Lower Duwamish Waterway Group

City of Seattle / King County / The Boeing Company

FINAL (100%) REMEDIAL DESIGN
BASIS OF DESIGN REPORT FOR
LOWER DUWAMISH WATERWAY UPPER REACH

For submittal to

U.S. Environmental Protection Agency
Seattle, WA

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Prepared by:

ANCHOR QEA

1201 3rd Avenue ♦ Suite 2600
Seattle, Washington ♦ 98101

in association with

Windward environmental LLC

200 West Mercer Street ♦ Suite 401
Seattle, Washington ♦ 981199

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ABBREVIATIONS

AC	activated carbon
AOC	Administrative Order on Consent
AOC4	fourth amendment to the Administrative Order on Consent
ARAR	Applicable or Relevant and Appropriate Requirements
BA	*Biological Assessment*
BAZ	biological active zone
BBP	benzyl butyl phthalate
BEHP	bis(2-ethylhexyl) phthalate
BMP	best management practice
BODR	*Basis of Design Report*
CFR	Code of Federal Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm	centimeter
CMP	corrugated metal pipe
COC	contaminant of concern
contractor	Remedial Action Contractor
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CQAP	*Construction Quality Assurance Plan*
CWA	Clean Water Act
cy	cubic yard
dB(A)	A-weighted decibel
DER	Data Evaluation Report
DSAY	discounted service acre-year
EAA	early action area
Ecology	Washington State Department of Ecology
EF	exceedance factor
EFH	Essential Fish Habitat
ENR	enhanced natural recovery
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FNC	federal navigation channel
FOS	factor of safety
FS	Feasibility Study
ft/s	feet per second
g	acceleration of gravity

GAC	granular activated carbon
H:V	horizontal to vertical (ratio)
HEA	Habitat Equivalency Analysis
HEC-RAS	Hydrologic Engineering Center – River Analysis System
ICIAP	Institutional Controls Implementation and Assurance Plan
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
LiDAR	Light Detection and Ranging
LTMMP	Long-Term Maintenance and Monitoring Plan
mg/kg	milligrams per kilogram
MHHW	mean higher high water
MLLW	mean lower low water
MNR	monitored natural recovery
MTCA	Model Toxics Control Act
N/A	not applicable
NAD83/91	North American Datum 83 through the 1991 adjustment
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NTU	nephelometric turbidity unit
NVHM	Nearshore Habitat Values Model
OC	organic carbon
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
pcf	pounds per cubic foot
PDI	pre-design investigation
Phase III Data Report	*Pre-Design Investigation Phase III Data Report for the Lower Duwamish Waterway Upper Reach*
PSNC	Puget Sound Nearshore Calculator
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RAA	remedial action area
RAL	remedial action level
RAO	remedial action objective
RAWP	Remedial Action Work Plan
RCP	Representative Concentration Pathway
RCW	Revised Code of Washington

RD	remedial design
RDWP	Remedial Design Work Plan
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RM	river mile
RMC	residuals management cover
ROD	Record of Decision
RTK-DGPS	real-time kinematic differential global positioning system
SCO	sediment cleanup objective
SMA	sediment management area
SPI	sediment profile imaging
STM	sediment transport model
T-117	Terminal 117
TCLP	toxicity characteristic leaching procedure
TIN	triangulated irregular network
USACE	U.S. Army Corps of Engineers
USC	United States Code
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UW	University of Washington
WAC	Washington Administrative Code
WCRP	Washington Coastal Resiliency Project
WDNR	Washington State Department of Natural Resources
WQMP	Water Quality Monitoring Plan

1 Introduction

This Final (100%) Remedial Design (RD) *Basis of Design Report* (BODR) for the Lower Duwamish Waterway Upper Reach describes the basis of design criteria and other key elements for implementing the cleanup remedy for the upper reach of the Lower Duwamish Waterway (LDW) Superfund Site in King County, Washington. The upper reach encompasses river miles (RMs) 3.0 to 5.0 of the LDW. This BODR has been prepared consistent with the U.S. Environmental Protection Agency (EPA)-approved *Remedial Design Work Plan for the Lower Duwamish Waterway Upper Reach* (RDWP; Anchor QEA and Windward 2019a) and the EPA's November 2014 *Record of Decision* (ROD; EPA 2014) as modified by an *Explanation of Significant Differences* (EPA 2021). This BODR was prepared on behalf of the City of Seattle, King County, and The Boeing Company, collectively referred to as the Lower Duwamish Waterway Group (LDWG). This BODR addresses comments received from EPA on the Pre-Final (90%) RD and presents additional engineering evaluations that have been completed in support of the Final (100%) RD.

1.1 Administrative Orders on Consent

In December 2000, LDWG[1] entered into an Administrative Order on Consent (AOC) for Remedial Investigation/Feasibility Study (RI/FS) with EPA and the Washington State Department of Ecology (Ecology) to conduct an RI/FS for the LDW. In September 2001, the LDW was formally added to the National Priorities List as a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund) site; in February 2002, Ecology listed the LDW as a cleanup site under the Washington Model Toxics Control Act (MTCA). EPA and Ecology have divided lead agency responsibility for addressing the site: EPA is responsible for administering the cleanup of the sediments in the waterway, and Ecology is responsible for controlling sources of pollution to the waterway. The *Lower Duwamish Waterway Remedial Investigation Report* (RI) was completed in 2010 (Windward 2010), and the *Final Feasibility Study, Lower Duwamish Waterway* (FS) was completed in 2012 (AECOM 2012). The ROD was issued by EPA in 2014.

Five amendments to the AOC have been signed. The first three amendments cover activities that have been performed prior to the start of RD. The fourth amendment (AOC4) includes development of the RD for the upper reach, progressing from the preliminary design phase (30%) through 60%, 90%, and final (100%) designs. This document represents the basis of design for the Final (100%) RD. The fifth amendment includes development of RD for the middle reach, which is on a different timeline and will be documented separately.

[1] The Port of Seattle was a member of LDWG until 2022, when it withdrew from LDWG.

1.2 Data Collection and Evaluation

The Final (100%) RD is supported by a design dataset that includes data collected during three phases of pre-design investigations (PDIs). The design data are described and presented in the *Pre-Design Investigation Data Evaluation Report* (DER; Anchor QEA and Windward 2022a) and the *Pre-Design Investigation Phase III Data Report for the Lower Duwamish Waterway Upper Reach* (Phase III Data Report; Appendix A of this document). These reports present summaries of the PDI investigations, including the chemistry and geotechnical results of the Phase I, Phase II, and Phase III PDIs. The PDI investigations were implemented in accordance with the following plans: the *Quality Assurance Project Plan for the Lower Duwamish Waterway Upper Reach: Pre-Design Investigation* (QAPP; Anchor QEA and Windward 2020); the *Quality Assurance Project Plan Addendum for the Lower Duwamish Waterway Upper Reach: Pre-Design Investigation Phase II* (Phase II QAPP Addendum; Anchor QEA and Windward 2021a); the *Quality Assurance Project Plan Addendum for the Lower Duwamish Waterway Upper Reach: Pre-Design Investigation Phase III* (Phase III QAPP Addendum; Anchor QEA and Windward 2022b); the *Quality Assurance Project Plan: Pre-Design Surveys of the Lower Duwamish Waterway Upper Reach* (Survey QAPP; Anchor QEA and Windward 2019b) and *Quality Assurance Project Plan Addendum: Pre-Design Surveys of the Lower Duwamish Waterway Upper Reach* (Survey QAPP Addendum; Anchor QEA and Windward 2021b); and the *Supplement to the Quality Assurance Project Plan Addendum: Pre-Design Surveys of the Lower Duwamish Waterway Upper Reach* (Supplement to the Survey QAPP Addendum; Anchor QEA and Windward 2022c).

Based on the remedial action levels (RAL) exceedance areas presented in the DER and updated based on incorporation of Phase III PDI data (Appendix A), remedial action areas (RAAs) and sediment management areas (SMAs) are defined in this BODR.

1.3 Purpose and Objectives

The objective of the BODR is to identify and establish design criteria for major elements of construction, present the technical evaluations of the design elements, and document how they apply to the overall remedial action for the selected remedy for the upper reach of the LDW, as set forth in the ROD (EPA 2014) and AOC4. The Final (100%) RD builds upon the previous design phases to refine design assumptions, respond to EPA comments on the Pre-Final (90%) RD, and provide updated estimates of quantities, durations, and costs to complete the remedial action.

This BODR includes analyses conducted to select the design approach, including a summary and detailed justification of design assumptions, restrictions, and objectives used in the design of the selected remedy as defined by the list of BODR requirements in Section 6.2 of the RDWP (Anchor QEA and Windward 2019a). A complete list of RD elements of the Final (100%) RD design deliverable is provided in Table 6-1 of the RDWP.

1.4 Note on Terminology

Several different terms appear with the design documents that refer to the roles and responsibilities of different individuals or entities during the construction phase. This section summarizes these terms and describes the key differences between these roles by defining the intent of each term. These terms are used in the design documents but do not replace or supersede definitions that appear in the construction contract documents.

Implementing Entity: As previously described, AOC4 covers the design of the remedy for the upper reach. The remedial action for the upper reach will be conducted under a Consent Decree or similar agreement with EPA and a group of performing parties. This future group is referred to as the Implementing Entity and will be responsible for adhering to the terms of the Consent Decree.

Owner: The Owner will be responsible for procurement and execution of the construction phase of the project. The Owner may be the Implementing Entity or may be a different agency, individual, or subset of the Implementing Entity, as determined by the Implementing Entity. The Owner will be authorized to make decisions on behalf of the Implementing Entity. The Owner will hire the Remedial Action Contractor (contractor) and will name a Project Representative to support them during construction. The Owner will also be responsible for construction quality assurance (QA) activities as described in the *Construction Quality Assurance Plan* (CQAP). The CQAP identifies additional roles and responsibilities for management of the construction of the Upper Reach remedy.

Project Representative: The term "Project Representative" refers to the Owner representative during construction who will assist the Owner with technical review and decision making on behalf of the Owner when technical issues arise. Some entities use the term "Resident Engineer" to describe this function.

Designer: Anchor QEA is the remedy designer overseeing the development of the Drawings, Specifications, and cost estimate. The Engineer of Record is employed by Anchor QEA and is responsible for the remedy design. The term "Engineer of Record" generally does not appear in the design documents except where the role of the Engineer of Record relates to consultation during the construction phase to support construction QA and design changes, if needed.

1.5 Report Organization

The remainder of this document is organized into the following sections:

- **Section 2:** Project Background, Site Conditions, and Data Sources
- **Section 3:** ARARs Compliance Evaluation
- **Section 4:** Extents of Contamination
- **Section 5:** Remedial Technology Assignment
- **Section 6:** Remedial Action Areas Development

- **Section 7:** Sediment Management Areas Development
- **Section 8:** Geotechnical Engineering Considerations
- **Section 9:** Structural Engineering Considerations
- **Section 10:** Remedial Technology Design
- **Section 11:** Environmental Protection During Construction
- **Section 12:** Site Access
- **Section 13:** Preliminary Construction Sequencing and Schedule
- **Section 14:** Quantity Calculations and Engineer's Cost Estimate
- **Section 15:** Construction Contracting Strategy
- **Section 16:** Contractor Quality Control and Construction Quality Assurance
- **Section 17:** Work by Others
- **Section 18:** References

The following appendices are attached to this document as supporting technical evaluations of the BODR:

- **Appendix A:** Phase III Data Report
- **Appendix B:** LDW Upper Reach Applicable or Relevant and Appropriate Requirements
- **Appendix C:** Clean Water Act Sections 401/404 and Rivers and Harbors Act Section 10 Substantive Compliance Report
- **Appendix D:** Section 408 Substantive Compliance Report
- **Appendix E:** Biological Assessment
- **Appendix F:** Design Considerations for cPAH RAL Exceedance Areas Relative to 2014 ROD RALs
- **Appendix G:** Geotechnical Design Analysis
- **Appendix H:** Structural Calculations
- **Appendix I:** Engineered Cap Chemical Isolation Design Analysis
- **Appendix J:** Engineered Protection Design Analysis for Engineered Caps and Area-Specific Technology
- **Appendix K:** Chemical Fate and Transport Modeling to Support Evaluations of Buried Contamination, ENR/AC Pilot, and Area-Specific Technology Locations
- **Appendix L:** No-Rise Evaluation
- **Appendix M:** Water Quality Effects Evaluation
- **Appendix N:** Green Remediation Evaluation and Implementation Approach
- **Appendix O:** Engineer's Cost Estimate
- **Appendix P:** Work by Others

This report and Appendices A through P make up Volume I of the Final (100%) RD. Other supporting design documents are provided separately in Volume II, and the Drawings and Specifications are provided in Volume III, as follows:

- **Volume II (Ancillary/Supporting Reports and Plans)**
  - **Part I:** Construction Quality Assurance Plan (includes Water Quality Monitoring Plan; Construction Sediment Sampling Quality Assurance Project Plan; Air, Noise, and Light Monitoring Plan; and Monitoring and Inadvertent Discovery Plan as appendices)
  - **Part II:** Permitting and Site Access Plan
  - **Part III:** Emergency Response Plan Outline
  - **Part IV:** Vessel Management Plan Requirements Outline
  - **Part V:** Preliminary Waste Determination
  - **Part VI:** Long-Term Maintenance and Monitoring Plan Annotated Outline
  - **Part VII:** Sediment Remedy Institutional Controls Implementation and Assurance Plan Outline
  - **Part VIII:** Community Outreach and Communications Plan
- **Volume III (Construction Documents)**
  - **Final (100%) Drawings**
  - **Final (100%) Specifications**

2 Project Background, Site Conditions, and Data Sources

2.1 Project Background

2.1.1 Site Description

The Duwamish River originates at the confluence of the Green and Black rivers near Tukwila, Washington, and flows northwest for approximately 12 miles prior to discharging into Elliott Bay in Puget Sound. In the early years of the twentieth century, the lower 6 miles of the Duwamish River were straightened and channelized into a commercial corridor for ship traffic, officially designated as the LDW and the East and West Waterways (located along Harbor Island). The LDW Superfund Site extends 5 miles upstream from the southern tip of Harbor Island to just upstream of the Turning Basin, a federally authorized and maintained navigation feature consisting of an area where ship traffic can turn around. The LDW Superfund Site has been divided into three reaches (lower, middle, and upper) that are each undergoing RD on different timelines, with the upper reach being the first reach for which RD is being performed. Although each reach is being designed separately, some design overlap at the boundaries between reaches is necessary to transition remedial actions between reaches. The upper reach of the LDW extends from Duwamish Waterway Park (RM 3.0) to the southern end of the LDW at RM 5.0 near the bridge on South 102nd Street (Figures 2-1 and 2-2). The average width of the upper reach is 540 feet.

The banks of the LDW include public and private properties that support industrial and marine activities as well as public access, utility corridors, street ends, and bridge crossings. Additional detail is provided in Section 2.3.

2.1.2 Remedy Summary

The selected remedy for the LDW is described in Section 13 of the ROD (EPA 2014). It addresses unacceptable human health risks associated with consumption of resident fish and shellfish and with direct contact (skin contact and incidental ingestion of sediment) from net fishing, clamming, and beach play. It also addresses ecological risks to bottom-dwelling organisms (benthic invertebrates) and wildlife.

RALs are contaminant concentrations in sediment that apply to specific locations and depths on a point-by-point basis (EPA 2014). Per the ROD, RALs are used to delineate areas that require active remediation. These RALs are dependent on the location, elevation (i.e., intertidal vs. subtidal), projected potential for natural recovery (i.e., recovery category), and shoaling conditions in the federal navigation channel (FNC). RAL depth intervals are as follows:

- **Intertidal Areas:** 0 to 10 centimeters (cm; 0 to 4 inches) and 0 to 45 cm (0 to 1.5 feet)

- **Subtidal Areas:** 0 to 10 cm (0 to 4 inches) and 0 to 60 cm (0 to 2 feet)[2]

Shoal areas[3] within the FNC also have their own set of RALs. Areas with RAL exceedances were delineated in the DER (Anchor QEA and Windward 2022a) and updated in the Phase III Data Report (Appendix A), as described in Section 4 of this BODR.

The following remedial technologies were identified in the ROD (EPA 2014):

- Dredging [4]
- Engineered sediment caps
- Partial dredge and capping
- Placement of a thin layer (nominal 6 to 9 inches) of clean material in areas that meet the criteria for enhanced natural recovery (ENR)
- Application of location-specific cleanup technologies to contaminated sediment in underpier areas or areas with structural or access restrictions (e.g., in the vicinity of dolphins/pilings, structures, and riprapped or engineered banks)
- Implementation of monitored natural recovery (MNR):
  - **MNR to Benthic Sediment Cleanup Objectives (SCOs):** Surface sediment contaminant concentrations are greater than benthic SCOs but below RALs.
  - **MNR Below Benthic SCOs:** Surface sediment contaminant concentrations are below RALs and benthic SCOs but greater than human health-based cleanup levels.[5]

The upper reach remedial technology assignments for each RAL exceedance area, which are based on ROD criteria (EPA 2014), were initially presented in the DER (Anchor QEA and Windward 2022a) and have been refined in Section 5 of this BODR to reflect the Final (100%) RD selected technology.

Early action areas (EAAs) comprise 19 acres (14% of the area) of the upper reach. These areas were identified for early cleanup actions to accelerate cleanup and reduce risks of exposure. Remedial actions at the four EAAs in the upper reach were conducted between 1999 and 2015. Post-remediation conditions of EAAs are factored into design of adjacent areas to maintain EAA remedy performance. Figure 2-3 shows the locations of the EAAs in the upper reach.

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[2] Subtidal RALs applicable to the 0- to 60-cm depth are dependent on recovery category designation and potential vessel scour areas (see ROD Table 28 [EPA 2014]).

[3] Shoal areas are locations within the FNC where the bed elevation is higher than the authorized navigation depth.

[4] The dredging technology also includes residuals management cover (RMC) placement to manage generated residuals and backfilling within defined habitat elevations or when needed to provide a stable post-construction condition.

[5] The human health-based cleanup levels are applied as 95th upper confidence limit on the mean on a site-wide basis for Remedial Action Objective (RAO) 1 and an area-specific basis for RAO 2.

2.2 Upland Source Control Sufficiency

Remedial construction of the upper reach is being coordinated with upland source control sufficiency evaluations by Ecology. Ecology works with the LDW Source Control Workgroup[6] on source control efforts for the LDW sediment cleanup.[7] Ecology has identified 24 source control areas for the LDW as part of its source control strategy (Ecology 2016) for the LDW sediment remedy. Nine of these source control areas drain to the upper reach and are summarized in Table 2-1.

Sufficiency recommendations were developed by Ecology and presented in the report titled *Lower Duwamish Waterway Source Control Sufficiency Evaluation Report, Upper Reach* (Ecology 2023). For RAAs where source control is determined not to be sufficient, the remedial action will be delayed until sources are sufficiently controlled. Based on Ecology recommendations in the report and as discussed with EPA, remedy implementation for RAA 18 will be deferred, as discussed in this section and Section 6.1.3.

Table 2-1
Summary of LDW Upper Reach Source Control Areas and Upland Cleanup Sites

Ecology Source Control Area	Upland Upper Reach Cleanup Sites[1]	Upland Cleanup Site Adjacent to In-Water Area with RAL Exceedances?
East Shoreline		
RMs 2.8–3.7 East: Boeing Plant 2/Jorgensen Forge EAA	Jorgensen Forge, Boeing Plant 2[2]	Yes, adjacent to EAAs Yes, adjacent to EAAs
RMs 3.7–3.9 East: Boeing Isaacson/Central King County International Airport	Boeing Isaacson Thompson	Yes
RMs 3.9–4.3 East: Slip 6	8801 E Marginal Way S, Container Properties[2]	Yes Yes
RMs 4.3–4.9 East: Boeing Developmental Center	Boeing Developmental Center	Yes
RM 4.9 East: Norfolk Combined Sewer Overflow/Storm Drain EAA	Emerald Gateway	No
West Shoreline		
RMs 2.2–3.4 West: Riverside Drive	Duwamish Waterway Park[3]	No
RMs 3.4–3.8 West: T-117 EAA	South Park Marina, T-117[2]	Yes Yes, adjacent to EAAs
RMs 3.8–4.2 West: Sea King Industrial Park	Precision Engineering	No

[6] The LDW Source Control Workgroup currently consists of representatives from Ecology, King County, City of Seattle, City of Tukwila, Port of Seattle, Puget Sound Clean Air Agency, Washington State Department of Transportation, and EPA; see ROD Section 13.2.7 (EPA 2014).

