment 4; however, 10 sediment samples collected during sediment studies were from locations within 12 feet of the FS shoreline. Five of these samples had concentrations greater than RALs.[24]

There are three seep sampling locations within Segment 4. A sample collected from one of these seeps (SP-33, located at RM 4.8 E on Map 14) had cPAH TEQs and a BEHP concentration greater than the PCULs.

3.3.4.2 Sediment transport

In the LDW FS (AECOM 2012a), Segment 4 was modeled as hard bottom, so sedimentation and scour information from the STM is not available. This segment was included in the 2019

[24] No bathymetry data were collected for Segment 4 in 2003. Therefore, elevation data for samples collected in this area are unavailable, and it is not known if samples collected near the shoreline in Segment 4 are sediment or bank samples. In this document, these samples are categorized as sediment samples because they were collected as part of sediment studies. Bathymetry in Segment 4 was assessed as part of the 2019 bathymetry survey, which will be presented in the PDI QAPP along with a proposed Recovery Category for this area (Recovery Category 2 was assumed in the Work Plan maps). If sediment remediation is needed in this segment, topography in this area will be further assessed.

bathymetry survey, which will be useful in identifying intertidal boundaries. Recovery categories have not been assigned in this area. Based on what is known about the geomorphology of this area, it appears that high flows are likely along the western and central areas. The eastern bank is protected by rows of pilings projecting from the bank upstream of the segment (see aerial photo insert on Map 14).

3.3.4.3 Dredging

The Norfolk EAA was dredged in 1999 (King County 1999). Approximately 5,190 CY of contaminated sediment was dredged and disposed at upland landfills. Boeing dredged approximately 60 CY of contaminated sediment from the vicinity of the south storm drain outfall (adjacent to the Norfolk EAA at RM 4.9E) in 2003 (Ecology 2007). This material was disposed at an upland landfill.

3.3.4.4 Available Data and RAL Exceedances

Segment 4 includes a total of 65 surface sediment sampling locations from the 0- to 10-cm interval and no subsurface locations. RAL exceedances are limited to the 0- to 10-cm samples along the eastern bank in this segment, and 60% of the samples that exceed sediment RALs exceed the RAL for PCBs. Benzoic acid, butyl benzyl phthalate, cPAHs (based on the ROD RAL),[25] and 1,4-dichlorobenzene were detected at concentrations above the RAL in this same area, but these exceedances were limited to one location each in samples collected between 1994 and 1997.

Data from the 2018 baseline 0- to 10-cm composite sample in Segment 4 (composite 24) suggest that concentrations for all four human health risk drivers are low relative to the RALs (i.e., 18 µg/kg for PCBs, 16.2 µg/kg for cPAH TEQ, 0.462 ng/kg for dioxin/furan TEQ, and 5.90 mg/kg for arsenic) (Maps 4 to 7). Only a small portion of Beach 8 is located in this segment, along the western shoreline.

3.3.4.5 Segment 4 Data Gaps

Potential sources and contamination in this segment indicate RAL exceedances of PCBs and a few other COCs along the eastern shoreline. Remedial actions, which occurred 16 and 20 years ago, removed most of this contamination (Section 3.3.4.3). Recent data suggest that PCB RAL exceedances remain in the vicinity of the EAA along the eastern shoreline but do not appear to extend beyond (Map 14). Contamination in this area of Segment 4 will be further investigated and bounded.

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[25] No existing data in Segment 4 would exceed the cPAH RAL based on the updated BaP toxicity value.

No RAL exceedances have been detected in the western and central portions of Segment 4 where flow is high; thus, data gaps are few in this area and limited data are needed.

3.4 Data Gaps

Based on the segment-specific assessments presented in this section, additional sediment data are required to delineate RAL exceedances within the upper reach. The conceptual design sampling plan to collect these data in Phases I and II (where needed) is discussed in detail in Section 4.

The conceptual design sampling plan in Section 4 also discusses the need for the following types of data that will be collected in Phase II or III to design the engineered remedy. These data types were also summarized in Appendix B of the AOC3 design strategy report (Integral and Windward 2019).

- Site-wide bathymetric survey to support the delineation of recovery category areas, potential vessel scour areas, and applicable RALs; this survey was conducted in April/May 2019 and the results will be provided as an appendix to the PDI QAPP.
- Sediment chemistry data from sediment intervals with RALs (0- to 10-cm, 0- to 45-cm, and 0- to 60-cm) to delineate RAL exceedances, as noted above
- Vertical (> 60 cm) extent data to determine depth of dredge prisms in dredge areas
- Vertical (> 60 cm) data below caps for cap design modeling
- Possible use of toxicity tests in areas where active remediation is anticipated and only benthic RAL exceedances exist
- Focused topographic surveys in bank areas with adjacent remedial action areas that have dredging or capping remedies
- Area-specific sediment geotechnical properties including geologic characterization, sediment index, and sediment strength and consolidation properties to:
    - Determine sediment stability and stable dredge cut side-slope requirements.
    - Characterize sediment dredgeability.
    - Support sediment consolidation assessment for cap design.
    - Support selection of dredge equipment.
    - Support design of sediment handling, transport, dewatering, treatment systems, and disposal requirements.
- Specialized surveys as appropriate for debris characterization

- Erosion/scour/disturbance process information (such as velocities, bathymetry, and engineering analyses) to support:
    - Delineation of MNR/ENR areas
    - Design of ENR/*in situ* treatment (depending on results of ENR/AC pilot study)
    - Cap design
    - Outfall scour protection

4 Conceptual Design Sampling Plan

This section presents the conceptual design sampling plan to collect PDI data, including:

- A plan for the collection of data needed to delineate boundaries of RAL exceedance areas and to support remedial technology applications in designing the remedy
- Media to be sampled: general location type and purpose; field sampling and laboratory analyses; bathymetric, hydrogeological, and geotechnical studies; an estimated number and spatial density of samples; and clearly stated rationale for tiering analyses

4.1 DQOs

The purposes of the PDI are to collect data needed to delineate remedial action areas and to support remedial technology applications in designing a remedy consistent with the ROD (ROD Tables 27 and 28 and ROD Figures 19, 20, and 21; EPA 2014b).[26] This PDIWP lays out the general strategy and sequencing of data collection that will be used to meet PDI data needs in the upper reach. Although it is expected that this general strategy will be applicable to the middle and lower reaches of the LDW as well, the approach outlined in this PDIWP is not necessarily binding to those reaches.

PDI data collection efforts will be conducted in at least two phases, as discussed in Section 2 and further described herein. Data quality objectives (DQOs) have been identified, eight for Phase I design sampling and six for Phase II (Table 4). Seven of the eight Phase I DQOs are based on delineating exceedances of the RALs listed in ROD Tables 27 and 28 (EPA 2014b); the eighth DQO is related to a visual inspection of banks in the upper reach.

Table 4
DQOs for Phases I and II of the PDI in the Upper Reach

Phase I	Phase II
DQO1 – Delineate 0–10-cm RAL exceedances in Recovery Category 2/3 DQO2 – Delineate 0–10-cm RAL exceedances in Recovery Category 1 DQO3 – Delineate 0–45-cm intertidal RAL exceedances in Recovery Category 2/3 DQO4 – Delineate 0–45-cm intertidal RAL exceedances in Recovery Category 1 DQO5 – Delineate 0–60-cm PCB RAL exceedances in potential vessel scour areas in Recovery Category 2/3	DQO9 – Sample areas under over-water structures, if feasible, to delineate RAL exceedances DQO10 – Further delineate RAL exceedances, as needed for unbounded areas DQO11 – Assess chemical and physical characteristics of banks (including topographic survey), as needed, depending on remedial technology selected for adjacent sediment and whether or not the bank is erosional DQO12 – Delineate vertical elevation of RAL exceedances in dredge (and dredge/cap) areas and

[26] ROD Table 27 is titled *Selected Remedy RAO 3 RALs*.

Phase I	Phase II
DQO6 – Delineate 0–60-cm RAL exceedances in Recovery Category 1 DQO7 – Delineate RAL exceedances in shoaling areas DQO8 – Conduct a visual inspection of the banks in the upper reach to identify features relevant to design, such as the presence/absence of bank armoring, and to plan how to access banks and areas under structures for sampling purposes	collect vertical information in cap areas where deeper contamination under caps may be located. DQO13 – Collect geotechnical data as needed depending on technology proposed and/or physical characteristics of remedial action areas DQO14 – Collect other engineering applicable data as needed (e.g., structures inspection, utility location verification, thickness of sediment on top of riprap layers)

cm: centimeter
DQO: data quality objective
PCB: polychlorinated biphenyl
RAL: remedial action level

Following Phase I design sampling, a data evaluation report will be prepared to present the data, define preliminary remedial action areas, assign preliminary technologies to these areas, and identify remaining potential data gaps. Based on that report, details regarding Phase II design sampling will be presented in a QAPP addendum, including specific design sampling locations and rationale, depths, analytes, and additional types of data and information needed to design the remedy in specific areas. The Phase II DQOs reflect these needs (Table 4). Phase III will be conducted if data gaps remain following Phase II or are otherwise identified during preparation or EPA review of the 30% design.

4.2 Phase I Conceptual Design Sampling Plan

This section presents the general principles for Phase I that will be applied in selecting specific sediment locations and intervals to sample to meet the Phase I DQOs (Table 4). This section also presents examples of Phase I design sampling designs for specific areas of the upper reach to provide a general demonstration of concepts. Analytes and tiering of analytical chemistry analyses are also discussed, as is visual bank characterization.

4.2.1 General Principles

A great deal of sediment data and other information have been collected in the LDW, as summarized in Section 3. These data are of great value in defining where design sampling locations are needed to delineate RAL exceedances, designate technology assignments for remedial action areas, and design an engineered sediment remedy.

In developing the design sampling and analysis approach using these data, a number of factors are important. Professional judgement, including participation by the Engineer of Record, is essential. Factors that will affect the location and number of samples include, but are not limited to:

- Locations of banks, slopes, structures, berthing areas, and the FNC
- Current bathymetry data
- Dredge history
- Known current and historical sources
- Sediment data – distribution, representativeness, recency, and results
- Presence or absence of multiple adjacent RAL exceedances
- Potential for changes in sediment quality since data were collected

Based on these factors, specific sampling locations will be selected in the PDI QAPP. The exact number and density of sampling locations throughout the upper reach will be determined in the QAPP. Two types of locations will be identified for sample collection: 1) locations for immediate analysis (Tier 1), and 2) locations for sample archival with Tier 2 analysis dependent on the results of Tier 1 analyses.[27] Both types of samples will be collected at the same time.

In general, three concepts (reoccupation, bounding, and spatial coverage) will be applied in determining where samples will be collected in Phase I. These three concepts are discussed below, along with a description of an example area that demonstrates the concept and how tiering will be applied. The sample locations in the examples are presented for conceptual purposes only and do not imply final approval with respect to sample locations or numbers. Application of these concepts will require best professional judgment to address site-specific factors in each area. Final sampling locations will be determined in consultation with EPA and documented in the QAPP.

4.2.1.1 Reoccupation

Maps 10 through 14 show existing sampling locations where RALs have been exceeded. Locations with RAL exceedances (or concentrations close to RAL exceedances) will be reoccupied as part of design sampling if the data are older than 10 years (e.g., RI/FS data). Locations will also be reoccupied if their samples were collected prior to and near recent disturbances (e.g., near early actions) (see Section 3.2). Locations with RI/FS data where RAL exceedances have not been reported will not be re-occupied unless the concentration is close to the RAL, or unless there is a site-specific reason to believe concentrations may have increased contrary to the general expectation for the site (see Section 2.2).

[27] Tiering enables the collection of data in a more targeted and efficient manner.

In addition to reoccupying an existing location, samples will be collected around the reoccupied location and archived for analysis if RAL exceedances are detected in the reoccupied location samples. Analysis of these archived samples, selected in consultation with EPA, will enable better bounding of the RAL exceedance in Phase I while enhancing spatial coverage. Archived samples may also be analyzed simply to enhance spatial coverage, depending on the Tier I results.

As an example of the above-described concepts, see Map 18. In this area (RM 3.0 to RM 3.15), five 0- to 10-cm design sampling locations are identified for reoccupation, because they had RAL exceedances based on older RI/FS data or provided perimeter monitoring data collected during or just following an early action (panel 1).

As shown in panel 2, at each of these five locations, samples would be collected at the same coordinates previously sampled, and several archive samples would be collected around these reoccupied locations (i.e., at locations for which no data exist). The analysis of the archive samples (Tier 2) would be triggered by RAL exceedances in the reoccupation samples (Tier 1) (see panel 3 for hypothetical Tier 1 results and selection of archive samples for Tier 2 analysis). Following the Tier 2 analyses, the combined data (panel 4) would be evaluated in the Phase I data evaluation report to determine whether a remedial action area should be defined; if so, spatial statistics and interpolation methods would be used to define the area's initial size and shape, and an initial remediation technology would be assigned based on the flowcharts in ROD Figures 19, 20, and 21 (panel 5). The Phase I data evaluation report would recommend whether further refinement should be conducted based on scale, technology assignment, and other factors. If further refinement were to be recommended, additional RAL exceedance delineation sampling would be conducted in Phase II following similar principles (see Section 4.3, where panel 6 is discussed).

4.2.1.2 Bounding

Areas with more than one existing RAL exceedance and documented historical sources, recent (< 10 years old) data with RAL exceedances, and exceedance factors greater than approximately 2 will be bounded with additional samples collected around the edges of these areas. Reoccupying locations previously sampled within these areas will not be necessary.

As an example, consider the area near RM 3.8 to RM 4.0 (Map 19). This area has two RAL exceedances (one recent) for PCBs on the west side of the waterway, a PCB RAL exceedance at depth in the navigation channel, and multiple RAL exceedances on the east side of the waterway between the ENR/AC pilot study intertidal subplots and south of the one subplot (panel 1 of Map 19). This example area contains a variety of data needs (panel 2) including reoccupation, bounding, and spatial coverage. The PCB RAL exceedances at RM 3.9 on the west and the RAL exceedances between the ENR/AC subplots would have design sampling locations placed to bound these existing RAL exceedances, with archive sampling locations placed further away. The area south of the AC plots would also be further assessed by reoccupying a sampling location and adding a design sample and two archive samples. Depending on the results of the Tier 1 analyses (panel 3), archive samples could also be analyzed. All of these results (panel 4) would be used to draw preliminary boundaries around these areas in the Phase I data evaluation report and assign preliminary technologies (panel 5). The data evaluation report would also recommend specific Phase II data collection for this area (see Section 4.3 for a discussion of the Phase II panels 6, 7, and 8 of Map 19).

4.2.1.3 Spatial coverage

Some areas warrant placement of samples for spatial coverage because existing data are limited, particularly in the 0- to 45-cm or 0- to 60-cm intervals, and in areas where there is reason to believe RAL exceedances may exist. Each interval is relevant because at each location, either the surface interval (0 to 10 cm) or the deeper interval (0 to 45 cm or 0 to 60 cm) could define the boundary of an exceedance area.

The extent of Phase I sampling in areas where no RAL exceedances are expected will depend on an assessment of the existing sample location and spatial coverage, the variability of existing data and a comparison of those data to the RAL, and the existence of and potential for nearby sources.

The number of samples needed to assess the deeper intervals will depend on the likelihood of RAL exceedances in a given area, which is a function of the stringency of the RAL relative to the location of potential sources. As an example, 0- to 60-cm samples are warranted in Recovery Category 1 areas in the navigation channel adjacent to areas with intertidal contamination (e.g., panel 2, Map 19).

On the other hand, in upstream areas with no identified historical COC sources, the likelihood of an elevated PCB concentration in the top 60 cm of sediment exceeding a Recovery Category 2/3 PCB RAL of 195 mg/kg OC is very low. Thus, very few samples are needed for this interval in Recovery Category 2/3 areas. An example of this type of area is RM 4.4 to RM 4.6 (Map 20). Other than benzyl alcohol (see Attachment A), this area has had only two RAL exceedances in the 0- to 10-cm samples analyzed as part of RI/FS and post-FS sampling events. These RAL exceedances were for total PCBs in two RI/FS samples with exceedance factors of 1.1 and 1.2 on the east side of the Turning Basin (nearby post-FS samples have not had PCB exceedances) (panel 1 of Map 20). The existing RAL exceedance locations would be re-occupied with nearby archive samples (panel 2 of Map 20).

The 0- to 45-cm composite samples from Beach 7 on the western side in this area had concentrations far below RALs.[28] Therefore, few samples would be placed in this intertidal area. In other areas with limited data, a few samples would be placed for spatial coverage of relevant intervals (panel 2 of Map 20). No samples are needed in the FNC in this area because it is dredged every two years and was last dredged in 2018/2019.

4.2.2 Depth Intervals and Analytes

For the design samples placed as described above, this section presents guidelines for which depth intervals should be sampled to delineate RAL exceedances, as well as which analytes should be analyzed in Phase I samples.

4.2.2.1 Intervals

Most locations will be sampled at two depth intervals to delineate RAL exceedances (see Figure 2). In the intertidal area, most locations will be sampled in the 0- to 10- and 0- to 45-cm intervals. In the subtidal areas, most locations will be sampled in the 0- to 10- and 0- to 60-cm intervals. Two intervals may not be sampled at a given location if recent data already exist for one of the intervals.

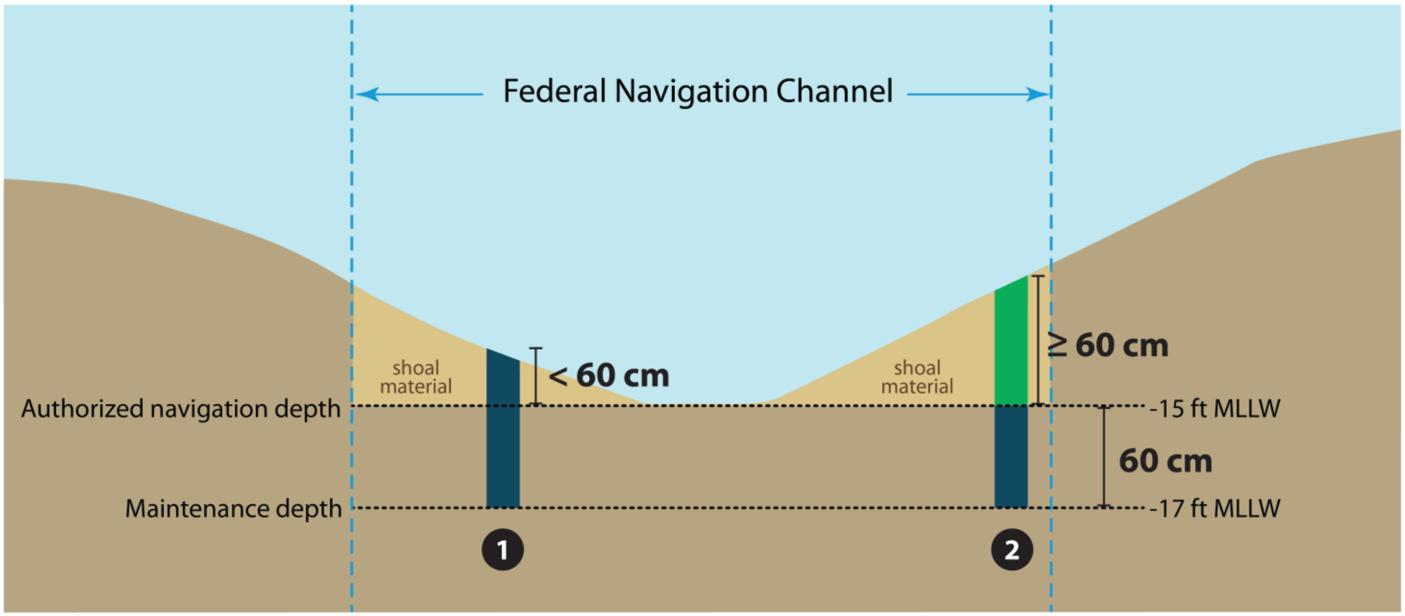
In FNC areas with shoals (current elevations shallower than the authorized depth of -15 feet MLLW), the 0- to 10-cm interval will be sampled and the 0- to 60-cm interval will be expanded as appropriate to include the shoal in the intervals analyzed (Figure 5). The subsurface sediment design sampling intervals will depend on the thickness of the shoal material. When the thickness of the shoal is less than 60 cm, one sample will be collected to -17 feet MLLW. When shoal material is more than 60 cm thick, two samples will be collected, as shown in Figure 5. To support FNC maintenance dredging, a 30-cm (1-foot) Z-sample will be collected from -17 to -18 feet MLLW and archived for locations in the FNC with shoals.[29] The Z-sample will be archived pending the chemical analysis of the intervals above -17 ft MLLW. If there are no RAL exceedances in the intervals above, the Z-sample will be analyzed. If there are RAL exceedances, deeper intervals may be needed to delineate the vertical extent of contamination. The analysis of these intervals may or may not include analysis of the Z-sample.

Specific field methods will be detailed in the QAPP regarding core depths, sampling intervals, and archiving approaches.

[28] The Beach 7 composite samples 95UCL concentrations were as follows: PCB = 160 µg/kg; cPAH TEQ = 63.4 µg/kg; dioxin/furan TEQ = 2.69 ng/kg; and arsenic = 7.97 mg/kg.

[29] The Z-sample is 1 foot (30 cm), which is a standard interval for Z samples.

Figure 5
Shoal Design Sampling Approach



1. When thickness of shoal material is less than 60 cm then the core will be taken to -17 ft MLLW and one sample will represent both the shoal material and the material between -15 ft and -17 ft MLLW. A 0-10 cm sample will also be collected.

2. When thickness of shoal material is greater than or equal to 60 cm then the core will be taken to -17 ft MLLW and two samples will be analyzed. One sample will represent shoal material and the other sample will contain the material between -15 ft and -17 ft MLLW. A 0-10 cm sample will also be collected.

Note: In both locations, 0- to 10-cm samples will also be collected and a 1-foot Z-sample will be archived.

4.2.2.2 Chemical Analyses

Detailed analyte lists for each Phase I sample will be presented in the QAPP along with sample-specific rationale. The analyte lists will be determined based on the sample type, interval, and recovery category (Table 5), according to the RALs presented in ROD Table 28. In general, Tier 1 samples in Phase I will be analyzed for all COCs with an applicable RAL, unless site-specific lines of evidence indicate a reduced analyte list is appropriate. The analyte list for archive samples will be determined based on nearby RAL exceedances and other identified site-specific concerns, if any.

Table 5
Analytes in Various Sample Types

Sample Type	Recovery Category 1			Recovery Category 2/3		
	0–10 cm	0–45 cm	0–60 cm	0–10 cm	0–45 cm	0–60 cm
Intertidal (Tier 1)	PCBs, arsenic, and other benthic COCs[1] (dioxins/ furans in a subset)	PCBs, arsenic, and other benthic COCs[1] (dioxins/ furans in a subset)	na	PCBs, arsenic, and other benthic COCs[1] (dioxins/furans in a subset)	PCBs and arsenic (cPAHs[2] and dioxins/furans in a subset)[3]	na
Subtidal (Tier 1)	PCBs, arsenic, and other benthic COCs[1] (dioxins/ furans in a subset)	na	PCBs, arsenic, and other benthic COCs[1] (dioxins/furans in a subset)	PCBs, arsenic, and other benthic COCs[1] (dioxins/furans in a subset)	na	PCBs[4]
Archive (Tier 2)	analyze only for COC(s) with RAL exceedance unless other site-specific concern			analyze only for COC(s) with RAL exceedance unless other site-specific concern		

Notes:

[1] Other benthic COCs are the benthic risk drivers included in ROD Table 27; the other benthic COC list excludes PCBs and arsenic because they are listed separately as human health risk drivers. PAHs, including cPAHs, are included in the other benthic COC list.

[2] cPAHs will be analyzed in 0–45-cm samples collected from intertidal beach play areas only. Using the updated BaP toxicity values, excess cancer risks for clamming are less than 1 x 10^{-6}, and thus cPAHs are not a COC for that pathway (see the Pre-Design Studies data evaluation report [Windward 2019a]).

[3] Per ROD Table 28, there are no RALs for other benthic COCs in the 0- to 45-cm interval in Recovery Category 2/3 areas.

[4] Per ROD Table 28, only PCBs have a RAL in the 0- to 60-cm interval in Recovery Category 2/3 areas.

BaP: benzo(a)pyrene
cm: centimeter
COC: contaminant of concern
cPAH: carcinogenic polycyclic aromatic hydrocarbon
na: not applicable (no RAL)
PCB: polychlorinated biphenyl
RAL: remedial action level
ROD: Record of Decision
SMS: Washington State Sediment Management Standards

Dioxins/furans will be analyzed in a subset of samples, because dioxins/furans are not expected to exceed the RAL in the upper reach based on the following lines of evidence:

- In all existing sediment data (RI/FS and post-FS), dioxins/furans have exceeded the RAL in only one 0- to 10-cm sample, which was collected adjacent to the T-117 EAA.
- Dioxins/ furans ranged from 0.462 J to 3.09 J ng/kg in 0- to 10-cm composite samples collected throughout the reach, 8 to 54 times lower than the RAL.
- Dioxins/furans ranged from 1.87 J to 6.41 J ng/kg in 0- to 45-cm composite samples collected from Beaches 5, 7, and 8, 4 to 15 times lower than the RAL.
- The highest dioxin/furan TEQ reported in a 0- to 60-cm sample from the upper reach was 5.88 ng/kg; the Recovery Category 1 RAL[30] is 25 ng/kg, over 4 times higher.

Therefore, dioxins/furans will be analyzed in a subset of Phase I Tier 1 samples based on existing data, potential sources, and spatial coverage. Archives will be retained for all samples.

4.2.2.3 Visual Bank Characterization

Bank conditions in the entire upper reach will be assessed via visual inspection during Phase I to identify where banks are armored or unarmored (definitions of armored and unarmored banks are in the RDWP, Section 2.1.7). Unarmored banks may be subject to bank erosion. Results of the visual assessment will be documented in the Phase I data evaluation report and used to plan additional bank data collection requirements during Phase II.

4.3 Phase II Conceptual Design Sampling Plan

This section presents a high-level summary of the Phase II conceptual design sampling plan. The results of the Phase II design sampling will be discussed in the Phase II data evaluation report, which will also contain a data gaps analysis conducted to determine if a third phase of design sampling is needed. The general approach for each of the Phase II DQOs is discussed in the following sections.

4.3.1 Refining RAL Delineation

The Phase I data evaluation report will include a recommendation regarding whether refinement of the Phase I RAL exceedance delineation is warranted for specific remedial action areas. If it is, then additional samples will be collected in the appropriate interval(s). Potentially two tiers of analysis may be conducted in Phase II, following the archive approach described for Phase I.

[30] No 0- to 60-cm RAL exists for dioxins/furans in Recovery Category 2/3 areas.

Examples of the process for additional RAL delineation are shown in panels 6, 7, and 8 of Map 19. These panels show how Phase II samples would be placed in remedial action areas to further refine the shapes of the interpolated remedial action areas, particularly on the edges of intertidal areas and recovery categories. The Phase II data would be included in the interpolation used to define the extent of the remedial action area; these data could also modify the preliminary technology assignment.

As needed for design (see Section 4.3.2), samples for vertical extent, bank characterization, and geotechnical data would be collected at the same time as Phase II RAL delineation samples. The vertical, bank, and geotechnical samples would be analyzed in one batch following the Phase II RAL delineation samples, unless tiering was required.