[7] Information on the current status of source control efforts can be found on Ecology's website at https://ecology.wa.gov/Spills-Cleanup/Contamination-cleanup/Cleanup-sites/Toxic-cleanup-sites/Lower-Duwamish-Waterway/Source-control.

Ecology Source Control Area	Upland Upper Reach Cleanup Sites[1]	Upland Cleanup Site Adjacent to In-Water Area with RAL Exceedances?
RMs 4.2–4.8 West: Restoration Areas	None	No

Notes:

1. Source: https://ecology.wa.gov/Spills-Cleanup/Contamination-cleanup/Cleanup-sites/Lower-Duwamish-Waterway/Source-control/Source-control-areas
2. Boeing Plant 2, Container Properties, and T-117 are EPA-led upland cleanup sites.
3. Information regarding the Duwamish Waterway Park Site is summarized from Ecology (2022a). This site was listed on Ecology's Confirmed and Suspected Contaminated Sites List in 2020.

EAA: early action area
RAL: remedial action level
RM: river mile
T-117: Terminal 117

The following four upland areas that are under Ecology-led upland cleanup processes are located immediately adjacent to areas with RAL exceedances in the LDW upper reach:

- **Boeing Isaacson Thompson:** This site is located near RM 3.8E and includes the Port of Seattle shoreline "sliver property" along a deteriorating bulkhead wall. Ecology has determined that sources are not considered sufficiently controlled at this site; therefore, design and construction for the adjacent sediment area (RAA 18) is being deferred to a later stage in the overall Superfund Site cleanup. Coordination with the upland site owner and Ecology is ongoing, and the design for RAA 18 is not included in the Final (100%) RD for the LDW upper reach. See Section 6.1.3 and Table 6-1 for additional discussion.
- **8801 E Marginal Way:** This site is located near RMs 3.9E to 4.0E and is sometimes referred to by other names, including CenterPoint Properties and PACCAR. Discussions with the upland site owner are ongoing to coordinate on site access needs for bulkhead reinforcement design considerations to support the sediment remedy at the base of the bulkhead (Table 6-1 and Section 9.2.3).
- **Boeing Developmental Center:** This site spans the upland area from RMs 4.3 to 4.9. A stormwater improvement project referred to as DC Stormwater Treatment Phase 2, which includes rerouting, combining, and adding treatment systems to some outfalls while abandoning others, is planned near the RAAs at the south end of the site. The project is scheduled to be completed by August 2024. Additional information about the sediment remedy in this area is available in Tables 6-1 and 9-5.
- **South Park Marina:** This site is located at RM 3.5W and includes the upland area adjacent to South Park Marina. Discussions with the upland site owner are ongoing to coordinate site access needs.

One additional upland cleanup site located adjacent to an LDW upper reach RAL exceedance area is under an EPA-led cleanup process:

- **Container Properties:** This site is located at RM 4.1E. The sediment cleanup extends up the bank. Coordination occurred throughout the design process with the upland site owner and EPA to ensure that the tie-in between sediment and upland remedies is appropriately designed (Table 6-1, Sections 8.3.8.2 and 10.3).

Ecology has completed its source control sufficiency evaluation for the upper reach; it was made available to LDWG in early July 2023 (Ecology 2023). EPA has determined that one sediment remedy location in the upper reach (RAA 18) is to be deferred based on the source control sufficiency evaluation presented in Ecology's report.

2.3 Site Conditions

The RDWP (Anchor QEA and Windward 2019a) provides a review of existing information and site conditions. In addition, comprehensive descriptions of the LDW environmental and physical site characteristics are presented in the RI (Windward 2010), FS (AECOM 2012), and the ROD (EPA 2014). Key site characteristics affecting RD are summarized in the following sections.

2.3.1 Tidal Elevations and Water Depth

The upper reach consists of 131 acres of intertidal and subtidal areas below mean higher high water (MHHW), which is 11.3 feet mean lower low water (MLLW) in the LDW as defined in the ROD (EPA 2014).[8] MHHW is the landward boundary that the selected remedy addresses, but remedial action occasionally extends beyond this elevation to provide a constructable and effective remedy. Approximately 55 acres of the upper reach are considered intertidal, with bed elevations between +11.3 feet MLLW, equivalent to MHHW, and -4 feet MLLW. Approximately 76 acres of the upper reach are considered subtidal, with bed elevations below -4 feet MLLW.

Based on National Oceanic and Atmospheric Administration (NOAA) annual prediction tide tables at the Eighth Avenue South tidal gauge (Station ID: 9447029), the predicted water surface elevation for 2025 at the site ranges from -3.88 feet MLLW to +12.53 feet MLLW, with an average of +6.50 feet MLLW (Table 2-2). Predictions are limited to a future 2-year period but are useful for understanding anticipated changes in tides over time and for remedial contractors to understand anticipated ranges of water depth during the first year of construction in the upper reach. The selected contractor will

[8] The Seattle tide gage, as reported by NOAA, has a MHHW elevation of 11.36 feet in MLLW datum (https://tidesandcurrents.noaa.gov/datums.html?id=9447130). For purposes of RD, the ROD-defined MHHW elevation is used. The minor discrepancy between ROD-defined MHHW and NOAA reported MHHW is not considered to have a material consequence for the remedy design and will not affect the effectiveness of the remedy.

ultimately sequence its work based on more refined predictions for time periods that match the available construction windows during the years in which construction will occur.

Table 2-2
LDW Predicted Tidal Data for 2020-2025

Year	Predicted Tide Elevations (feet MLLW)		
	Mean	**Minimum**	**Maximum**
2020	+6.50	-3.79	+12.68
2021	+6.48	-4.07	+12.71
2022	+6.46	-3.21	+12.55
2023	+6.45	-3.23	+12.56
2024	+6.50	-3.35	+12.68
2025	+6.50	-3.88	+12.53

Notes:
Source: https://tidesandcurrents.noaa.gov/noaatideannual.html?id=9447029
This table includes the predicted tide data available for the 8th Avenue South tide gauge, which include the past and upcoming 2 years (i.e., 2020 through 2025 at the time of this report).
MLLW: mean lower low water

2.3.2 Federal Navigation Channel

The upper reach includes the Turning Basin (RMs 4.6 to 4.7) and the FNC, both of which are maintained[9] by the U.S. Army Corps of Engineers (USACE; Figure 2-3). In this reach, the authorized FNC width is 150 feet, and the authorized depth is -15 feet MLLW. The FNC covers 32 acres of the 76-acre subtidal area of the upper reach.

2.3.3 Infrastructure

Infrastructure within the upper reach, shown in Figure 2-3, includes waterfront facility berthing, overwater structures (e.g., piers, docks, floats, bulkheads, flow diversion structures, covered boat slips), piling (e.g., erosion control structures, fendering, mooring piles), bridges, and utilities (e.g., underwater cables and pipe structures, overwater cables, storm drains, outfalls).

2.3.4 Waterway Usage

Waterway uses are summarized in RDWP Section 2.5 (Anchor QEA and Windward 2019a) and include the following:

- **Tribal Use and Treaty Rights:** The LDW is one of the locations of the Muckleshoot Indian Tribe's commercial, ceremonial, and subsistence fishery for salmon, as part of its usual and

[9] Recent maintenance dredging performed by USACE has been limited to areas in the FNC south of RM 4.0.

accustomed fishing area. The Suquamish Tribe actively manages aquatic resources north of the Spokane Street Bridge, just north of the LDW study area (EPA 2014).

- **Beach Play and Tribal Clamming:** Beach play and tribal clamming were considered in the RI/FS/ROD process in the development of cleanup levels and RALs.
- **Public Shoreline Access:** Public shoreline access locations are considered in the RD in order to maintain public safety and reduce the impacts of construction on the public.
- **Waterway-Dependent Users:** Waterway-dependent users include waterfront property owners and their tenants who are supported by bank infrastructure (e.g., docks, piers, wharves, berthing areas); operators of commercial tug, barge, and cargo vessels; marinas; yacht clubs; yacht manufacturers; and recreational users.
- **Federal Navigation Channel:** The FNC supports water-dependent industry along the LDW. The RD applies appropriate buffers as defined in the ROD (EPA 2014) to support USACE's ability to maintain the FNC.

2.3.5 Upland Land Use

The upper reach is adjacent to upland property in the cities of Seattle and Tukwila and unincorporated King County. The uplands surrounding the LDW upper reach are mixed industrial, commercial, residential, and some park/open space. The northern extent of the LDW upper reach is bordered by the South Park neighborhood on the west bank (to approximately RM 4.0) and the Georgetown neighborhood on the east bank (to approximately RM 3.3). RD considers restrictions appropriate to residential land uses (e.g., noise restrictions during construction). Upland properties are owned by a variety of landowners, as shown in Figure 2-3.

A detailed summary of historical land uses is provided in the FS (AECOM 2012). Habitat restoration areas in the upper reach are discussed in Section 2.3.11.

2.3.6 Early Action Areas

Four EAAs are located within the upper reach (Norfolk EAA, Boeing Plant 2 EAA, Jorgensen Forge EAA, and Terminal 117 [T-117] EAA). The RDWP summarizes the cleanup of each EAA (Anchor QEA and Windward 2019a). Additional cleanup work is anticipated at the Jorgensen Forge EAA but will take place following the LDW upper reach construction in nearby SMAs (based on schedule information available at the time of this Final (100%) RD). Coordination with the sediment cleanup will occur as needed. Existing conditions for the EAAs inform the cleanup approach in adjacent areas in this BODR, as described in Section 6.1.

2.3.7 Enhanced Natural Recovery/Activated Carbon Pilot Plot

In 2015 to 2020, LDWG implemented a pilot study to assess whether the performance of ENR material amended with activated carbon (AC) was more effective than ENR alone in reducing the bioavailability of polychlorinated biphenyls (PCBs) in contaminated sediments in the LDW. Results of the study are available in the Year 3 monitoring report (Wood et al. 2021). One of three plots, the intertidal plot, is within the upper reach at RM 3.9E. The pre-construction data for this plot, which comprises two subplots, is shown on Phase II QAPP Addendum Map A-25 (Anchor QEA and Windward 2021a). In summary, an average thickness of 10.3 inches of gravelly/sandy material was placed, with a minimum thickness of 6 inches and maximum thickness of 14 inches (Amec Foster Wheeler et al. 2018). Sections 10.4 and 10.5 discuss the results of the pilot study as they relate to the upper reach design.

2.3.8 Hydrodynamics and Sediment Transport

The upper reach is an estuarine environment, with freshwater entering from the Green/Duwamish River system and saltwater originating from Puget Sound. The location of the upstream interface between freshwater and marine layer flows, referred to as the saltwater wedge, is variable within the upper reach depending upon both river flow and tidal stage. During times of high river flow and low tide stages, the saltwater wedge does not enter the upper reach, whereas during low-flow conditions and high tide stages, the saltwater wedge can extend upstream of the upper reach. The upstream-most location or "toe" of the saltwater wedge is typically located between Slip 4 (RM 2.8) and the Turning Basin (RM 4.7); however, the salt wedge can extend upstream as far as RM 10.2 during low flow from the Green River and high tides (WRIA 9 2021).

The Howard Hanson Dam at the head of the Green River is managed to perform flood control during storm events. As a result, the dam limits the maximum flows within the LDW. High-flow events considered in design incorporate the effects of Howard Hanson Dam management.

The hydrodynamics and sediment transport of the LDW (summarized in RI Section 2.6 and FS Section 2.1.3 [Windward 2010; AECOM 2012]) were modeled during development of the sediment transport model (STM; QEA 2008), which was prepared to support the RI/FS. Additional detail on the hydrodynamics and suspended-sediment transport of the LDW is available in a recent University of Washington study (McKeon et al. 2020) and the U.S. Geological Survey (USGS) study (USGS 2018), respectively.

The primary focus of the recent modeling study by the University of Washington (UW) on the Duwamish River Estuary was on the seasonal changes in structure and dynamics in a salt wedge estuary (McKeon et al. 2020). Part of the UW study included an analysis of sediment load estimates entering the estuary (not deposition or sediment transport within the waterway) using newer USGS data than were available at the time when the STM was developed. UW concluded that recent sediment loads derived from the USGS data collected between 2013 and 2020 may be 50% less than the sediment loads derived from the data that were available at the time of the STM. This is consistent with the findings from the analysis conducted by USGS (2018) that also suggested that the current upstream sediment load estimate may be up to 50% lower than previous estimates used in the STM.

Although the reasons behind this difference remain uncertain (potentially including methodological differences in estimates and true differences in loads), the implications of this change were investigated by LDWG/EPA sediment transport modeling team. The team conducted an evaluation to determine the effects on STM calibration results if the estimated upstream sediment load was decreased by approximately 50% (Integral et al. 2019). This evaluation indicated that a 50% reduction in upstream sediment load would not affect the overall reliability of the STM (LDWG 2021). The STM was calibrated to measured deposition rates throughout the LDW, so revising upstream sediment loads and recalibrating to the same deposition rates did not significantly change deposition patterns or amounts but did change the estimated percent of upstream load retained in the LDW. The reduced estimate of sediment load resulted in STM predictions of reduced transport of fine sediments through the LDW into Elliott Bay.

The LDW is net depositional, with the majority of sediments entering the LDW originating from the upstream Green River catchment. Based on the original STM calibration, approximately 220,000 metric tons of upstream sediment and 1,100 metric tons of sediment from lateral loads enter the LDW annually. Approximately 81,000 metric tons of the sediment is deposited between RMs 4.0 and 4.9, where the water velocity is reduced due to the widening and deepening of the LDW (i.e., the Turning Basin and the FNC) compared to upstream channel dimensions. The Turning Basin within the upper reach acts as a trap for suspended solids entering the LDW. Coarser grain-sized suspended solids (i.e., sands) tend to deposit in the Turning Basin, and finer-grained sediments tend to be transported and deposited farther downstream in the LDW, as well as a portion that passes through the LDW toward East Waterway, West Waterway, and Elliott Bay.

2.3.9 Erosive Forces

Erosive forces within the LDW upper reach affect the stability of bed sediment or placed materials, such as capping materials. These erosive forces are generated from naturally occurring and human-induced forces. Natural forces that occur in the LDW include wind-generated waves and hydrodynamic flows (i.e., current velocities). Human-induced forces include propwash and vessel wakes in the upper reach. Human-induced influences also include constrictions in flow due to bridge abutments. Potential effects of erosive forces and influences on capping areas are discussed in Section 10.3.

2.3.10 Presence of Debris

Debris is common in industrial waterways such as the LDW, deposited over decades of waterway use. Submerged and emergent debris are considered in the application of remedial technologies, including the type of remedial equipment used. Specifically, debris present in dredge areas will be removed as part of the remedy. Debris outside of dredging areas is not targeted for removal as part of this project. Though not anticipated, if debris outside of SMAs is encountered that interferes with construction activities or poses a threat of release associated with cleanup within an SMA, it will be removed in consultation with EPA.

For purposes of this RD, debris has been categorized as either of the following: 1) debris that is identified for removal prior to dredging (Identified Debris); or 2) debris removed with the sediment during dredging (Incidental Debris).

Section 11.2 discusses best management practices (BMPs) for handling debris, and detailed requirements are included in the Specifications (Volume III). Debris observed during the PDI is shown in DER Maps 2-6a through 2-6f (Anchor QEA and Windward 2022a). Specific Identified Debris areas, which will be managed separately as discussed in Section 10.2.3, are shown on the Drawings (Volume III).

The following areas of Identified Debris have been observed and are subject to specific review and considerations during design:

- Large debris piles in RAA 22
- Scattered concrete intermittently along the eastern shoreline of RAAs 22, 24/25/26, and 27
- Concrete rubble used as bank armoring in RAA 27
- Concrete rubble and wood in and around RAAs 32 and 33/34/35

Note that this list is limited to surficial, large debris that were visually observed during low tide site investigations. Other debris, including buried debris, may be encountered by the contractor during construction.

2.3.11 Existing Habitat Conditions

Habitat for aquatic species and aquatic-dependent species exists in the LDW and extends from the riparian area above the upper elevation of the site at MHHW (+11.3 feet MLLW) down to the Deep Subtidal areas of the LDW. These areas are all considered habitat and are divided into the following habitat types based on elevation:

- **Deep Subtidal:** Deeper than -10 feet MLLW
- **Shallow Subtidal:** -10 feet MLLW to -4 feet MLLW
- **Lower Intertidal:** -4 feet MLLW to +4 feet MLLW
- **Upper Intertidal:** +4 feet MLLW to +11.3 feet MLLW
- **Riparian:** Above MHHW (+11.3 feet MLLW)

These existing habitat types, except riparian, are shown in Figure 2-4a along with ROD-defined "habitat areas." Figure 2-4b includes bank vegetation (trees and shrubs), which is an indicator for the riparian condition. The ROD defines "habitat areas" as all areas of the waterway with elevations above -10 feet MLLW and establishes requirements for remediation in such areas (EPA 2014). Figure 2-4b includes potential clamming areas, existing bank conditions, bank vegetation conditions, and existing habitat restoration projects to provide context for the habitat types.

Bank habitat data collection occurred as part of the PDI Phases I and II in 2020 and 2021. As part of this data collection effort, vegetation conditions along the riverbank in the entire upper reach were documented via visual inspection. Vegetation was documented along riverbank stations, including vegetation type, percent cover, and plant communities. Conditions were documented for top of bank (above MHHW in the riparian zone), mid-bank (below MHHW in the intertidal zone), and toe of slope (area below bank observed during the low tide inspections in the intertidal zone). The results of the vegetation observations are shown in Figure 2-4b as existing bank vegetation. Overall, the bank vegetation consists of a mix of native trees, landscaping trees, native shrubs, and non-native shrubs. Banks were also observed to document condition, including where banks are armored (i.e., engineered surface armoring) or unarmored (i.e., discontinuous armoring, poorly placed/maintained armoring, or vegetated) or bulkheaded. As shown in Figure 2-4b, approximately 41% of the upper reach bank areas are armored, 46% are unarmored, and 13% are bulkheaded.

Additionally, RI Section 2.8 and FS Section 2.1.5 (Windward 2010; AECOM 2012) summarize the habitat types in the entire LDW. The habitat types in the LDW include intertidal marshes, intertidal mudflats, unarmored and armored intertidal areas, and subtidal areas. Intertidal marshes contain marsh soils (generally fine-textured and nutrient-rich), supporting grasses, sedges, rushes, and various other plants. For example, the Hamm Creek and Turning Basin restoration areas contain intertidal marshes within the upper reach.

Intertidal mudflats are generally defined as the gently sloping areas from MLLW up to the edge of intertidal marsh vegetation (Blomberg et al. 1988). They are unvegetated, with sand or mud substrate, and represent most of the intertidal area within the upper reach.

Approximately 48 acres of the upper reach were identified in the ROD as potential clamming areas based on bathymetric elevations (i.e., shallower than -4 feet MLLW), substrate, and salinity conditions (EPA 2014). Due to the relatively coarse scale used to create the ROD maps, a portion of these 48 acres overlaps with the armored bank at Container Properties (approximately RMs 4.0 to 4.1); the armored bank is not a potential clamming area. Potential clamming areas are a subset of the intertidal areas.

Existing habitat restoration projects that have been constructed (or are currently planned for construction) within the upper reach include the following:

- The King County shoreline habitat restoration project between RMs 3.3W and 3.4W, which includes restoration of 300 linear feet of upland and intertidal habitat

- The Boeing Plant 2 South Site habitat project between RMs 3.3E and 3.6E, which includes 1.2 acres of restored marsh habitat, 0.95 acre of restored riparian habitat, and 0.69 acre of restored intertidal habitat
- The Duwamish River People's Park and Shoreline Habitat project between RMs 3.5W and 3.9W (formerly T-117), which restored 14 acres of native riparian buffer, intertidal marsh, intertidal shoreline, and subtidal habitat
- The Hamm Creek habitat area located at RM 4.3W, where 1 acre of emergent salt marsh, 2 acres of freshwater wetlands, and nearly 2,000 feet of the Hamm Creek streambed have been restored
- The Muckleshoot Tribe habitat area at Kenco Marine, which is located near the Turning Basin at RM 4.6W, where 0.43 acre of emergent marsh and intertidal habitat and 0.23 acre of riparian habitat have been restored
- Multiple restoration projects within the Turning Basin (RM 4.7W) that have included derelict vessel removal, fill removal, creosote-treated piling and derelict structure removal, fill and large woody debris placement, and riparian and emergent plantings, resulting in 5 acres of restored intertidal habitat from 1996 through 2007 (Seaport Planning Group 2009)

2.4 Basemap Development

A basemap of the upper reach has been prepared as part of the design process and serves as the basis for the Drawings (Volume III). The basemap includes information from bathymetric and topographic surveys, structures and debris surveys, utility reviews and surveys, and review of other information. The horizontal datum for the basemap is North American Datum of 83 through the 1991 adjustment (NAD83/91), State Plane Coordinate System, Washington North Zone, measured in U.S. Survey Feet. The vertical datum for the basemap is in feet MLLW (based on the 1983 to 2001 tidal epoch).

2.4.1 Bathymetric and Topographic Surveys

Bathymetric and topographic surveys were conducted as part of the PDI. Phase I and Phase II survey collection methods and results are described in detail in the DER (Anchor QEA and Windward 2022a). Phase III survey collection methods and results are described in the Phase III Data Report (Appendix A).

In summary, bathymetric surveying was used to collect data throughout the upper reach, and topographic surveying was used to supplement the bathymetry data on bank areas within or adjacent to RAL exceedance areas up to MHHW. Where the bathymetric and topographic survey coverage overlapped, the bathymetry data are generally used as the basis of the basemap due to greater data density. Gaps in spatial coverage between the Phase I bathymetric and Phase II topographic surveys were filled via interpolation and use of publicly available Light Detection and

Ranging (LiDAR)[10] data from the Puget Sound LiDAR Consortium (PSLC 2016) for the Preliminary (30%) RD. These data gap areas were the focus of the Phase III PDI topographic survey, and results from that survey have been incorporated into the project basemap to reduce or eliminate the use of interpolation and LiDAR data in these areas. Figures 2-5a through 2-5k show how the data were merged to create a composite elevation dataset for the basemap.

2.4.2 Structure and Debris Surveys

Location data and information on structures were obtained from the Waterway User Survey (Integral et al. 2018). The topographic survey team also collected survey point data for significant bank features, such as structure corner points, debris areas, and outfalls. The locations of significant debris features were delineated in more detail during the Phase III topography data collection. These features have been integrated into the basemap.

2.4.3 Utilities

Location data and information on outfalls were originally obtained from the LDW RI (Windward 2010) and Ecology's 2014 outfall inventory (Leidos 2014) and further updated based on Ecology's 2020 Outfall Inventory Updates for the LDW (Leidos 2020). In addition, outfall information has been supplemented by information available from the LDWG parties. As noted previously, outfall information was also collected during the topographic surveying activities for outfalls in or adjacent to RAL exceedance areas, and this information was used to update or replace the existing information from the Outfall Inventory Updates. Finally, a review of available documents, such as as-builts from recent construction projects in or near the site, was also completed. The updated outfall information is presented in the figures in this report.

In addition to outfalls, there is one known active utility crossing in the upper reach associated with the current South Park Bridge, and there are abandoned utility crossings associated with the former bridge (Roark 2022). The location of these crossings was incorporated into the basemap from the South Park Bridge construction documents provided by King County (KCDOT 2010). During the Phase II PDI, LDWG conducted utility locate research and utility clearance through 811. Through this review, no additional crossings were identified.

2.4.4 Other Basemap Data

A variety of other data have been incorporated into the basemap, including the following:

- Aerial photography
- Property boundary maps

[10] LiDAR data collection methods, interpretation, resolution, and accuracy are described in detail in the LiDAR submittal report (Quantum Spatial 2016).

- Construction project as-built surveys (including EAAs, habitat projects, and ENR/AC Pilot plot boundaries)
- USACE centerline and stationing
- Habitat features along bank areas

2.5 Data Sources and Evaluations

PDI chemistry data used in the Final (100%) RD were collected over three phases between 2019 and 2022, as summarized in the DER (Anchor QEA and Windward 2022a) and the Phase III Data Report (Appendix A). The DER evaluations, which incorporated the PDI data into the design dataset, are a key input to this BODR and include the following:

- Combined new and existing sediment chemistry data based on the data management rules presented in the DER
- Comparisons of sediment chemistry data to the RALs based on the ROD criteria
- Adjusted recovery category areas based on ROD criteria
- Interpolated sediment chemistry data to delineate RAL exceedance areas
- Assignment of preliminary remedial technologies based on ROD criteria

The methods used to define remediation areas are presented in Sections 4 through 6 of this BODR. Section 4 describes how the horizontal and vertical extents of contamination are defined. Section 5 presents the Final (100%) RD assignment of remedial technologies. Section 6 builds on the considerations presented in Sections 4 and 5 and, combined with engineering considerations, develops and presents RAAs. Section 7 describes the approach for grouping RAAs into SMAs.

The DER also summarizes the following PDI data that support the RD:

- Geotechnical investigations
- Bank visual inspections
- Structures inspections
- Bathymetric, topographic, and other surveys
- Other engineering design data

These data are used in Section 8 (Geotechnical Engineering Considerations), Section 9 (Structural Engineering Considerations), Section 10 (Remedial Technology Design), and, as supporting information, across other sections of this document.

3 ARARs Compliance Evaluation

This section describes the Applicable or Relevant and Appropriate Requirements (ARARs) embodied in the federal and state laws that govern the work, as identified in the ROD (EPA 2014). Some of the ARARs include requirements to obtain permits and approvals. Pursuant to Section 121 of CERCLA (United States Code [USC] Title 42, Section 9621), no permits are required for on-site remedial actions. Only substantive requirements of these laws and implementing regulations apply. EPA will determine substantive compliance with ARARs in coordination with resource agencies, as EPA deems appropriate, using the supporting information presented in this section and related appendices.

ARARs fall into several categories including cleanup and waste management standards, water quality and waterway protection, environmental protection, air quality and noise, and archaeological, cultural, and historic resources. This section describes how compliance with ARARs will be achieved and documented. In general, measures that address ARAR compliance are documented in the Specifications (Volume III). However, some ARARs will require the preparation of specific deliverables, as noted in the following sections. Appendix B contains supplemental details for each of the laws and regulations described herein.

3.1 Hazardous Substance Cleanup and Sediment Quality

Specific cleanup levels and RALs are identified in ROD Sections 8.2.1 and 13.2.1, respectively (EPA 2014). The RALs are being used to delineate areas where remedial action is necessary. Implementing remedial actions (e.g., dredging, capping, ENR) will not, by itself, address the ARARs associated with cleanup standards, including Sediment Management Standards. MTCA is Washington's environmental cleanup law (Revised Code of Washington [RCW] 70.105D, Washington Administrative Code [WAC] 173-340) and implements sediment standards under WAC 173-204. The remedy has been designed to meet RALs at the time of the remedy construction completion. Successful implementation of the remedy will be documented in a construction completion report, and long-term monitoring will be developed as part of the Long-Term Maintenance and Monitoring Plan (LTMMP). Maintenance and monitoring will begin at the completion of the upper reach construction and will document compliance with (or progress toward) meeting cleanup levels as well as the continued effectiveness of the remedy. Although natural recovery processes are ongoing, the 10-year period for achieving cleanup levels through natural recovery will begin after sediment remedial construction is completed for the entire LDW site unless otherwise determined by EPA.

3.2 Surface Water Quality

Several federal and state programs regulate surface water quality, including the following:

- Ambient Water Quality Criteria per Clean Water Act (CWA) Section 304(a) and 33 USC 1314(a)

- National Toxics Rule Standards (40 Code of Federal Regulation*s* [CFR] 131.36[b][1]) as applied to Washington (40 CFR 131.36[d][14])
- Washington State Water Pollution Control Act (RCW 90.48)
- Washington State Water Quality Standards (WAC 173-201A)

Sediment remediation will improve surface water quality in combination with source control implementation under state-lead authority. According to the ROD, surface water standards shall be at least as stringent as all of the following:

- "All water quality standards in WAC 173-201A;
- Ambient Water Quality Criteria unless it can be demonstrated that such criteria are not relevant and appropriate for the LDW or for a specific hazardous substance; and
- The National Toxics Rule." (EPA 2014)

Monitoring for relevant Ambient Water Quality Criteria will occur during construction. For any construction-related discharges to the LDW, water quality monitoring will occur per an approved Water Quality Monitoring Plan (WQMP; included in the CQAP [Volume II, Part I, Appendix A]), BMPs will be employed, as needed, for the protection of water quality, and response actions will be required in the event of any exceedances of the compliance criteria identified in the WQMP.

The water quality standards for surface water implement portions of the federal CWA by specifying the designated uses for water in Washington. For the Duwamish River, designated uses include aquatic life uses for rearing and migration, recreation uses for primary contact, and water supply uses for all uses except domestic water.

3.3 Waste Management

Several federal and state laws regulate the characterization, storage, and transportation for disposal of waste materials derived from remediation activities. These include the following regulations pertaining to solid waste disposal; waste treatment, storage, and disposal; and land disposal of waste:

- Solid Waste Disposal Act (42 USC 6901-6992K; 40 CFR 257-258)
- Solid Waste Management (RCW 70.95; WAC 173-350)
- Resource Conservation and Recovery Act, Hazardous Waste (42 USC 6901-6992K, 40 CFR 260-279)
- Dangerous Waste Management (RCW 70.105; WAC 173-303)
- Toxic Substances Control Act (15 USC 2605; 40 CFR 761.61[c])
- Resource Conservation and Recovery Act, Land Disposal Restrictions (42 USC 6901-6992K; 40 CFR 268)

All material removed from the upper reach will be managed in a commercial permitted disposal site. Based on the data in the RI (Windward 2010) and DER (Anchor QEA and Windward 2022a), a hazardous/dangerous waste screening was performed comparing bulk concentrations of toxicity characteristic leaching procedure (TCLP) constituents to 20 times the TCLP regulatory levels (the "20 times rule" commonly used as a screening tool), and two RAAs (18 and 22) were identified for additional characterization. This screening is inherently conservative, and when applied to an individual sample, an additional level of conservatism results: waste characterization applies to bulk material, which would more appropriately be characterized using a composite approach rather than an individual sample approach.

A preliminary waste characterization was performed, as described in Volume II, Part V, on three composite sediment samples (two from RAA 18 [northern and southern areas] and one from RAA 22) and on composite samples representing three debris piles. All sediment and debris samples passed the TCLP, and sediment from the southern portion of RAA 18 and RAA 22 was determined not to be a toxic dangerous waste. In addition, acute toxicity testing was conducted, as described in Volume II, Part V, which confirmed that the debris will not need to be managed as dangerous waste. Sediment from the northern portion of RAA 18 was preliminarily determined to be a toxic dangerous waste based on the results of the bulk chemistry and the book designation procedure defined in WAC 173-303-100(5)(b). A bioassay was not performed on sediment from the northern portion of RAA 18 because sufficient sample material was not available. As described in Section 2.2, action in RAA 18 is being deferred. A complete preliminary waste determination for this RAA will be performed when appropriate.

Sediments in the upper reach are also not expected to contain concentrations of PCB compounds regulated under the Toxic Substances Control Act. The highest total PCB concentration in sediment was 233 milligrams per kilogram (mg/kg) in the 0 to 10 cm interval at location NFK305. The sample was collected in 1995. Subsequent samples collected in the vicinity of this location found much lower concentrations of PCBs. All other samples collected in the upper reach had total PCB concentrations below 50 mg/kg, which is the concentration above which materials are regulated under the Toxic Substances Control Act.

Characterization of wastes for disposal acceptance will be based on data from the RD and supplemented as needed during the remedial action. The specific disposal facility and modes of transportation will be proposed by the contractor, subject to EPA review and approval. All off-site disposal or recycling of remediation wastes will be at permitted facilities in compliance with EPA's Off-Site Rule (40 CFR 300.440).

When material is staged or transferred between modes of transportation, the transfer will be performed at an existing permitted commercial transfer facility, or a new transfer facility will be established with appropriate permitting or substantive permitting compliance. A transportation and disposal plan will be prepared after a contractor is selected as a pre-construction submittal as part of the contractor's Remedial Action Work Plan (RAWP) for EPA review and approval.

Shipments of material from the site for disposal will be documented and quantities reconciled to confirm that material removed from the site is disposed of properly. For material that is not regulated as hazardous/dangerous waste, trip tickets will be reconciled with waste receipts issued by the disposal facility. If any material is found to be regulated as hazardous/dangerous waste, manifests will be used to track the material from the point of generation to disposal. The transportation and disposal plan will contain additional details about the characterization, handling, and documentation of material removed from the site. Quantities of waste removed from the site will be reported during construction and summarized in the construction completion report.

If characterization of sediment determines that any of the removed material will be regulated as hazardous/dangerous waste, the contractor will obtain a generator identification number and manage the material characterized as hazardous/dangerous waste in a facility permitted to manage such material. The material would be treated prior to disposal to meet the requirements of applicable land disposal restrictions. Any hazardous/dangerous waste removed from the upper reach will be managed at facilities operating in conformance with their operating permits; facility compliance will be confirmed with the appropriate EPA Off-Site Rule contact prior to shipping any waste from the site. The episodic generation provisions of 40 CFR 262 Subpart L and WAC 173-303-173 will apply to the remedial action for any sediment found to be regulated as hazardous or dangerous waste.

3.4 Dredge/Fill and Other In-Water Construction Work

Several federal and state programs regulate the discharge of dredged and fill materials and in-water construction work. These programs include the following:

- CWA Sections 401 and 404 (33 USC 1341, 1344; 40 CFR 121.2, 230, 232; 33 CFR 320, 322-323, 328-330)
- Hydraulic Code Rules (RCW 77.65; WAC 220-660)
- Dredged Material Management Program Suitability Determination (RCW 79.105.500; WAC 332-30-166 [3])
- Rivers and Harbors Act Section 10 (33 USC 403)
- Rivers and Harbors Act Section 408

EPA will issue a CWA Section 404 ARAR Memorandum defining requirements for CWA Section 401 compliance (i.e., cleanup actions meet applicable water quality standards). The Final (100%) RD includes evaluations to predict potential water quality effects due to dredging, as described in Appendix M. Based on these evaluations, no acute or chronic water quality exceedances of contaminants of concern (COCs) are predicted. EPA and Ecology will use this information to develop specific water quality monitoring requirements in the CWA Section 404 ARAR Memorandum. Prior to construction, EPA will issue a finding that substantive requirements of the CWA Section 404 ARAR Memorandum have been met, potentially with conditions determined in coordination with Ecology. The WQMP (Volume II, Part I, Appendix A) describes the specific requirements for monitoring water quality during construction and steps to be taken to mitigate exceedances of water quality standards, if any occur. The WQMP will be finalized to reflect any conditions or requirements contained in the CWA Section 404 ARAR Memorandum. The results of water quality monitoring and any corrective actions taken will be regularly reviewed during construction to assess the need for any corrective actions and summarized in the construction completion report.

A key element of compliance with CWA Section 404 is evaluation of the placement of dredged or fill material within waters of the United States. Federal regulations (40 CFR 230) set forth specific standards to implement CWA Section 404(b)(1). No material will be placed in the water until EPA has reviewed and approved the characterization results. Appendices C and D present the *Clean Water Act Sections 401/404 and Rivers and Harbors Appropriations Act Section 10 Substantive Compliance Report* and the *Section 408 Substantive Compliance Report*, respectively, for the remedy.

Although a Washington Department of Fish and Wildlife Hydraulic Project Approval is not required for this project, substantive compliance will require the implementation of conditions to avoid or reduce potential impacts to aquatic species or habitats during construction. Examples of these conditions include the following:

- Work within established in-water work windows for the waterbody.
- Establish a staging area in a location that will prevent contaminants from entering waters of the state.
- Clearly mark boundaries establishing limits of work.
- Check equipment daily for leaks, and complete repairs before using equipment in or near the water.
- During excavation, complete each pass with the clamshell or dragline bucket.
- Do not stockpile dredged material waterward of the ordinary high water mark.
- Dispose of dredged bed materials in an approved disposal site.
- To reduce turbidity, hopper dredges, scows, and barges used to transport dredged materials to the disposal or transfer sites must completely contain the dredged material.

The Specifications (Volume III) identify conditions to be required.

The Final (100%) RD does not include open-water disposal or beneficial reuse of sediments. Therefore, there are no specific requirements of the Dredged Material Management Program that are currently incorporated into the design.

Requirements for dredging, capping, ENR, and backfill elevations have been established in the ROD (EPA 2014) and were designed to accomplish the following: 1) preserve navigation and commerce by maintaining elevations below the authorized depth in the FNC; and 2) preserve habitat at elevations between -10 feet MLLW and MHHW. Any existing structures that are demolished or modified as part of the project will be either restored to provide the functional equivalent of existing conditions or permanently removed with consent of the owner.

3.5 Fisheries, Wildlife, and Endangered Species

Several regulations relate to fisheries, wildlife, and endangered species, including the following:

- Endangered Species Act (ESA) (16 USC 1531-1544)
- Migratory Bird Treaty Act (16 USC 703-712; 50 CFR 10 and 21)
- Bald and Golden Eagle Protection Act (16 USC 668; 50 CFR 22)
- Bald Eagle Protection Rules (RCW 77.12.655; WAC 232-12-292)

In accordance with Section 7 of the ESA (16 USC 1536), a BA is provided in Appendix E of this BODR. The BA is intended for EPA to submit to the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) to initiate formal consultation about the potential effects of the proposed remedial action and ways to reduce those effects on species listed under the ESA (Appendix E). The impact of remedial activities on all habitat types, including the ROD-defined "habitat areas" (EPA 2014), are being evaluated during RD to comply with CWA Section 404 and Section 7 of the ESA to support the BA. The result of the habitat evaluation will determine if the remedial activities are expected to improve or degrade habitat conditions relative to existing conditions.

NMFS and USFWS will issue a Biological Opinion that states whether EPA has ensured that its action is not likely to jeopardize the continued existence of a listed species or result in the destruction or adverse modification of critical habitat. Biological Opinions provide an exemption for the "incidental take" of listed species (e.g., harassment, harm, pursuit, hunting, shooting, wounding, killing, trapping, capturing, or collecting) while specifying the extent of incidental take allowed, the reasonable and prudent measures that would reduce impacts from the federal action, and the terms and conditions with which EPA must comply.

Consideration of the effects of federal actions on Essential Fish Habitat (EFH) for covered species including salmonids is required under the Magnuson-Stevens Fishery Conservation and Management Act (16 USC 1801) and its implementing regulations. Typically, state or federal agencies planning actions that might adversely affect an EFH-managed species must formally consult with NMFS regarding the action. An EFH evaluation is included in the BA (Appendix E).

Allowable periods of in-water work have been identified as designated by NMFS and USFWS and published on the USACE website (see Section 13 for details on the in-water work window scheduling assumptions). Specific habitat mitigation measures, including the use of habitat compatible substrates and restoring pre-construction grades and elevations within habitat areas are incorporated into the RD. The Biological Opinion may include additional conservation measures (such as restrictions on allowable work periods in certain areas) to further reduce impacts.

During the remedial action, steps will be taken as needed to protect habitat for migratory birds and avoid disturbances of their nests and eggs.

If the nearest documented bald eagle nest is within the buffer distances to the remedial construction activity, construction will occur outside the bald eagle nesting season. If the nearest documented bald eagle nest is farther away from the project site than the buffer distances, the proposed action will be considered to be compliant with the Bald and Golden Eagle Protection Act. Information from the Washington Department of Fish and Wildlife bald eagle database will be obtained prior to construction to determine whether any bald habitats (e.g., nests, roosts, and forage) are present in the vicinity of the upper reach.

3.6 Floodplain Protection

In order to comply with the Floodplain Management Procedures (40 CFR 6, Appendix A, Section 6; see also Executive Order 11988), RD will avoid adversely impacting floodplains and wetlands wherever possible and consider flood hazards and floodplain management. If there is no practicable alternative to locating in or affecting floodplains or wetlands, potential impacts will be reduced to the extent practicable. In accordance with this regulation, the design will maintain the flood carrying capacity within the LDW. Details of the Flood Rise Analysis that was conducted as part of Final (100%) RD are described in Section 10.8 and Appendix L.

3.7 Shoreline Management

The City of Seattle Shoreline Master Program (Seattle Municipal Code 23.60A), City of Tukwila Shoreline Master Program (Tukwila Municipal Code 18.44),[11] and King County Shoreline Master Program (King County Code 21A.25) govern the shoreline areas within 200 feet of the ordinary high water mark. However, the Shoreline Management Act (RCW 90.58; WAC 173-26) provides exceptions for cleanup actions. Per RCW 90.58.355 and WAC 173-27-044, remedial actions at a facility pursuant to a Consent Decree, order, or agreed order are not required to obtain shoreline permits or undergo local review. Although the project qualifies for an exception from the Shoreline Management Act, the proposed activities would all be allowed uses and incorporate BMPs or conservation measures to avoid, minimize, or mitigate for potential adverse impacts to the shoreline environment, consistent with mitigation sequencing requirements. The project will still substantively comply with the

[11] Although the City of Tukwila Shoreline Master Program was not listed as an ARAR in the ROD, Tukwila Municipal Code Section 18.44 is being considered during RD.