4.3.2 Vertical Delineation

Once the preliminary boundary and the remedial technology for each remedial action area have been established in the Phase I data evaluation report, if dredging or partial dredging/capping is the anticipated remedy for an area, additional information will be needed in Phase II to refine the vertical extent of RAL exceedances and establish if partial dredging/capping is appropriate based on these depths. Vertical information is also needed in capping areas to design the cap, but delineating the full vertical extent of contamination (i.e., the sediment depth at which all COC concentrations are below RALs) is not needed because the cap design assumes an infinite source of contaminant underlying the cap.

According to the ROD (EPA 2014b), "if greater than 1 ft of contamination would remain after dredging to sufficient depth to accommodate a cap, sediments will be partially dredged and capped." Thus, the full vertical extent of contamination is needed to define the required dredging elevation(s) and to document that expected concentrations in the post-dredge surface (Z-sample) are below RALs. The placement of the cores to delineate the vertical extent of contamination will be based on Phase I results and other information, such as local bathymetry.

Additional data on contamination at depth (> 60 cm) outside of dredging and capping areas are not required by the ROD. The RI (Windward 2010a), FS (AECOM 2012a), and Supplemental FS (AECOM 2012b) presented subsurface data and various subsurface analyses[31] used by EPA to determine the protective selected remedy provided in the ROD, including the subsurface RALs and where they apply. Subsurface data from the RI/FS will be considered along with Phase I and Phase II data in the data evaluation reports and if specific subsurface data from outside

[31] RI/FS subsurface data are summarized in Section 4 of the RI (Map series 4-17, 4-26, 4-33, 4-41, 4-69); Section 2.3.2 (Map 2-12 series), Table 10-1, and Appendix E of the FS; and the Supplemental FS (Figure 3).

dredging and capping areas are needed for design and remedy implementation, these data may be collected in Phases II or III.

4.3.3 Geotechnical Data

In Phase II, the appropriate geotechnical data will be collected to inform the engineering design. Geotechnical data are required to establish design criteria that inform dredge prism development; engineered capping design; and work conditions around completed remedial actions and existing infrastructure, utilities, and debris. While the design will specify the allowance for the use of mechanical and hydraulic dredging methodologies, these data are also required to allow the contractor to select suitable dredging equipment for use during construction.

Specifications for geotechnical data will be provided in the QAPP or a QAPP addendum, and the majority of geotechnical data will be collected during the implementation of Phase II PDI activities. Potential geotechnical data needs to support RD will include the following types of data. Note that not every area will need every analysis. For example, index properties are likely to be correlated with the other properties and thus other geotechnical properties will not likely be needed at every location.

- **Shear Strength**. Shear strength data are required to inform general sediment stability design considerations, develop stable dredge cuts (i.e., side-slopes), assess bank stability, and characterize sediment dredgeability. Subgrade sediment shear strength data are also required to inform engineered capping design and ENR materials selection and placement. Specific methods for the collection of shear strength data may include *in situ* vane shear tests, cone penetrometer tests, or calculation of shear strength based on other known geotechnical properties.
- **Compressibility/Settlement and Consolidation.** Sediment strength data are required to determine the bearing capacity of subgrade sediments, specifically how subgrade sediments will compress/settle following engineered cap placement. Additionally, consolidation of placed cap materials must be evaluated to assist with identifying the minimum required cap material thicknesses and evaluating cap thickness verification surveys. Specific methods for the collection of subgrade compressibility/settlement data include use of a Shelby tube (separate effort from collection of environmental data) to collect an undisturbed sample for laboratory analysis. Consolidation data will be obtained using samples of engineered capping materials and standard geotechnical laboratory testing methods, or calculation of predicted consolidation based on other known geotechnical properties.

- **Index Properties.** Geotechnical index properties include grain size, moisture content, bulk density, and plasticity (i.e., Atterberg Limits). These data are required to inform all facets of engineering design, including dredging, capping, and ENR, and to assess bank and in-water slope stability. Index property data are also useful in the design of sediment handling, transport, dewatering, and treatment systems.

Where appropriate, geotechnical data that consider the needs described above will also be collected within bank areas that are adjacent to active sediment remedial action areas in the upper reach, as described in Section 4.3.4.

4.3.4 Bank Areas

A variety of scenarios can be envisioned wherein a bank is located adjacent to an active sediment remedial action area. This section describes how typical scenarios will be addressed. If an active remedial action area is located adjacent to a bank, bank data will be collected in Phase II (as described below).

A field visual survey of all banks (including under-pier areas) in the upper reach will be conducted in Phase I. As needed in Phases II and III, banks will be further characterized in areas adjacent to remedial action areas, potentially including surface and subsurface sediment collection and analysis, geotechnical data collection, consideration of seeps, and consideration of topography as appropriate. Details of Phase II bank characterization will be presented in general in the QAPP with additional details in the Phase II QAPP addendum.

The Pre-Design Studies compiled existing bank data and collected additional bank data where data gaps were identified by Ecology.[32] Based on this combined effort, one bank area was identified (at RM 4.7 W in the Turning Basin) where bank data collection (horizontal and vertical) will be required during Phase II of the PDI if sediment remediation is needed adjacent to this area. Results of the Phase I PDI may also identify additional bank areas for environmental characterization during Phase II.

[32] To supplement existing bank data, 11 bank samples were collected in the LDW (3 in the upper reach) as part of the Pre-Design Studies based on the analysis presented in the surface sediment QAPP (Windward 2018a). In coordination with Ecology, exposed banks were sampled if they had not already been characterized in past surveys, if they were not located adjacent to upland properties under or expected to be under an Agreed Order for site investigation, if adjacent sediment data did not exist or had concentrations greater than sediment RALs, and if the bank was sampleable. Bank samples were collected at elevations of +4 to +12 ft MLLW and were analyzed for the analytes listed in Table 20 of the ROD (EPA 2014b), with a subset analyzed for dioxins/furans. Results are presented in the draft Pre-Design Studies data evaluation report (Windward 2018b).

4.3.4.1 Bank Characterization

Bank areas located adjacent to active sediment remedial action areas will be characterized up to mean higher high water. The number and specific locations of bank samples to be collected will be developed during Phase II investigation planning, and will be based on existing information, elevation range, armoring condition, and the type of sediment remediation proposed for the adjacent in-water area.

For unarmored banks, surface and/or subsurface sample data will be collected where appropriate and archived for potential analysis. Subsurface sample depth limits and sediment thickness will be determined based on evaluation of available data, bank conditions, slope, and other factors that may inform the ability to collect the data and limitations on doing so.

Armored banks will require investigation using alternate methodologies. If needed, sediments accumulated on top of existing armor material and/or within the interstices of the armor rock will be sampled. In addition to chemical testing, sediment thickness testing will be performed using probing methods to be described in the PDI QAPP. Sediment thickness data will be used to calculate accumulated sediment thickness and to inform the selection of appropriate remediation technologies for the bank area.

4.3.4.2 Seeps

The locations of active seeps have been surveyed as part of the RI and seeps have been sampled during the RI and the Pre-Design Studies. Based on these two efforts, the locations of seeps are generally known, although they may vary from time to time depending on conditions. Bank areas located adjacent to active sediment remedial action areas will be visually observed to confirm if active seeps are present, and existing seep data will be reviewed to assess seep water quality. If water quality data suggest that sediment at a location could become re-contaminated post-remedy, Ecology will be notified for upland investigation/cleanup coordination.

4.3.4.3 Topographic Surveys

Topographic survey data will be required for certain bank areas as needed for design (i.e., areas adjacent to active sediment remedial action areas or in areas with identified data needs based on Phase I and II data) to provide elevation information related to intertidal and subtidal areas, assist with cut/fill calculations during remediation design, assess slope stability, and assess habitat conditions/considerations. The EPA-approved survey QAPP will be amended as necessary to address topographic surveying requirements during Phase II investigation activities. Topographic survey data will be combined with available bathymetry survey data for use in remedial design.

4.3.5 Other Engineering-related Information

Other engineering-related efforts will be conducted in Phase II or Phase III, as needed, such as:

- Groundwater data (for use in cap design) will come from existing groundwater studies. If groundwater flow rate data are needed for cap design in bank areas, site-specific data collection may be necessary.
- Debris surveys may be performed to identify surficial debris types and specific locations, depending on the results of the bathymetric survey. Debris surveys, if needed, will employ either side-scan sonar and/or visual inspection.
- Overwater infrastructure (e.g., location, dimensions, conditions) and utility location data, as necessary to inform remediation technology selection (i.e., dredging versus engineered capping), construction offsets and no-work area locations, infrastructure support elements, etc.
- Waste characterization data may be collected to inform material handling, transport, dewatering, and disposal procedures.

Specific treatability studies (such as elutriate tests) are not anticipated to be needed at this time for remedial design; however, if such a need is identified during completion of PDI activities, an addendum to the PDIWP will be prepared and submitted for agency review and approval.

4.4 Phase III Conceptual Design Sampling

The Phase II data evaluation report may identify remaining data gaps that need to filled as part of a Phase III sampling effort. In addition, Phase III needs could be identified in the 30% design package or following EPA comments on 30% design package.

Phase III could include the collection of additional data from any of the aforementioned categories. In addition, benthic toxicity testing could be conducted in Phase I, II, or Phase III if benthic COC RAL exceedances exist in a given area sufficiently large to warrant further investigation[33] and lacking human health COC RAL exceedances. Benthic toxicity testing, where appropriate, will require the simultaneous collection of sediment for chemistry and toxicity testing and expedited chemical analysis. Additional details will be presented in the PDI QAPP.

[33] Per EPA's responsiveness summary (EPA 2014a), "a single isolated exceedance of a benthic SCO will not trigger additional remedial action. Instead, it will trigger additional monitoring to determine the nature and extent of the contamination in that area. Additional remedial action may be warranted if, for example, monitoring indicates a cluster of three or more points with COC concentrations exceeding the benthic SCO."

In addition, Phase III could include the collection of data needed for:

- Design (e.g., waste characterization)
- Additional structure inspections/structural engineering assessments(e.g., dredge setback and under-pier construction information)
- Confirmation of MNR to benthic SCO areas, if needed (i.e., areas with chemical concentrations greater than the benthic SCO but less than the RAL for Recovery Category 2/3)

5 Schedule

This section provides a list of deliverables and the schedule for implementing the PDI effort per AOC4 (EPA 2018). All schedule durations are in calendar days.

- The PDI QAPP/health and safety plan was submitted to EPA 60 days after receipt of EPA comments on the revised draft PDIWP (i.e., November 26, 2019).
- Upon approval of the QAPP or QAPP addendum, PDI field work will be completed in accordance with the schedule provided in the RDWP (180 days allotted to each phase of field collection, chemical analysis, and validation), unless otherwise approved by EPA.
- PDI data will be due to EPA 10 days after receipt of validated PDI sampling data. Within a design sampling phase, two tiers of analytical rounds are possible. Following receipt of analytical results from the Tier 1, a working meeting with EPA will be held to determine which archive samples should be analyzed for Tier 2. A data package will be submitted after data from both tiers have been received and validated.
- Two PDI data evaluation reports will be submitted to EPA. The first PDI data evaluation report will be submitted to EPA 60 days after submittal of all PDI data from the first phase of data collection. The second PDI data evaluation report will be submitted to EPA 45 days after submittal of all PDI data from the second phase of data collection. If Phase III design sampling is conducted, a Phase III data evaluation report will be submitted to EPA 45 days after submittal of all Phase III data. EPA comments on the data evaluation reports will be reflected in subsequent deliverables, rather than submitted in revised versions of the data evaluation reports.

6 References

AECOM. 2012a. Final feasibility study, Lower Duwamish Waterway. Prepared for Lower Duwamish Waterway Group. AECOM, Seattle, WA.

AECOM. 2012b. 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. AECOM, Seattle, WA.

AECOM. 2018. Terminal 117 cleanup. Removal action completion report. Phase 1: sediment and upland cleanup. Final. Prepared for the Port of Seattle for submittal to US Environmental Protection Agency. AECOM Environment, Seattle, WA.

AMEC Foster Wheeler, DOF, Floyd|Snider. 2016. Corrective measure implementation report. AMEC Foster Wheeler Environment & Infrastructure, Inc., Dalton Olmsted & Fugelvand, Inc., and Floyd|Snider, Inc, Seattle, WA.

Anchor, Windward. 2019. Quality assurance project plan: pre-design surveys of the Lower Duwamish Waterway upper reach. Final. Anchor QEA and Windward Environmental LLC, Seattle, WA.

Ecology. 2007. Lower Duwamish Waterway source control action plan for Early Action Area 7. No. 07-09-003. Washington Department of Ecology, Northwest Regional Office, Bellevue, WA.

Ecology. 2017. Sediment cleanup user's manual II. Guidance for implementing the cleanup provisions of the sediment management standards, Chapter 173-204 WAC. Draft for review and comment through July 7, 2017. Pub. No. 12-09-057. Revised April 2017. Toxics Cleanup Program, Washington State Department of Ecology, Olympia, WA.

Ecology. 2018. 10000 W Marginal Place S initial investigation field report. Washington State Department of Ecology, Seattle, WA.

Ecology. 2019. Sediment cleanup user's manual II. Guidance for implementing the cleanup provisions of the sediment management standards, Chapter 173-204 WAC. May 2019 revised draft for 60 day review and comment. Pub. No. 12-09-057. Toxics Cleanup Program, Washington State Department of Ecology, Olympia, WA.

Ecology, Leidos. 2018. Lower Duwamish Waterway source control status report, January 2014 through December 2016. Washington State Department of Ecology and Leidos, Bellevue, WA.

EPA. 2014a. Record of Decision, Lower Duwamish Waterway Superfund Site. Part 3. Responsiveness summary. US Environmental Protection Agency, Region 10, Seattle, WA.

EPA. 2014b. Record of Decision. Lower Duwamish Waterway Superfund Site. US Environmental Protection Agency.

EPA. 2018. Remedial design statement of work, LDW Upper Reach, Lower Duwamish Waterway Superfund site. Attachment to the *Fourth Amendment of the Administrative Order on Consent for Remedial Investigation/Feasibility Study*. US Environmental Protection Agency, Region 10, Seattle, WA.

EPA. 2019. Integrated Risk Information System (IRIS) database [online]. US Environmental Protection Agency, Washington, DC. [Cited 1/15/19.] Available from: http://www.epa.gov/iris/.

Fourie HW, Fox D. 2016. Revised evaluation guidelines for benzyl alcohol in marine sediments. 2016 Sediment Management Annual Review Meeting, May 4, 2016. DMMP Agencies. pp 96-106.

Integral, Anchor QEA, Windward. 2018. Recovery category recommendations report. Draft. Submitted to EPA September 13, 2018. Integral Consulting Inc., Anchor QEA, and Windward Environmental LLC, Seattle, WA.

Integral, Windward. 2019. Design strategy recommendations report. Final. Integral Consulting Inc. and Windward Environmental LLC, Seattle, WA.

Integral, AECOM. 2018. Final joint long-term monitoring and maintenance plan. Lower Duwamish Waterway Superfund Site, Terminal 117 Early Action Area. Integral Consulting Inc. and AECOM Environment, Seattle, WA.

King County. 1999. Norfolk sediment remediation project-closure report. Prepared for Elliott Bay/Duwamish Restoration Program. King County Department of Natural Resources, Seattle, WA.

King County. 2017. Delivering on a promise to replace the South Park Bridge [online]. King County. Updated October 27, 2017. Available from: https://www.kingcounty.gov/elected/executive/constantine/initiatives/south-park-bridge.aspx.

SAIC. 2008. Lower Duwamish Waterway, RM 3.7-3.9 east, early action area 6: summary of existing information and identification of data gaps. Prepared for Toxics Cleanup Program, Washington State Department of Ecology. Science Applications International Corporation, Bothell, WA.

USACE, EPA, Ecology, DNR. 1991. Decision on the suitability of dredged material tested under PSDDA evaluation procedures for the South Park Marina maintenance dredging project (OYB-2-012574) to be disposed of at the Elliott Bay open-water disposal site. US Army Corps of Engineers, US Environmental Protection Agency, Washington State Department of Ecology, and Washington State Department of Natural Resources, Seattle, WA.

USACE, EPA, Ecology, DNR. 1999. Determination on the suitability of proposed maintenance dredged material from the Duwamish Yacht Club dredging project (1998-2-02213) evaluated under Section 404 of the Clean Water Act (CWA) for open-water disposal at the Elliott Bay disposal site. US Army Corps of Engineers, US Environmental Protection Agency, Washington State Department of Ecology, and Washington State Department of Natural Resources, Seattle, WA.

USACE. 1999. Dredging summary and analysis report, Duwamish Waterway maintenance dredging, March-June 1999. US Army Corps of Engineers. Seattle District, Seattle, WA.

USACE, EPA, Ecology, DNR. 2007. Determination regarding the suitability of proposed dredged material from Delta Marine Industries, Duwamish River, Seattle, King County, for beneficial use or unconfined open-water disposal at the Elliott Bay nondispersive site. US Army Corps of Engineers, US Environmental Protection Agency, Washington State Department of Ecology, and Washington State Department of Natural Resources, Seattle, WA.

USACE, EPA, Ecology, DNR. 2010. Determination on the suitability of supplemental characterization of proposed dredged material from King County Department of

Transportation South Park Bridge Project (Corps application: NWS-2009-1586) in Duwamish River, Washington evaluated under Section 404 of the Clean Water Act for open-water disposal at a DMMP non-dispersive open-water disposal site. US Army Corps of Engineers, US Environmental Protection Agency, Washington State Department of Ecology, and Washington State Department of Natural Resources, Seattle, WA.

USACE. 2013. Determination regarding the suitability of proposed dredged material from the Duwamish Yacht Club, Seattle, WA evaluated under Section 404 of the Clean Water Act for unconfined open-water disposal at the Elliott Bay non-dispersive disposal site. US Army Corps of Engineers.

USACE, EPA, Ecology, DNR. 2018. Determination regarding the suitability of maintenance dredged material from the Duwamish River navigation channel evaluated under Seciton 404 of the Clean Water Act for unconfined open-water disposal at the Elliott Bay nondispersive site. US Army Corps of Engineers, US Environmental Protection Agency, Washington State Department of Ecology, and Washington State Department of Natural Resources, Seattle, WA.

Wilbur Consulting. 2004. Final preliminary site investigation report for the South Park Bridge project. Prepared for King County Department of Transportation. Wilbur Consulting, Inc., Seattle, WA.

Windward. 2003. Lower Duwamish Waterway remedial investigation. Task 5: Identification of candidate sites for early action, technical memorandum: Data analysis and candidate site identification. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2010a. Lower Duwamish Waterway remedial investigation. Remedial investigation report. Final. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2010b. Lower Duwamish Waterway remedial investigation. Remedial investigation report. Final. Prepared for Lower Duwamish Waterway Group. Appendix I. Source control area-related facility information. Windward Environmental LLC, Seattle, WA.

Windward, Integral. 2017. Pre-design studies work plan. Appendix C. Data management plan. Lower Duwamish Waterway Superfund site. Draft. Prepared for the Lower Duwamish Waterway Group for submittal to EPA Region 10. Windward Environmental LLC and Integral Consulting Inc., Seattle, WA.

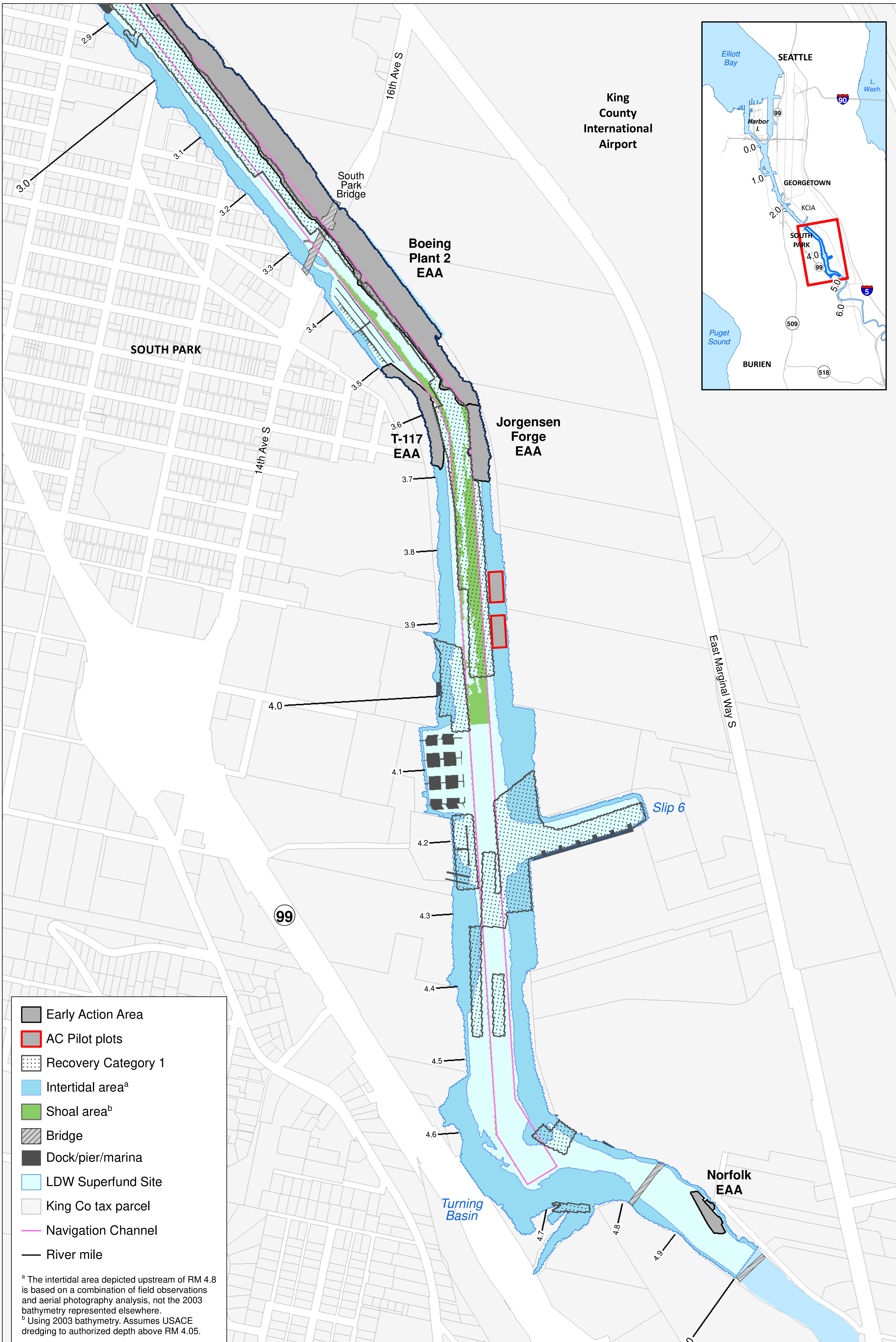
Windward. 2018a. Lower Duwamish Waterway baseline surface sediment collection and chemical analyses - quality assurance project plan. Final. Windward Environmental LLC, Seattle, WA.

Windward. 2018b. Lower Duwamish Waterway pre-design studies data evaluation report (Task 6). Draft. Submitted to EPA December 17, 2018. Windward Environmental LLC, Seattle, WA.

Windward, Integral. 2018. Technical memorandum: Compilation of existing data. Final. Submitted to EPA on November 19, 2018. Windward Environmental LLC and Integral Consulting Inc., Seattle, WA.

Windward. 2019a. Implications of updated toxicity values for benzo(a)pyrene. Windward Environmental LLC, Seattle, WA.

Windward. 2019b. Lower Duwamish Waterway surface sediment data report. Final. Submitted to EPA February 8, 2019. Windward Environmental LLC, Seattle, WA.