Shoreline Management Act by resulting in no net loss of ecological function, and in fact, will result in a net gain, based on the habitat evaluation completed for the Biological Assessment in Appendix E.

3.8 Air Emissions and Noise

The following federal and state laws regulate the impacts of air emissions:

- Clean Air Act (42 USC 7401-7671q; 40 CFR 50)
- Washington Clean Air Act (RCW 70.94; WAC 173-400)
- Noise Control Act (RCW 70.107; WAC 173-60-040, 050)

In addition, compliance with noise requirements will be required for the cities of Seattle and Tukwila and unincorporated King County areas when working close to residential areas (upland and liveaboard) adjacent to the project site perimeter to limit the extent of possible noise impacts to the community (Seattle Municipal Code Chapter 25.08; Tukwila Municipal Code Chapter 8.22; King County Title 12.86). For the remedial action, reasonable precautions must be taken to accomplish the following: 1) prevent the release of air contaminants; 2) prevent fugitive dust from becoming airborne; and 3) maintain and operate the source to limit emissions (RCW 70.94). The Specifications (Volume III) require that the contractor's operations limit air emissions. The project will comply with these ARARs through the development of the design specifications and BMPs implemented during construction.

Maximum permissible environmental noise levels for sound sources measured at or within the boundary of a receiving property, subject to exemptions, are specified in Section 11.3.1.2, along with time of day considerations and BMPs during construction.

3.9 Historic Resources

The following federal laws regulate historic resources:

- National Historic Preservation Act Section 106 (16 USC 470; 36 CFR 800)
- Native American Graves Protection and Repatriation Act (25 USC 3001 et seq.)
- American Indian Religious Freedom Act (42 USC 1196 et seq.)

The effect of the remedial activity on any district, site, building, structure, or object included or eligible for inclusion in the National Register of Historic Places will be evaluated in consultation with the State Historic Preservation Office during RD. An *Archaeological Monitoring and Inadvertent Discovery Plan* has been prepared (Volume II, Part I, Appendix D) to be implemented by the Implementing Entity or contractor during construction.

The LDW and its surrounding area have a long history of pre-colonial tribal use, and cultural resources are known to exist in areas of land and shoreline along the waterway. It is possible that inadvertent disturbance of Native American or other cultural materials from earlier times may occur as a result of sediment dredging. To protect Native American burials and cultural items, the regulations require that if such items are inadvertently discovered during excavation, the excavation must cease, and the affiliated tribes must be notified and consulted. The Specifications (Volume III) require the contractor to monitor for cultural resources and to cease excavation should such items be observed in the materials being loaded onto the barges. If Native American or other cultural materials may be unearthed, the National Historic Preservation Act (16 USC 470), American Indian Religious Freedom Act (42 USC 1196 et seq.), and their implementing regulations require that federal agencies must also consider the possible effects on historic sites. If an agency finds a potential adverse effect on historic sites or structures, the agency must evaluate alternatives to avoid, minimize, or mitigate the impact, in consultation with the State Historic Preservation Officer. The Specifications also require the contractor to cease excavation should such materials be observed in the materials being removed.

4 Extents of Contamination

For the purpose of RD, the term "extents of contamination" in this BODR refers to the horizontal and vertical limits that exceed thresholds for application of an active remedial technology per the ROD (EPA 2014).

The predicted horizontal and vertical extents of contamination, defined based on the design dataset, reflect the spatial extent of sediment that exceeds RALs and represents the minimum remediation surface. This section describes the methods used to develop the horizontal and vertical extents of contamination for the site.

4.1 Horizontal Extents of Contamination

The horizontal extent of contamination was defined using the design dataset and applying geostatistical interpolation methods, as described in the DER (Anchor QEA and Windward 2022a). This delineates the areas with RAL exceedances in the upper reach. The horizontal extents of contamination adjacent to banks were extrapolated to the MHHW elevation. Appendix K in the DER provides a detailed analysis of the geostatistical interpolation methods. Updated Phase III RAL exceedance area maps are provided in the Phase III Data Report (see Appendix A, Attachment A.4).

4.1.1 Horizontal Interpolation Methods

PCBs were selected as the primary COC for geostatistical interpolation because PCBs delineate a majority[12] of the RAL exceedance areas in the upper reach. Other COCs exceeding RALs in localized areas were evaluated separately. Interpolations were performed on two sediment depth-defined datasets over which RALs are applied: surface sediment, defined as 0 to 10 cm (0 to 4 inches); and subsurface sediment, defined as 0 to 45 cm (0 to 1.5 feet) in intertidal areas, 0 to 60 cm (0 to 2 feet) in subtidal areas, and shoaling intervals in the FNC.[13] The interpolated results for PCBs and other COCs, in surface and subsurface sediments, were combined in the final RAL exceedance area footprint, which served as the foundation to establish the horizontal extents of contamination.

Interpolation method selection and application were developed through a series of technical meetings with LDWG and EPA statisticians. The following two interpolation methods were selected based on the assessment described in the DER (Anchor QEA and Windward 2022a):

- **Indicator Kriging (PCBs):** Indicator kriging was selected as the preferred method for PCB interpolation. Indicator kriging has been successfully applied to support RD and remedial

[12] Based on the results of the interpolation work described in the DER (Anchor QEA and Windward 2022a), PCBs were estimated to account for 88% of the RAL exceedance areas in the upper reach. This percentage was calculated as the ratio of interpolated RAL exceedance area circumscribed by PCBs (in acres) to the total RAL exceedance area circumscribed by all COCs (see DER Appendix K Map K-4a [Anchor QEA and Windward 2022a]).

[13] The maximum concentration in any shoaling interval or the -15- to -17-foot MLLW interval (i.e., 2 feet below authorized FNC depth in the upper reach of LDW) was selected for each shoaling core location.

action in the Lower Fox River, Green Bay, Wisconsin (Kern et al. 2008; Wolfe and Kern 2008; Anchor QEA and Tetra Tech 2016) and is recommended for use in sediment RD in Portland Harbor, Portland, Oregon.

- **Thiessen Polygons (other COCs):** In localized areas, the RAL exceedance area boundary was expanded where other COCs exceeded RALs but PCBs did not. The RAL exceedance area boundaries for COCs other than PCBs were established using Thiessen polygons, a simpler geometric and deterministic interpolation method.

4.1.2 Horizontal Interpolation Results

Indicator kriging provides quantitative, probabilistic information directly in the interpolation output and is a primary line of evidence for assessing the uncertainty of the PCB RAL boundary. The indicator kriging results represent the probabilities of exceeding the applicable depth-specific and area-specific PCB RALs, expressed in units of percent. The indicator kriging maps presented in the Phase III Data Report (Appendix A) include contours ranging from 20% to 80% probabilities of exceedance, at 10% intervals, as shown in Maps A.4-6a through A.4-6c in Appendix A, Attachment A.4. The 50% (median) PCB RAL exceedance boundary combined for both surface and subsurface sediments is overlain with Thiessen polygons for other COCs where they extend beyond the PCB boundary, as shown in Figures 4-1a through 4-1d.

The 50% probability of exceedance contour represents the median or central tendency estimate of the horizontal PCB RAL exceedance boundary (i.e., horizontal extent of contamination for PCBs). On the Fox River and Hudson River sediment cleanup sites, the median kriging estimate was similarly used to define the remediation boundary for RD (Thornburg et al. 2005; QEA 2007; Kern et al. 2008; Wolfe and Kern 2008; Anchor QEA and Tetra Tech 2016). The 50% (median) probability of exceedance contour plus Thiessen polygons for other COCs was therefore used as the minimum basis for setting RAA boundaries in the upper reach. In consultation with EPA, additional Phase III PDI samples were collected to further reduce the uncertainty of RAL exceedance area boundaries in specific locations, and these Phase III data are incorporated in the Final (100%) RD (including in the revised interpolation discussed in this section).

As described in Section 6 of this BODR, the RAA boundaries (i.e., remediation footprint) were expanded beyond the interpolated RAL 50% probability exceedance area boundaries to address engineering and constructability considerations. As a result, the RAAs provide even greater confidence that RAL exceedances are being comprehensively addressed by RD.

In total, 36 distinct RAL exceedance areas were identified in the upper reach, as shown in Figure 4-2. These areas include RAL exceedances and interpolation-only areas.

4.2 Vertical Extents of Contamination

The vertical extent of contamination within RAL exceedance areas was defined on a point-by-point basis using sediment core sample data, the conceptual site model, and, as a line of evidence, historical dredging limits adjacent to the FNC, as documented in USACE post-dredge surveys. As detailed in Table A.1-3 of Appendix A, there are two elevation datasets available for each sediment core location: the real-time kinematic differential global positioning system (RTK-DGPS) field measurement and the bathymetric mudline elevation. The RTK-DGPS field measurements typically registered a lower mudline elevation than the bathymetry data, leading to a more conservative estimate (i.e., deeper) of the bottom elevation of contamination. Thus, the RTK-DGPS-derived elevations were used to define the vertical extents of contamination.

The ROD does not define RALs for vertical data collected deeper than the 0- to 45-cm or 0- to 60-cm intervals outside of shoaled areas of the FNC. The vertical extent delineation assumes that once an area has been designated for dredging based on results in surface or subsurface RAL intervals, dredging would be advanced to a depth interval whereby the post-dredge surface (assessed as a 1-foot depth core interval) would not exceed the surface RALs (0- to 10-cm [0- to 4-inch] RALs).[14] The vertical extent of contamination is based on the bottom elevation of the deepest vertical core interval with concentrations greater than a surface RAL, with at least 1 foot of sediment with no surface RALs exceedances below. For PDI cores that advanced into the native alluvium, the top 1-foot interval of the native alluvium layer was sampled separately from the sediment above. No RAL exceedances were reported in samples from the native alluvium layer (see DER Map 3-4 series [Anchor QEA and Windward 2022a]). Therefore, sediment remediation does not extend into the native alluvium.

As noted previously, contamination was considered vertically bounded if there was at least one 1-foot sampling interval below the depth of contamination without surface RAL exceedances. When neighboring cores indicated a different vertical extent of contamination, the horizontal halfway point between the two cores generally defined the extent over which each dredge elevation or thickness was applied.

To define the required dredge elevation, the vertical extent of removal at each core location was adjusted downward (i.e., deeper removal) considering engineering factors such as constructability. Section 10.2.4 provides detail on how the vertical extent of contamination was translated into required dredge elevation or required dredge thickness for areas where dredging is the selected technology.

[14] The surface sediment RALs used to evaluate the vertical intervals were based on the recovery category associated with each location. The surface sediment RAL for PCBs is the same in all recovery categories (ROD Table 28 [EPA 2014]).

5 Remedial Technology Assignment

Remedial technology assignments were initially defined in the Phase II QAPP Addendum and then updated in the DER (Anchor QEA and Windward 2022a). Remedial technologies assignments are assigned to each RAL exceedance area based on Figure 19 and Revised Figure 20 of the ROD (EPA 2014), taking into account many factors including mudline elevation, RAL exceedance factor, depth of contamination, and recovery category designation.

Potential remedial technologies identified in the ROD (EPA 2014) for intertidal and subtidal areas include the following:

Intertidal:

- MNR below benthic SCO[15]
- MNR to benthic SCO[16]
- Area-specific technology
- ENR
- Partial dredge and engineered cap
- Dredge and backfill

Subtidal:

- MNR below benthic SCO
- MNR to benthic SCO
- Area-specific technology
- ENR
- Partial dredge and engineered cap
- Dredge (with backfill in habitat areas)
- Engineered cap

The preliminary remedial technology assignments from Table L-1 of the DER (Anchor QEA and Windward 2022a) included multiple technology options for areas with data gaps or areas that spanned boundaries with different applicable technologies (e.g., intertidal/subtidal areas, recovery categories, large areas with varied sample results). For the Final (100%) RD, the technology assignments have been updated based on available data, site condition information, and engineering considerations, and are summarized in Table 5-1 and Figures 5-1a and 5-1b. Figure 5-2 shows sample locations where MNR to benthic SCO is applicable (see Section 10.7.1 for further discussion on this topic).

[15] Per the ROD, MNR below benthic SCO will be applied where the concentration of all COCs is less than the RAL and the RAO 3 cleanup levels (benthic SCO criteria), but greater than the human health-based (RAOs 1 and 2) cleanup levels (which are measured on an LDW-wide or area-wide basis; EPA 2014).

[16] Per the ROD, MNR to benthic SCO will be applied where the concentration of any of the 39 RAO 3 COCs (i.e., excluding the human health COCs PCBs and arsenic) is less than the RAL but greater than the RAO 3 cleanup levels (benthic SCO criteria; Table 27 of the ROD [EPA 2014]) and modeling results indicate that the COC will be reduced to the benthic SCO criteria within 10 years of the completion of remedial action (EPA 2014).

Table 5-1
Final (100%) Remedial Design Technology Assignments by RAL Exceedance Area

RAL Exceedance Area	Technology Assignment[1]	Notable Factors Impacting Technology Assignment
1	Dredge	None
2	Dredge	None
3	Dredge	None
4	Dredge	None
5	Dredge	This area includes a dredge offset from the South Park Bridge fender.
6	Dredge	None
7	ENR	None
8	Dredge	None
9	None	This is an interpolation-only area.[2,3] This area is not considered constructable due to its location immediately beneath and behind the bridge fendering system, where access is too restricted for equipment to operate. No remedial action is planned.
10	ENR	None
11	None	Due to its proximity to the South Park Bridge, the required dredge offset distance, the small size of the horizontal footprint, and the RAL exceedance being driven by mercury and fluoranthene with relatively low exceedance factors of 1.04 and 1.1, respectively, no remedial action is planned for this area (LDWG 2023).
12	Dredge	None
13	ENR	This area is located on a steep slope. The material selection for ENR in this area has a coarser gradation to enhance stability compared to ENR that is placed on gentler slopes or in flat areas.
14	Partial Dredge and Cap and Dredge	Partial dredge and cap over FNC and 10-foot buffer; dredge and backfill outside of 10-foot buffer
15	Partial Dredge and Cap and Dredge	Partial dredge and cap over FNC and 10-foot buffer; dredge and backfill outside of 10-foot buffer
16	Partial Dredge and Cap and Dredge	Partial dredge and cap over FNC and 10-foot buffer; dredge and backfill outside of 10-foot buffer
17	Dredge	None
18	Deferred	The remedy at RAA 18 is deferred as discussed in Sections 2.2 and 6.1.3.
19	Dredge	None
20	Dredge	None
21	None	This former interpolation-only area was sampled during Phase III PDI (location LDW22-SC800) and confirmed to be below the RAL. No remedial action is planned.
22	Dredge	Debris piles will be removed to the existing surrounding mudline surface plus 2 feet of additional removal (consistent with the surrounding dredge depth [see Section 10.2.4] and to provide sufficient removal depth to allow for placement of 2 feet [60 cm] of clean backfill material).

RAL Exceedance Area	Technology Assignment[1]	Notable Factors Impacting Technology Assignment
23	ENR	None
24	Dredge and Area-Specific Technology	An area-specific technology (amended cover; see Section 10.5) has been applied to a portion of the area due to adjacent structure(s) and in the offset area immediately east of the ENR/AC Pilot plot.
25	Dredging	None
26	Dredge and Area-Specific Technology	An area-specific technology (amended cover; see Section 10.5) has been applied to a portion of the area to avoid impacts to the armored slope.
27	Dredge and Partial Dredge and Cap[4]	The bank of RAA 27 will require reconstruction after excavation. The reconstructed bank has been designed to provide function as a cap, if necessary, and long-term monitoring and institutional controls will be required if it is designated as a cap. If a cap is not needed (based on post-excavation sampling during construction), the same bank reconstruction detail will be used, but there would not be a need for long-term monitoring of cap performance or related institutional controls.
28	Dredge	Although the current Slip 6 elevations are within the range of habitat elevations defined in the ROD, Slip 6 is a permitted berth. Therefore, the dredge area will not be backfilled for habitat purposes.
29	Dredge	None
30	Dredge	None
31	Dredge	None
32	Dredge	None
33	ENR	None
34	Dredge	None
35	Dredge	None
36	ENR	None

Notes:

1. The technology assignment of "dredge" also requires backfill to restore existing grade in habitat areas (i.e., -10 feet MLLW and above).
2. Interpolation-only areas are artifacts from the interpolation analysis and do not include a sample location with an RAL exceedance.
3. Phase III sampling was not conducted to confirm the "interpolation-only" classification of this area because of sampling equipment access limitations.

Due to unknown sediment quality on the bank slope, an engineered cap is being designed for the area. Post-removal testing will occur to determine if the engineered cap is required or whether the cap substrate will serve only as backfill below the armor surface.

AC: activated carbon
cm: centimeter
ENR: enhanced natural recovery
FNC: federal navigation channel
MLLW: mean lower low water
PDI: pre-design investigation
RAL: remedial action level
ROD: Record of Decision

6 Remedial Action Areas Development

Following assignment of remedial technologies, areas with RAL exceedances were developed into RAAs based on three primary considerations: engineering considerations, review of adjacent chemistry results, and constructability of the assigned technology. Additionally, review of potential RAL exceedance area boundary uncertainties was performed as a modifying consideration. The Preliminary (30%) RD RAA extents were then defined using engineering best professional judgment. These processes are described in the following sections. Following receipt of Phase III PDI data, these considerations were revisited, resulting in the updated RAA footprints that are presented in the Final (100%) RD.

Figures 6-1a through 6-1l show the RAA boundaries in relationship to the RAL exceedance areas, and Figures 6-2a through 6-2j show the RAA boundaries in relation to the design dataset sample locations and results.

6.1 Engineering Considerations

One step in the RAA development process involved reviewing the interpolated RAL exceedance area boundaries with the overlying engineering design factors. These design factors vary slightly for each of the different remedial technologies but generally result in the RAA boundaries that are more linear (e.g., straight lines) and expand the remedial action footprint to encompass a larger area compared to the RAL exceedance areas.

In some locations, engineering considerations result in an RAA boundary that is inside the interpolated RAL exceedance area boundary; for example, where construction offsets from structures or armored slopes will be required to protect structures or armored slopes. Areas where the RAA boundary may not capture the full interpolated RAL exceedance area boundary are discussed in Table 6-1.

The engineering considerations described in the following sections were used to define the Final (100%) RD RAA boundaries.

6.1.1 Geometry Considerations

For RAAs where dredging or partial dredging and capping are the planned remedial technology, RAL exceedance areas were enclosed by dredging toe-of-cut boundary lines composed of straight lines and constructable angles for dredging feasibility. The toe of cut represents the boundary where the contractor will be required to conduct full vertical depth removal. The toe of cut is generally set at or outside of the RAL exceedance area boundaries (i.e., typically captures a larger area than the RAL exceedance area). For RAL exceedance areas that extend up a slope, the toe of cut was sometimes set inside the RAL exceedance area. In these cases, the dredge side slope was checked to confirm that the dredging removes the full depth of RAL interval exceedance within the full extent of the RAL exceedance area. For ENR and amended cover placement areas, the RAA boundaries were not squared off in straight lines because material placement over irregular shapes is less challenging than material removal. A 10-foot horizontal buffer was added around the RAL exceedance area boundary when developing ENR RAAs. No horizontal buffer is added to amended cover areas because they are directly adjacent to dredge areas and structures.

6.1.2 Site Physical Conditions

Factors including but not limited to slopes, berthing depth requirements, presence of debris, presence of armored slopes, and presence of structures in the uplands adjacent to a bank were also considered. For example, when a RAL exceedance area is present on a sloped area, the RAA boundaries were developed using straight lines that were drawn parallel and perpendicular to existing contours to the extent possible. This was done to define action areas that are more stable for dredging and backfilling and to provide dredge prisms that are easier to measure during construction to confirm that the contractor is complying with design Drawings and Specifications.