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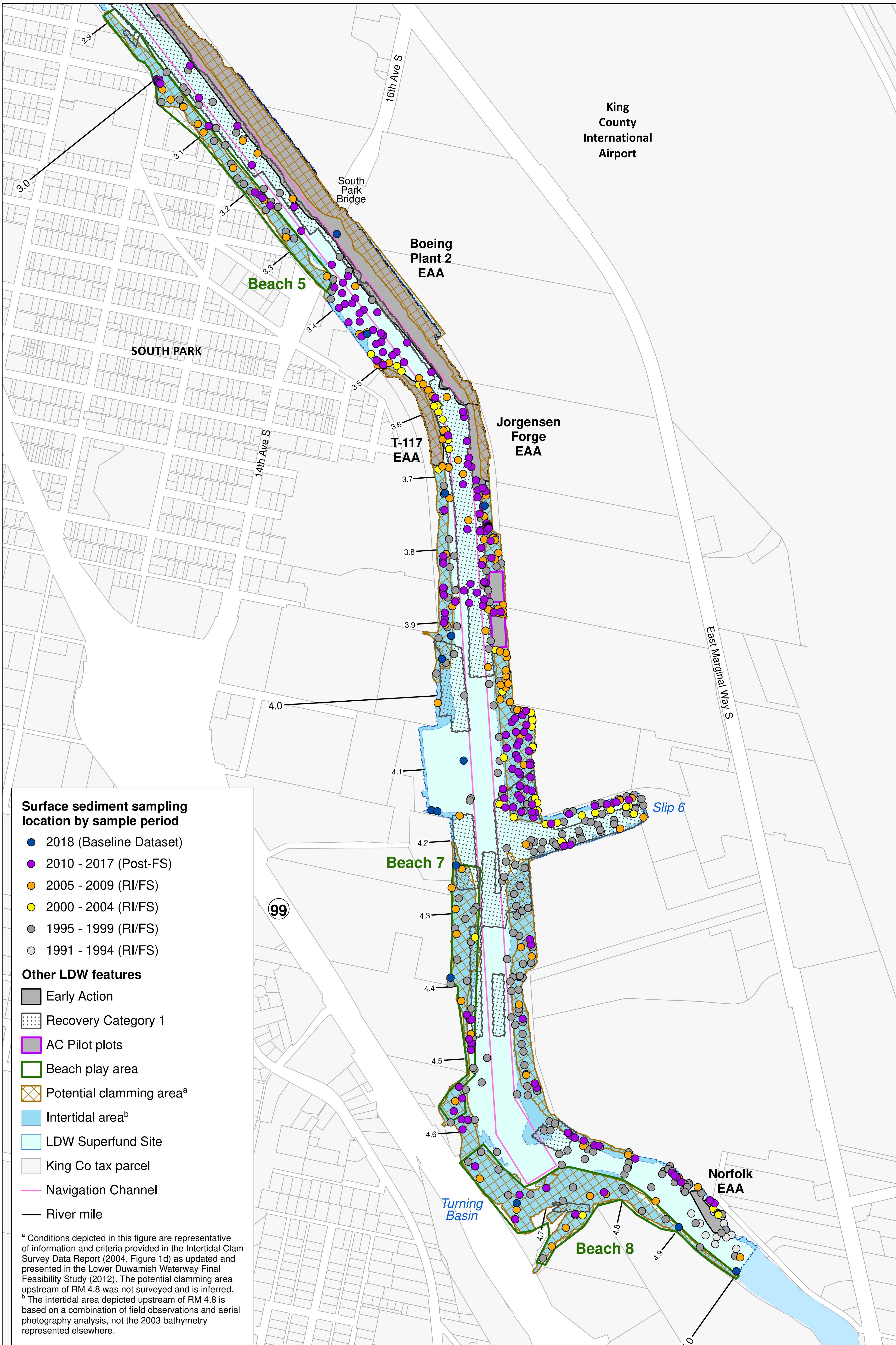
Map 1. Overview of the LDW upper reach (RM 3.0 to RM 5.0)



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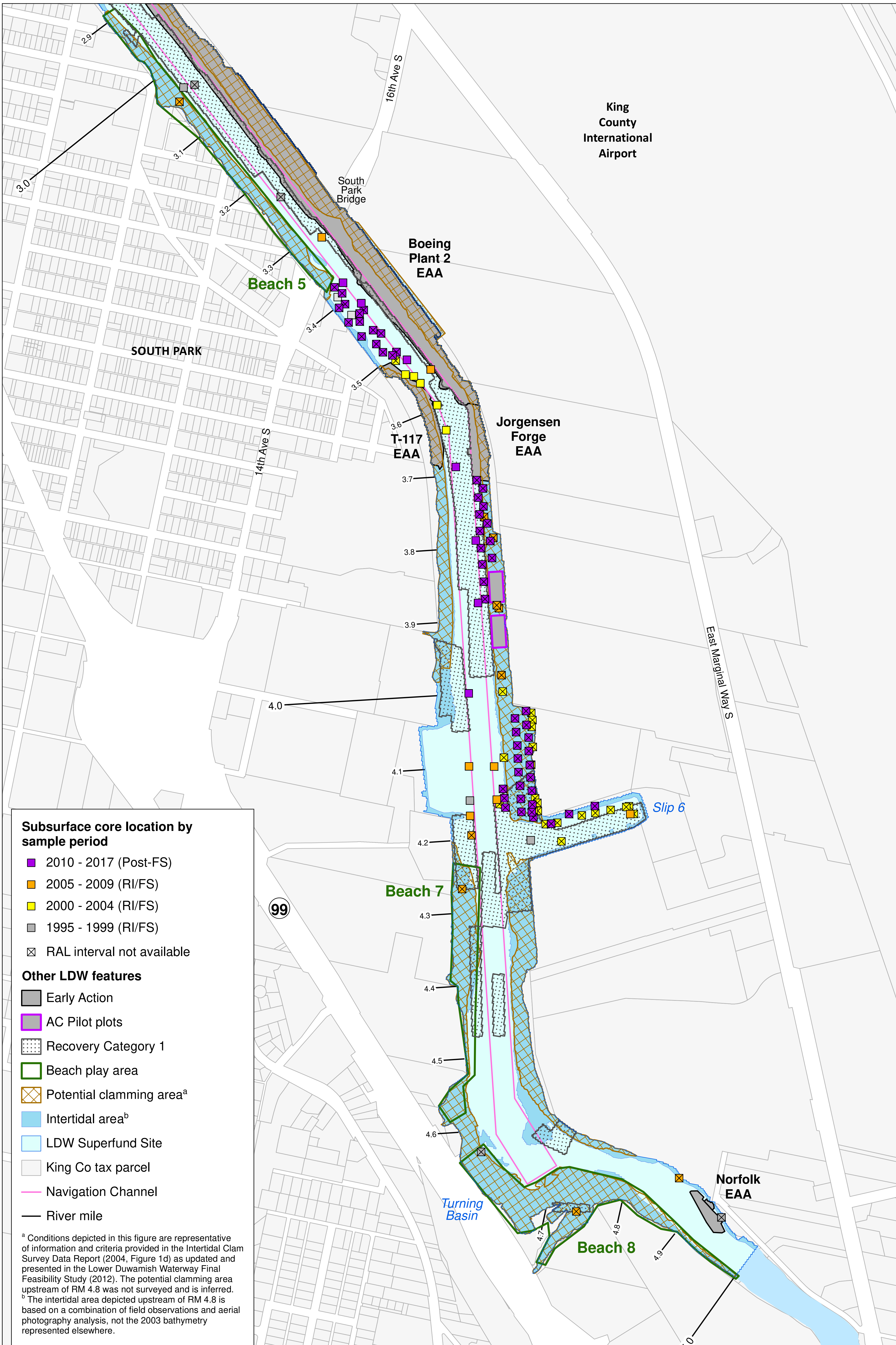
N

0 500 1,000 Feet

0 200 400 Meters

Map 2. Existing surface sediment sampling locations in the LDW upper reach by sample period

LDW Upper Reach Pre-Design Investigation Work Plan



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N

0 500 1,000 Feet

0 200 400 Meters

Map 3. Existing subsurface sediment sampling locations in the LDW upper reach by sample period

LDW Upper Reach Pre-Design Investigation Work Plan

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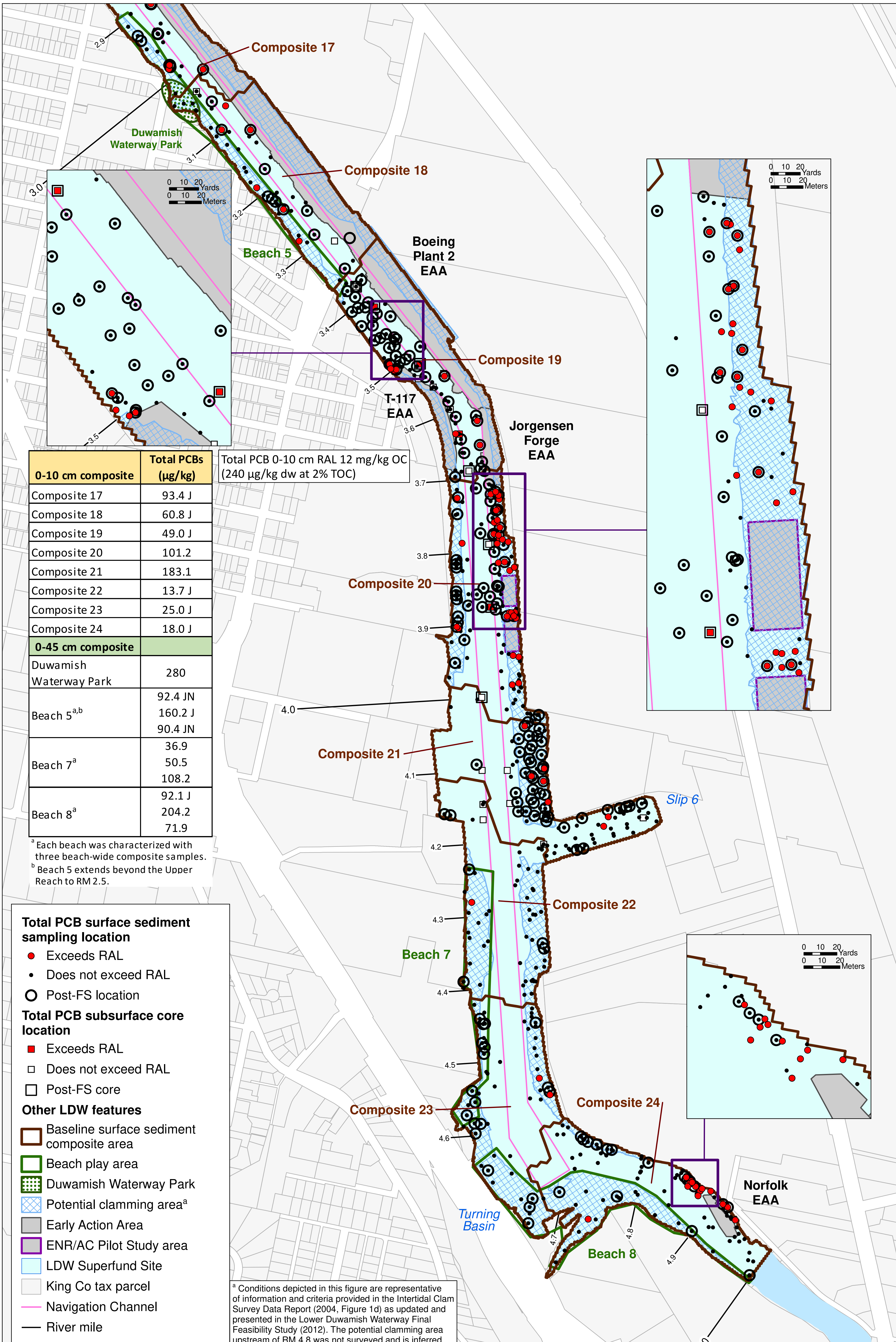

0-10 cm composite	Total PCBs (µg/kg)
Composite 17	93.4 J
Composite 18	60.8 J
Composite 19	49.0 J
Composite 20	101.2
Composite 21	183.1
Composite 22	13.7 J
Composite 23	25.0 J
Composite 24	18.0 J
0-45 cm composite	
Duwamish Waterway Park	280
Beach 5[a,b]	92.4 JN
	160.2 J
	90.4 JN
Beach 7[a]	36.9
	50.5
	108.2
Beach 8[a]	92.1 J
	204.2
	71.9

[a] Each beach was characterized with three beach-wide composite samples.
[b] Beach 5 extends beyond the Upper Reach to RM 2.5.

Prepared by craigh, 12/16/2019; W:\Projects\Duwamish AOC4\GIS\Maps and Analyses\Work Plan\PDI WP\Map 04 6849 Surface sediment compositing data - wAllSed - tPCBs.mxd

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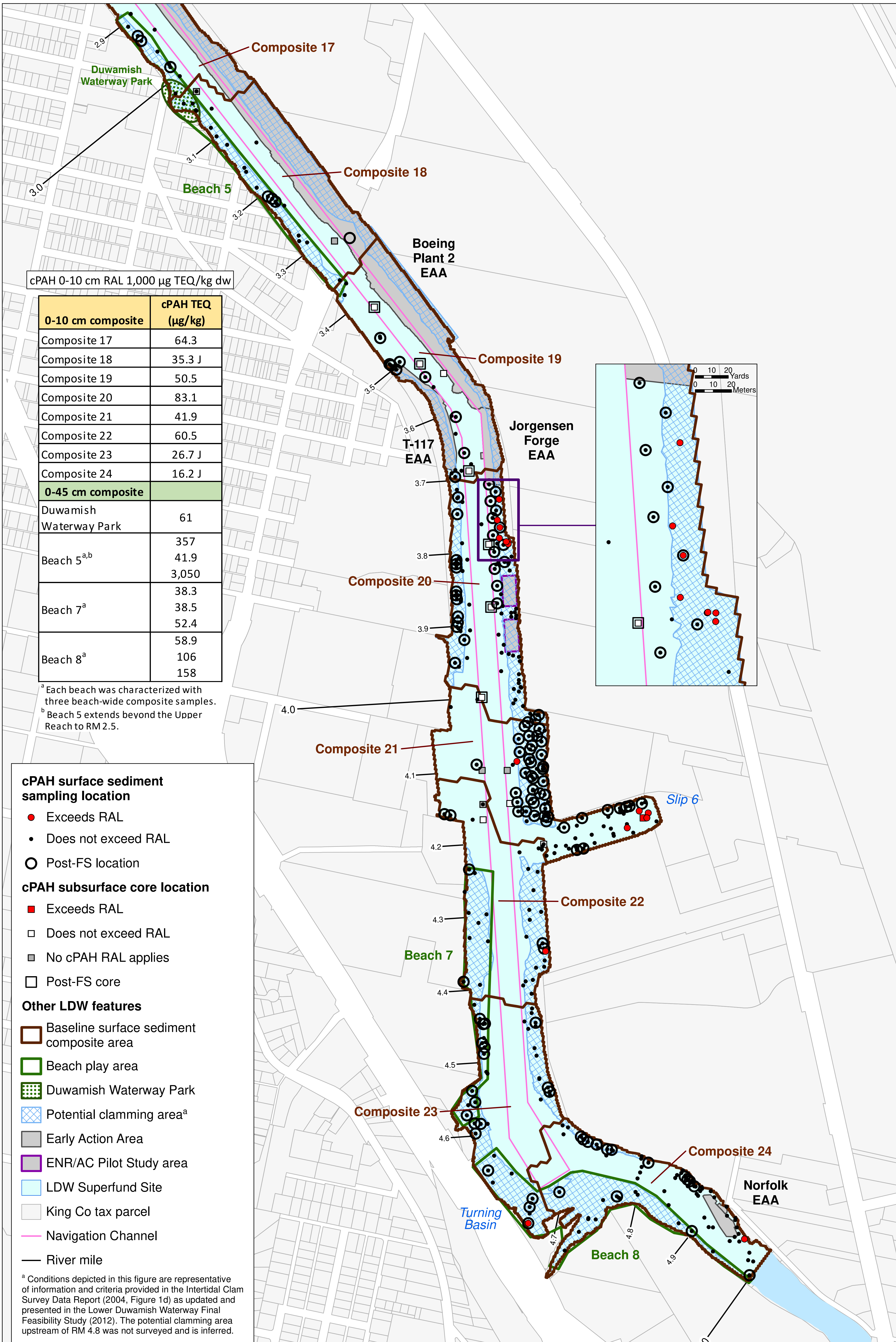
N

0 200 400 Yards
0 200 400 Meters

Map 4. Total PCB results compared to RAL in the LDW upper reach



cPAH 0-10 cm RAL 1,000 µg TEQ/kg dw

0-10 cm composite	cPAH TEQ (µg/kg)
Composite 17	64.3
Composite 18	35.3 J
Composite 19	50.5
Composite 20	83.1
Composite 21	41.9
Composite 22	60.5
Composite 23	26.7 J
Composite 24	16.2 J
0-45 cm composite	
Duwamish Waterway Park	61
Beach 5[a,b]	357 41.9 3,050
Beach 7[a]	38.3 38.5 52.4
Beach 8[a]	58.9 106 158

[a] Each beach was characterized with three beach-wide composite samples.
[b] Beach 5 extends beyond the Upper Reach to RM 2.5.

Prepared by craigh, 12/16/2019; W:\Projects\Duwamish AOC4\GIS\Maps and Analyses\Work Plan\PDI WP\Map 05 6849 Surface sediment compositing data - wAllSed - cPAH.mxd

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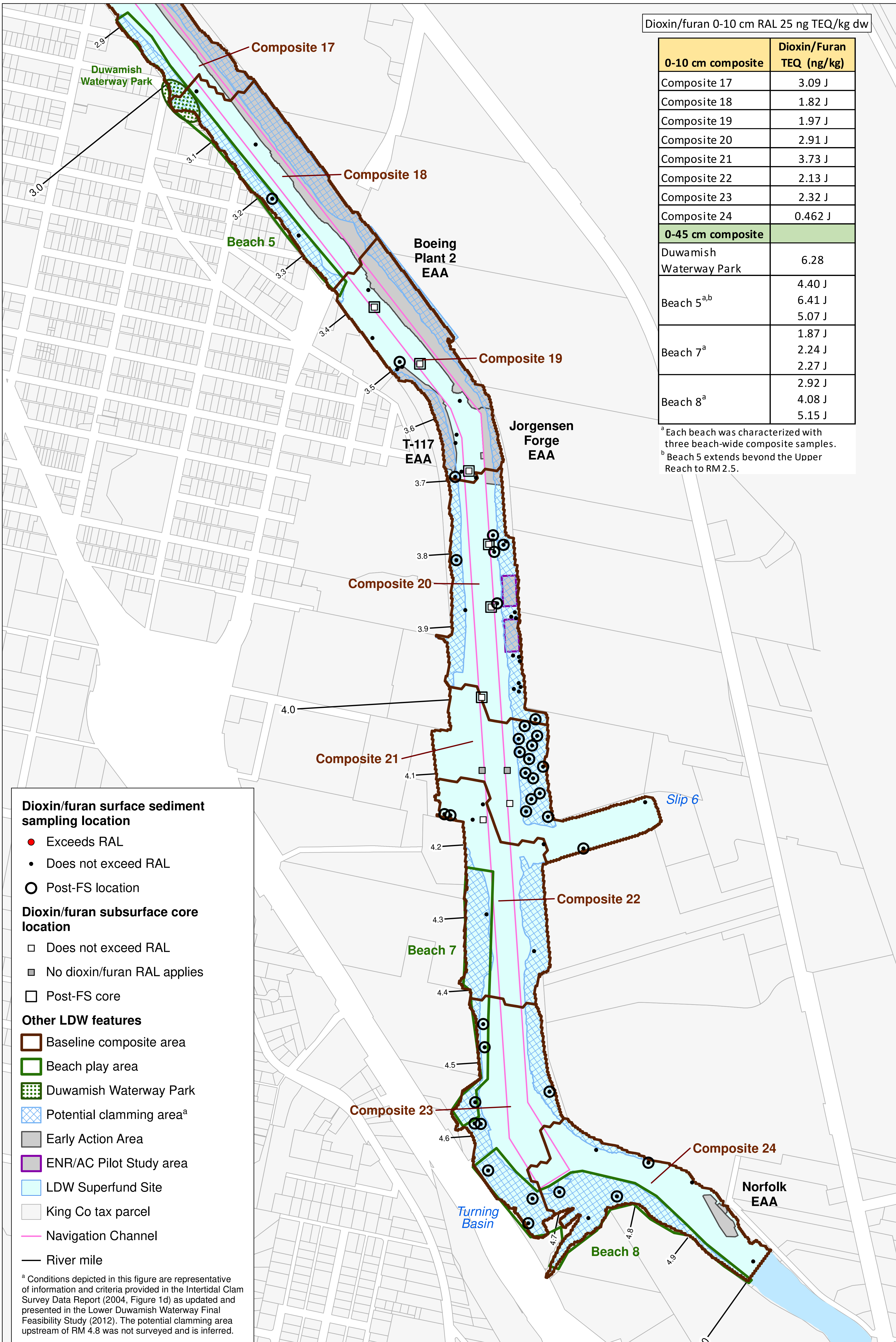
N

0 500 1,000 Feet

0 200 400 Meters

Map 5. cPAH TEQ results compared to RAL in the LDW upper reach

LDW UPPER REACH PRE-DESIGN INVESTIGATION WORK PLAN



Dioxin/furan 0-10 cm RAL 25 ng TEQ/kg dw

0-10 cm composite	Dioxin/Furan TEQ (ng/kg)
Composite 17	3.09 J
Composite 18	1.82 J
Composite 19	1.97 J
Composite 20	2.91 J
Composite 21	3.73 J
Composite 22	2.13 J
Composite 23	2.32 J
Composite 24	0.462 J
0-45 cm composite	
Duwamish Waterway Park	6.28
Beach 5[a,b]	4.40 J 6.41 J 5.07 J
Beach 7[a]	1.87 J 2.24 J 2.27 J
Beach 8[a]	2.92 J 4.08 J 5.15 J

[a] Each beach was characterized with three beach-wide composite samples.
[b] Beach 5 extends beyond the Upper Reach to RM 2.5.

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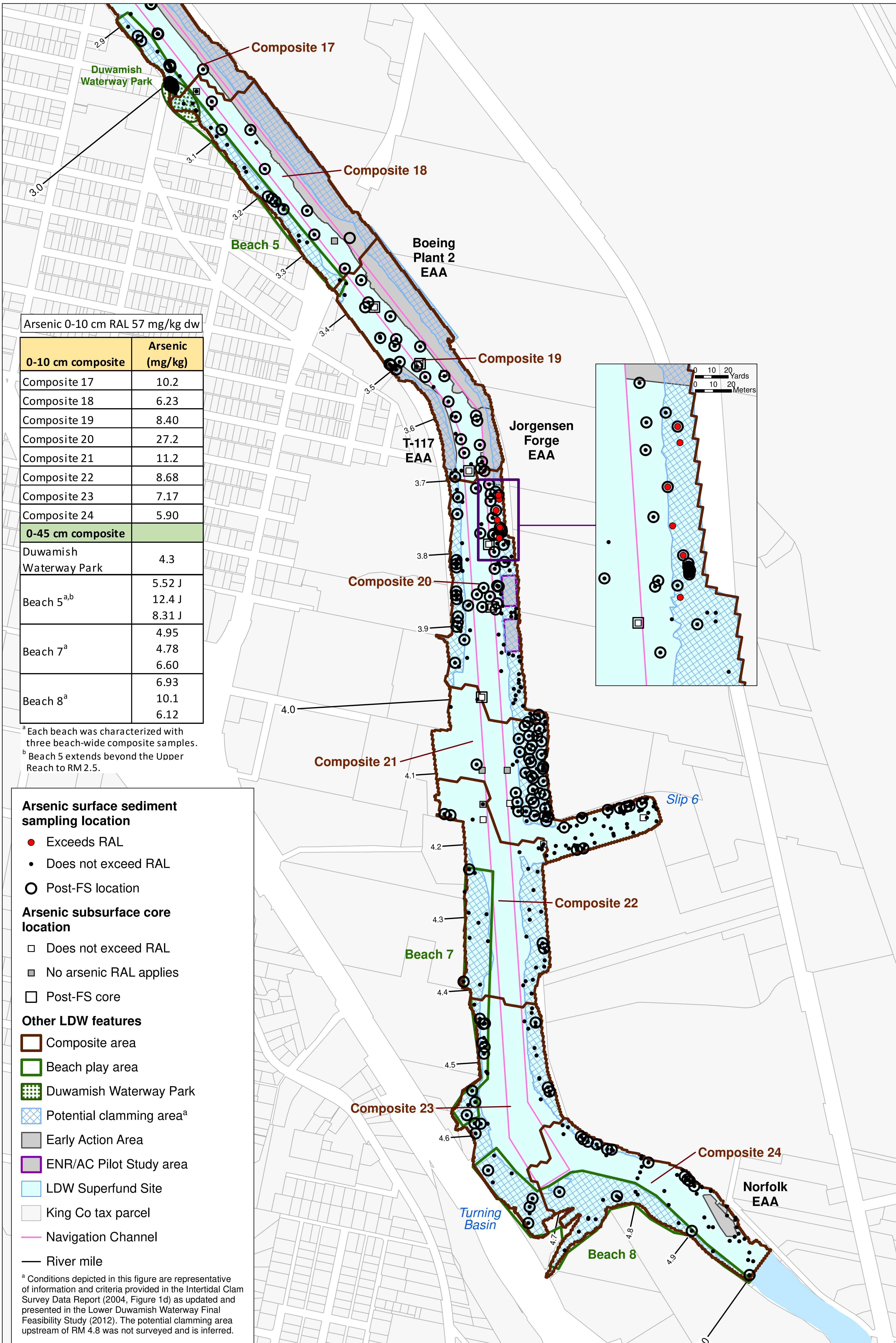
Map 6. Dioxin/furan TEQ results compared to RAL in the LDW upper reach

Prepared by craigh, 12/16/2019; W:\Projects\Duwamish AOC4\GIS\Maps and Analyses\Work Plan\PDI WP\Map 06 6849 Surface sediment compositing data - wAllSed - DF.mxd



Arsenic 0-10 cm RAL 57 mg/kg dw

0-10 cm composite	Arsenic (mg/kg)
Composite 17	10.2
Composite 18	6.23
Composite 19	8.40
Composite 20	27.2
Composite 21	11.2
Composite 22	8.68
Composite 23	7.17
Composite 24	5.90
0-45 cm composite	
Duwamish Waterway Park	4.3
Beach 5[a,b]	5.52 J 12.4 J 8.31 J
Beach 7[a]	4.95 4.78 6.60
Beach 8[a]	6.93 10.1 6.12

[a] Each beach was characterized with three beach-wide composite samples.
[b] Beach 5 extends beyond the Upper Reach to RM 2.5.

[a] Conditions depicted in this figure are representative of information and criteria provided in the Intertidal Clam Survey Data Report (2004, Figure 1d) as updated and presented in the Lower Duwamish Waterway Final Feasibility Study (2012). The potential clamming area upstream of RM 4.8 was not surveyed and is inferred.

N

0 500 1,000 Feet

0 200 400 Meters

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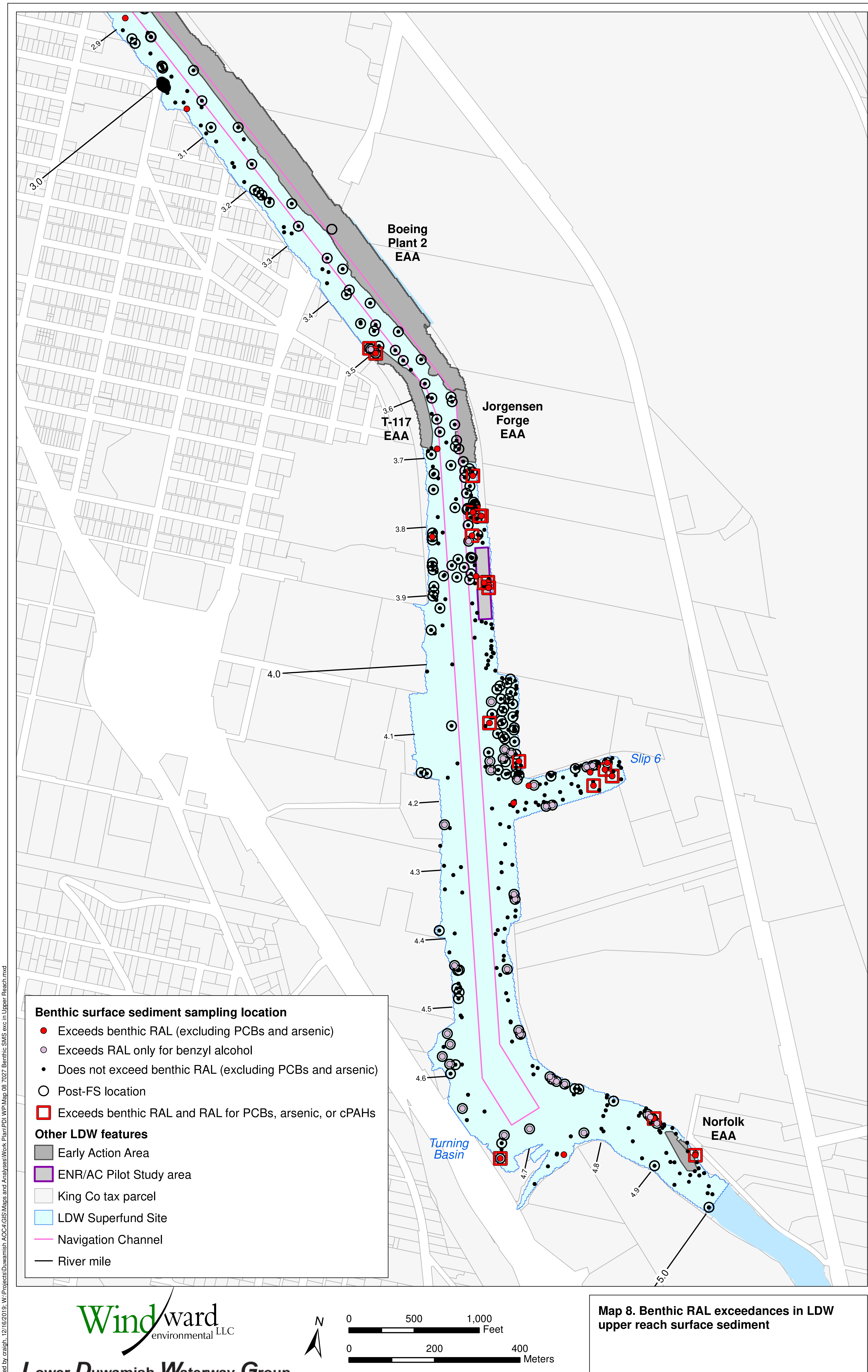
Map 7. Arsenic results compared to RAL in the LDW upper reach

LDW Upper Reach Pre-Design Investigation Work Plan

Prepared by craigh, 12/16/2019; W:\Projects\Duwamish AOC4\GIS\Maps and Analyses\Work Plan\PDI WP\Map 07 6849 Surface sediment compositing data - wAllSed - Arsenic.mxd



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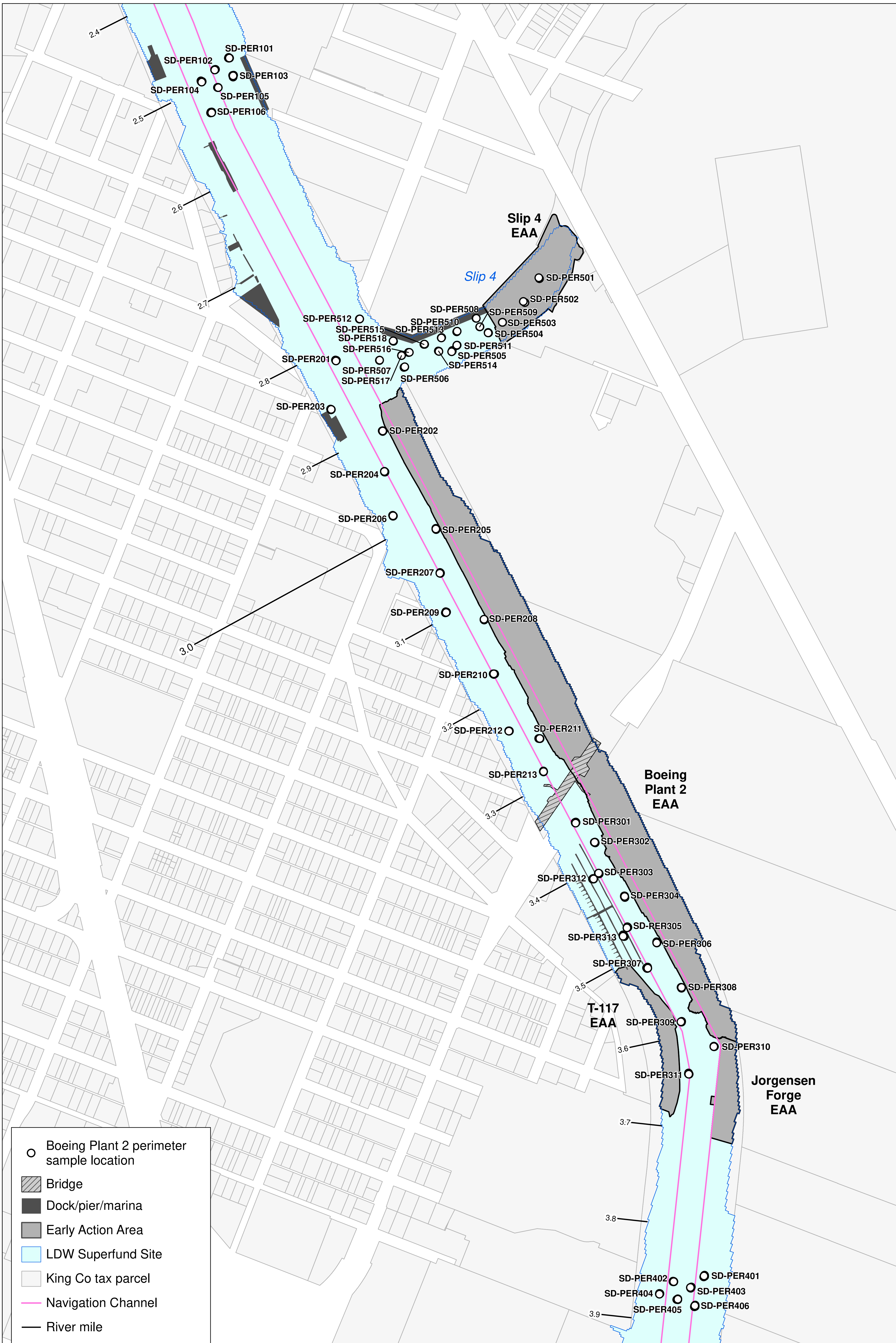
Map 8. Benthic RAL exceedances in LDW upper reach surface sediment

Prepared by craigh, 12/16/2019; W:\Projects\Duwamish AOC4\GIS\Maps and Analyses\Work Plan\PDI WP\Map 08 7027 Benthic SMS exc in Upper Reach.mxd



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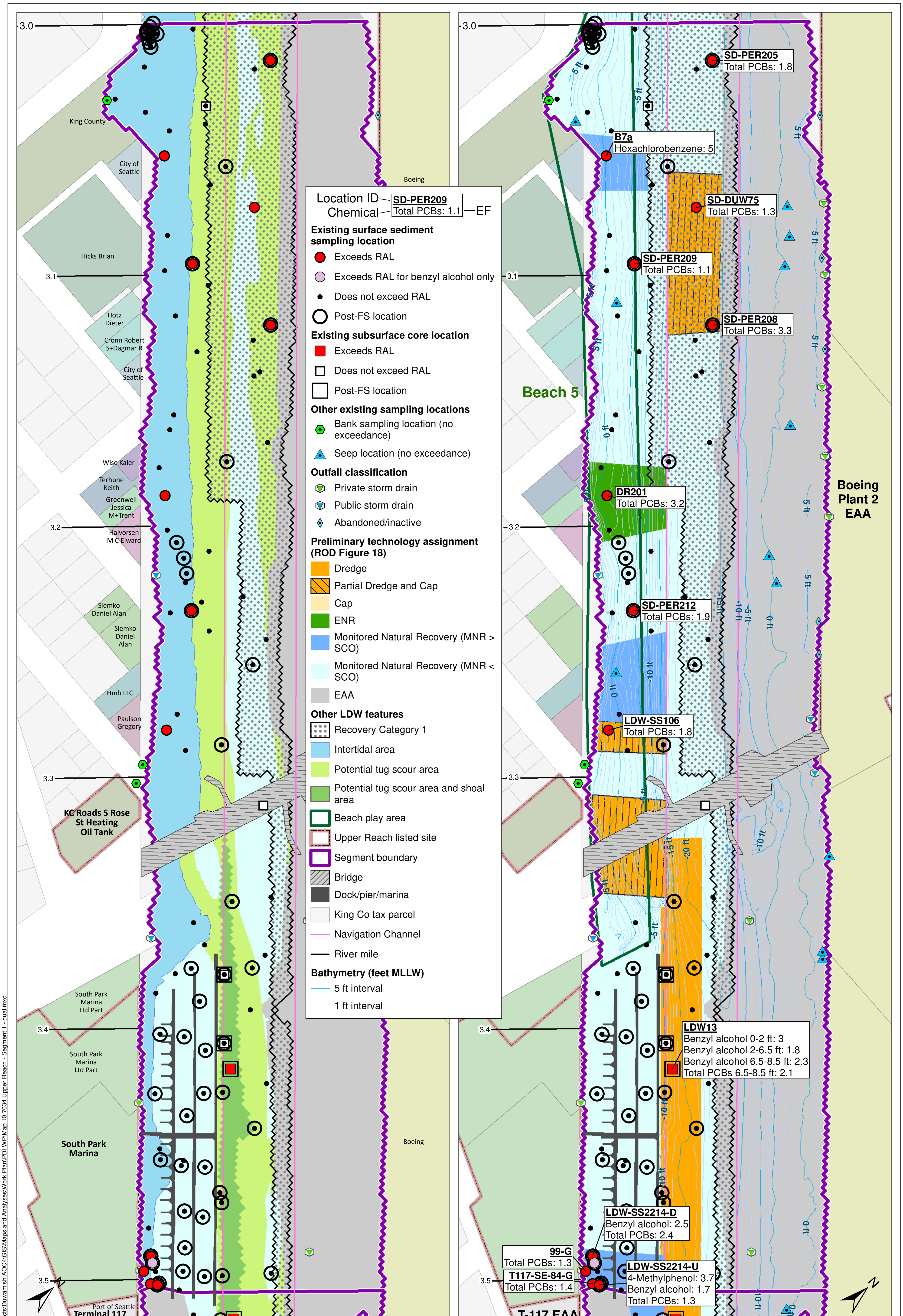
N
0 400 800 Feet
0 100 200 Meters

Map 9. Boeing Plant 2 perimeter sample locations in the LDW



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0 200 400 Feet

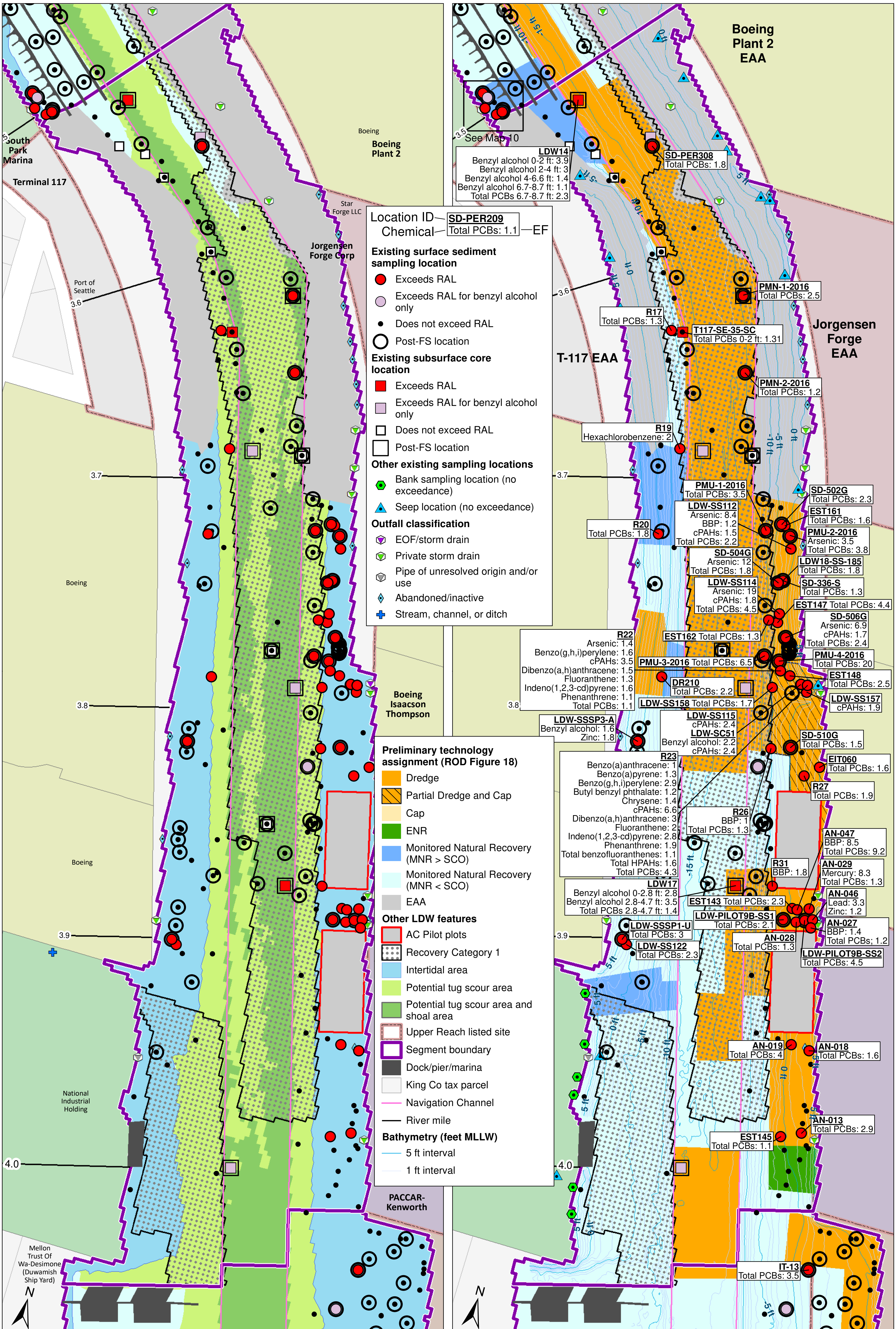
0 50 100 Meters

Scale is the same for each inset map

Map 10. Segment 1 (RM 3.0 to RM 3.5) sediment RAL exceedances, bathymetry, and ROD Figure 18 remedial action areas

LDW Upper Reach Pre-Design Investigation Work Plan

Prepared by craigh, 12/16/2019; W:\Projects\Duwamish AOC4\GIS\Maps and Analyses\Work Plan\PDI WP\Map 10 7034 Upper Reach - Segment 1 - dual.mxd



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0 200 400 Feet

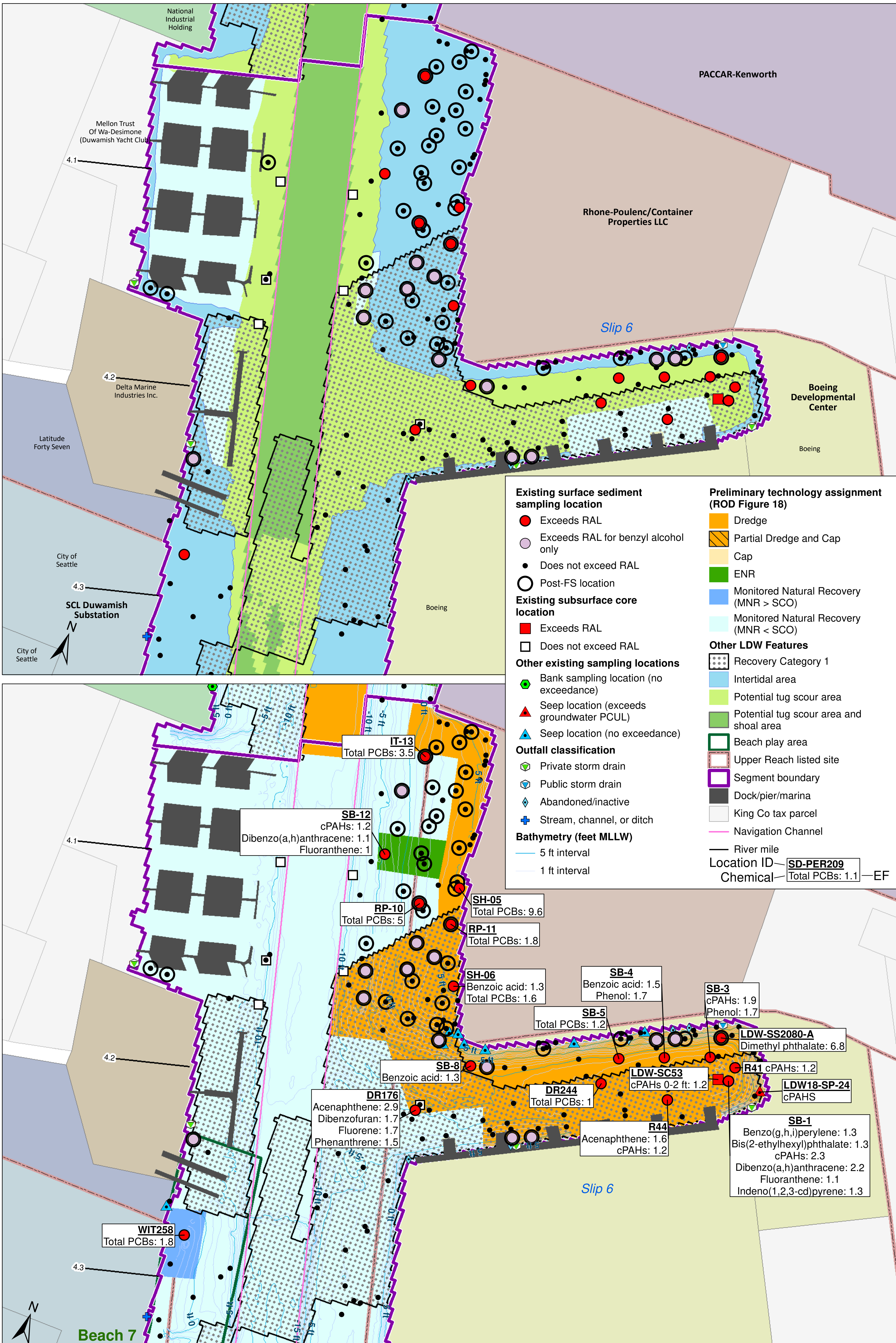
0 50 100 Meters

Scale is the same for each inset map

Map 11. Segment 2 (RM 3.5 to RM 4.05) sediment RAL exceedances, bathymetry, and ROD Figure 18 remedial action areas

LDW Upper Reach Pre-Design Investigation Work Plan

Prepared by craigh, 12/16/2019; W:\Projects\Duwamish AOC4\GIS\Maps and Analyses\Work Plan\PDI WP\Map 11 7034 Upper Reach - Segment 2 - dual.mxd



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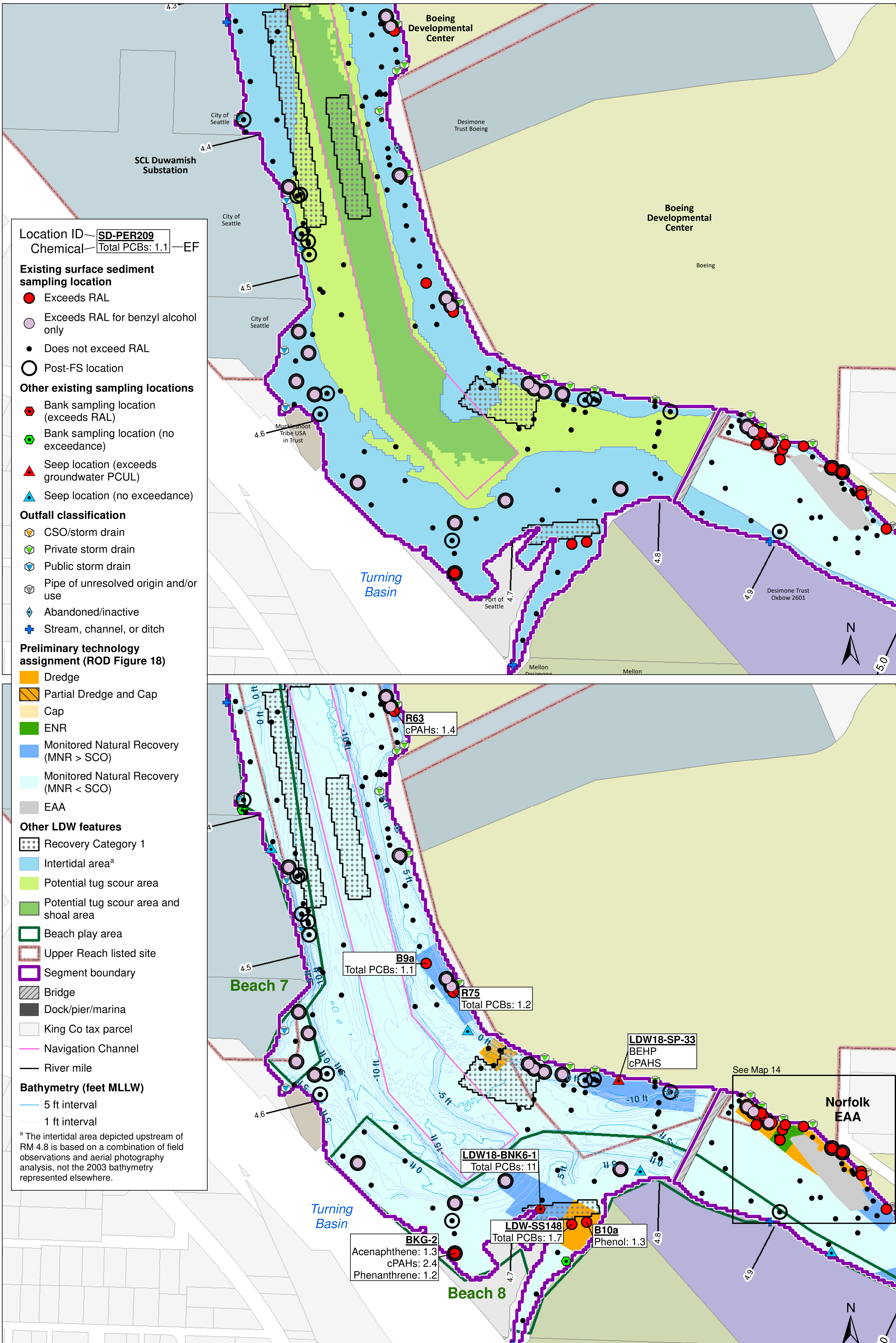
0 200 400 Feet
0 50 100 Meters
Scale is the same for each inset map

Map 12. Segment 3a (RM 4.05 to RM 4.35) sediment RAL exceedances, bathymetry, and ROD Figure 18 remedial action areas

LDW UPPER REACH PRE-DESIGN INVESTIGATION WORK PLAN

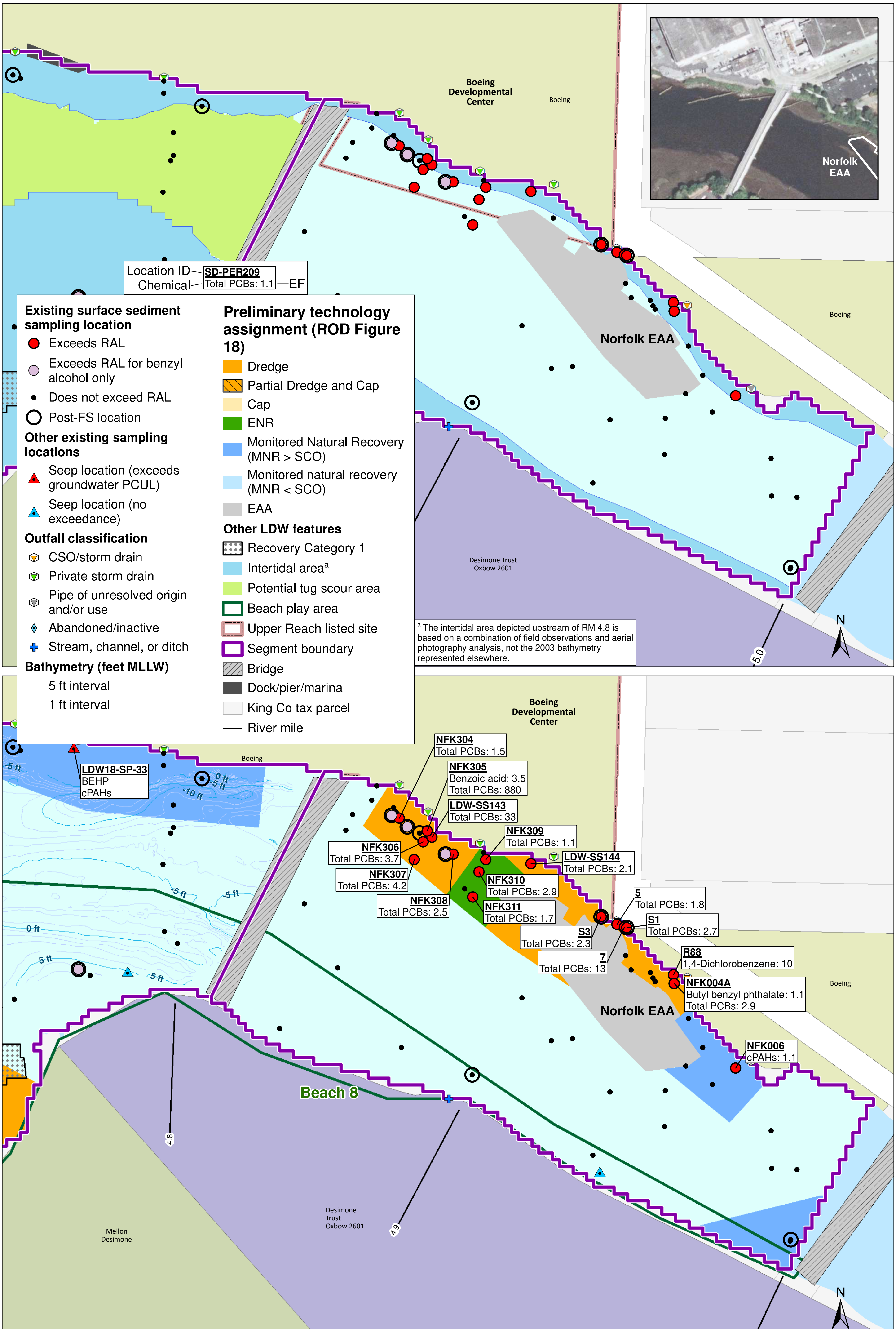
Prepared by craigh, 12/16/2019; W:\Projects\Duwamish AOC4\GIS\Maps and Analyses\Work Plan\PDI WP\Map 12 7034 Upper Reach - Segment 3a - dual.mxd



0 300 600 Feet
0 100 200 Meters
Scale is the same for each inset map

Map 13. Segment 3b (RM 4.35 to RM 4.8) sediment RAL exceedances, bathymetry, and ROD Figure 18 remedial action areas

LDW Upper Reach Pre-Design Investigation Work Plan



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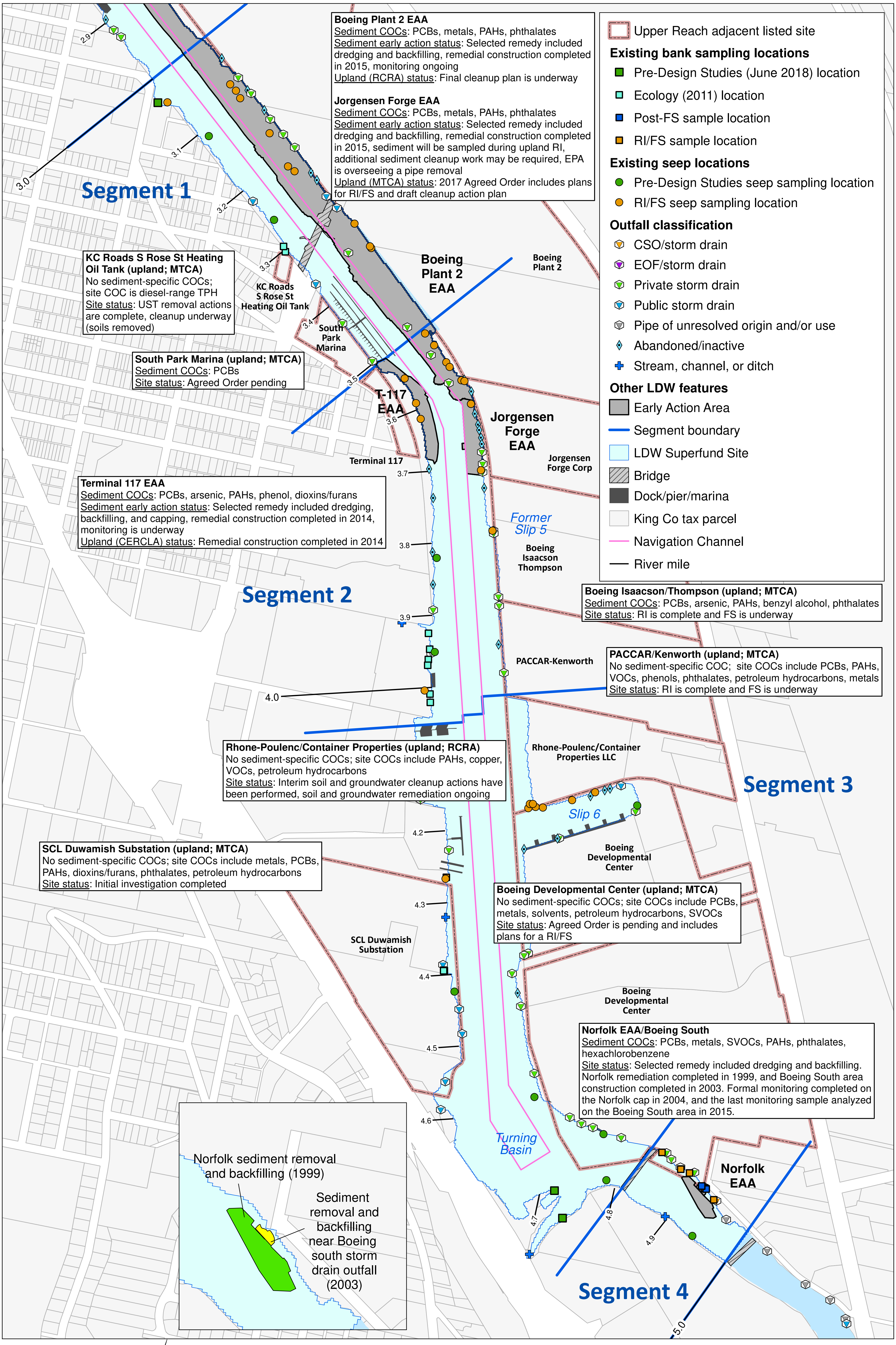
0 100 200 Feet