Site physical conditions specifically consider slope stability and offsets as follows:

1. **Sediment Stability/Side Slope Angles:** Following definition of the toe of the dredge cut for dredge prisms, side slope angles were established to leave a stable long-term post-dredge surface or to provide a slope angle that is stable during construction but would need to be backfilled to a flatter slope angle to achieve long-term stability. The side slope is the area over which the dredge cut slopes up from the dredge elevation/depth to meet the existing mudline. Side slopes are constructed at slope angles defined by recommendations from the geotechnical analyses (Section 8).
2. **Structure Offsets:** For dredging areas, horizontal offsets from structures (e.g., the South Park Bridge, bulkheads along CenterPoint Properties) were included based on a review of available data compared to dredge depths. Horizontal offsets represent an area adjacent to the structure that needs protection where no dredging or excavation will be allowed to prevent adverse impacts to the adjacent structure.[17] The offset distance includes a horizontal offset from the top of the daylight cut, which is where the dredge cut side slope intersects the existing mudline. For ENR and area-specific technologies that include material placement areas, no offsets were determined to be necessary.
3. **Utility Offsets:** Based on a records review, public and private utility locate, and property owner outreach during Phase II PDI activities, only one active submarine utility line was identified in the upper reach. This buried line is located within the footprint of the South Park Bridge and is at an elevation -37.7 feet MLLW, well below planned dredging activities. Because of the depth of this

[17] Offsets are discussed further in Sections 8 and 9. A 3-foot dredge offset from structures is used in Pre-Final (90%) RD.

utility, King County Roads Services Division confirmed that no offset is needed from the active utility line (Roark 2023). An additional waterway crossing consisting of abandoned electric utility lines associated with the former South Park Bridge was also identified in the area. Detailed drawings obtained from King County indicate that the elevation (approximately -23 feet MLLW) at which the lines crossed the LDW is close to the elevation of the planned dredging activities. In addition, a cable lying on the mudline near the old bridge alignment has been abandoned in place. King County Road Services Division has confirmed that any of these abandoned lines, if they are encountered during construction, are approved to be removed and disposed of (Roark 2022). Similar to the approach implemented during the Boeing Plant 2 EAA dredging, no offset has been defined related to these abandoned lines.

6.1.3 Adjacent Early Action Areas, Upland Site Cleanup, and Habitat Site Conditions

1. **Adjacent EAAs:** RAAs bordering EAAs were evaluated based on the horizontal and vertical extent of EAA post-dredge surfaces. In cases where buried contaminated material is interpreted to potentially remain between the RAA dredge prism and EAA post-dredge surface, RAA boundaries were expanded to create a continuous remedy. Specifically, this occurred for RAAs 1/2/3 and 4/5/6, adjacent to the Boeing Plant 2 EAA. Phase III PDI data collected in these EAA border areas were reviewed to confirm the horizontal boundaries for these RAAs. This evaluation occurred for the other EAAs, and it was determined that no adjustments were required.
2. **Upland Site Cleanups:** As discussed in Section 2.2, there are five upland cleanup sites (four Ecology-led and one EPA-led) that are adjacent to LDW upper reach RAL exceedance areas. The remedy for one of the RAL exceedance areas (RAA 18) needs to be further assessed and coordinated with the upland site in a process outside the upper reach design but within the context and timing of the overall LDW Superfund Site cleanup. Additional details about this area are as follows:
    a. **RAA 18 (adjacent to the Boeing Isaacson Thompson upland site; Figure 6-1f):** Due to unbounded contamination adjacent to a deteriorating bulkhead, understanding of the adjacent upland RD progress, and Ecology's determination that upland sources are not considered sufficiently controlled, the remedy at RAA 18 is being deferred. Deferral of the remedy at this area will allow for integration of the upland and in-water cleanup actions, which will improve the overall remedy effectiveness, decrease the risk for recontamination, and provide time for source control sufficiency prior to in-water remedial action. An integrated cleanup of RAA 18 and the upland area may also have the potential to improve the habitat condition at this location. Until the upland cleanup is at a design stage sufficient to develop an integrated cleanup action, an appropriate sediment/bank design is not feasible. Additional in-water data were collected during the Phase III PDI to support subsequent in-water design efforts. A coordinated sediment cleanup at RAA 18 can be

implemented within the overall time frame for the LDW Superfund Site, as shown in the timeline comparison in Figure 6-3.

3. **Habitat Areas**: Information from recently constructed habitat areas (e.g., the Duwamish River People's Park and Shoreline Habitat project) was reviewed to set RAA boundaries along the habitat areas to provide for a logical transition between habitat areas and the adjacent RAA.

6.1.4 Review of Other Available Engineering Information that Informs the Physical Conceptual Site Model

Review of the USACE historical post-dredge and condition survey records from 1945 to 1978 indicated that maintenance dredging extended horizontally beyond the FNC in some locations during past dredge events. This led to adjustment of the RAA toe of cut in one area during the Preliminary (30%) RD and Intermediate (60%) RD. This RAA (RAA 1/2/3) was adjusted to set the toe of cut inside the RAL exceedance area boundary to best match the RAA removal extents with the lateral dredging extents interpreted from historical dredging records in that area. Phase III PDI data were collected to verify the horizontal extent of contamination in RAAs 1/2/3 and 4/5/6, and the dredge prisms have been adjusted accordingly.

6.2 Review of Adjacent Chemistry Results

Another step in developing RAAs involved reviewing design dataset sampling results immediately outside of the RAL exceedance areas. Sample results near RAL exceedance areas were reviewed on a point-by-point basis, and engineering best professional judgment was used to decide if and how far to extend the RAA boundary. Specifically, samples that were close to exceeding the RAL (i.e., between a RAL exceedance factor of 0.9 and 1) were reviewed with respect to proximity to RAL exceedance areas and magnitude of nearby exceedances. Data density was also considered when looking at specific areas where expansion of RAAs beyond the initial engineering considerations could be warranted. No adjustments were made to boundaries following this review of the data.[18]

6.3 Constructability

After defining RAAs based on engineering considerations and a review of adjacent data, areas were reviewed from a holistic perspective to identify potential constructability issues and reduce complexity from a contractor's constructability standpoint. Constructability refers to the ease and feasibility for a remediation contractor to construct the RD and is affected by the type of equipment the contractor uses, physical site conditions, and ability by the Owner to effectively monitor and measure the contractor's work. Similar to engineering considerations, constructability considerations typically expand the area covered by an RAA (compared to the RAL exceedance area). Areas where

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[18] Though no adjustments were made solely based on review of the adjacent chemistry results, several locations with exceedance factors between 0.9 and 1.0 were encompassed into RAAs as a result of engineering considerations.

the RAA boundary may not capture the entire RAL exceedance area boundary are discussed in Table 6-1.

Modifications to RAAs to address constructability considerations include the following:

- Merging of areas near one another (e.g., RAAs 1/2/3 and 14/15/16): Leaving small areas between RAAs will complicate construction and reduce efficiency. Remediating those small areas between RAL exceedance areas can also help address other practical considerations such as residuals management requirements.
- Incorporating small areas that are contained within a large RAL exceedance area but where the interpolation predicts there is not a RAL exceedance: Although these small interior areas with no RAL exceedances do not require action, the RD assumes that including these areas (e.g., RAA 27) will result in overall more efficient and cost-effective removal than relying on the dredging precision that would be necessary to exclude these areas.
- Considering equipment access limitations: Site restrictions that may limit the ability for equipment access will be evaluated to avoid specifying a remedial action that is not feasible to construct due to equipment inaccessibility.

6.4 Consideration of Interpolation Uncertainties in RAA Boundaries

This section discusses interpolation uncertainty and how such uncertainty informs further adjustments, if warranted, to RAA boundaries beyond the adjustments already made for engineering considerations, review of adjacent chemistry results, and constructability.

As noted in Section 4.1.2, the 50% probability of exceedance contour for PCBs in combination with Thiessen polygons for other COCs (i.e., RAL exceedance areas) was used as the RAL exceedance boundary, which was the starting basis for setting RAA boundaries.

During their development, RAA boundaries were compared at a high level against the RAL exceedance area probability of exceedance contour banding maps that showed probability from 20% to 80% of PCBs exceeding RALs based on data interpolation.

Figures 6-4a through 6-4c show the boundaries of RAL exceedance areas, probability of exceedance bands (20% to 80%), and the Final (100%) RD RAA boundaries. As the figures show, the RAA boundaries typically extend well beyond the RAL exceedance area boundaries due to design adjustments for engineering factors, adjacent sediment chemistry, and constructability. This expansion of the RAA boundaries addresses much of the potential uncertainty in the interpolation, effectively removing much of the area with 40% to 30% probability of exceedance, and provides a high level of confidence in achieving the intent of the ROD by actively remediating these larger areas.

Where significant areas in the 30% to 40% uncertainty range remained outside of the RAA boundaries during the Intermediate (60%) RD, additional Phase III data were collected to inform revisions to RAA boundaries.

6.5 Summary of Remedial Action Areas

Table 6-1 summarizes the unique or specific considerations for each RAA beyond the general considerations described in Section 6.1. Appendix F discusses one additional RAA for an area where the ROD (EPA 2014) carcinogenic polycyclic aromatic hydrocarbon (cPAH) RALs are exceeded.

The total surface area of the RAL exceedance areas included in the 100% RD, delineated as described in Section 4, is 330,900 square feet (or 7.6 acres). For comparison, the total surface area of the RAAs is 633,400 square feet (15.1 acres), which is an 91% increase from the RAL exceedance areas.

RAL exceedance area numbering presented in the DER (Anchor QEA and Windward 2022a) and Preliminary (30%) RD has been retained for Final (100%) RD. For areas that have merged, the RAA is referred to using all associated RAL exceedance area numbers (e.g., “RAA 1/2/3”). Numbering for the Drawings (Volume III) has been replaced with SMA numbering (Section 7).

Table 6-1
RAA Development Considerations

RAA	Area-Specific RAA Development Considerations[1]
1/2/3	• Western toe of slope adjusted based on review of Phase III PDI data. • Eastern boundary expanded to overlap with Boeing Plant 2 EAA based on review of as-built survey data. • RAL exceedance areas 1/2/3 merged due to proximity and associated constructability considerations. • Non-RAL exceedance areas encompassed within RAA due to constructability considerations.
4/5/6	• Western toe of slope adjusted based on review of Phase III PDI data. • Eastern boundary expanded to overlap with Boeing Plant 2 EAA based on review of as-built survey data. • RAL exceedance areas 4, 5, and 6 merged due to proximity and associated constructability considerations. • Non-RAL exceedance areas encompassed within RAA due to constructability considerations. • Dredge offset from South Park Bridge fenders applied.
7	• No area-specific considerations.
8	• No area-specific considerations.
9	• This is an interpolation-only area and not considered constructable (Table 5-1); remedial action is not planned in this area.
10	• No area-specific considerations.
11	• Due to its proximity to the South Park Bridge, the required dredge offset distance, the small size of the horizontal footprint, and the low RAL exceedance factor, no remedial action is planned for this area (LDWG 2023).
12	• No area-specific considerations.
13	• The typical 10-foot ENR buffer has been reduced along the marina basin to avoid placement of material in the berthing area. The buffer was maintained on the north and south sides of RAA 13 along the bank above the marina basin. This modification of the buffer in the basin is not expected to reduce the effectiveness of ENR in this location because the sample exceeding the RAL is located on the less depositional armored bank, whereas the marina basin itself is a depositional area.
14/15/16	• RAL exceedance areas 14, 15, and 16 merged due to proximity and associated constructability considerations. • Review of Boeing Plant 2 EAA post-dredge data confirms the eastern boundary matches EAA dredge limits. • Review of T-117 EAA post-dredge data confirms the western boundary matches EAA dredge limits. • Non-RAL exceedance areas encompassed within RAA due to constructability considerations.
17	• Review of Jorgensen Forge EAA post-dredge data confirms the eastern boundary matches EAA dredge limits.

RAA	Area-Specific RAA Development Considerations[1]
18	• Source control sufficiency and coordination of remedy with adjacent upland cleanup (Boeing Isaacson Thompson) process is necessary for RAA 18. An integrated upland/in-water remedy will be developed that will follow a timeline compatible with the upland cleanup process (Figure 6-3) but within the overall LDW site cleanup.
19/20	• RAL exceedance areas 19 and 20 merged due to proximity and associated constructability considerations. • Western toe adjusted based on review of habitat construction as-builts and Phase III PDI data.
21	• This is a former interpolation-only area that was verified to not exceed RALs based on Phase III PDI data (location 800). Remedial action is not planned in this area.
22	• Adjacent ENR/AC Pilot plot is used to define the edge of the RAA for design purposes. • Debris removal area adjacent to sheetpile wall. • Coordination with adjacent upland cleanup property (8801 East Marginal Way) conducted throughout design phases.
23	• Western toe adjusted based on review of habitat construction as-builts.
24/25/26	• Dredge offset from sheetpile wall applied; area-specific technology to be used in offset area.[2] • RAL exceedance areas 24, 25, and 26 merged due to proximity and associated constructability considerations. • Coordination with adjacent upland cleanup property (8801 East Marginal Way) conducted throughout design phases.
27	• Non-RAL exceedance areas encompassed within RAA due to constructability considerations. • Eastern revetment footprint set based on several factors, including proximity to upland remediation features, existing slope geometry, required cut thickness for material placement requirements, etc. See Section 10.3 for more details. • Coordination with adjacent upland cleanup property (Container Properties) conducted throughout design phases.
28	• Discrete areas merged due to proximity and associated constructability considerations.
29	• No area-specific considerations.
30	• No area-specific considerations.
31	• No area-specific considerations.
32	• Interpolation extrapolated to MHHW line up steep armored bank; eastern toe adjusted accordingly (see Section 4.1 for further discussion). • Coordination with adjacent upland cleanup property (Boeing Developmental Center) conducted throughout design phases.

RAA	Area-Specific RAA Development Considerations[1]
33/34/35	• Interpolation extrapolated to MHHW line up steep armored bank; eastern toe adjusted accordingly (see Section 4.1 for further discussion). • RAAs merged due to proximity. ENR placement in RAL exceedance area 33 expanded to meet adjacent dredging in RAL exceedance areas 34 and 35. • Coordination with adjacent upland cleanup property (Boeing Developmental Center) conducted throughout design phases.
36	• No area-specific considerations.

Notes:

1. Area-specific RAA considerations are in addition to practical engineering considerations, review of adjacent chemistry results, constructability of the assigned technology, and RAL exceedance area boundary uncertainties, as described in Section 6.1.
2. Dredge offset areas are identified where dredging was determined to create risk of armored slope or structure instability or potential failure. Dredge offsets are also applied to protect structures from physical contact with construction equipment. ENR placement is proposed for use in offset areas where the adjacent sediment concentrations are below the ENR upper limit, whereas an area-specific technology is proposed for offset areas where concentrations exceed the ENR upper limit (see Section 10.5 for more information on the area-specific technology).

AC: activated carbon
EAA: early action area
ENR: enhanced natural recovery
FNC: federal navigation channel
MHHW: mean higher high water
PDI: pre-design investigation
RAA: remedial action area
RAL: remedial action level
RD: remedial design
USACE: U.S. Army Corps of Engineers

7 Sediment Management Areas Development

SMAs[19] have been developed to facilitate construction management by organizing the overall project into areas that are manageable for construction. SMAs do not change the RAA extents; rather, they provide a consistent nomenclature for referring to areas in design and construction management. Generally, SMAs consist of grouped or subdivided RAAs with similar logistical considerations such as common construction methods, adjacent locations, and similar site conditions. SMAs are used in the construction drawings to define discrete areas for construction management (e.g., construction sequencing).

SMAs also serve as discrete areas over which remedy construction progress can be evaluated with QA/quality control (QC) protocols, subsequent construction steps or contingency actions can be performed as needed, and SMA construction can be determined complete as the cleanup progresses. The CQAP (Volume II, Part I) provides details on the specific QA/QC protocols during construction, and the associated contractor requirements are included in the Specifications (Volume III).

SMA designations are based on engineering judgment. Factors that affect SMA delineation include recontamination risk of remediation areas and adjacent areas during construction, technology types and construction methods, administrative and site access considerations, and subdivisions of large RAAs, as discussed in the following sections.

7.1 Recontamination Risk During Construction

The development of SMAs considered the potential for recontamination of remediated areas and adjacent areas that are not actively remediated as the construction progresses. The following considerations have been reviewed to develop SMAs that limit the risk of recontamination during construction:

- The proximity of RAAs to one another
- Potential vessel propwash from contractor operations
- Remedial technologies being used (i.e., dredging and placement activities)
- The phasing of dredging and placement activities
- Construction activities occurring over multiple in-water work seasons

If it is determined that RAAs have the potential to pose a recontamination risk to one another, this would be a reason to combine these RAAs within one SMA such that the sequencing of the work within the individual SMA can be completed in an appropriate order to reduce the potential for

[19] SMAs for RD are used in a different context than described under Washington State Sediment Management Standards. Under those standards, SMAs support cleanup decision making during the RI/FS. For the remedial design described in this BODR, SMAs are used to organize the design for other reasons as described in the RDWP (Anchor QEA and Windward 2019a).

recontamination. For example, the RAAs 32 and 33/34/35 were combined into a single SMA, in part due to their proximity.

7.2 Technology Types and Construction Methods

The type of remedial technology or equipment used to implement the remedy at a specific location is also a factor in developing SMAs. There is a preference to consolidate and complete areas with similar technology types at the same time within the construction sequence to improve QC. An example of this consideration is the use of two SMAs in RAA 27 to separate work anticipated to be conducted by land-based versus water-based equipment.

7.3 Administrative and Site Access Considerations

Administrative considerations have also been considered in developing the SMAs, including site access constraints and property ownership. Combining areas with similar administrative considerations will facilitate efficiency by allowing for work with similar constraints to be completed at the same time, limiting interruptions to particular operators or general waterway navigation. For example, the areas surrounding the South Park Bridge are grouped into a single SMA.

7.4 Subdivisions of Large RAAs

Large dredging RAAs (i.e., RAAs 1/2/3 and 4/5/6) were subdivided into SMAs representing approximately 10,000 cubic yards (cy) of material because that was considered to be a fair representation of the amount of dredging that could occur in 1 to 2 weeks, after which remedy construction progress evaluation (as described in the CQAP) would be performed. For these large dredging areas, the recontamination risk from residuals during construction (between the adjacent SMAs) is managed through the specific sequencing of the work, the QA/QC of the dredging, the framework for contingency action decisions, and subsequent construction steps. QA measures and the contingency action decision process for SMAs is described in the CQAP.

7.5 Summary of Sediment Management Areas

RAAs have been grouped into SMAs for Final (100%) Design, as described in Table 7-1 and as shown in Figure 7-1, based on the specific factors discussed previously and shown in the Drawings included in Volume III. The SMA numbering sequence starts at the most upstream location and progresses downstream. SMAs include subareas designated by letters (e.g., "SMA 1B") to further differentiate discrete areas that have been grouped together as one overall SMA. The BODR text that follows Section 7 refers to SMA numbering to the extent possible. In certain cases, RAA numbering continues to be used when specific evaluations that used RAA boundaries are referenced.

Table 7-1
SMA Development Considerations

SMA	RAA	Specific Considerations for SMA Development
1	32, 33/34/35	Recontamination risk from residuals; site access
2	30, 31	Recontamination risk from residuals
3	29	Discrete area
4	28	Discrete area
5	27B (partial), 27C (partial), 27D (partial)	Construction method; site access (upland)
6	27A, 27B (partial), 27C (partial) , 27D (partial)	Construction method; site access (in-water)
7	24/25/26A, 24/25/26B	Discrete area
8	23	Discrete area
9	22A, 22B	Discrete area
10[1]	18	Discrete area
11	19/20, 36	Discrete area
12	14/15/16, 17	Recontamination risk from residuals
13	13	Discrete area
14	4/5/6D, 8, 10, 12	South Park Bridge area
15	4/5/6A (partial), 4/5/6C, 4/5/6D, 7	Subdivisions of large RAAs
16	4/5/6A (partial), 4/5/6B	Subdivisions of large RAAs
17	1/2/3B (partial), 1/2/3C (partial), 1/2/3D	Subdivisions of large RAAs
18	1/2/3A, 1/2/3B (partial), 1/2/3C (partial)	Subdivisions of large RAAs

Notes:

1. RAA 18 is being deferred for source control sufficiency and until the upland cleanup is at a design stage that is sufficient to develop an integrated cleanup action with in-water cleanup. An SMA number has still been assigned to the RAA for current and future reference.

RAA: remedial action area
SMA: sediment management area

8 Geotechnical Engineering Considerations

This section presents the results and recommendations of the geotechnical engineering evaluations for the LDW upper reach. Appendix G presents a more detailed discussion of the geotechnical engineering evaluations completed to support Final (100%) RD.

8.1 Geotechnical Field Investigation Summary

Subsurface geotechnical conditions at the site were investigated by Anchor QEA as part of the Phase I and Phase II PDI efforts completed in 2020 and 2021. The DER (Anchor QEA and Windward 2022a) and Appendix G of this BODR describe the geotechnical investigation and results.