0 40 80 Meters

Scale is the same for each inset map

Map 14. Segment 4 (RM 4.8 to RM 5.0) sediment RAL exceedances, bathymetry, and ROD Figure 18 remedial action areas



Map 15. EAAs and adjacent listed sites in the LDW upper reach

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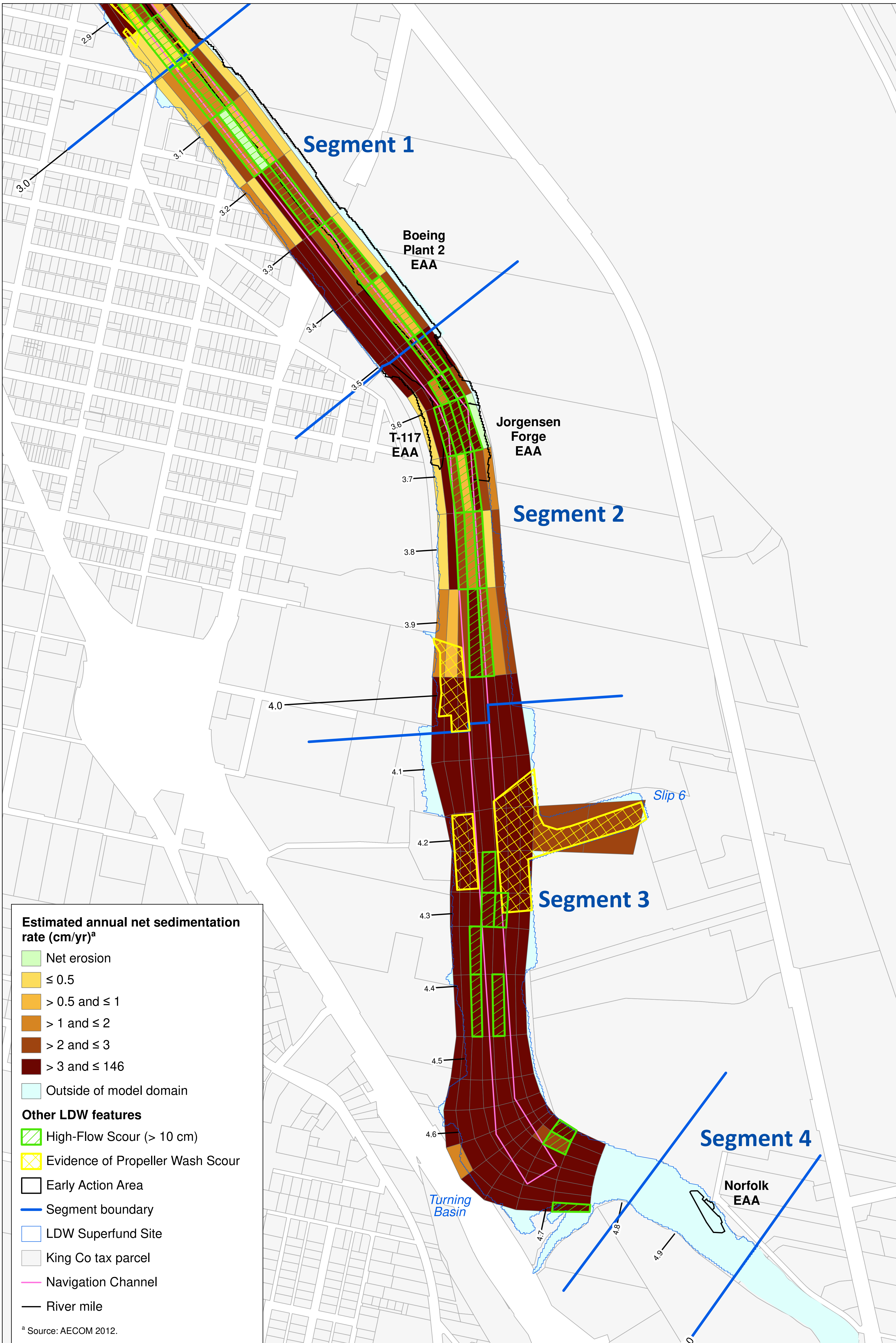
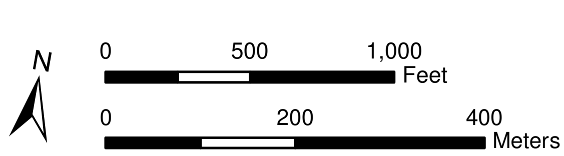
Prepared by craigh, 12/16/2019; W:\Projects\Duwamish AOC4\GIS\Maps and Analyses\Work Plan\PDI WP\Map 15 7054 EAAs and listed sites.mxd





Map 16. Estimated annual net sedimentation rates and scour areas in the LDW

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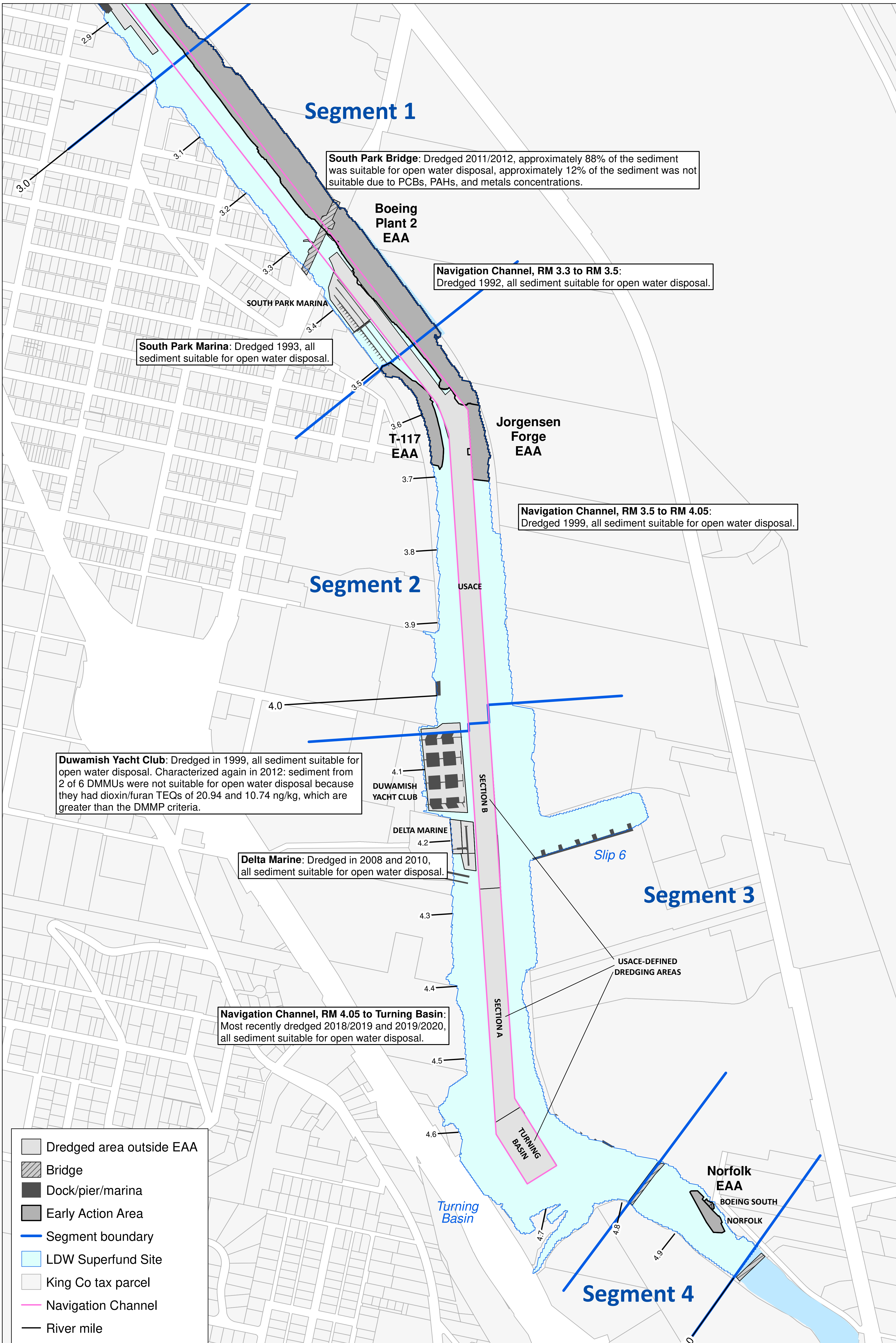
Prepared by craigh, 12/16/2019; W:\Projects\Duwamish AOC4\GIS\Maps and Analyses\Work Plan\PDI WP\Map 16 7051 Estimated annual net sedimentation rates.mxd



N

0 500 1,000 Feet

0 200 400 Meters

Prepared by craigh, 12/16/2019; W:\Projects\Duwamish AOC4\GIS\Maps and Analyses\Work Plan\PDI WP\Map 17 7055 Dredge areas.mxd

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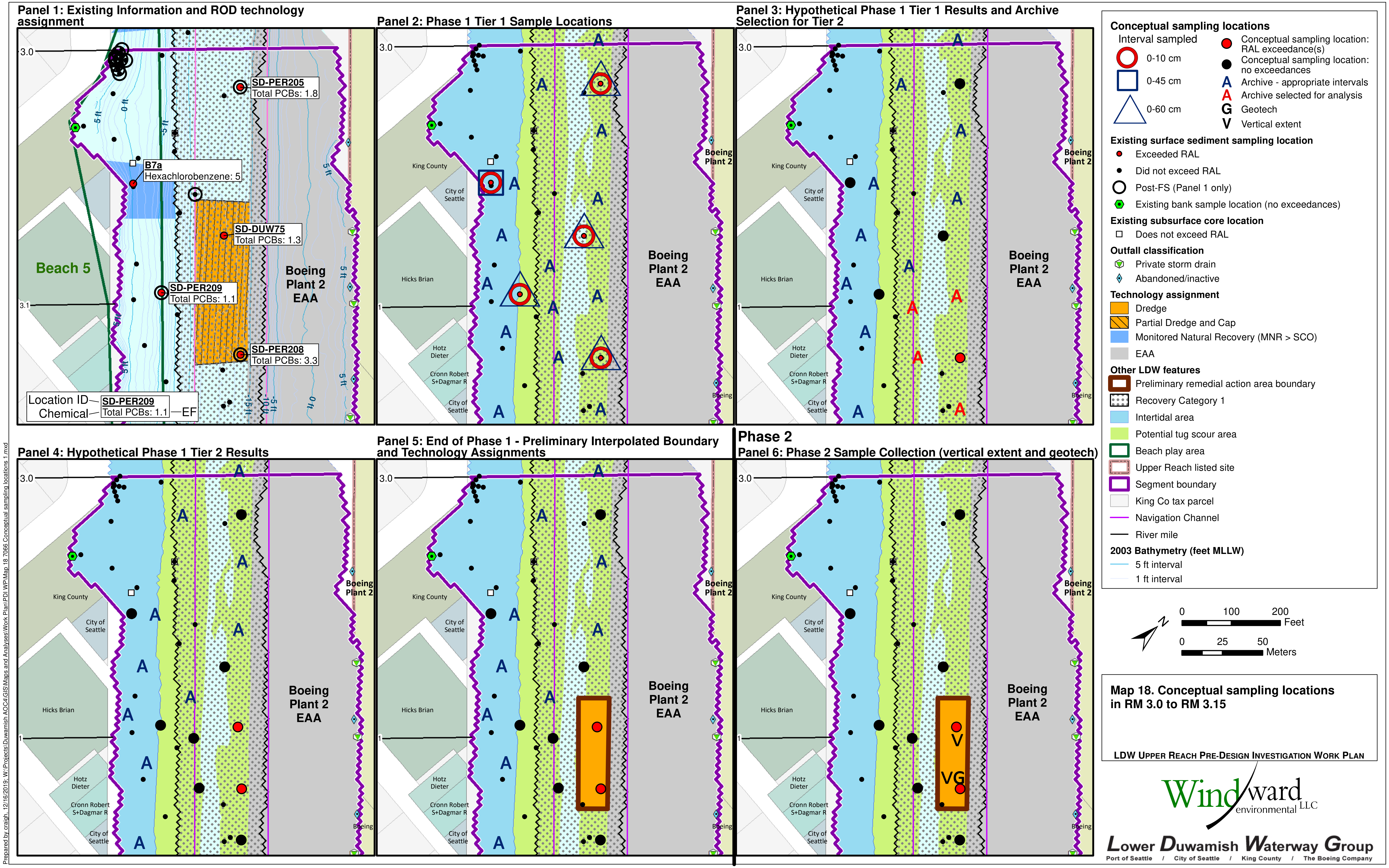
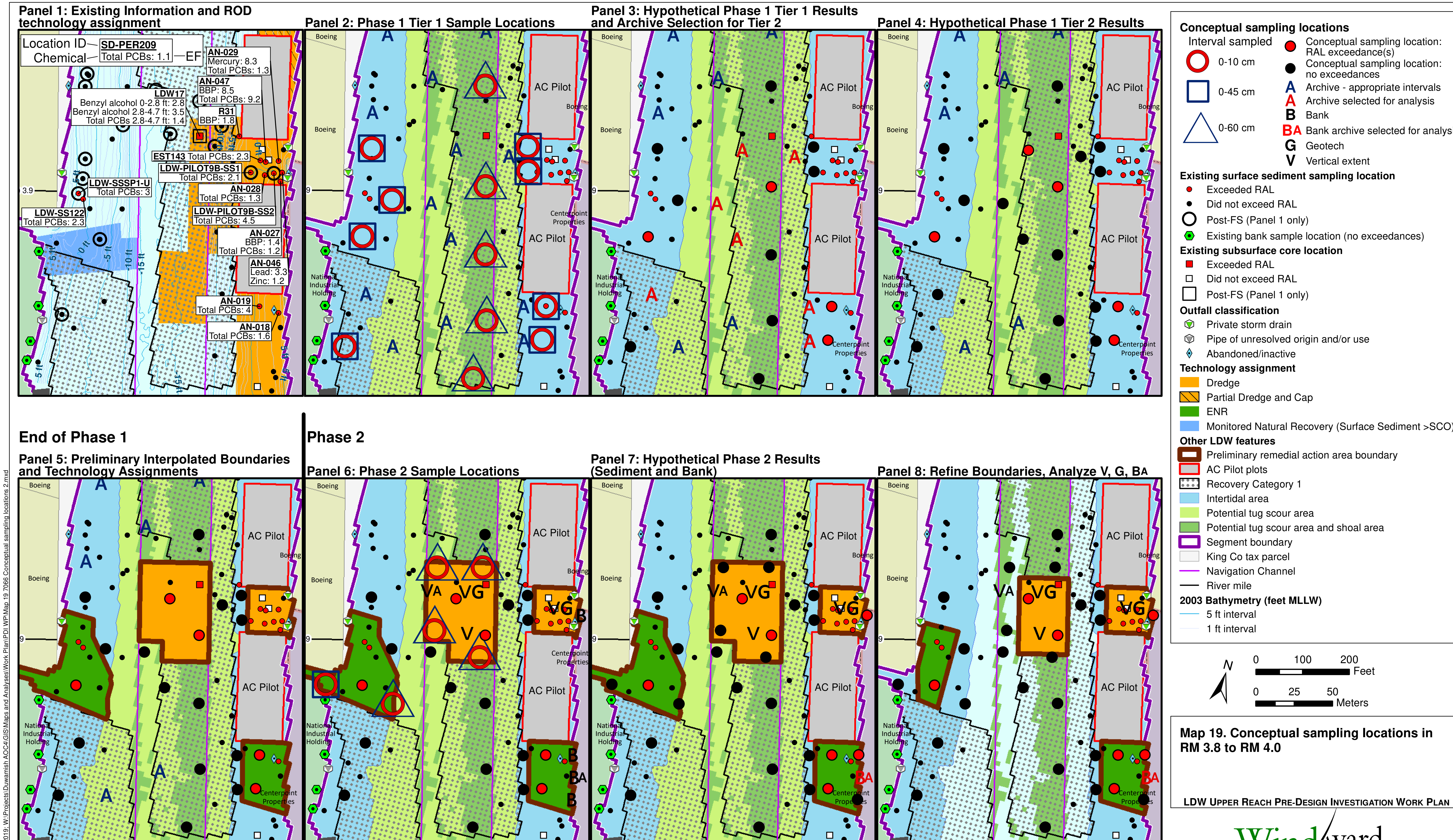
Map 17. Areas in the LDW upper reach dredged since 1992



Map 18. Conceptual sampling locations in RM 3.0 to RM 3.15

LDW Upper Reach Pre-Design Investigation Work Plan



Map 19. Conceptual sampling locations in RM 3.8 to RM 4.0

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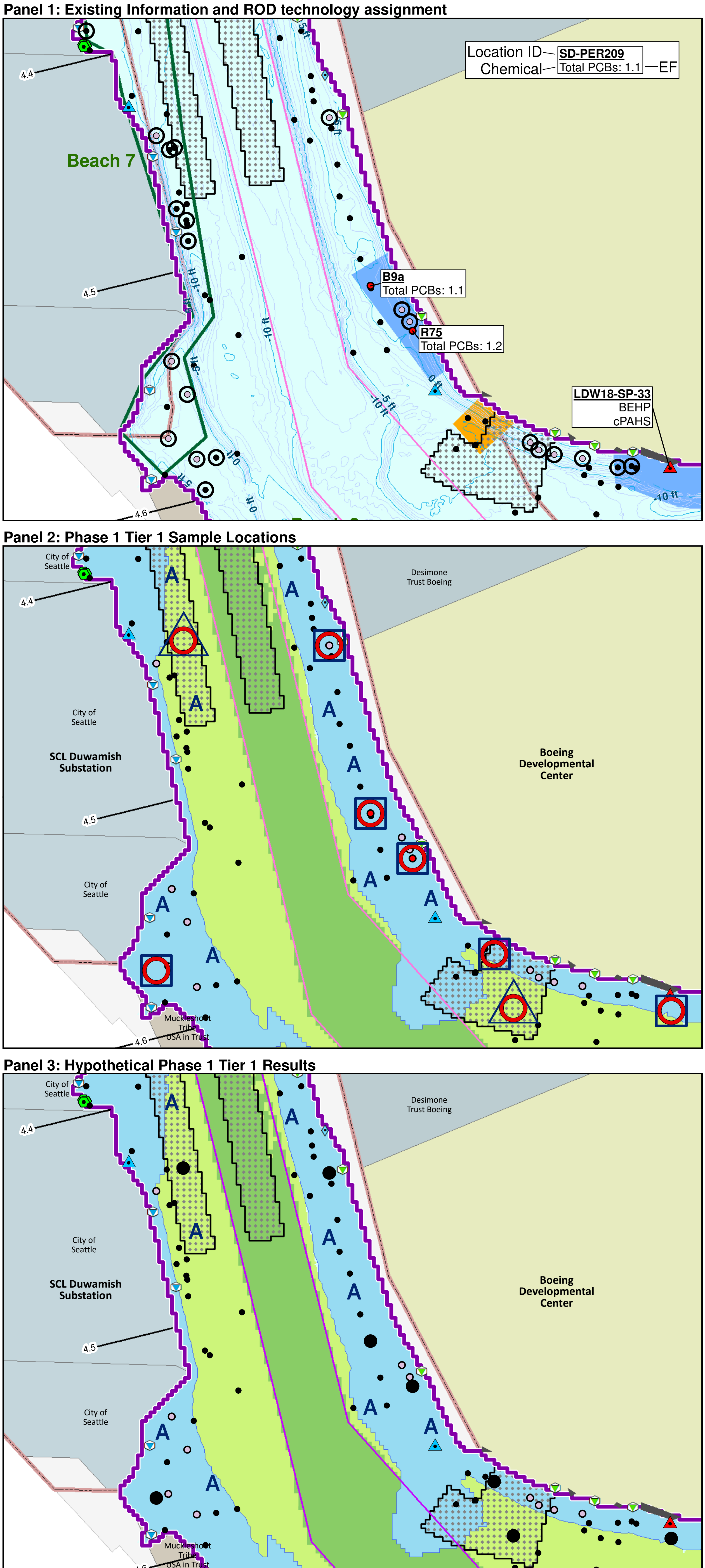
Prepared by craigh, 12/16/2019; W:\Projects\Duwamish AOC4\GIS\Maps and Analyses\Work Plan\PDI WP\Map 19 7066 Conceptual sampling locations 2.mxd



Conceptual sampling locations

Interval sampled
- 0-10 cm
- 0-45 cm
- 0-60 cm
- Conceptual sampling location: RAL exceedance(s)
- Conceptual sampling location: no exceedances
- A Archive - appropriate intervals

Existing surface sediment sampling location
- Exceeds RAL
- Exceeds RAL for benzyl alcohol only
- Does not exceed RAL

Other existing sampling locations
- Bank sampling location (no exceedance)
- Seep location (exceeds groundwater PCUL)
- Seep location (no exceedance)

Outfall classification
- Private storm drain
- Public storm drain
- Abandoned/inactive

Technology assignment
- Dredge
- Monitored Natural Recovery (MNR > SCO)

Other LDW features
- Recovery Category 1
- Intertidal area
- Potential tug scour area
- Potential tug scour area and shoal area
- Beach play area
- Dock/pier/marina
- Upper Reach listed site
- Segment boundary
- King Co tax parcel
- Navigation Channel
- River mile

Bathymetry (feet MLLW)
- 5 ft interval
- 1 ft interval

N

0 200 400 Feet

0 50 100 Meters

Map 20. Conceptual sampling locations in RM 4.4 to RM 4.6

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Prepared by craigh, 12/16/2019; W:\Projects\Duwamish AOC4\GIS\Maps and Analyses\Work Plan\PDI WP\Map 20 7066 Conceptual sampling locations 3.mxd

Attachment A to Appendix C. Benzyl Alcohol Supplemental Information

Introduction

To support an approach to biological testing for benzyl alcohol during remedial design, this attachment summarizes information about benzyl alcohol and changes to analytical methods that may affect the link between concentrations and potential toxicity. The Pre-Design Investigation Quality Assurance Project Plan (PDI QAPP) will include a proposed approach to biological testing.

Benzyl alcohol is an aromatic organic alcohol that is present in a wide variety of plants, including edible fruits, teas, and flowering plants. It is also produced industrially for use as a solvent, a preservative, and feedstock for the manufacture of other chemicals and is a transient intermediate by-product of toluene oxidation. Benzyl alcohol is readily biodegradable, with 94% degradation measured in a standard 28-day test conducted under aerobic conditions (NIH 2019), and thus is not persistent in sediment. It is not hydrophobic, with an octanol-water partition coefficient range of 1.00 to 1.16 (EPA 1989; Montgomery 2000). Therefore, benzyl alcohol is of low concern for bioaccumulation (EPA 1989).

Washington State's benzyl alcohol sediment cleanup objective (SCO) (57 µg/kg) was established in 1986 based on the apparent effects threshold for the Microtox® bioassay. Benzyl alcohol was rarely detected in sediment collected in Washington State, including in the Lower Duwamish Waterway (LDW), prior to 2010 (Fourie and Fox 2016). LDW locations with benzyl alcohol data are shown on Map A-1. In the remedial investigation/feasibility study (RI/FS) dataset for the LDW (Windward 2010; AECOM 2012), benzyl alcohol was rarely detected in surface and subsurface sediment samples with reporting limits (RLs) that ranged from 0.9 to 4,200 µg/kg, with a median of 33 µg/kg,[1] and there were very few detected results that exceeded the benzyl alcohol SCO (Table A-1, Figure A-1). However, investigations conducted since 2010 have reported greater detection frequencies and exceedances of the SCO in sediment collected throughout Washington State, including in the LDW (Fourie and Fox 2016). Benzyl alcohol concentrations, total organic carbon (TOC), and percent fines are provided in Table A-2 for the upper reach locations that only have exceedances of the benzyl alcohol remedial action level (RAL).

[1] RLs are sample specific and are affected by sample dilution. The highest RL values reflect samples that were diluted in order to get target semi-volatile organic compound concentrations within calibration ranges.

Table A-1
Summary of LDW-wide Surface and Subsurface Sediment Benzyl Alcohol Data

Date Range	No. of Sediment Samples	Benzyl Alcohol Detection Frequency	Number of Non-Detect Locations with Reporting Limits greater than SCO	Number Locations with Detected SCO Exceedances	Detected SCO Exceedance Frequency
RI/FS Dataset					
1990–1994	99	0%	5	0	0%
1995–1999	649	1.5%	102	0	0%
2000–2004	125	8%	9	1	0.8%
2005–2009	572	4%	46	24	4.2%
Post-FS Dataset					
2010–2014	865	64%	21	332	38.4%
2015–2018	155	44%	4	24	15.4%

Notes:
FS: feasibility study
LDW: Lower Duwamish Waterway
RI: remedial investigation
SCO: sediment cleanup objective

Table A-2
Surface sediment Samples in the Upper Reach that Exceed the RAL for Only Benzyl Alcohol

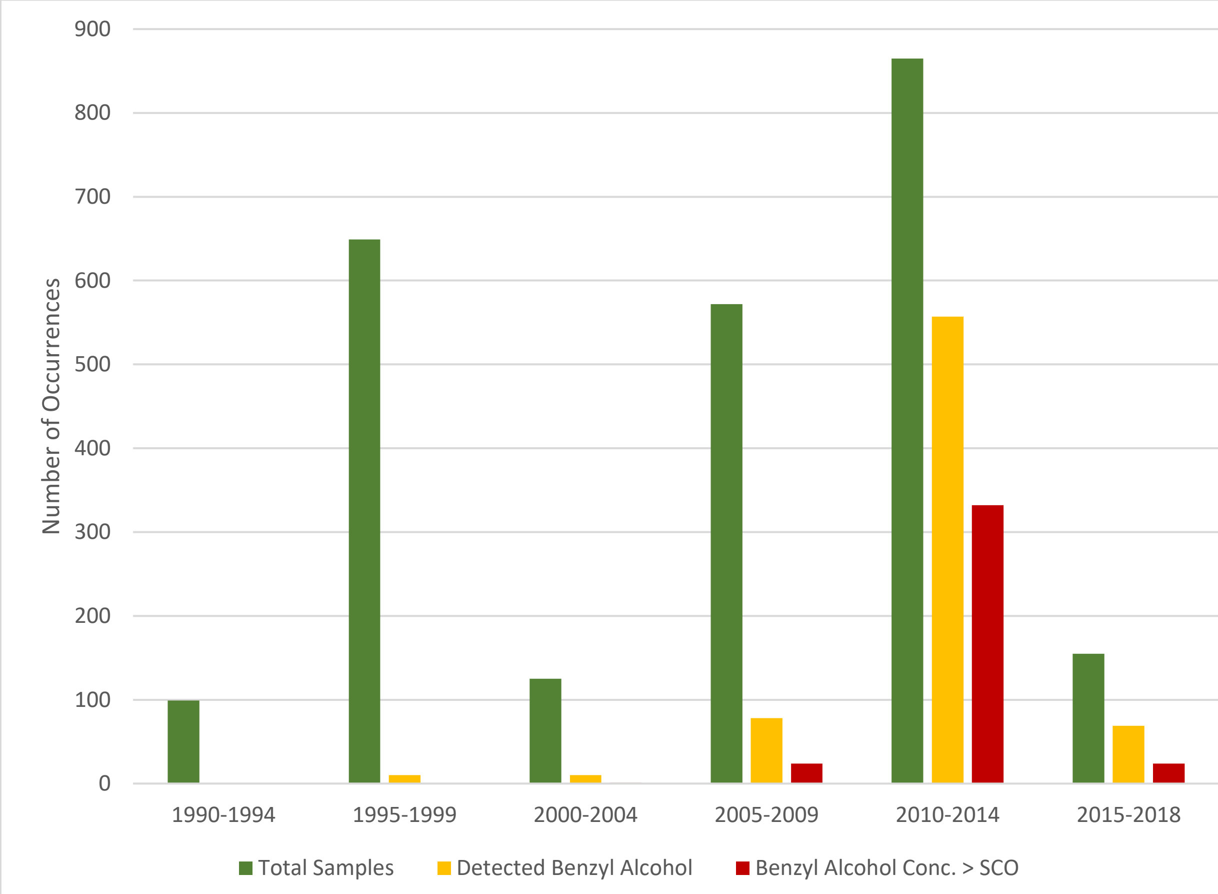
Sample Name	Benzyl Alcohol Conc. (µg/kg)	Benzyl Alcohol RAL (µg/kg)	TOC (% dw)	Fines (% dw)
LDW18-SSOT-DeltaMarine	600	114	2.40	78.6
LDW-SS2085-A	360	114	2.35	77.7
LDW-SS2089-A	360	114	3.53	89.3
LDW-SS2089-D	300	114	3.31	88.8
LDW-SS2083-A	290	57	2.66	92.0
LDW-SS2082-U	280	57	4.00	94.2
LDW-SS2214-A	280 J	114	2.70	94.5
LDW-SS2092-A	250	114	1.99	71.7
LDW-SSBDC2-U	230	114	2.35	57.4
LDW-SS2094-D	220	114	2.46	60.2

Sample Name	Benzyl Alcohol Conc. (µg/kg)	Benzyl Alcohol RAL (µg/kg)	TOC (% dw)	Fines (% dw)
LDW-SS2097-D	220	114	2.17	73.6
LDW-SSBDC2-D	200	57	2.23	60.8
RP-24	200 J	57	1.38	63.1
LDW-SS2214-U	190 J	114	2.69	92.0
LDW-SSSP3-A	180	114	1.56	0.1
LDW-SS2090-D	150	114	3.24	83.9
LDW-SS2200-D	150	114	2.38	63.1
RP-20	150 J	114	3.78	89.2
LDW-SS2200-A	140	114	2.33	55.5
LDW-SS2201-A	140	114	1.70	67.2
LDW-SSBDC2-A	140	57	1.28	57.3
LDW-SS2090-A	130	114	3.32	81.7
LDW-SS2201-D	130	114	2.58	74.0
RP-25	130 J	57	1.92	67.8
LDW-SS2078-A	120 J	114	3.13	90.0
LDW-SS2078-D	120 J	114	3.27	61.7
LDW-SS2099-D	120 J	114	4.01	67.5
LDW-SSBDC3-D	120	114	1.66	60.6
RP-17	110	57	1.98	74.7
RP-12	66	57	2.66	59.7

Notes:

dw: dry weight
J: estimated concentration
RAL: remedial action level
TOC: total organic carbon

Figure A-1
Number of Samples with Benzyl Alcohol Detected and Detected Concentrations Above the SCO in LDW Surface and Subsurface Sediment Samples



The history of benzyl alcohol exceedances in the upper reach of the LDW is consistent with the LDW-wide trends (Table A-3). There were no benzyl alcohol concentrations in the 0- to 10-cm samples in the RI/FS dataset that exceeded the SCO. After 2010, the detection frequency and number of SCO exceedances increased dramatically, with 48% of the samples having concentrations greater than the SCO. All benzyl alcohol exceedances in surface sediment in the upper reach (Map A-2) are associated with studies conducted after 2010.

Table A-3
Summary of Benzyl Alcohol Sediment Data in the Upper Reach of the LDW

Sediment Interval and Dataset	No. of Sediment Samples	Benzyl Alcohol Detection Frequency	No. of SCO Exceedances	Exceedance Frequency
0–10 cm – RI/FS	234	2%	0	0%
0–60 cm – RI/FS	25	12%	2	8%
0–10 cm – post-FS	128	77%	62	48%
0–60 cm – post-FS	5	100%	5	100%

Notes:
FS: feasibility study
LDW: Lower Duwamish Waterway
RI: remedial investigation
SCO: sediment cleanup objective

Analytical Improvements

In 2016, the U.S. Army Corps of Engineers (USACE) reviewed the changes in benzyl alcohol concentrations on behalf of the Dredged Material Management Program (DMMP) and concluded that the most likely cause of the dramatic increase in benzyl alcohol detections and concentrations since 2010 is changes in the analytical methods used for the analysis of semi-volatile organic compounds (SVOCs) (Fourie and Fox 2016). The changes in analytical methods include improvements in sample extraction methods, extract cleanup methods, and analytical technology, including chromatographic equipment and instrument conditions, such as injection port temperatures.

Benzyl alcohol is quantified as a SVOC using U.S. Environmental Protection Agency (EPA) method 8270. This method was developed for the analysis of non-polar organic compounds, such as polycyclic aromatic hydrocarbons and phthalates. Benzyl alcohol is more chemically reactive than these non-polar compounds, and laboratories have historically had difficulty with benzyl alcohol recoveries due to chromatographic interferences. Specifically, benzyl alcohol has a strong tendency to react with high-molecular-weight humic materials present in a sample.

In the 1990s, the standard sediment sample mass for SVOC analysis was large (60 to 100 g wet weight [ww]) compared to the mass required by current extraction protocols (20 to 30 g ww). The larger sediment masses were necessary to achieve the required sensitivity for target analytes. However, the large sample sizes also resulted in high levels of high-molecular-weight humic materials and other reactive materials. The presence of these potentially interfering compounds required additional cleanup steps that removed both the interfering compounds and the benzyl alcohol.

In order to increase the efficiency and sensitivity of their protocols, laboratories have developed protocols that enable them to reduce the sediment mass required for analysis. Less mass reduces the presence of humic materials that can cause matrix interferences in the sample extract. Fewer interferences reduces the need for post-extraction cleanup steps and improves the chromatographic performance of the sample. It appears that the improvements in laboratory protocols have resulted in the increased detections and concentrations of benzyl alcohol (Fourie and Fox 2016).

If the analytical method changes are responsible for the changes in benzyl alcohol detections and concentrations, then the 1986 sediment concentrations used to set the SCO were biased low relative to the results currently being reported. Therefore, an SCO exceedance based on current analytical methods is not directly comparable to an SCO exceedance in samples collected prior to the analytical method changes. As a result, the benzyl alcohol concentration at which toxicity occurs may be greater than the SCO when samples are analyzed with the updated analytical methods.

Toxicity of Benzyl Alcohol

The Washington State Sediment Management Standards allow a toxicity override when chemical sediment criteria are exceeded. This override is particularly important when chemistry results are subject to interpretation (e.g., different method, unusual mixture). Toxicity tests may also provide another line of evidence supporting the update of SCOs based on previous analytical methods.

In the upper reach of the LDW, bioassays have been conducted for 20 surface sediment samples (Map A-2). All of the samples, which were collected in 2011 as part of a sediment characterization study conducted in the vicinity of the former Rhone-Poulenc facility (Cardno Entrix 2012), passed all of the bioassays. The highest benzyl alcohol concentration that passed all three bioassays in surface sediment was 260 µg/kg (Table A-4). This concentration is more than four times greater than the SCO of 57 µg/kg.

Table A-4
Bioassay Results for Surface Sediment Samples Conducted in the LDW Upper Reach for Which Only Benzyl Alcohol Exceeded the SCO

Sample	Benzyl Alcohol Conc. (µg/kg)	Benzyl Alcohol Conc.> Benthic SCO?	Additional SCO Exceedance? [1]	Amphipod	Larval	Polychaete	Overall
Surface Sediment							
IT1	14	no	no	pass	pass	pass	pass
IT3	19	no	no	pass	pass	pass	pass
IT7	43	no	no	pass	pass	pass	pass
IT5	49	no	no	pass	pass	pass	pass
IT11	65	yes	no	pass	pass	pass	pass
BKG-2	68	yes	Yes – SVOC[2]	pass	pass	pass	pass
IT13	87	yes	Yes - PCBs	pass	pass	pass	pass
IT8	93	yes	no	pass	pass	pass	pass
IT6	96	yes	no	pass	pass	pass	pass
IT14	100	yes	no	pass	pass	pass	pass
BKG-6	110	yes	no	pass	pass	pass	pass
IT9	110	yes	no	pass	pass	pass	pass
IT10	110	yes	no	pass	pass	pass	pass
BKG-1	120	yes	no	pass	pass	pass	pass
IT2	120	yes	no	pass	pass	pass	pass

Sample	Benzyl Alcohol Conc. (µg/kg)	Benzyl Alcohol Conc.> Benthic SCO?	Additional SCO Exceedance? [1]	Amphipod	Larval	Polychaete	Overall
BKG-3	170	yes	no	pass	pass	pass	pass
BKG-5	180	yes	no	pass	pass	pass	pass
IT12	220	yes	no	pass	pass	pass	pass
BKG-4	260	yes	no	pass	pass	pass	pass
IT4	260	yes	no	pass	pass	pass	pass
Subsurface sediment							
DMMU 4	60	yes	no	pass	pass	pass	pass
DMMU 12	66	yes	no	pass	pass	pass	pass
DMMU 17	68	yes	no	pass	pass	pass	pass
DMMU 11	72	yes	no	pass	fail (SCO)	pass	pass
DMMU 5	82	yes	no	pass	pass	pass	pass
DMMU 7	86	yes	yes – PCBs[3]	pass	fail (SCO)	pass	pass
DMMU 10	91	yes	no	pass	pass	pass	pass
LDW13 2-7.2C2	100	yes	no	pass	fail (CSL)	pass	fail
LDW16 0-2.5C	130	yes	no	pass	fail (CSL)	pass	fail
DMMU 8	140	yes	no	pass	pass	pass	pass
DMMU 9	140	yes	no	pass	pass	pass	pass
LDW17 0-3.5C	160	yes	yes - PCBs	pass	fail (CSL)	pass	fail
DMMU 6	200	yes	no	pass	fail (SCO)	pass	pass
LDW18 0-2.8C	290	yes	no	pass	fail (SCO)	pass	pass

Notes:

Source: Cardno Entrix (2012) and Fourie and Fox (2016)

1. SCO exceedances for chemicals other than benzyl alcohol.
2. Sample also exceeded the SCO for 2,4-dimethylphenol, dibenzofuran, five individual PAHs, and total LPAH.
3. Primary sample had PCB concentration below the SCO, field duplicate sample exceeded the SCO for PCBs.

CSL: cleanup screening level

DMMU: dredged material management unit

DMMP: Dredged Material Management Program

LDW: Lower Duwamish Waterway

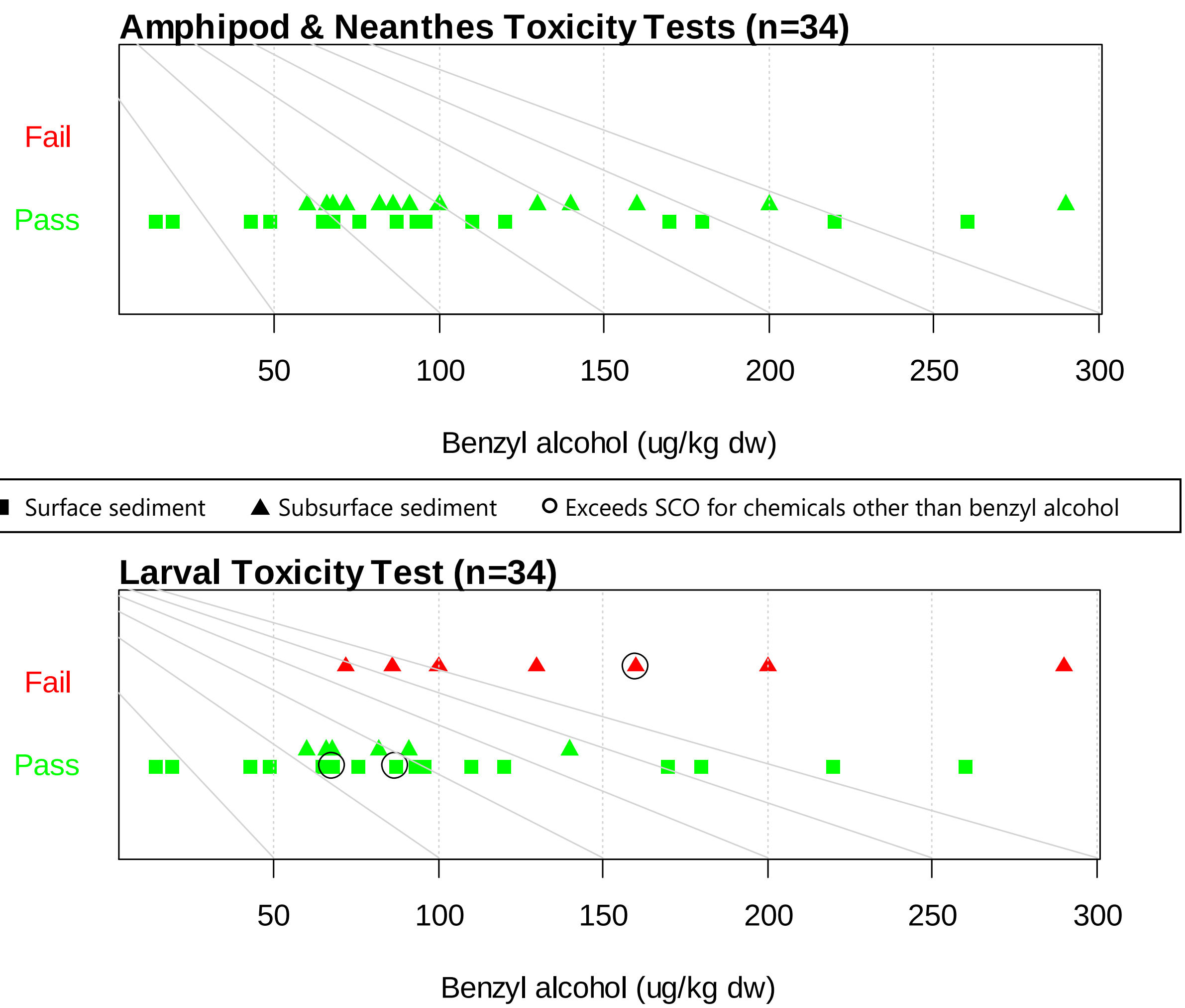
LPAH: low-molecular-weight polycyclic aromatic hydrocarbon

PAH: polycyclic aromatic hydrocarbon
PCB: polychlorinated biphenyl
SCO: sediment cleanup objective
SVOC: Semi-volatile organic compounds

In addition to the 20 surface sediment samples, 14 subsurface composite sediment samples were submitted for bioassay testing for dredge disposal decisions. The data for the subsurface samples are provided in Table A-3. The subsurface composites samples were collected by the ACOE to characterize shoal material throughout the LDW (USACE 2013) and for dredge material characterization in the Navigation Channel between RM 4.05 and RM 4.65 (USACE et al. 2018)(Map A-2[2].

[2] Only the shoal characterization locations are shown on Map A-1.

Figure A-2. Summary of benzyl alcohol concentrations for samples passing (green) and failing (red) SMS biological criteria



Conclusions

The benzyl alcohol remedial action level (RAL) is set at the benthic SCO (in Recovery Category 1 areas) or two times the benthic SCO (in Recovery Category 2/3 areas). The sediment concentrations used to set the benthic SCO were lower than the concentrations that would be quantified today because of chromatographic interferences in the analysis of benzyl alcohol.

The Seattle District Dredge Material Management Program (DMMP) agencies (Ecology, USACE, EPA and Washington Department of Natural Resources) recommend re-evaluation of the benzyl alcohol DMMP guidelines in its 2016 clarification paper because they "do not believe that benzyl alcohol is a chemical of significant concern at the concentrations found in many dredging projects" using current analytical methods (Fourie and Fox 2016). Recent sediment samples from the LDW upper reach have had concentrations of benzyl alcohol similar to those discussed in the DMMP's clarification paper. A toxicity testing approach that considers this information will be outlined in the PDI QAPP or QAPP addendum.

References

AECOM. 2012. Final feasibility study, Lower Duwamish Waterway. Prepared for Lower Duwamish Waterway Group. AECOM, Seattle, WA.

Cardno Entrix. 2012. Sediment Investigation of lower Duwamish Waterway - data summary report. Cardno Entrix, Syracuse, NY.

Ecology. 2019. Sediment cleanup user's manual II. Guidance for implementing the cleanup provisions of the sediment management standards, Chapter 173-204 WAC. May 2019 revised draft for 60 day review and comment. Pub. No. 12-09-057. Toxics Cleanup Program, Washington State Department of Ecology, Olympia, WA.

EPA. 1989. Health and environmental effects document for benzyl alcohol. EPA/600/8-90/033. US Environmental Protection Agency, Cincinnati, OH.

Fourie HW, Fox D. 2016. Revised evaluation guidelines for benzyl alcohol in marine sediments. 2016 Sediment Management Annual Review Meeting, May 4, 2016. DMMP Agencies. pp 96-106.

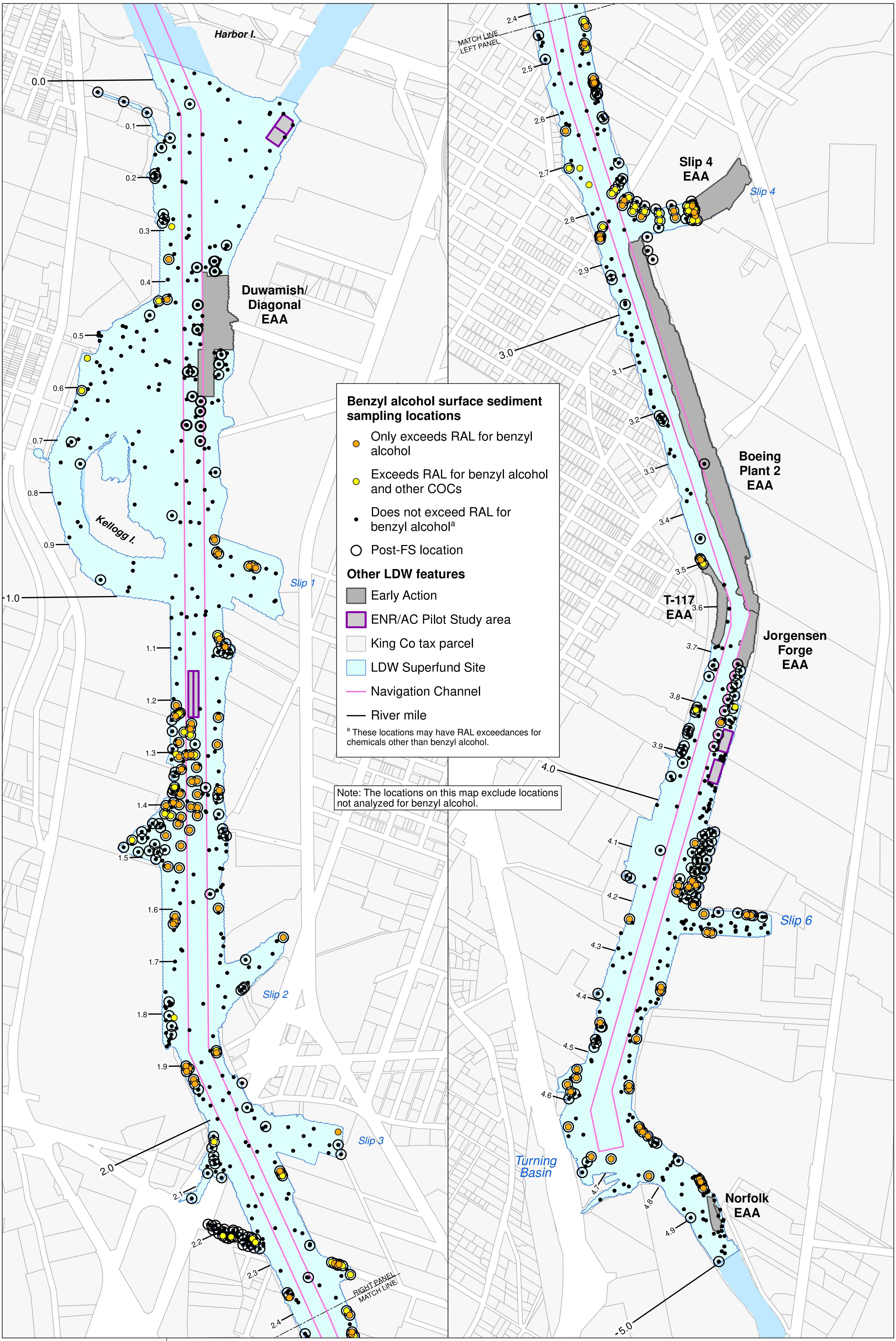
Montgomery JH. 2000. Groundwater Chemicals Desk Reference. 3rd ed. CRC/Lewis Publishers, Boca Raton, FL.

NIH. 2019. Hazardous substances data bank. A TOXNET database [online]. National Institutes of Health, US National Library of Medicine, Bethesda, Maryland. Available from: https://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.

USACE. 2013. Data report - Lower Duwamish Waterway, East Waterway, and West Waterway subsurface sediment characterization. Prepared by HDR Engineering, Inc., Science and Engineering for the Environment LLC, and Ken Taylor Associates. US Army Corps of Engineers, Seattle, WA.

USACE, EPA, Ecology, DNR. 2018. Determination regarding the suitability of maintenance dredged material from the Duwamish River navigation channel evaluated under Seciton 404 of the Clean Water Act for unconfined open-water disposal at the Elliott Bay nondispersive site. US Army Corps of Engineers, US Environmental Protection Agency, Washington State Department of Ecology, and Washington State Department of Natural Resources, Seattle, WA.

Windward. 2010. Lower Duwamish Waterway remedial investigation. Remedial investigation report. Final. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.



Map A-1. Benthic RAL exceedances in LDW surface sediment

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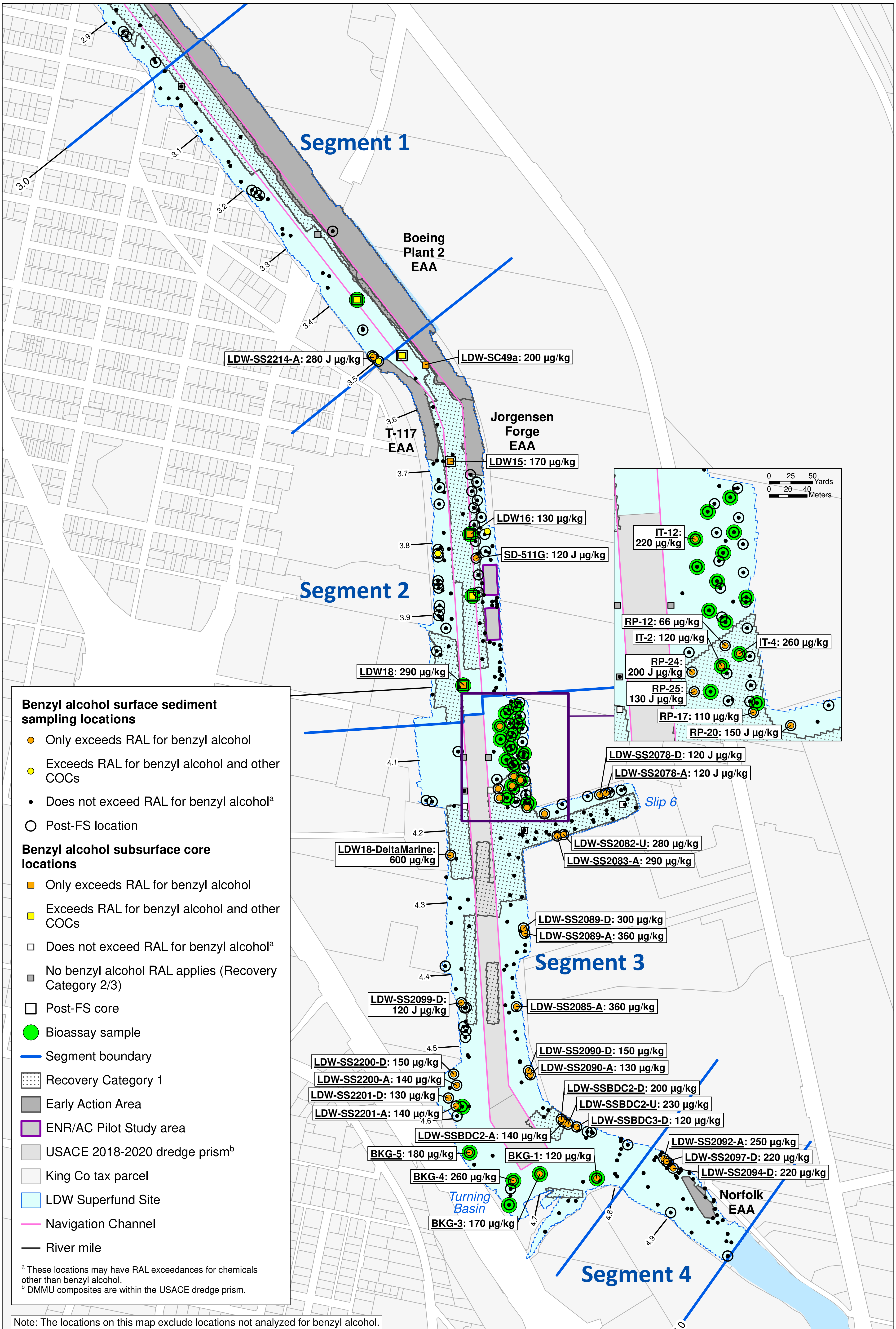

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Map A-2. Benzyl alcohol RAL exceedances and toxicity test results in the LDW upper reach

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ATTACHMENT B TO APPENDIX C. EARLY ACTION AREA MONITORING DATA SUMMARY

Introduction

This attachment to the Pre-Design Investigation Work Plan (PDIWP) describes post-construction monitoring for the four early action areas (EAAs) in the upper reach of the Lower Duwamish Waterway (LDW) and summarizes data available within these EAAs. An understanding of current conditions in the EAAs will inform the sampling design and data interpretation for areas adjacent to EAAs. The data presented in this attachment are post-construction data within the EAA boundaries. The monitoring activities within the four EAAs in the upper reach are summarized in Table B-1. Sampling that occurred outside of the EAA boundaries (i.e., perimeter sampling) is included in the PDIWP discussions.