The locations of these geotechnical investigations are presented in Figures 8-1a and 8-1b. Additional details, including boring logs, in situ testing data, and results of laboratory geotechnical testing results, are presented as attachments to Appendix G.

8.2 Subsurface Stratigraphy

This section describes the three major geologic units encountered during the geotechnical PDI. Subsurface conditions encountered during the geotechnical investigation are in general agreement with those presented in the RI/FS and consist of recent sediments overlying alluvium within the waterway. Fill material was encountered overlying the alluvium unit in upland locations, and based on the history of river realignment, it is expected to be present in shoreline bank areas to below MLLW where the historical river channel was filled and in other shoreline locations where the grade was raised to support upland development.

General descriptions of the soil and sediment layers and their geotechnical characteristics identified from the borings and investigations advanced at this site are presented in the following sections in order from the ground surface downward.

8.2.1 Fill

Fill soils were encountered at two locations during the Phase II PDI field program and at several other upland locations investigated for other projects. The specific geologic interpretation of "fill" is indicated on historical boring logs from Boeing Plant 2, both the east and west banks at the South Park Bridge, and at several properties that are not adjacent to SMAs (e.g., near RM 3.0 west; and between RMs 3.5 and 3.6 west at Terminal 117). Given the river history of channelization, fill is likely present along many banks of the upper reach that have not been geotechnically investigated.

Generally, this material was placed in early 1900s to regrade the existing fluvial plain created by the Duwamish River to support shoreline development and the re-channelization of the river. The unit weight of this material is assumed to vary, but for preparing design recommendations it is assumed to be conservatively represented using an overall average value of 135 pounds per cubic foot (pcf), based on laboratory direct shear test results of sample intervals identified as fill. Grain size distribution testing shows that this material is mostly sand with varying amounts of silt. In areas where fill was more randomly or recently placed, the fill is expected to contain anthropogenic materials such as debris, which would be typical of historical shoreline development filling activities in active industrial areas. The moisture content in the fill unit generally ranges from 6% to 28%. Direct shear testing of the fill indicates a peak friction angle average of 36 degrees and a residual friction angle average of 33 degrees.

The findings associated with the two upland borings completed by Anchor QEA in 2021 are in general agreement with historical investigations completed by others.

8.2.2 Recent Sediments

Recent sediments were encountered throughout the intertidal and subtidal areas. Recent sediments are defined as material that has deposited on top of the alluvium layer and are distinctly characterized by finer gradation and soft consistency compared to the alluvium layer below. Recent sediments were naturally deposited by river flows entering the upper reach from upstream following the creation of the waterway.

The thickness of this unit across the site varies widely and is thickest in areas of historical dredge activities in the FNC and Slip 6. Based on a review of laboratory testing results, a total unit weight of 100 pcf was assumed to best represent average overall conditions, with percent moisture content ranging from 34% to 97%. Atterberg limits (plasticity) testing indicates that this material is typically nonplastic to very low plasticity, an indication that the finer fractions are mostly silt rather than clay. Direct shear testing indicates a peak friction angle of 34 for the recent sediments, and a residual friction angle of 33 degrees. Vane shear testing and full flow penetrometer testing indicate undrained shear strengths ranging as shown in Figure G2-1 of Appendix G. Grain size analyses indicate that this material is approximately 30% sand and 70% silt and clay, with silt content ranging from 22% to 62% and clay content ranging from 2% to 7%.

8.2.3 Alluvium

Investigations prior to the PDI describe the alluvium in reference to an upper alluvium unit and a lower alluvium unit. Because the distinction between the upper alluvium and lower alluvium is not important in the context of the sediment cleanup, in the DER, the description of these materials was simplified by combining the upper alluvium and lower alluvium into a single alluvium unit, recognizing that there are some gradational changes in the alluvium with depth (Anchor QEA and Windward 2022a). Alluvium was observed to underlie the recent sediments and is mostly coarse-grained material with pockets, lenses, and layers of silt and clay. Silt content of the fine-grained layers is as high as 76%, and clay content is as high as 16%. Silt and clay content in the mostly coarse-grained material was observed to be as low as 1.5% within this unit. This unit has a typical specific gravity of 2.5 to 2.7, is nonplastic, has a typical total unit weight of 125 pcf, and has a measured average peak friction angle of 37 degrees and a measured average residual friction angle of 32 degrees.

The alluvium unit was the deepest layer encountered during the geotechnical PDI.

8.3 Geotechnical Engineering Design Recommendations

This section summarizes the results and design recommendations based on the geotechnical analyses presented in Appendix G for the following:

- Dredge prism side slope stability
- Backfill side slope stability
- Cap bearing capacity, settlement, and slope stability
- Lateral earth pressures for bulkhead evaluations
- Geotechnical recommendations for pile design
- Bank slope stability
- Seismic performance of caps

Details regarding the processes, assumptions, models, and approach used to develop the geotechnical engineering design recommendations are provided in Appendix G. The following sections describe the results of these analyses as they relate to RD.

8.3.1 Dredge Prism Side Slope Stability

Dredging is required on intertidal and subtidal slopes, and dredge cuts also require side slopes to reach the design removal elevation or depth. The stability of dredge prism side slopes was evaluated using limit equilibrium methods implemented by the Rocscience SLIDE2 software (SLIDE) and confirmed using slope stability chart solutions presented in USACE (2003).

Target slope stability factors of safety are 1.3 for short-term conditions (e.g., a dredge cut before backfill is placed), 1.5 for long-term conditions (e.g., a final post-backfill slope angle), and 1.3 for rapid drawdown conditions in accordance with USACE (2003) and as described in Appendix G. As described in Appendix G, temporary side slopes of 2 horizontal to 1 vertical (2H:1V) and permanent unarmored side slopes of 3H:1V have acceptable factors of safety, whereas acceptable stability of steeper permanent side slopes can be achieved using armor rock.

8.3.2 Backfill Side Slope Stability

Backfill, consisting of sand and gravel materials as described in Section 10.6, will be placed following dredging in habitat areas (i.e., elevations higher than -10 feet MLLW). In deeper dredging areas, there will be a backfill slope that transitions from the backfill downward to meet the post-dredge surface below elevation -10 feet MLLW. Backfill may also be used following steeper temporary cuts that would be made to limit the removal of clean slope materials (e.g., transition slopes adjacent to the Boeing EAA where clean backfill was placed). As described in Appendix G, backfill side slopes of 3H:1V have an acceptable slope stability factor of safety for sand and gravel habitat materials. Steeper backfill slope angles (up to 2H:1V) have acceptable factors of safety in cases where armor rock is used.

8.3.3 Cap Geotechnical Evaluations

This section describes geotechnical evaluations for the following factors that govern cap design:

- Bearing capacity, which evaluates the degree to which the subgrade strength is sufficient to support the weight of the cap
- Settlement, which evaluates whether the subgrade beneath the cap will compress under the weight of the cap
- Slope stability, which evaluates the degree to which the cap and the subgrade will remain stable (not move) in sloped areas

As noted in Table 6-1, there is a potential need for a cap to be constructed on the excavated slope along the Container Properties shoreline (RAA 27/SMA 5). In addition, the Final (100%) RD includes partial dredging and capping in SMA 12B.

Cap subgrade bearing capacity and post-construction cap settlement were assessed for an example 4-foot-thick cap. The static slope stability of a cap along the Container Properties shoreline was also evaluated using limit equilibrium methods.

Caps will typically be constructed after dredging or excavation and in most cases will not raise the ground surface above the existing grade. As such, caps constructed under these conditions will balance out the subgrade loads by replacing the load imposed by the dredged sediment (unloading the subgrade) with a load imposed by the cap. For these conditions, the bearing capacity of the subgrade to support the cap was calculated and found to have an acceptable factor of safety. The settlement caused by the cap load is estimated to be on the order of 2 to 3 inches. Differential settlement of the cap or the cap subgrade is not anticipated to be significant and would not reduce the effectiveness of caps if it were to occur, as discussed in Appendix G.

In summary, the major conclusions of cap geotechnical evaluation presented in Appendix G are as follows:

- A 4-foot-thick cap has acceptable bearing capacity factors of safety. Thus, no consolidation periods are required between placement of cap lifts.
- Post-cap subgrade settlement in dredge areas is estimated to range from 2 to 3 inches.

- The majority of post-cap subgrade settlement is estimated to occur within 120 days after cap construction.
- A 2H:1V armored slope cap constructed along the Container Properties shoreline has an acceptable static slope stability factor of safety.

These subgrade settlement estimates are important to consider in the construction QA of the placed caps because surveys of the cap surface will reflect both the thickness of the cap material and the consolidation of the subgrade.

8.3.4 ENR and Area-Specific Technology Geotechnical Considerations

In limited circumstances, cover material will be placed with a final surface above the existing grade, for example, in ENR placement areas and offset areas where dredging cannot be accomplished against structures. As described in Section 10.5.2, offset locations will use area-specific technologies, which entail placement of a relatively thin cover (9 to 15 inches of sandy gravel material). Because some mixing of cover materials with surface sediments is acceptable, bearing capacity and settlement evaluations for ENR and area-specific technologies using thin cover are unnecessary. To enhance stability, coarser materials will be used for the ENR that will be placed on the slopes in the South Park Marina, as discussed in Table 5-1.

8.3.5 Lateral Earth Pressures for Bulkhead Evaluations

Lateral earth pressure recommendations were developed to support structural evaluations for existing bulkheads. Structural evaluations, in turn, are used to develop recommendations regarding dredging and capping adjacent to existing bulkhead structures and to assess whether offsets or other measures are needed to protect bulkheads. Appendix G presents specific lateral earth pressure recommendations for structural design evaluations.

8.3.6 Evaluation of Dredge Offsets from Structures

As described in Appendix G, dredging immediately adjacent to shoreline structures will reduce the lateral support provided by the sediment adjacent to the structure (i.e., the passive earth pressure). Reduction in passive earth pressure can cause structural damage if not appropriately considered in the RD. One way to limit or prevent the reduction of passive earth pressure is to offset the dredge cut a sufficient distance from the structure. This section provides a summary of the dredge offset evaluation that is described in more detail in Appendix G.

The extent to which passive earth pressure is reduced by adjacent dredging is a function of the offset distance, the depth of dredging, and the slope angle of the dredge cut. Appendix G presents the following conclusions from this evaluation:

- Without a dredge offset, resisting forces (i.e., passive earth pressures) are reduced from 38% to 75% of full passive earth pressure for dredge slope cuts ranging from 1H:1V to 2H:1V.
- Passive earth pressure reduction factors are presented in Appendix G for use during structural evaluations to develop recommended dredge offsets. Section 9 describes dredge offsets in more detail.

8.3.7 Geotechnical Recommendations for Piling

Pilings are anticipated to be removed and replaced to facilitate access for dredging at some locations. There may also be a need for isolated pile removal for derelict piles that do not have any identified current or future use but may be inhibiting access for nearby remediation.

Replacement piles are expected to support lateral loads from river currents and boat traffic. Any piles that are removed that support net fishing will also be replaced and designed to resist forces imposed by the nets, which will be evaluated in coordination with tribal fishers. Piles are assumed to be replaced to provide "in kind" functions to piles that are removed; however, because timber piles require chemical treatment to limit decay, timber piles will be replaced with steel piles during reconstruction.

To support structural engineering evaluations, geotechnical design recommendations for replacement piling are presented in Appendix G. The recommendations include modeling parameters to be used in lateral pile design analysis software (i.e., LPile) so that pile deflection and embedment can be determined by the structural engineer. Results of these evaluations inform the sizing (diameter, wall thickness, and length) of the replacement piles, as described in Section 9.

8.3.8 Bank Slope Stability

The RD includes dredging near existing waterfront facilities and shorelines. Dredging removes sediments that support the toe of the slope and hence the resisting force against a potential sliding mass.

8.3.8.1 SMA 12B – T-117 Bank

The bank adjacent to T-117 in SMA 12B includes a temporary 2H:1V dredge cut that will be capped in the channel and backfilled on the slope to reestablish a final 3H:1V slope. Appendix G presents the results of slope stability evaluations for an example cross section through this area. The slope stability evaluation concluded that both short-term and long-term factors of safety are acceptable.

8.3.8.2 SMA 5 – Container Properties Bank

Dredging on the mudflat at Container Properties will extend up the bank. Appendix G presents geotechnical stability evaluations of the Container Properties bank slope (SMA 5), including short-term stability during construction, long-term stability post-construction, long-term seismic stability, and consideration of rapid drawdown. The bank excavation cut is assumed to be 2.5H:1V or flatter. The bank would be reconstructed with an armored revetment consisting of sand and gravel backfill (which could also function as a cap, if needed) overlain by armor rock to a final post-construction 2.5H:1V slope.

The bank slope has acceptable factors of safety for short-term, long-term, seismic, and rapid drawdown conditions, assuming an armor layer consisting of quarry spall to light riprap-sized armor material.

8.3.8.3 Other Bank Areas

For other bank areas, it is assumed that minor thickness cuts (i.e., 1 to 2 feet below existing grade) can be made while maintaining an acceptable bank slope stability factor of safety.

8.3.9 Seismic Performance of Caps

The upper reach lies in a seismically active region and is characterized by sources of strong ground shaking (earthquakes) including the Cascadia Subduction Zone and relatively shallow crustal zones such as the Seattle fault zone. Seismic performance of caps was evaluated by considering liquefaction potential and seismic stability of caps on slopes. Work included estimating liquefaction-induced settlement, and estimating potential deformations (movement) of caps on slopes during an earthquake. Caps placed in flat areas such as SMA 12B would not be damaged from seismic deformation.

Two different earthquakes were evaluated. The 100-year return interval earthquake was evaluated (peak ground acceleration = 0.19g [g= acceleration of gravity]), consistent with the 100-year modeling time frame considered for contaminant transport evaluation. In addition, the larger, 475-year earthquake (peak ground acceleration = 0.41g) was considered. This larger earthquake has a 10% probability of exceedance in a 50-year time frame and is a commonly considered earthquake for Superfund sediment remedies. The following summarizes the major conclusions of the seismic performance evaluation:

- Liquefaction is predicted under both the 100-year and 475-year earthquakes. Liquefaction results in loss of soil strength (i.e., reductions in bearing capacity) and settlement.
- Cone penetrometer test records were analyzed for liquefaction-induced settlement; predicted settlements range from 3 to 14 inches (median settlement 7 inches) under either earthquake scenario.

- For a cap along the shoreline in SMA 5 at Container Properties, deformation is predicted to be less than 0.5 inch in the 100-year earthquake and 8 to 16 inches in the 475-year earthquake. The cap would be protected by a layer of armor rock, which enhances the seismic stability of the slope. For the cap at SMA 12B, deformation is not a design consideration because the cap will be constructed on level ground; therefore, there is no slope that would trigger earthquake deformation.

Based on the liquefaction assessment and slope displacement estimates, the RD is expected to have acceptable seismic performance. Anticipated settlement and displacement under the 100-year event is expected to be significantly less than proposed cap thicknesses. During a larger 475-year earthquake, the cap and underlying sediments may move down the slope, but the cap is not expected to be significantly damaged because the movement is predicted to be less than the overall cap thickness.

Post-earthquake assessment and mitigation measures are recommended based on this analysis and will be identified in the LTMMP. Assessment typically includes visual inspections and bathymetry surveys following seismic events above a defined threshold to evaluate the condition of caps. Cap repairs, if needed, could be readily implemented by adding more cap materials to address any localized thinning associated with post-earthquake deformation or settlement.

Details of the seismic performance evaluation are presented in Appendix G.

8.4 Summary of Geotechnical Engineering Design Recommendations

Table 8-1 summarizes the key geotechnical engineering recommendations presented in this section of the BODR.

Table 8-1
Summary of Key Geotechnical Engineering Design Recommendations

Remediation Element	Geotechnical Evaluation	Conclusion
Dredging	Temporary Side Slopes	• 2H:1V side slopes have acceptable FOS.
	Long-Term Side Slopes	• 3H:1V side slopes have acceptable FOS.
	Structural Offset Evaluations	• Passive earth pressures should be reduced adjacent to structures unless dredge prisms are offset. Reduction factors for use in structural engineering evaluations are presented in Appendix G.
Capping	Bearing Capacity	• Caps up to 4 feet thick have acceptable bearing capacity FOS.
	Subgrade Settlement	• Settlement of 2 to 3 inches is predicted for caps in dredge and cap areas. Differential settlement of caps and cap subgrade will be minor and is not predicted to affect the performance of caps. • Settlement is estimated to occur within 120 days after cap placement.
	Static Slope Stability	• A 2.5H:1V slope cap placed along the Container Properties shoreline at SMA 5 would have acceptable slope stability FOS.
	Seismic Performance	• Estimated displacement of 2.5H:1V slope caps along the Container Properties shoreline at SMA 5 under 100-year earthquake is less than 0.5 inch. • Estimated displacement of 2.5H:1V slope caps along the Container Properties shoreline at SMA 5 under 475-year earthquake is 8 to 16 inches. • The LTMMP will describe measures for post-earthquake inspections.
Backfill	Long-Term Side Slopes	• For sand and gravel backfill, 3H:1V side slopes have acceptable FOS. • For armor rock backfill, 2H:1V side slopes have acceptable FOS.

Notes:
FOS: factor of safety
H:V: horizontal to vertical (ratio)
SMA: sediment management area

9 Structural Engineering Considerations

Within the upper reach, there are several structures and utilities that are adjacent to SMAs. Structural engineering evaluations were used to develop measures to protect or replace existing structures or utilities that may be affected during implementation of the proposed remedial actions. This section presents the results and recommendations of the structural engineering evaluations for the Final (100%) RD. Supporting design criteria are provided in Appendix H.

Visual inspections of structures were conducted during PDI activities. The following sections describe the structures identified within or adjacent to SMAs and structural engineering design considerations that were evaluated for the Final (100%) RD.

9.1 Structure Types

Structure types located within or adjacent to SMAs include bridges, marinas, wharves, bulkheads, piles, dolphins, timber groins, stormwater outfalls, and utility crossings. Tables 9-1 and 9-2 present these structure types relative to the respective SMA, citing SMA numbers and general riverbank locations. These tables also identify the structure types, specific facility name, and notable descriptions/features.

9.1.1 Overwater/In-Water Structures

Overwater structures consist of wharves, marina floats, and the South Park Bridge. In-water structures include bulkheads, single pile fields, dolphins, and South Park Bridge bascule piers and fendering systems. Along the west riverbank, structures within or adjacent to SMAs include the South Park Marina floats and guide piles, the South Park Marina gravity block wall bulkhead, and the South Park Bridge west riverbank abutment. South of the South Park Marina, a pile-supported pier was recently constructed as part of habitat construction following completion of the T-117 EAA.

The bulkheads along the east bank include closely spaced timber soldier piles and lagging (stubs), steel sheetpiles, and steel soldier piles with a variety of lagging materials. The southern end of the east bank site area near RM 4.9 includes several rows of timber groins (closely spaced untreated timber piles[20] that function for river flow diversion and shoreline erosion protection). Other SMAs have structures including single creosote-treated timber piles and multiple-timber-pile dolphin structures. Treated timber piles are also used for some of the guide piles in the South Park Marina; other guide piles in the marina have been replaced with steel piles since the time of original construction.

[20] The determination that the timber piles are untreated is based on visual and tactile observation during inspection. The color of the timber has uniformly weathered, and the branch stubs indicate the groins were not dressed. Treated timber would discolor unevenly and would be dressed by smoothing out the branch stubs. The surface of the timber was also scraped and jabbed during inspection and did not indicate the discoloration or residue typical of treated timber.

With the exception of the South Park Bridge and the southern bulkhead on the Boeing Isaacson Thompson property, the majority of existing structures evaluated within the LDW upper reach lack as-built record drawings, and the initial design and current load capacities are unknown.

Table 9-1
LDW Upper Reach Overwater/In-Water Structures Within or Adjacent to SMAs

SMA	Structure Name (ID No.)[1]	Structure Type	Description	Adjacent Property	Riverbank Location
14	ST02	Bridge	South Park Bridge, bascule pier and fendering system	Boeing, King County	RM 3.3 East and West
13, 14	ST20	Marina	South Park Marina, floats and guide piles	South Park Marina	RM 3.5 West
13	ST19	Bulkhead and armored slope	Gravity block wall and armored slope	South Park Marina	RM 3.5 West
7, 9	ST03	Bulkheads	Steel and timber piles	Boeing, CenterPoint Properties	RMs 3.8 to 4.0 East
7	ST03	Armored slope	Armored slope	CenterPoint Properties	RM 4.0 East
8	ST17	Piles	Single timber pile field	Boeing	RM 3.9 West
6	ST04	Dolphins and piles	Timber piles	Container Properties	RMs 4.0 to 4.1 East
4	ST05	Wharves	Concrete pile-supported piers and wharf	Boeing	RM 4.2 East
3	ST07	Wharf	Timber pile-supported wharf	Boeing	RM 4.6 East
2	ST10	Piles	Single timber pile field	Port of Seattle	RM 4.7 West
1	ST07	Groins	Untreated timber pile groins	Boeing	RM 4.9 East

Notes:
1. Structure ID No. corresponds to the structural field inspection forms presented in DER Appendix F (Anchor QEA and Windward 2022a).

RM: river mile
SMA: sediment management area

As discussed in Section 2.4.3, there are also two identified subsurface utility crossings in the upper reach (associated with the former and current South Park Bridge). The location of these crossings is provided within the King County South Park Bridge construction as-built drawings and has been incorporated into the project basemap. The crossing under the current South Park Bridge is an active utility line. The second crossing consists of three individual abandoned electrical lines that served the former bridge.

9.1.2 Outfalls

There are several public and privately owned stormwater outfalls and one combined sewer/ stormwater outfall along the upper reach east and west riverbanks consisting of PVC, ductile iron, corrugated metal pipe (CMP), cast iron, steel, or concrete pipeline material of various sizes, physical properties, and support conditions. Some of the outfalls remain active while others have been abandoned or are inactive.

Outfalls located within SMAs on the east bank are mostly ground-supported, with some that are supported by the existing bulkhead structures. All outfalls located within SMAs on the west bank are ground-supported.

Table 9-2
LDW Upper Reach Outfall Structures Within or Adjacent to SMAs[1,2]

SMA	Outfall Name (ID No.)	Active or Inactive	Pipe Diameter (inches)	Pipe Material	Adjacent Property	Riverbank Location
13	2214	Active	15	PVC	South Park Marina	RM 3.5 West
	17th Avenue Storm Drain	Active	15	PVC		RM 3.5 West
9	2075	Active	30	Ductile iron	CenterPoint Properties	RM 3.9 East
	2076	Inactive	30	Steel		RM 3.9 East
	2077	Active	18	Ductile iron	Boeing	RM 3.9 East
7	2074	Inactive	8	CMP	CenterPoint Properties	RM 3.9 East
	2073	Active	18	Ductile iron (in concrete casing)		RM 4.0 East
1	2092	Active[3]	18	Ductile iron	Boeing	RM 4.9 East
	2097	Active[3]	8	Steel		RM 4.9 East
	DC16	Active[3]	6	Ductile iron		RM 4.9 East
	2096	Active[3]	6	Cast iron		RM 4.9 East
	2093	Active	24	Concrete		RM 4.9 East
	2094	Inactive	12	Concrete		RM 4.9 East

Notes:
1. The outfall information is from the LDW RI and Leidos 2014 and 2020 outfall inventory surveys (Windward 2010; Leidos 2014, 2020), supplemented with information obtained during the PDI and from LDWG.
2. Outfalls within 30 feet of the SMA boundary are considered to be "adjacent" for the purposes of this table.
3. This outfall will be abandoned by the time of construction as part of the Boeing Development Center Stormwater Improvements project, as discussed in Section 2.2.

CMP: corrugated metal pipe
RM: river mile
SMA: sediment management area

9.2 Structural Engineering Design Evaluations

Dredging and capping can affect the integrity of structures located adjacent to the work because new loading conditions are imposed on structures. The following structural engineering design considerations were evaluated to develop the engineering design recommendations presented in Section 9.3.

9.2.1 Dredge Offsets

Dredge offsets are routinely considered in engineering design to protect existing structures and slopes, including armored slopes, that could otherwise be adversely affected by dredging activities.

Dredging reduces the passive earth pressure that provides lateral support to structures. Recommended passive earth pressure reduction factors for structural evaluations are provided in the *Geotechnical Design Analysis* (Appendix G).

Dredge cut thicknesses adjacent to each structure in question have been reviewed to develop dredge offset distances. A minimum 3-foot dredge offset is generally recommended for protection of structures from construction equipment. Two specific structure locations require different offsets, as follows:

- **South Park Bridge:** Based on coordination with the bridge owner, King County Roads, a minimum 2-foot offset is required for the bridge fendering system to protect the fendering system from damage by contact with the contractor's equipment. This offset has been incorporated into the Drawings for SMA 14 (Volume III). A spotter will be required for any work within 30 feet of the bridge footprint.
- **CenterPoint Properties Bulkhead:** Based on additional structural engineering assessments and considering the unknown design and condition of the southern segment of the existing bulkhead, a minimum 5-foot offset is required for dredging in SMA 7 to protect this bulkhead in this area from damage due to the loss of passive soil pressure during dredging. This offset has been incorporated into the Drawings (Volume III).

9.2.2 Load Restrictions

Load restrictions for specific structures are considered in engineering design because the design and current load-carrying capacity for the structures is not known in most cases. The assigned load restriction must consider maintaining the estimated structural capacity and minimizing potential impacts to the structure.

Structure types that could warrant load restrictions include wharves and shoreline bulkheads. A temporary restriction on loading of the top of the structure may be required during dredging activities adjacent to the structure. Areas where load restrictions are practicable and necessary (Table 9-3) are included on the Drawings (Volume III).

In addition to vertical load restrictions, temporary lateral load restrictions will be used for the timber groin structures to protect them during adjacent dredging. The contractor will be prohibited from mooring equipment on these structures during dredging, and dredging work will not be conducted in this location when lateral loads from river currents could be imparted on these structures. Temporary lateral load restrictions will be lifted for the timber groin structures after backfill has been placed.

Where temporary load restrictions are used, backfill will restore the capacity of the structure to its pre-construction condition.

9.2.3 Bulkhead Shoring/Support

Bulkhead shoring/support is considered for a bulkhead structure when a load limit is not sufficiently protective or there is a significant depth or extent of dredging required adjacent to an existing bulkhead structure. Although shoring can also be used to protect banks where significant dredge depths may be required at the bottom of the bank, no such shoring is included in the Final (100%) RD.

Bulkhead shoring/support is needed to facilitate removal of the debris adjacent to the north end of the CenterPoint Properties bulkhead (SMA 9). As shown in the structural Drawings (Volume III) and presented in Appendix H, the shoring in these locations will consist of a shoring sheetpile wall installed in front of the existing bulkhead wall. This sheetpile wall will be driven immediately adjacent to the bulkhead in two segments (approximately 25 feet long and 50 feet long) adjacent to a 140-foot section of shoreline approximately 1.5 feet waterward of the existing bulkhead, with return walls that connect back to the existing bulkhead to seal each end. The area between the existing and replacement wall will be filled in with reinforced cement grout.

9.2.4 Overhead Structure Vertical Clearance

Overhead structure vertical clearance refers to the space needed for construction equipment to work or pass beneath a structure that spans the waterway. For example, when the South Park Bridge is in its typical position to allow street traffic to cross the river, vessel traffic passing beneath the bridge must be shorter than the posted vertical clearance. Overhead structure vertical clearance considerations are applicable at the South Park Bridge (ST02) and South 98th Street (Boeing) Bridge (ST08) crossing, both inside and outside of the FNC. Overhead vertical clearance of the South Park Bridge in the closed position (open to traffic) is posted at 29 feet. In the open position (closed to street traffic), the South Park Bridge overhead vertical clearance is 125 feet (NOAA 2017). The measured vertical clearance of the South 98th Street Bridge is presented on the Drawings (Volume III).

9.2.5 Outfall Discharge Bed Erosion Protection/Energy Dissipation

Another structural consideration for ground-supported outfalls is to incorporate engineered discharge bed erosion protection measures into the design to dissipate energy from outfall flows. Outfalls may be armored or supported on splash pads/aprons or other flow energy dissipator systems to protect the bank from erosion due to the outfall flow discharge. Outfall discharge bed erosion protection details are presented on the Drawings (Volume III) (see Table 9-3 for location details).

9.2.6 Demolition and Replacement

Some in-water structures that impede or restrict access to remedial construction will be demolished permanently or temporarily removed during construction and replaced. Candidate structures for permanent demolition include treated timber piles and dolphins. Pilings that serve as tribal fishing piles will be removed and replaced with steel piles. No outfall structures are currently identified for demolition and replacement because active outfalls within remediation footprints will be protected in place and inactive/abandoned outfalls are assumed to have already been removed or are not expected to impede remediation activities. If inactive/abandoned outfalls are encountered in the dredge prism and impact the contractor's ability to complete the remediation work, they will be removed, and remaining pipe in the bank will be grouted. If previously unknown outfalls are encountered, the contractor will be directed to coordinate directly with the Implementing Entity to assess the appropriate path forward for the outfall.

Table 9-3 provides a summary of the protective options that are applicable to the structure types located within an SMA. Applicable engineering design consideration and a summary of structure design recommendations are presented in Section 9.3.

Table 9-3
Structure Types and Engineering Design Considerations for LDW Upper Reach SMAs

Structure Type	Structural Considerations						SMA
	Dredge Offsets	Load Restrictions	Bulkhead Shoring/Support	Overhead Structure Vertical Clearance	Outfall Discharge Bed Erosion Protection	Demolition or Removal and Replacement	
Bridges	●			●			1, 14
Wharves	●						4
Bulkheads	●	●	●				7, 9, 13
Timber Piles						●	1, 2, 6, 8
Timber Dolphins						●	6
Timber Groins		●					1
Utility Crossings	●						14
Outfalls	●				●		1, 7, 9, 13

Notes:
LDW: Lower Duwamish Waterway
SMA: sediment management area

9.3 Summary of Structural Actions

This section summarizes the structural engineering design action or requirement that is included in the Final (100%) RD for overwater/in-water structures and outfalls located within and adjacent to SMAs. Each requirement considers the condition of the structure, future use of the structure, and construction cost efficiency.

9.3.1 Overwater/In-Water Structures

Overwater/in-water structures adjacent to or within SMAs have been evaluated to develop requirements for structural protection. Table 9-4 summarizes these actions. During coordination on timber groin structures in SMA 1, it was ascertained that these structures may be the property of the Washington State Department of Natural Resources (WDNR), and it is uncertain whether they would be allowed to be replaced after removal. Based on this information, these structures will be left in place because dredging can be conducted immediately adjacent to the untreated timber groins in lieu of removal and replacement. The approach for the timber groins is described in Table 9-4 and presented on the Drawings (Volume III).

Table 9-4
Upper Reach Overwater/In-Water Structures Planned Actions

SMA	Structure Name (ID No.)	Structure Type	Description	Structure Owner	Adjacent Property	Planned Action
14	ST02	Bridge	South Park Bridge, bascule pier and fendering system	King County	Boeing, King County	• 2-foot dredge offset from bridge fender. • Spotter required when working within 30 feet of bridge footprint. • Overhead clearance.
9	ST03	Bulkhead	Steel and timber pilings	Port of Seattle	Boeing, CenterPoint Properties	• Bulkhead shoring/ support for debris pile removal along the north end of the wall.
7	ST03	Bulkhead and armored slope	Steel sheetpile and armored slope	CenterPoint Properties	CenterPoint Properties	• 5-foot dredge offset from bulkhead. • Set top of dredge slope at known toe of armoring.

SMA	Structure Name (ID No.)	Structure Type	Description	Structure Owner	Adjacent Property	Planned Action
6	ST04	Dolphins and piles	Timber piles	Container Properties	Container Properties	• Demolish timber dolphins to facilitate dredging. • Replace actively used tribal fishing piles.
2	ST10	Piles	Single timber pile field	Port of Seattle	Port of Seattle	• Demolish timber piles to facilitate dredging.
1	ST07	Groins	Untreated timber pile groins	WDNR	Boeing	• Protect in-place timber pile groins during dredging (e.g., no tying up equipment, etc.). • Demolish individual timber piles to facilitate dredging.

Note:
SMA: sediment management area
WDNR: Washington State Department of Natural Resources

9.3.2 *Outfalls*

Outfalls located within or adjacent to SMAs have been evaluated to develop requirements for dredging setbacks/offsets, and outfall energy dissipation for bank erosion protection. Table 9-5 presents planned actions as they apply to the outfall structures.

Table 9-5
LDW Upper Reach Outfall Structures Planned Actions[1]

SMA	Outfall Name (ID No.)	Active or Inactive	Pipe Diameter (inches)	Pipe Material	Owner[2]	Planned Action
13	2214	Active	15	PVC	South Park Marina	• Protect in place.
	17th Avenue Storm Drain	Active	15	PVC	City of Seattle	• No action; location is outside SMA and should not be impacted by construction activities.
9	2075	Active	30	Ductile iron	CenterPoint Properties	• Protect in-place outfall (no offset) by working in the dry, if possible, and temporarily covering the outfall to prevent plugging it with dredged or placed materials.

SMA	Outfall Name (ID No.)	Active or Inactive	Pipe Diameter (inches)	Pipe Material	Owner[2]	Planned Action
	2076	Inactive	30	Steel	Unknown	• Demolish if encountered within dredge footprint.
	2077	Active	18	Ductile iron	Boeing	• Protect in place.
7	2074	Inactive	8	CMP	Unknown	• Demolish if encountered within dredge footprint.
7	2073	Active	18	Ductile iron	CenterPoint Properties	• Protect in place. • Install discharge bed erosion protection (i.e., energy dissipation).
1	2092	Active[3]	18	Ductile iron	Boeing	• If encountered during dredging, remove sediment around the outfall (no offset required).
1	2097	Active[3]	8	Steel	Boeing	• If encountered during dredging, remove sediment around the outfall (no offset required).
1	DC16	Active[3]	6	Ductile iron	Boeing	• If encountered during dredging, remove sediment around the outfall (no offset required).
1	2096	Active[3]	6	Cast iron	Boeing	• If encountered during dredging, remove sediment around the outfall (no offset required).
1	2093	Active	24	Concrete	Boeing	• Protect in place. • Install discharge bed erosion protection (i.e., energy dissipation).
1	2094	Inactive	12	Concrete	Unknown	• If encountered during dredging, remove sediment around the outfall (no offset required).

Notes:

1. The outfall information is from the LDW RI and Leidos 2014 and 2020 outfall inventory surveys (Windward 2010; Leidos 2014, 2020), supplemented with information obtained during the PDI and from LDWG.
2. Outfall ownership is based on “Outfall Type” information provided in Ecology outfall inventory (Leidos 2020). When Ecology inventory notes private storm drain, ownership was assumed to be the same as the parcel owner. For inactive/abandoned outfalls where parcel ownership has changed since abandonment of the outfall, the ownership is listed as unknown.
3. This outfall will be abandoned by the time of construction as part of the Boeing Development Center Stormwater Improvements project, as discussed in Section 2.2.

CMP: corrugated metal pipe
LDW: Lower Duwamish Waterway
LDWG: Lower Duwamish Waterway Group
RI: Remedial Investigation
SMA: sediment management area

10 Remedial Technology Design

This section describes the development of design criteria for the selected RD elements summarized in Section 2.1.2. This section also describes the design analyses conducted to select the criteria, including a summary and detailed description of objectives, design assumptions, and restrictions (where appropriate) that are used in the design of the remedial actions. Specifically, details are provided for the following:

- Equipment selection
- Dredge design
- Engineered cap design
- ENR design
- Area-specific technology design
- Material types and placement methods
- MNR
- Flood rise analysis
- Climate change design considerations
- Maintenance, monitoring, and institutional controls

Application of the criteria is demonstrated on the Drawings, and details of implementing these criteria are provided in the Specifications (Volume III).

10.1 Equipment Selection

Equipment selection for sediment remediation projects must be carefully considered by contractors using their experience with the site conditions, standard and specialized equipment they have used and have access to, and the expertise of their personnel. Equipment selection is typically based on the ability of the equipment and contractor means and methods to meet performance-based specifications that set forth detailed performance requirements to be achieved by the contractor. These performance specifications include specified materials characteristics, earthwork tolerances, environmental criteria (e.g., water quality and sediment chemistry), schedule requirements, health and safety, and quality-of-life considerations (e.g., air, noise, and light).

Using performance specifications allows experienced remediation contractors to develop the appropriate means and methods for using equipment that they determine is the most appropriate for the different site conditions they will encounter in the upper reach. The use of performance-based design approaches are key lessons learned from previous EAAs (see Table 2-2 of the RDWP [Anchor QEA and Windward 2019a]). Performance-based specifications inform the operational characteristics and requirements of the project design and allow for contractor expertise, use of specialized equipment, and contractor flexibility to perform the work based on the constraints of the design and unique site characteristics.

The design approach to inform the contractor's equipment selection uses a combination of performance-based specifications with some use of method-based specifications, which are specifications that direct the contractor to conduct specific work in a specific manner. An example of a performance specification is to set the water quality criteria that the contractor will be required to meet during in-water operations but not tell the contractor what equipment to use to meet that performance criterion. An example of a method specification is to tell the contractor to dredge a side slope from the top of the cut slope to bottom of the cut slope to limit the risk of slope failure.

Of key importance for any mechanical dredging project is the type of dredge bucket(s) that is used, which is discussed in detail in Section 10.2.1. For the upper reach, the contractor will be required to use an environmental-type closing bucket as the primary dredge technology. The use of alternate buckets will be based on acceptance from the Project Representative if conditions are encountered that may not be suitable for an environmental bucket, such as hard substrate, debris, and/or bank areas.

In general, requiring a contractor to use a specific piece of equipment or method (e.g., method specifications) can ultimately be limiting and may prevent the contractor from applying its experience on how to best accomplish the dredging work while meeting environmental performance criteria. In this sense, using only method specifications can have the unintended consequence of a dredging project that is less environmentally protective than a project where the contractor can choose the equipment and bring its experience to bear. Thus, for this project, remediation equipment selection will be done by the contractor to meet performance specifications that dictate the required environmental outcomes, the monitoring that will be conducted, and the contingency actions that will be taken to assure environmental protectiveness.

The contractor will identify proposed equipment in the RAWP, subject to review and approval by the Owner and EPA. A QA/QC program is detailed in the CQAP (Volume II, Part I) and reflected in the project Specifications (Volume III) to confirm that the work identified in the specifications, design drawings, and RAWP are being measured and met as construction proceeds. The contractor will be required to modify procedures and equipment as needed to meet the performance specifications, and this process is described in the CQAP.

Based on past experience, the following sections include discussion of the specific equipment that is anticipated to be used by the contractor.

10.2 Dredge Design

This section documents the basis for dredging equipment selection and describes the dredge prism design criteria, dredging tolerances, and anticipated dredging production rates. Additionally, this section describes support activities associated with dredging, including material transloading, upland transport and disposal, post-dredge sampling, dredge residuals management, and post-dredge backfilling.

10.2.1 Dredging Equipment Selection

The FS included screening of removal process options, including mechanical dredging methods (e.g., mechanical cranes and barge-mounted excavators), hydraulic dredging methods, and upland excavation (AECOM 2012). The FS discusses the infeasibility of using hydraulic dredging as the primary dredge method due to the following:

- Impacts to waterway users
- Lack of upland space to dewater hydraulically dredged slurry
- Inability to remove debris

Hydraulic dredging entrains significant amounts of additional water (e.g., typically four to seven times the volume of dredged sediment), which requires a large area for dewatering and water treatment processes, increases the energy used, adds complexity, and generates additional waste streams (e.g., process water, expended treatment media). Hydraulic dredging also transports the dredged materials as a slurry through a hydraulic transport pipeline that extends from the hydraulic dredge to the dewatering site, sometimes located miles away; these transport pipelines are typically floating and obstruct the use of the waterway where the pipeline is located. Hydraulic dredging had been retained in the FS for location-specific circumstances where the total amount of water generated would be small and controllable. Evaluation during the Preliminary (30%) RD determined that hydraulic dredging would not be required for the upper reach.

Mechanical dredging and excavation are the most commonly practiced forms of sediment removal in the Puget Sound region, with approximately 90% of projects in the region using it during project implementation. These methods are adopted in the Final (100%) RD as the primary removal equipment for in-water work. Mechanical dredging is expected to be the optimal method in open-water areas because of its effective removal of consolidated sediment, debris, and other materials such as piling and riprap; and its relatively compact operational footprint, thus reducing the potential impact to existing waterway operations. Dry excavation using conventional earth-moving equipment working above the water line is also retained for use in intertidal and embankment areas, but it is expected to be implementable only for a low percentage of the removal volume because of access limitations and location of SMAs.