Table B-1
Summary of monitoring activities within EAAs in the Upper Reach

RM	EAA	Construction Complete	Monitoring Events	Sediment Intervals	COCs
3.0–3.6 E	Boeing Plant 2	2015	2015	0–10 cm (33 locations)	PCBs, PAHs, arsenic, dioxins/furans, other SMS
			2016	0–10 cm (33 locations)	
			2018	0–10 cm (33 locations)	
3.5–3.7 W	T-117	2015	2019	0–10 cm (4 locations)	PCBs, PAHs, arsenic, dioxins/furans (2 locations), phenol
3.6–3.7 E	Jorgensen Forge	2014	2015	0–10 cm and 0–2 cm (19 locations)[a]	PCBs, metals
			2016	0–10 cm, 0–60 cm, and 0–2 cm (19 locations)[a]	
4.9–5.0 E[b]	Norfolk	1999	1999	0–10 cm (4 locations)[c]	PCBs, PAHs, arsenic, other SMS
			2000	0–10 cm (4 locations)	
			2001	0–10 cm (4 locations)	
			2002	0–10 cm (4 locations)	
			2003	0–10 cm (4 locations)	
			2004	0–10 cm (4 locations)	

Notes:

a Jorgensen Forge identified 22 locations (Anchor QEA and Farallon 2016); 3 locations are outside the removal action boundary and not included here.

b The Boeing south storm drain removal, conducted in 2003, was also in this area. Monitoring for PCBs began in 2004; the most recent monitoring event was in 2017.

c Includes only monitoring locations; additional sampling occurred in 2002, 2006, 2008, and 2011.

COC: contaminant of concern

EAA: early action area

PAH: polycyclic aromatic hydrocarbon

PCB: polychlorinated biphenyl

SMS: Washington State Sediment Management Standards

Boeing Plant 2

Construction was completed at the Boeing Plant 2 EAA in 2015, and the remediation achieved all stated objectives (AMEC Foster Wheeler et al. 2016). Under U.S. Environmental Protection Agency (EPA) oversight, The Boeing Company (Boeing) is conducting post-construction monitoring at the Boeing Plant 2 EAA. Boeing is collecting 0- to 10-cm sediment samples at 33 locations. These samples are being analyzed for Washington State Sediment Management Standards (SMS) analytes[1] and dioxins/furans. Results for Year 0 (2015), Year 1 (2016), and Year 3 (2018) analyses are currently available.[2] Total polychlorinated biphenyl (PCB) results are shown on Map B-1 and SMS chemical results with respect to benthic sediment cleanup objectives (SCOs) (WAC 173-204-562) are shown on Map B-2. Additional sampling will be conducted in 2020, 2022, and 2025 (Wood 2018).

In addition to this monitoring, Boeing is performing voluntary monitoring at the Duwamish Sediment Other Area (DSOA) backfill area (Wood 2019). Dredging and backfill construction work was compeleted at the DSOA backfill area in March 2015. The samples in this area were collected between April 2015 and October 2018. Sample locations are shown on Figure B-1. These samples are representative of material that has accumulated on top of the DSOA backfill area cap; sample depths vary depending on the amount of sediment deposition that has occurred since the remedial action. The DSOA samples are being analyzed for conventional parameters and PCB Aroclors. Figure B-2 shows total PCB results for the depositional material as a function of time, Figure B-3 shows post-construction depositional material depths (i.e., surficial silt thicknesses) at sampling locations as a function of time, and Figure B-4 shows total organic carbon (TOC) results for the depositional material (Wood 2019).

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[1] These analytes include the 47 SMS analytes listed in Washington Administrative Code (WAC) 173-204-562., Other reported results include carcinogenic polycyclic aromatic hydrocarbon (cPAH) toxic equivalent (TEQ) and total polycyclic aromatic hydrocarbons (PAHs).

[2] Dioxin/furan TEQ results ranged from 0.0547 UJ (not detected at given estimated concentration) to 0.173 J (estimated concentration) ng /kg in Year 0 (2015), from 0.106 J to 1.28 J ng /kg in Year 1 (2016), and from 0.0547 UJ to 1.28 J ng /kg in Year 3 (2018).

Figure B-1
DSOA Sampling Locations

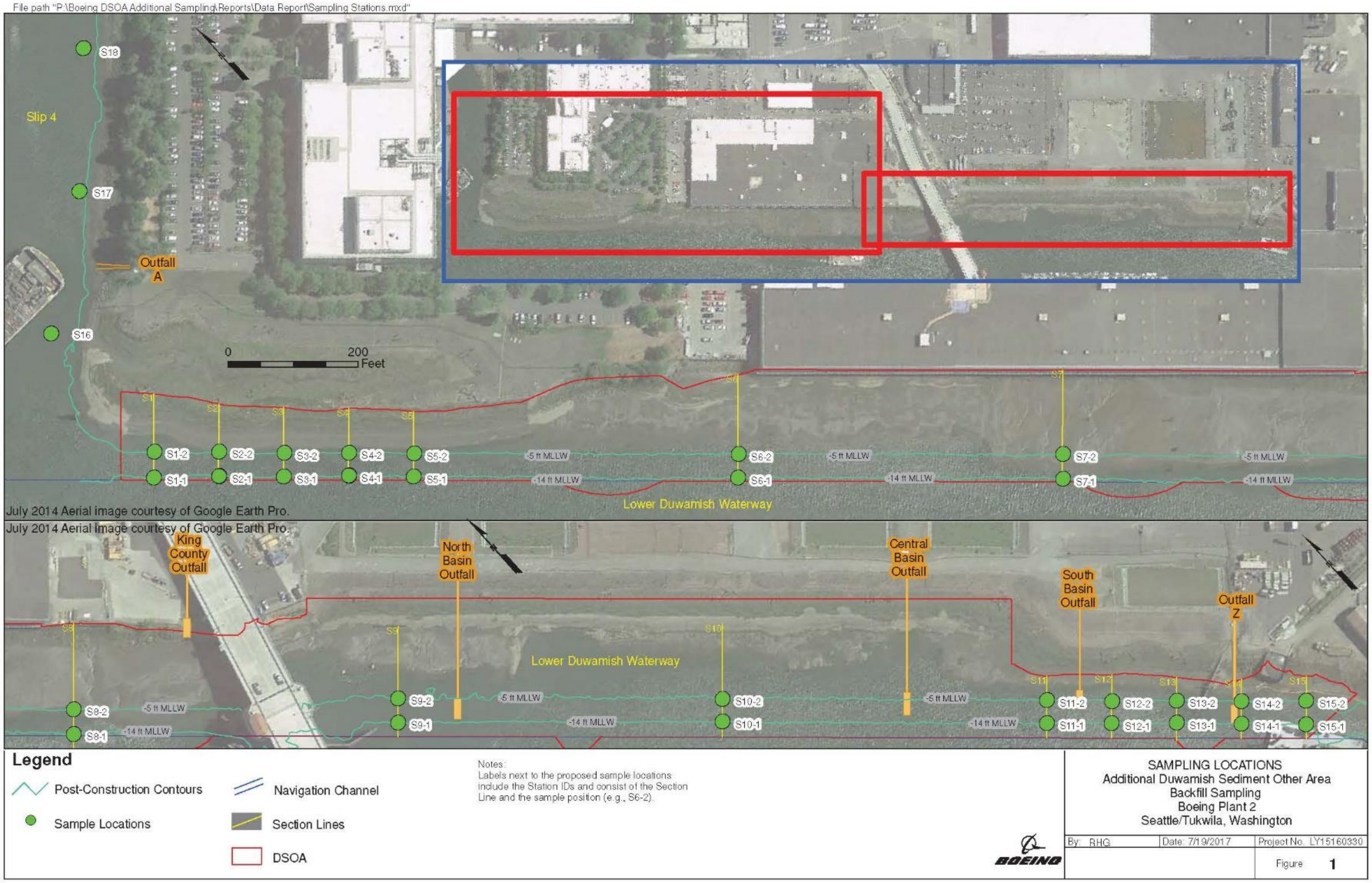


Figure B-2
DSOA Total PCB Results (Wood 2019)

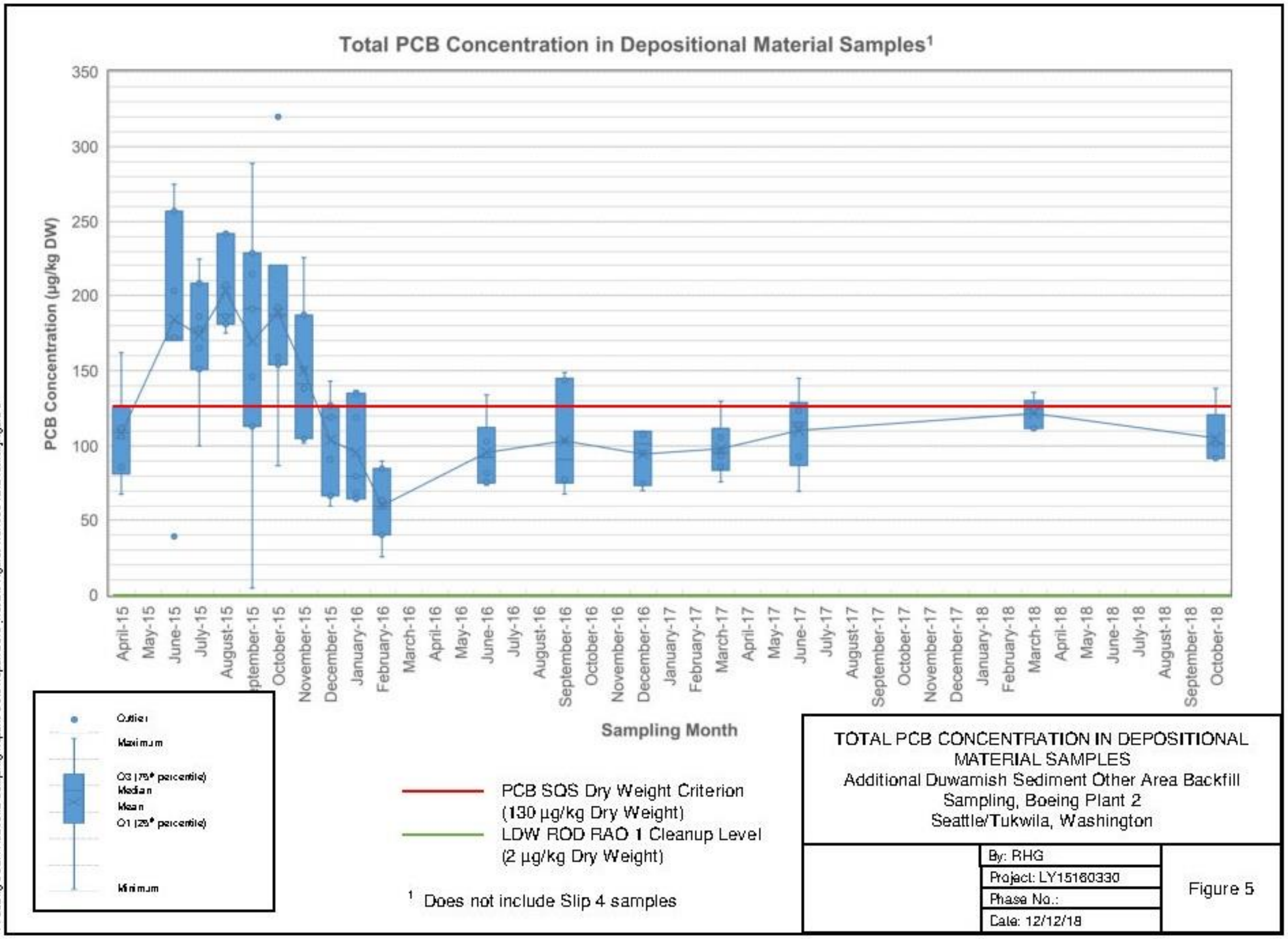


Figure B-3
Surficial Silt Thicknesses at DSOA Sampling Locations

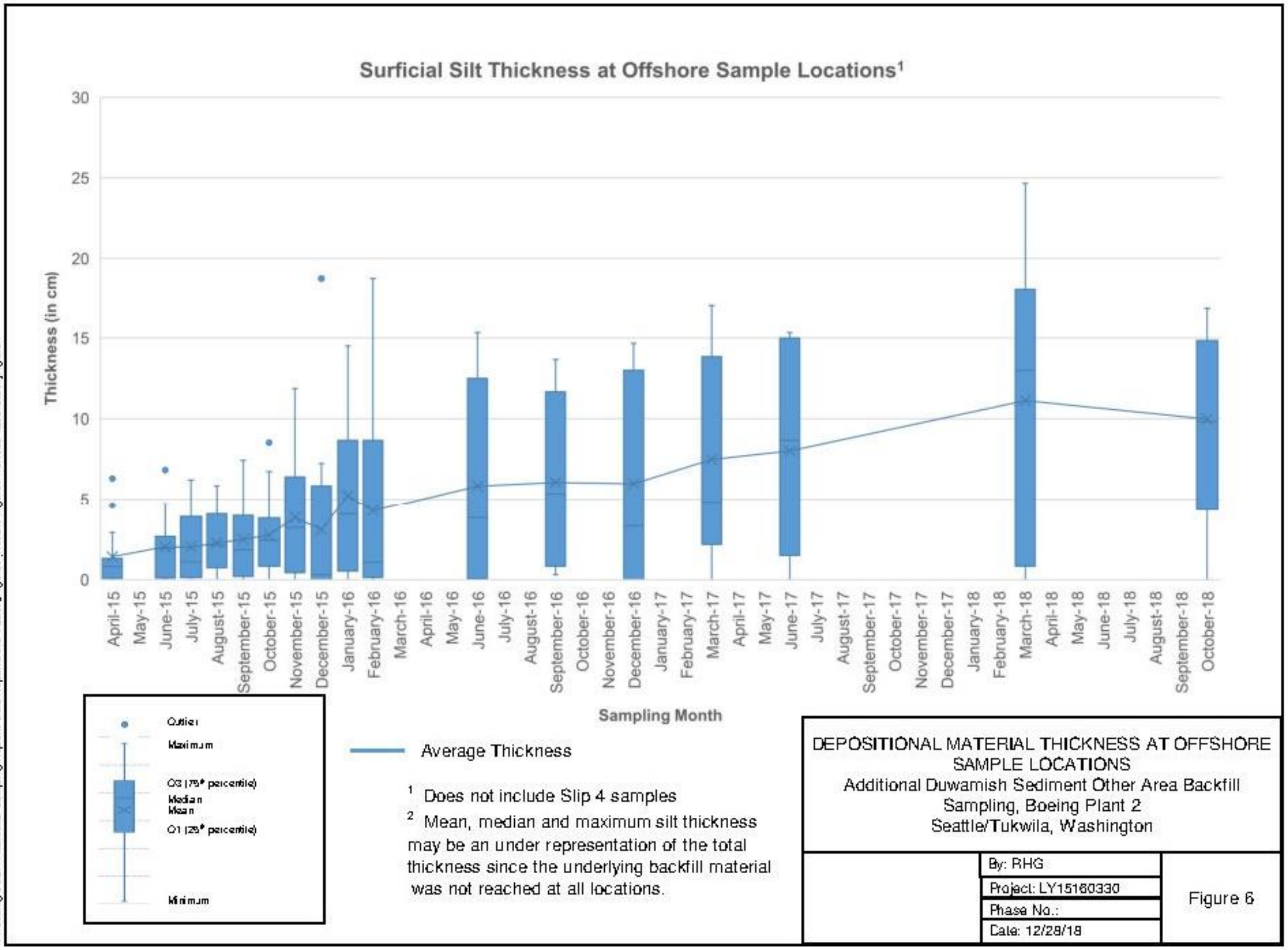
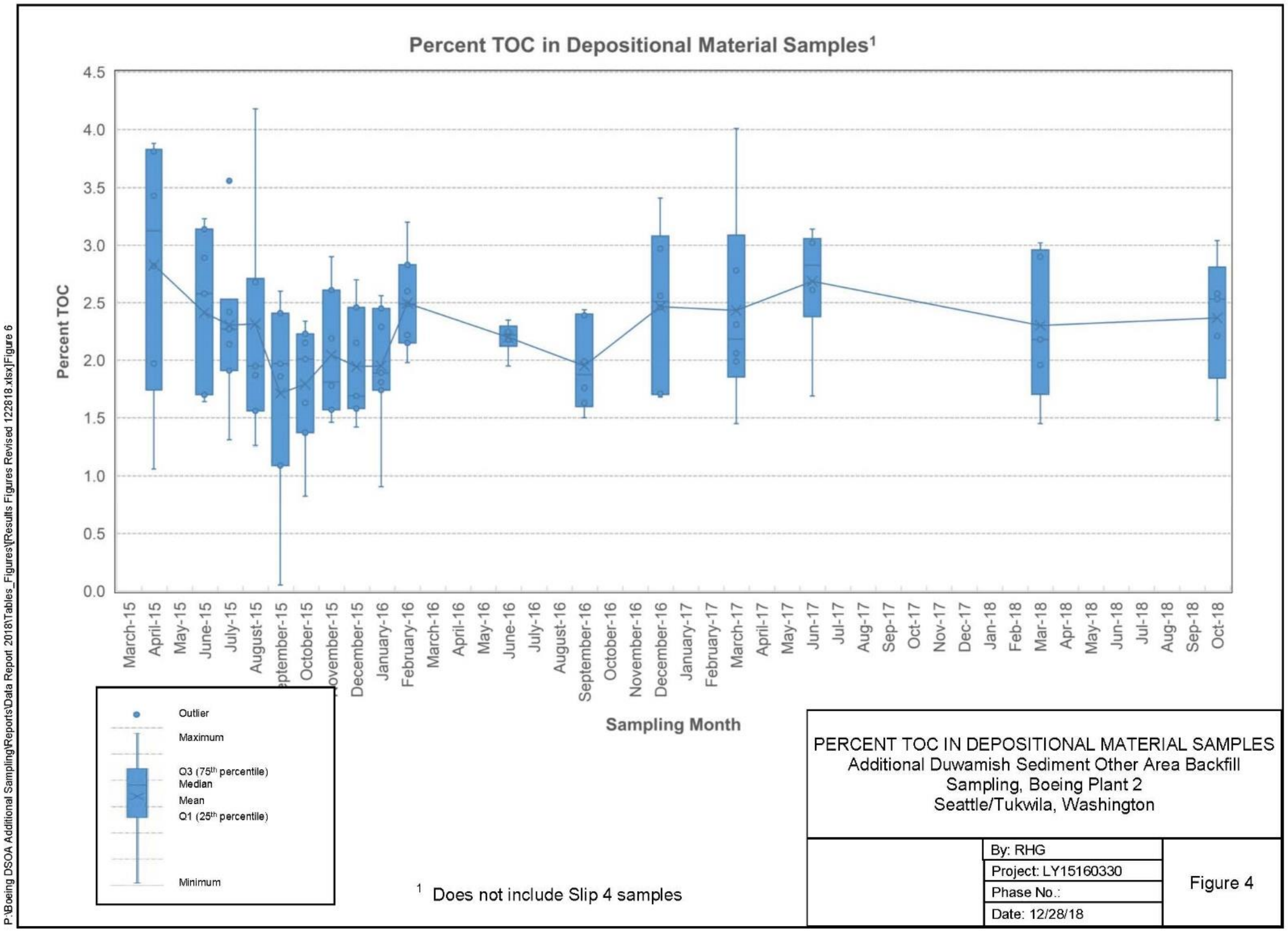


Figure B-4
DSOA Percent TOC Results



Jorgensen Forge

Construction at the Jorgensen Forge EAA was completed in 2014. The Earle M. Jorgensen Company (EMJ) conducted post-construction sediment sampling in 2015 and 2016. Additional sampling was conducted in spring 2019 at the Jorgensen Forge EAA;[3] the data summary report containing the results of that sampling is expected in 2019. Additional remediation may be required for this site. In addition, five post-construction surface sediment samples were collected by Boeing in 2015 within the Jorgensen Forge EAA (Map B-3).

Post-construction total PCB results are shown on Map B-3 for all samples. The 0-10cm samples collected by Boeing and the Jorgensen 2016 surface sediment results are compared to the SMS on Map B-4. Within the EAA, 0- to 2-cm and 0- to 10-cm sediment samples were collected from 20 locations. In addition, sediment cores were collected in 2016 to characterize the 0- to 60-cm sediment interval.[4]

All of the samples were analyzed for total PCBs (Aroclors) and metals. PCBs were the only COC detected at concentrations above the benthic SCO.[5] Sediment PCB concentrations were above the benthic SCO at seven locations (Map B-4). The total PCB concentrations in the 0- to 60-cm samples were all below the benthic SCO.

[3] Locations of sediment sampling are unavailable.

[4] Three of the samples collected during this effort were collected from intervals less than 60 cm deep (i.e., 0 to 18 cm, 0 to 32 cm, and 0 to 50 cm). Samples were collected from the 0- to 18-cm and 0- to 32-cm intervals in order to characterize the backfill material, which was placed to a depth of 18 and 32 cm, respectively, at these locations. The reason the 0- to 50-cm sample was not collected from the 0- to 60-cm interval is unknown.

[5] The benthic SCO of 12 mg/kg OC was the removal action level.

Terminal 117

Construction was completed at the Terminal 117 EAA in 2015, and the remediation achieved all stated objectives (AECOM 2018). Sediment monitoring is being conducted at the Terminal 117 EAA. The first round of post-construction sediment monitoring sampling occurred in 2019. Additional sediment monitoring will occur in 2021, 2023, and 2025 (Integral and AECOM 2018). Samples were collected from the 0- to 10-cm interval at four locations within the dredge/cap area.

Samples were analyzed for arsenic, PAHs, phenol, PCBs, and conventional parameters; two samples were analyzed for dioxins/furans. Post-construction sediment PCB concentrations are shown on Map B-5. There were no exceedances of the benthic SCO (Map B-6) or the dioxin/furan remedial action level (RAL).

Norfolk

King County monitored four Norfolk EAA cap locations (NFK501, NFK502, NFK503, and NFK504) annually from 1999 to 2004 (Map B-7). In addition, three sediment samples were collected by the Washington State Department of Ecology (Ecology) in 2002, four locations were sampled as part of the LDW remedial investigation sampling in 2006, one sample was collected to characterize LDW upstream sediment in 2008, and three samples were collected by Ecology to characterize sediments in the vicinity of outfalls in 2011.

Adjacent to the Norfolk EAA, Boeing collected sediment samples from the 0- to 5-cm interval at two locations annually from 2010 to 2017 in the vicinity of the Boeing South storm drain outfall (Map B-6).

Post-construction total PCB results are shown on Map B-7. Sediment data are shown relative to benthic SCOs (WAC 173-204-562) on Map B-7. Benthic SCOs were exceeded for bis(2-ethylhexyl) phthalate, butyl benzyl phthalate, benzyl alcohol, PAHs, and total PCBs at least once during the monitoring (Maps B-7 and B-8).

References

AECOM. 2018. Terminal 117 cleanup. Removal action completion report. Phase 1: sediment and upland cleanup. Final. Prepared for the Port of Seattle for submittal to US Environmental Protection Agency. AECOM Environment, Seattle, WA.

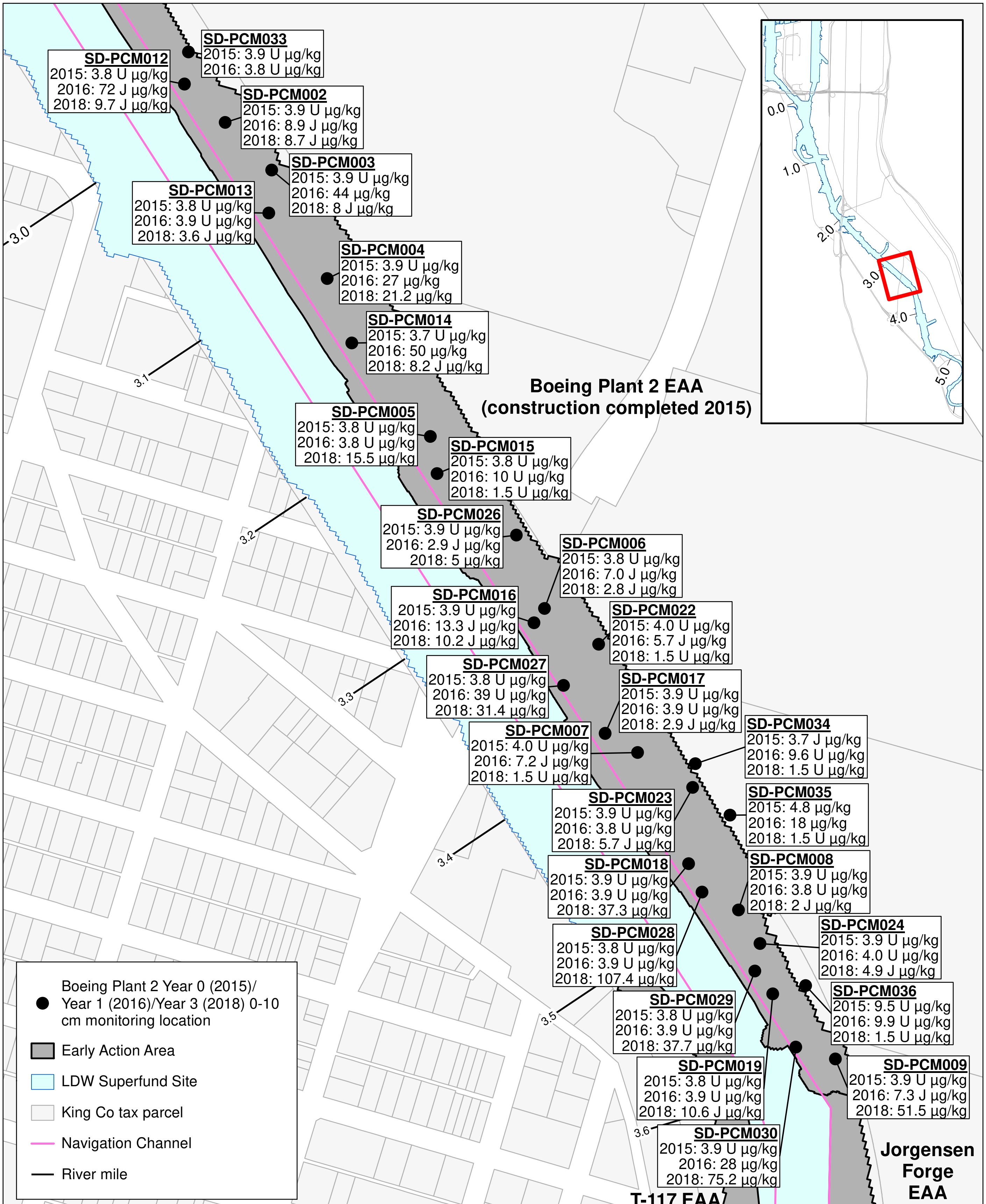
AMEC Foster Wheeler, DOF, Floyd|Snider. 2016. Corrective measure implementation report. AMEC Foster Wheeler Environment & Infrastructure, Inc., Dalton Olmsted & Fugelvand, Inc., and Floyd|Snider, Inc, Seattle, WA.

Anchor QEA, Farallon. 2016. Surface sediment sampling data evaluation report. Jorgensen Forge early action area removal action. Addendum No. 2 to the operations, monitoring, and maintenance plan. Anchor QEA, LLC and Farallon Consulting, LLC, Seattle, WA.

Integral, AECOM. 2018. Final joint long-term monitoring and maintenance plan. Lower Duwamish Waterway Superfund Site, Terminal 117 Early Action Area. Integral Consulting Inc. and AECOM Environment, Seattle, WA.

Wood. 2018. Post-construction surface sediment monitoring report - year 3. Duwamish sediment other area and southwest bank corrective measure and habitat project. Wood Environment & Infrastructure Solutions, Inc., Lynnwood, WA.

Wood. 2019. Additional Duwamish Sediment Other Area backfill sampling data report. Duwamish Sediment Other Area and Southwest Bank Corrective Measure and Habitat Project. Wood Environment & Infrastructure Solutions, Inc., Lynnwood, WA.



Map B-1. Total PCB concentrations at monitoring locations in the Boeing Plant 2 Early Action Area

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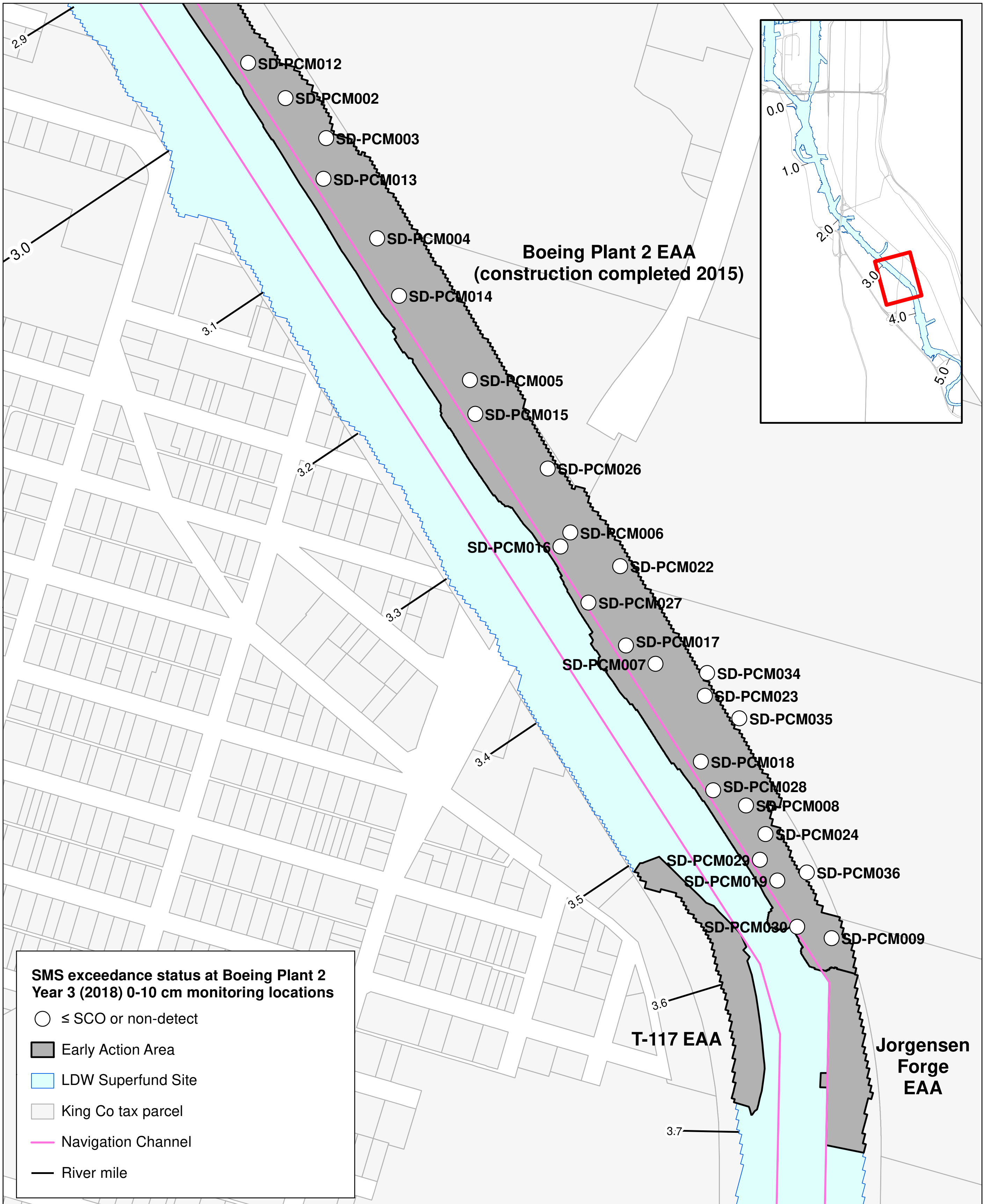

Map B-2. Comparison of Boeing Plant 2 monitoring data with benthic SCO from Washington SMS

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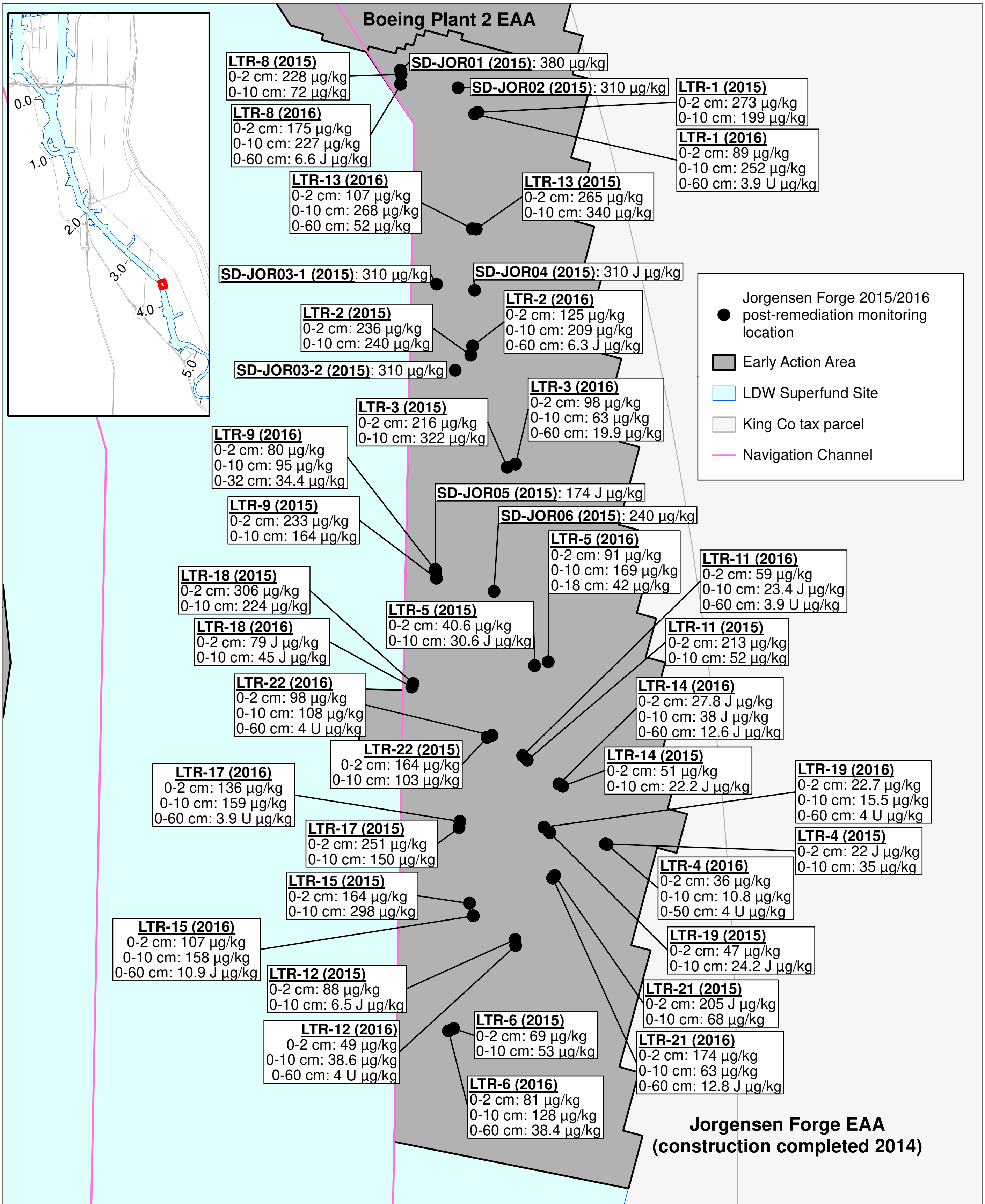

N
0 30 60 Feet
0 10 20 Meters

Map B-3. Total PCB concentrations at monitoring locations in the Jorgensen Forge Early Action Area

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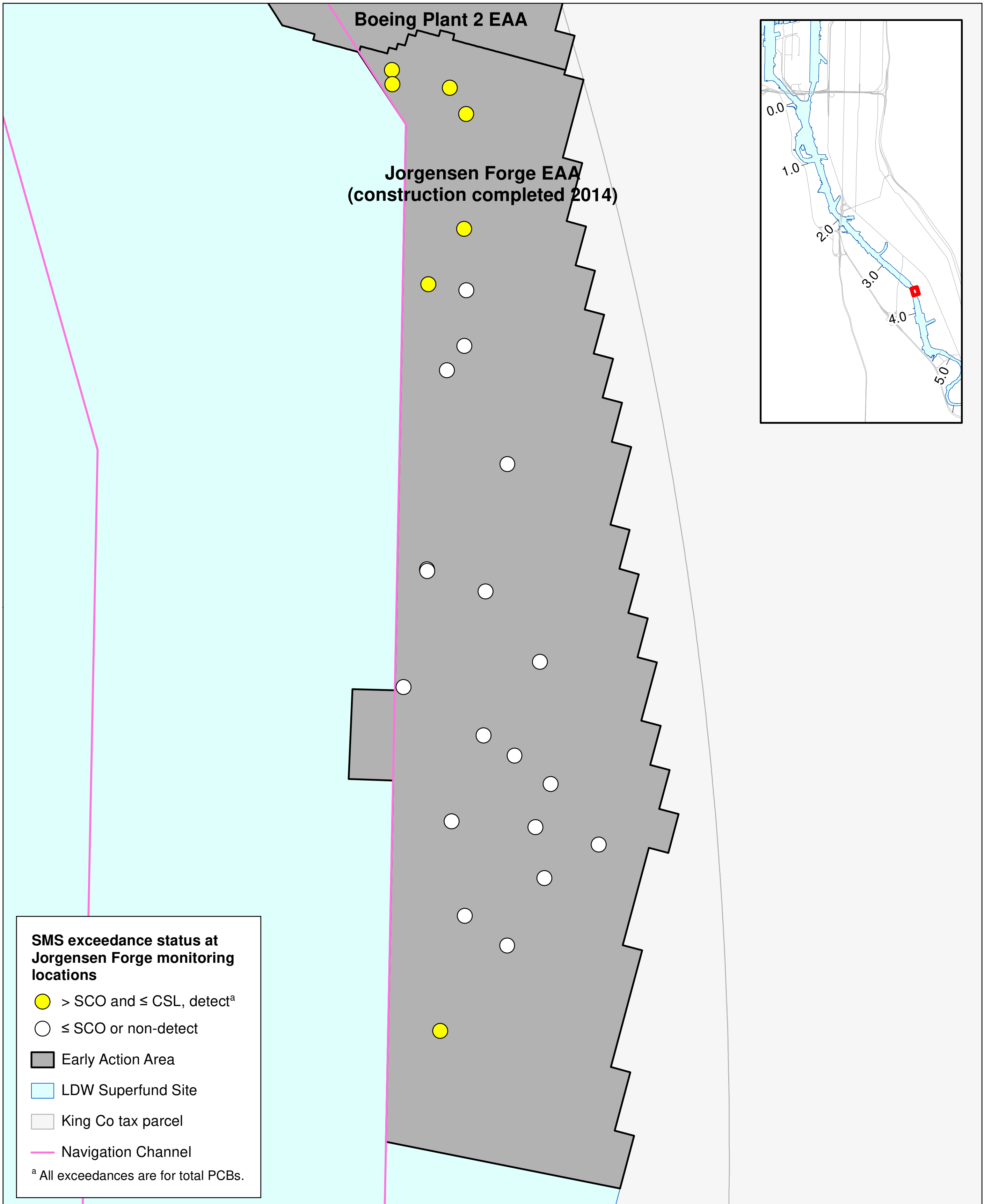

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Map B-4. Comparison of Jorgensen Forge monitoring data with benthic SCO from Washington SMS

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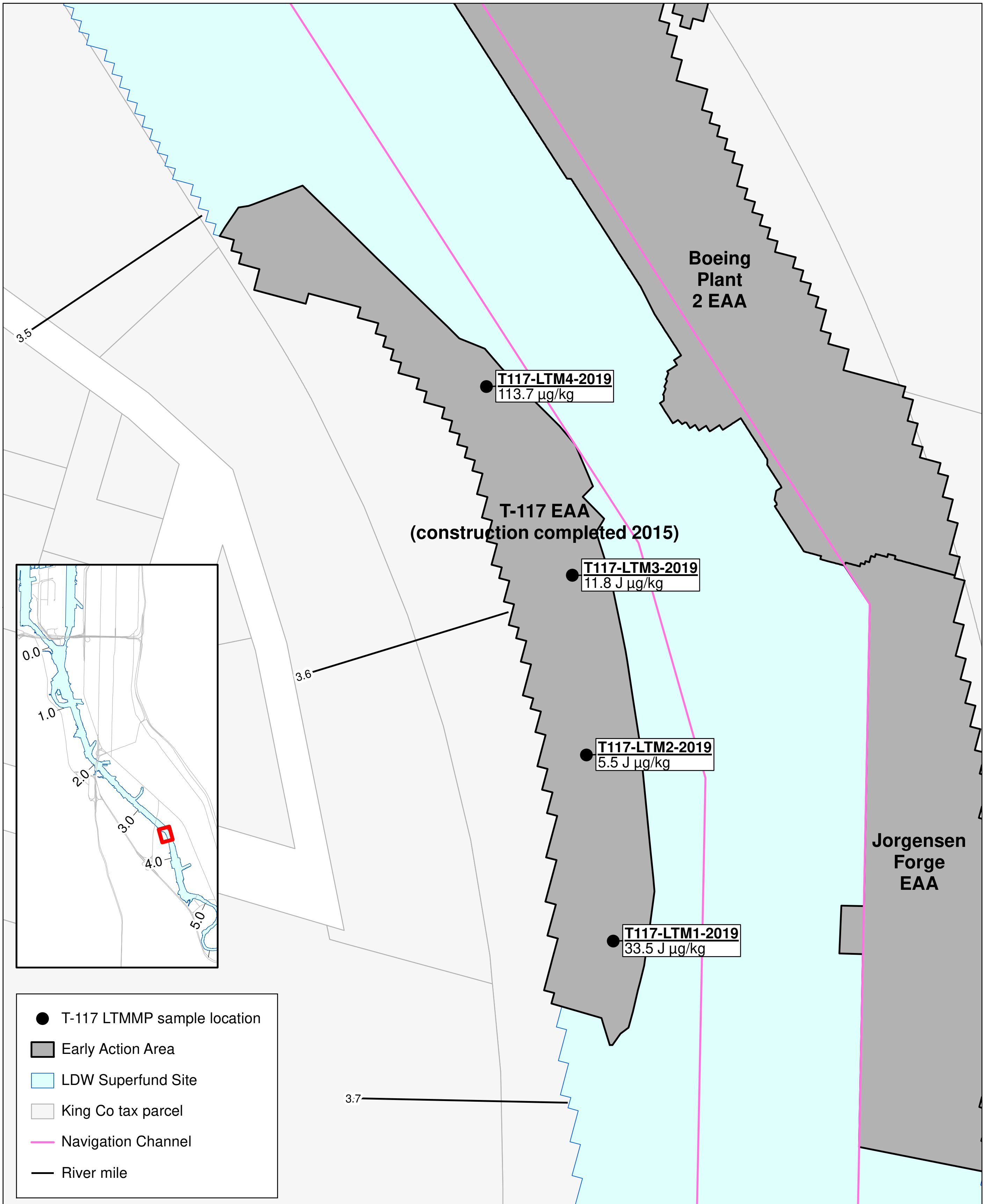

N
0 50 100 Feet
0 20 40 Meters

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Map B-5. Total PCB concentrations at monitoring locations in the T-117 Early Action Area

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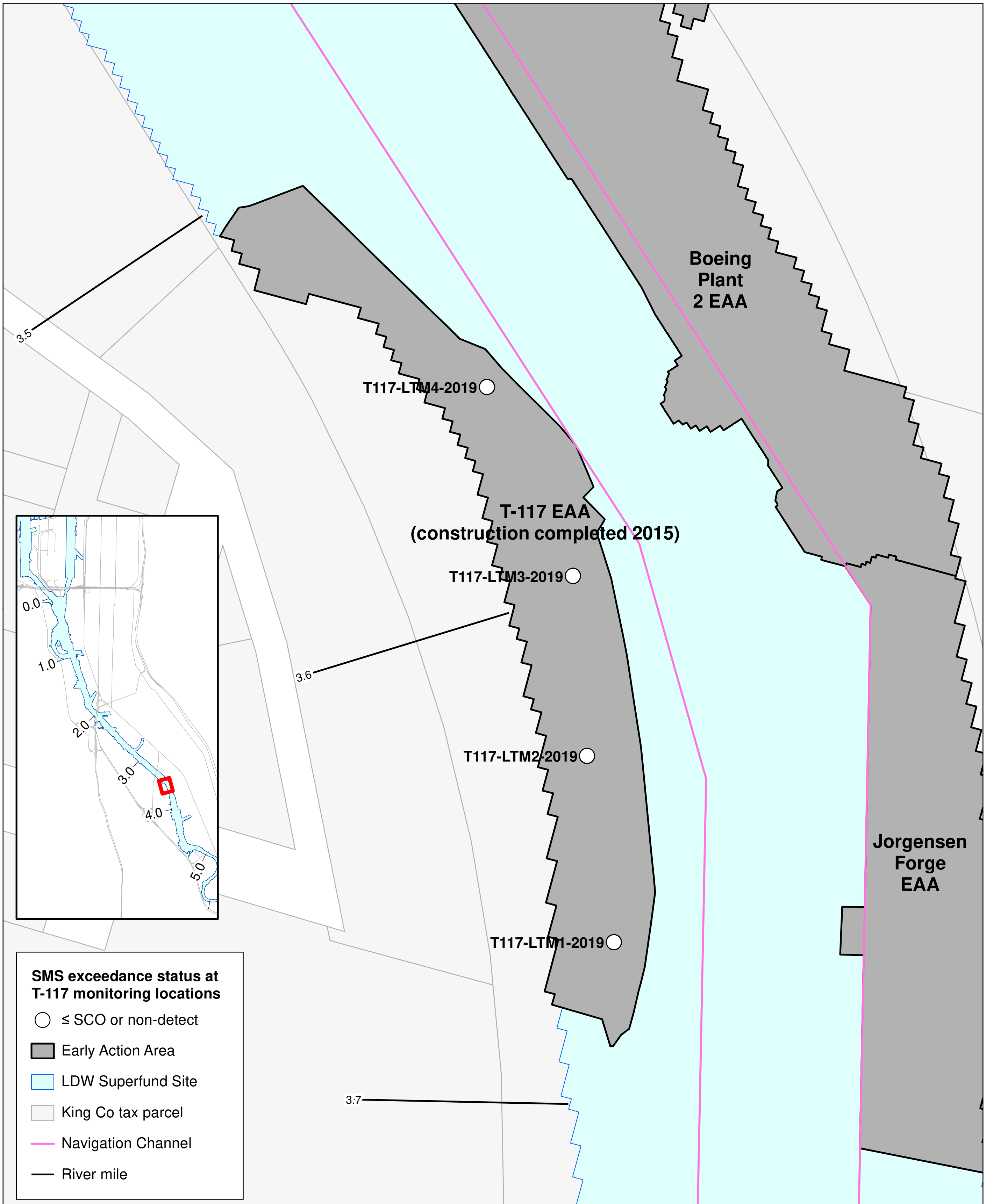

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Map B-6. Comparison of T-117 monitoring data with benthic SCO from Washington SMS

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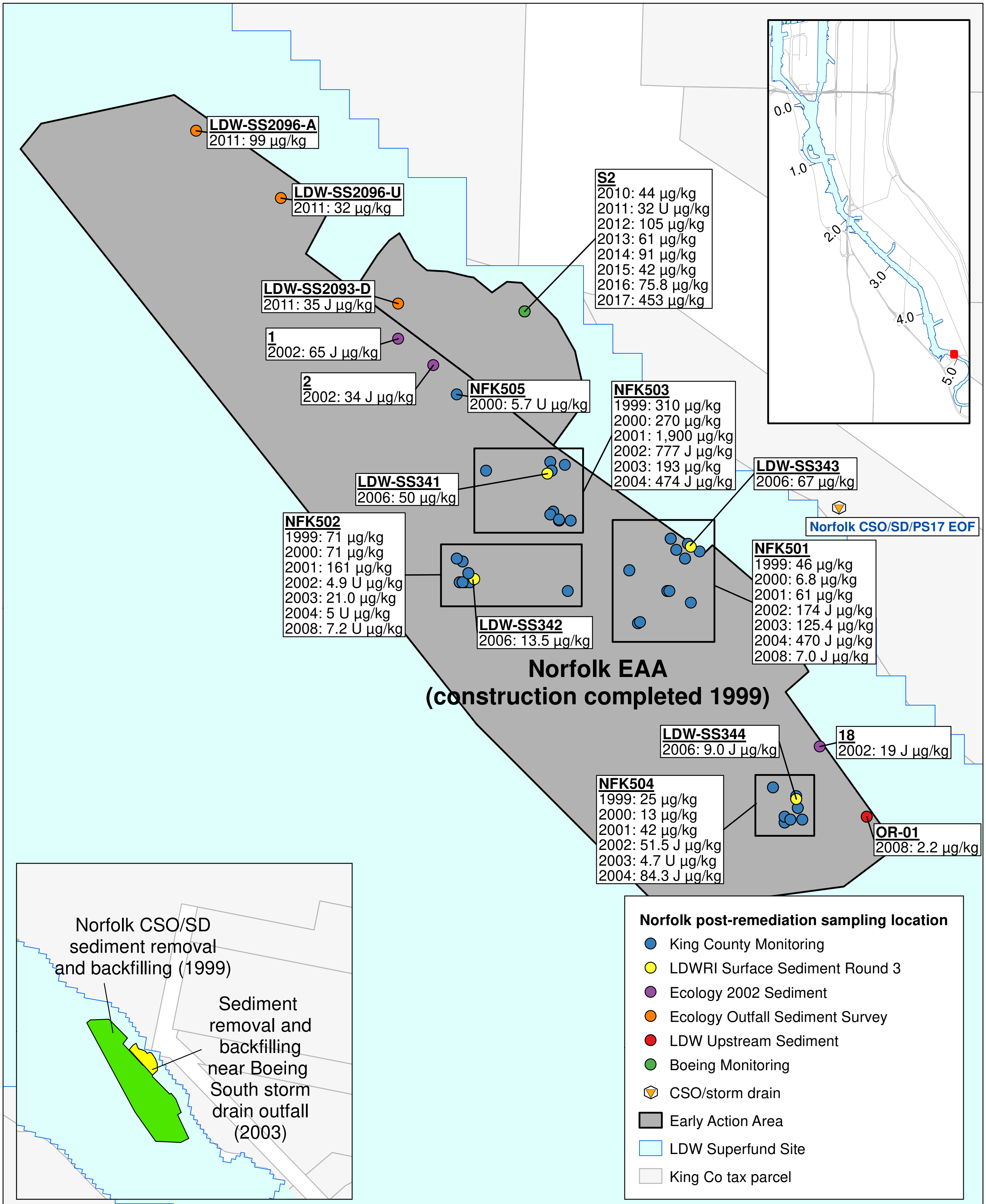

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N
0 20 40 Feet
0 5 10 Meters

Map B-7. Total PCB concentrations at monitoring locations in the Norfolk Early Action Area and Boeing South storm drain area

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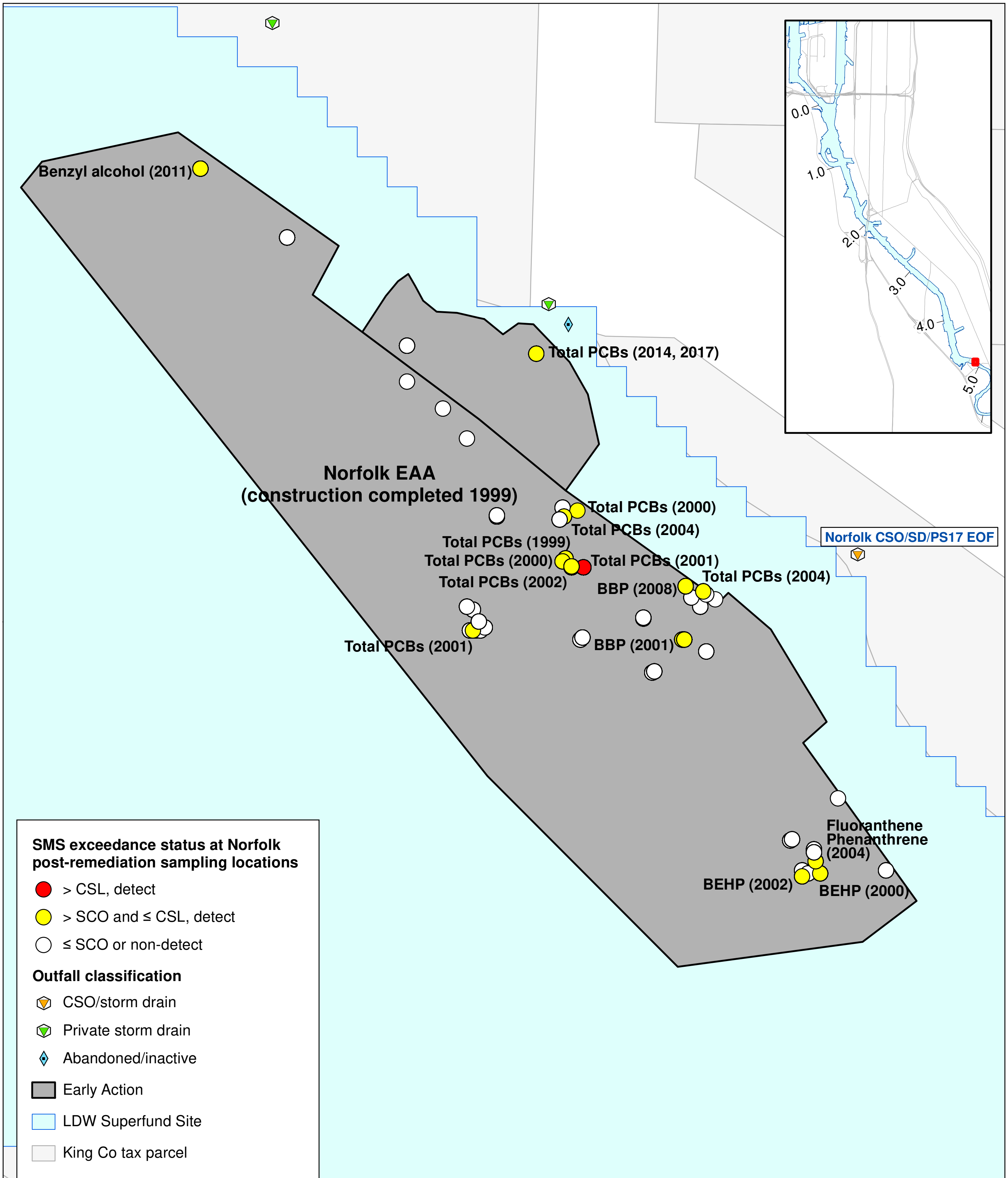

Note: For visual clarity, samples with exceedances are layered on top of samples collected in close proximity; top layering does not necessarily indicate most recent sampling.

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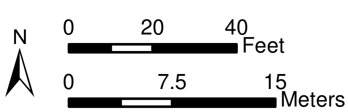

Map B-8. Comparison of Norfolk monitoring data with benthic SCO and CSL from Washington SMS

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