10.2.1.1 Mechanical Dredging Equipment and Bucket Selection

Mechanical dredges employ a bucket to retrieve sediment from the bed of the waterway, move the sediment up through the water column, and place it into an adjacent haul vessel (such as a barge) for transport and disposal. Two major categories of mechanical dredges are differentiated based on the method of bucket deployment. The first category uses a wire attached to a crane or derrick to lower the bucket to the bed and retrieve sediment. The second category deploys the bucket at the end of the arm of an excavator or backhoe and is sometimes referred to as an articulated fixed-arm dredge. Mechanical dredges can be further classified by the type of bucket used, such as conventional open clamshell bucket or environmental buckets (Exhibit 10-1). The *Technical Guidelines for Environmental Dredging of Contaminated Sediments* (USACE 2008a) described the following types of mechanical dredge buckets:

- **Conventional Clamshell Bucket:** This conventional dredge consists of a wire-supported, open clamshell bucket. This bucket is often used from a barge-mounted derrick crane and is a heavy bucket with teeth that are suitable for digging consolidated materials, handling debris, and penetrating deeply into sediment to allow higher production rates.
- **Environmental Bucket:** The environmental (or closed) bucket is a near watertight or sealed bucket (when complete bucket closure is possible) as compared to the conventional open bucket. Recent designs (e.g., Cable Arm) also incorporate a level-cut capability as compared to a circular-shaped cut for conventional buckets. The environmental bucket is typically lighter in weight than conventional clamshell bucket and can be ineffective when dredging consolidated sediment, rock, or debris.
- **Articulated Bucket:** Articulated buckets include both conventional buckets and environmental buckets but use a hydraulic closing mechanism to operate the bucket instead of a cable or wire pulley system. The articulated bucket is typically supported by an articulated, fixed arm (e.g., Hydraulic Profiling Grab bucket system, Young Manufacturing rehandling bucket). Articulated buckets may have tighter control on bucket location than a bucket suspended on a cable or wire pulley system. Articulated buckets used for sediment remediation dredging are typically 3 to 8 cy in size and are fully closing.

Table 10-1 provides a comparison of both conventional and environmental buckets, including the benefits and constraints typically associated with each technology.

Table 10-1
Comparison of Conventional and Environmental Dredge Bucket Benefits and Constraints

Bucket Type	Benefits	Constraints
Conventional	• Minimizes entrained water in dredge bucket, which reduces the need for water management during offloading and disposal • Capable of removing hard sediments • More effective at removing debris	• Potential loss of sediment and increased resuspension into water column when bucket is raised • Typically result in a less even dredged surface compared to a level-cut environmental bucket
Environmental	• Reduces potential loss of sediment and resuspension when bucket is raised through the water column • Some environmental buckets have level-cut capability, which can increase precision. • Low resuspension in unconsolidated sediment deposits	• Captures more water than conventional bucket; this issue is exacerbated when precision (thin) cuts are required • May be unable to remove hard sediments or debris • Closed design can increase “bow wake” as bucket digs into sediment, causing local resuspension and residuals around digging site.

Exhibit 10-1
Different Bucket Types

Conventional clamshell bucket

Environmental bucket

Articulated bucket (horizontal profile grab)

Environmental buckets have been designed to work with mechanical dredging equipment (e.g., derrick cranes or hydraulic excavators). However, minimizing the loss of sediment out of the bucket does not necessarily mean reducing suspended solids or lowering turbidity. As discussed in Wang et al. (2002), environmental buckets have not been proven to reduce suspended sediments in all site conditions.

When used in unconsolidated sediment without significant debris, environmental buckets have been shown to be effective at reducing loss of sediment from the bucket. Unconsolidated sediments are anticipated to occur in many dredge areas in the upper reach, which supports the use of an environmental bucket as the primary technology for removal.

The selection of dredge bucket and equipment is project- and contractor-specific and can vary depending on location-specific factors even for a single dredging project. The best equipment for one task may be unsuitable for another task. Dredging soft sediments in open water with minimal debris can be effectively accomplished with a conventional derrick crane and environmental and closed buckets. Constrained dredging in limited access areas may be more appropriately accomplished using an articulated bucket. In site conditions with significant debris, neither environmental buckets nor conventional buckets may be able to fully close; any bucket technology tends to lose most or all of the dredged sediment from the bucket as it is raised through the water column when debris prevent complete bucket closure.

As discussed in Section 10.1, the contractor will be required to use an environmental-type closing bucket as the primary dredge technology. It is anticipated that a 6- to 8-cy-sized dredge bucket would reasonably be used for dredging in most locations given the size of the project and requirements for bank dredging. However, in areas that contain small to larger debris (e.g., heavy vegetation, rock and concrete slabs, intact and broken pilings, and fused debris piles) or harder sediment, environmental buckets are anticipated to be ineffective; therefore, a heavier bucket with conventional digging capabilities or a specialized bucket to remove debris would likely be the type of equipment selected by the contractor.

Dredging operations have well-established BMPs to limit sediment disturbance and manage potential water quality effects (USACE 2008a). Operational and engineering controls will be defined in the construction Specifications (Volume III), which the contractor will be required to implement. Construction BMPs related to mechanical dredging and reducing water quality effects during dredging are discussed in Sections 11.1 and 11.2.

10.2.2 Land-Based Excavation

Land-based excavation using excavators, backhoes, and other conventional earth-moving equipment may be used to remove intertidal and bank area materials. Excavation in these areas may be coordinated "in the dry" during periods of low tidal elevations; however, depending on weather, tides, scheduling, and contractor production, it will be necessary to conduct some intertidal sediment removal (excavation or dredging) below water. Intertidal sediment and shoreline bank soil excavation "in the dry" reduces the potential for release of impacted intertidal sediment and shoreline bank soils to the LDW by removing the sediment accessible from the upland when the tides are low and the sediment is exposed.

Given the geometry of the bank areas and the typical reach of upland-based equipment, it is anticipated that materials removed from the bank areas may need to be placed into a temporary upland stockpile area or directly into trucks, depending on site access agreements and available upland space. Thus, any land-based work will require access, staging areas, loading operations, and ground transportation. These logistical factors tend to favor accomplishing the work with floating equipment, although that can be impractical in shallow water areas such as at the Container Properties bank (SMA 5) where excavation and material placement will occur. No other SMAs are anticipated to require land-based excavation, although provision for land-based access is depicted on the Drawings (Volume III) in other locations to support activities such as material placement.

10.2.3 Debris Removal

As discussed in Section 2.3.10, Identified Debris are located within several dredging footprints. Identified Debris is generally considered to be debris that is anticipated to require specialty equipment to remove (i.e., unlikely to be removed with a dredge bucket). The contractor will be required to remove Identified Debris within an SMA prior to dredging that SMA.

There are two large deposits in SMA 9 presumed to be anthropogenic waste materials associated with former industrial activities that are classified as Identified Debris for removal. Removal of this Identified Debris will require installation of a shoring sheetpile wall adjacent to the existing bulkhead wall (Section 9.2.3) and is expected to occur before dredging of the adjacent sediments within the SMA. The debris in front of the sheetpile shoring wall will be removed to the surrounding mudline plus 2 additional feet. Although the Specifications will not require the contractor to attempt to lower the height of debris piles behind the new sheetpile (before or after installation), the situation will be assessed, and if it is in the interest of the contractor or Owner to try to remove debris from the space between the sheetpiles, that decision would be made as an adaptive management strategy during construction. Debris between the existing and new sheetpile walls will be left in place if it cannot practicably be removed and will be covered with reinforced cement grout following installation of the sheetpile wall. Additionally, if the debris piles waterward of the new sheetpile wall extend further than 2 feet below the mudline, that portion may also be left in place unless observed conditions in the field support a decision by the Project Representative to direct the removal of additional debris. Clean backfill will be placed over the footprint of debris removal that occurs waterward of the new sheetpile wall. Section 10.2.7.1 discusses characterization of the debris piles for disposal.

In addition to Identified Debris, Incidental Debris may be encountered during dredging. Incidental Debris will not be separately removed prior to dredging and will be handled, transported, and disposed of with the dredged sediment.

10.2.4 Dredge Prism Design

As described in Section 6, horizontal limits of the RAAs were set to encompass the RAL exceedance area and modified to account for engineering considerations, review of adjacent chemistry results, and constructability considerations. Vertical extent of contamination was defined on either an elevation or thickness basis to remove material exceeding any of the RALs applicable to surface sediments. The dredge prism design combines these considerations to target removal of the horizontal and vertical extents of contamination.

Dredge elevations were used as the basis for the vertical extent of dredging when data suggest similar elevations of contamination over a contiguous area. The basis for the dredge elevation used in design is the field-measured mudline elevation for the relevant vertical cores, as summarized in Appendix A Table A.1-3. In general, elevation-based cuts were used in areas within the FNC due to the typical nature of past dredging to constant dredge elevations in these areas (suggesting that contaminant releases would have been expected to settle above a similar elevation). For elevation-based dredge prisms, core data were reviewed to establish the deepest extent of contamination, which was then rounded to the next deepest half-foot interval for constructability purposes. For example, if the bottom of the deepest core interval exceeding surface RALs was at -18.3 feet MLLW, the required dredge elevation was set to -18.5 feet MLLW. This rounding to the next deeper interval results in a more conservative dredge cut design. Bathymetric survey measurements during construction will confirm that the required dredge elevation has been met.

Dredge thickness cuts were used as the basis for the vertical extent of dredging when vertical core data suggested similar thicknesses of contamination within an area. This approach generally occurred in areas outside the FNC and in areas that are along slopes because historically, these areas would have had natural sloping contours upon which contamination could have accumulated to consistent thicknesses instead of consistent elevations. Thickness cuts were also assigned to some areas within the FNC or berthing areas with vertically bounded contamination with only RAL exceedances in the 0- to 10-cm (0- to 4-inch) or 0- to 60-cm (0- to 2-foot) intervals. For these areas, the vertical extent of dredging was assigned a minimum dredge thickness because the data indicate that contamination is found only on the upper surface of the sediment bed at that location. The design thickness cut defines a three-dimensional surface that will be the required dredge surface for use by the contractor, and the actual cut thickness to achieve the design surface will be adjusted by the contractor during construction to reflect any mudline elevation changes between the design bathymetry dataset and the pre-construction bathymetry dataset. Bathymetric survey measurements during construction will confirm that the required dredge thickness surface has been met.

Dredge thicknesses were defined by the depth of contamination, using the interface between the core interval that exceeded the surface RALs and the core interval that was below the surface RALs. For example, at a location with a 0- to 45-cm (0- to 1.5-foot) RAL exceedance and the next two 1-foot core intervals also exceed the surface RALs, but the third 1-foot core interval does not exceed the surface RALs, the dredge thickness was set as 3.5 feet. If a thickness cut area only had an exceedance in the subsurface RAL interval (i.e., 0 to 45 cm or 0 to 60 cm), the dredge thickness was set to the subsurface RAL interval thickness (i.e., 1.5 feet or 2 feet). In contrast to elevation-based dredge depth locations, extra depth was not added to thickness cuts because the thickness cut is already delineated to constructable 0.5-foot intervals. In addition, the core compaction correction process that was used during the PDI effectively "expands" the thickness of the RAL exceedance interval in the core, which may result in a conservative estimate of thickness. Surface-only RAL exceedances (i.e., 0 to 10 cm [0 to 4 inches]) were assigned a required dredge thickness cut of 1 foot to account for constructability considerations.

RAAs with multiple cores may have had different assigned vertical contamination elevations or thicknesses and were therefore broken into subareas, with each subarea having a different required dredging elevation or thickness. These subareas are notated with a letter following the RAA label (e.g., RAA 1/2/3A). RAA subareas are shown in Figures 6-1a through 6-1l. Table 10-2 summarizes the vertical dredge prism design basis for each RAA subarea and notes which SMA(s) the RAA subarea falls within.

Table 10-2
Dredge Prism Vertical Design by SMA and RAA

SMA	RAA Subarea	Elevation or Depth of Contamination Based on Vertical Core Data Within RAA	Basis of Dredge Elevation/Thickness[1]	Required Dredge Elevation/ Thickness
18	1/2/3A	• 510 unbounded at -18.6 feet MLLW • 509 bounded at -21.2 feet MLLW • 751 bounded at -20.6 feet MLLW • 753 bounded at -21.4 feet MLLW	-21.4 feet MLLW	-21.5 feet MLLW
17, 18	1/2/3B	• 513 bounded at -21.5 feet MLLW • 753 bounded at -21.4 feet MLLW	-21.5 feet MLLW	-22.0 feet MLLW
17, 18	1/2/3C	• 514 bounded at -20.5 feet MLLW • 517 bounded at -20.8 feet MLLW • 520 bounded at -20.4 feet MLLW • 521 bounded at -19.9 feet MLLW	-20.8 feet MLLW	-21.0 feet MLLW
17	1/2/3D	• 519 unbounded at -18.2 feet MLLW • 755 bounded at -22.7 feet MLLW	-22.7 feet MLLW	-23.0 feet MLLW

SMA	RAA Subarea	Elevation or Depth of Contamination Based on Vertical Core Data Within RAA	Basis of Dredge Elevation/Thickness[1]	Required Dredge Elevation/ Thickness
15A, 16	4/5/6A	• 527 bounded at -20.3 feet MLLW • 529 bounded at -17.5 feet MLLW • 532 bounded at -20.4 feet MLLW • 533 bounded at -20.2 feet MLLW • 758 bounded at -19.3 feet MLLW • 761 bounded at -19.9 feet MLLW • 762 bounded at -20.4 feet MLLW	-20.4 feet MLLW	-20.5 feet MLLW
16	4/5/6B	• 531 bounded at -21.2 feet MLLW • 759 bounded at -22.0 feet MLLW	-22.0 feet MLLW	-22.5 feet MLLW
14D, 15A, 16	4/5/6C	• 534 bounded at -21.4 feet MLLW • 535 bounded at -21.6 feet MLLW • 537 bounded at -20.7 feet MLLW • 538 bounded at -21.9 feet MLLW	-21.9 feet MLLW	-22.0 feet MLLW
14D	4/5/6D	• 539 bounded at -20.9 feet MLLW • 553 has no interval > surface RAL	-20.9 feet MLLW, but this would not result in the necessary removal of the subsurface RAL interval (0–60 cm [0–2 feet]) over the whole area; therefore, a 2-foot thickness cut used instead	Surface designed using a 2-foot thickness cut
14C	8	• 543 has no interval > surface RAL	Surface (0–10 cm [0–4 inch]) RAL interval exceedance (SS145)	Surface designed using a 1-foot thickness cut
14A	12	No vertical core; bounded by subsurface (0–60 cm) RAL interval (SC155)	Surface (0–10 cm [0–4 inch]) RAL interval exceedance (SS155)	Surface designed using a 1-foot thickness cut

SMA	RAA Subarea	Elevation or Depth of Contamination Based on Vertical Core Data Within RAA	Basis of Dredge Elevation/Thickness[1]	Required Dredge Elevation/ Thickness
12B	14/15/16	• 568 bounded at -24.4 feet MLLW • 571 has no interval > surface RAL • T-117-SE-35-SC core bounded at 8-foot depth • 776 variable contamination; unbounded at -26.0 feet MLLW • 777 variable contamination; unbounded at -26.7 feet MLLW • 778 variable contamination; unbounded at -26.5 feet MLLW • 781 variable contamination; unbounded at -17.9 feet MLLW • 782 bounded at -25.0 feet MLLW • 783 variable contamination; unbounded at -18.8 feet MLLW • 784 variable contamination; bounded at -22.4 feet MLLW	Dredging to accommodate placement of an engineered cap (maximum cap thickness is 48-inches, see Section 10.3)	-23.0 feet MLLW
12A	17	• 576 has one interval (2–3 feet) that exceeds the surface RAL, but the area has no subsurface RAL (0-60 cm) exceedances.	Surface (0–10 cm [0–4 inch]) RAL interval exceedance (SS213, LTR-20-2018)	Surface designed using a 1-foot thickness cut
10	18A through 18E – Deferred; see Section 6.1.3	N/A	N/A	N/A
11A	19/20	• 609 bounded at 3.5-foot depth • 795 bounded at 3.5-foot depth	3.5-foot thickness	Surface designed using a 3.5-foot thickness cut
9	22A	• 804 bounded at 5-foot depth	Review of historical non-RAL interval data SD-513 and SD-515 to supplement limited vertical information and offshore cores to develop anticipated lens of buried contamination	-17.0 feet MLLW

SMA	RAA Subarea	Elevation or Depth of Contamination Based on Vertical Core Data Within RAA	Basis of Dredge Elevation/Thickness[1]	Required Dredge Elevation/ Thickness
9	22B	• 621 has no interval > surface RAL • 622 bounded at 1.5-foot depth	1.5-foot thickness, but this would not result in the necessary removal of the subsurface RAL interval (0–60 cm [0–2 feet]) over the subtidal area; Therefore, a 2-foot thickness cut used instead	Surface designed using a 2-foot thickness cut
7	24/25/26A	• 632 bounded at 3.5-foot depth	3.5-foot thickness	Surface designed using a 4.0-foot thickness cut
7	24/25/26B	• 635 bounded at 2.5-foot depth • 644 has no interval > surface RAL • 808 bounded at 2.5-foot depth • 809 bounded at 2.5-foot depth • 810 bounded at 2.5-foot depth	2.5-foot thickness	Surface designed using a 2.5-foot thickness cut
6	27A	• 648 bounded at 4.5-foot depth • 653 bounded at 3.5-foot depth	4.5-foot thickness	Surface designed using a 4.5-foot thickness cut
5, 6	27B	• 649 bounded at 2.5-foot depth • 650 has no interval > surface RAL • 652 bounded at 2.5-foot depth • 654 bounded at 2.5-foot depth • 655 has no interval > surface RAL • 657 has no interval > surface RAL • 658 bounded at 2.5-foot depth • 659 bounded at 2.5-foot depth • 660 bounded at 2.5-foot depth	2.5-foot thickness	Surface designed using a 2.5-foot thickness cut
5, 6	27C	• 662 bounded at 2.5-foot depth • 663 bounded at 3.5-foot depth • 664 bounded at 2.5-foot depth • 665 bounded at 3.5-foot depth • 666 bounded at 3.5-foot depth	3.5-foot thickness	Surface designed using a 3.5-foot thickness cut
5, 6	27D	• 669 bounded at 4.5-foot depth • 670 has no interval > surface RAL	4.5-foot thickness	Surface designed using a 4.5-foot thickness cut
4	28	• 674 has no interval > surface RAL	Subsurface (0–60 cm [0–2 foot]) RAL interval exceedance (SC349, SC671)	Surface designed using a 2-foot thickness cut
3	29	• 683 has no interval > surface RAL • 684 has no interval > surface RAL	Subsurface (0–45 cm [0–1.5 foot]) RAL interval exceedance (IT379)	Surface designed using a 1.5-foot thickness cut

SMA	RAA Subarea	Elevation or Depth of Contamination Based on Vertical Core Data Within RAA	Basis of Dredge Elevation/Thickness[1]	Required Dredge Elevation/ Thickness
2B	30	• 694 bounded at 1.5-foot depth	1.5-foot thickness	Surface designed using a 1.5-foot thickness cut
2A	31	• 814 has no interval > surface RAL	Subsurface (0–45 cm [0–1.5 foot]) RAL interval exceedance (IT697)	Surface designed using a 1.5-foot thickness cut
1B	32	• 698 has no interval > surface RAL	Surface (0–10 cm [0–4 inch]) RAL interval exceedance at multiple sample locations	Surface designed using a 1-foot thickness cut
1A	33/34/35B	• 699 has no interval > surface RAL • 701 has no interval > surface RAL • 702 has no interval > surface RAL	Surface (0–10 cm [0–4 inch]) RAL interval exceedance at multiple sample locations	Surface designed using a 1-foot thickness cut

Notes:

1. Elevations are based on RTK-DGPS field measurements, as discussed in Section 4.2.

cm: centimeter
MLLW: mean lower low water
N/A: not applicable
PDI: pre-design investigation
RAA: remedial action area
RAL: remedial action level
RD: remedial design
RTK-DGPS: real-time kinematic differential global positioning system
SMA: sediment management area

10.2.4.1 Dredge Cut Side Slopes

Dredge cut side slopes were evaluated as described in Section 8 by identifying typical side slope angles and computing the factor of safety for the dredge cut slope under both short-term conditions (prior to backfilling) and long-term conditions (post-construction). Based on these evaluations, it was determined that dredge cut side slopes of 3H:1V should be used to maintain an adequate factor of safety for the long-term condition, whereas dredge cut side slopes of 2H:1V are allowable for the short-term condition. Where dredge cuts are thin (on the order of 1 to 2 feet thick), vertical side slopes are indicated because dredge buckets cannot practicably grade such a small slope.

Internal slopes between dredge units are assumed to be cut at 2H:1V, with the toe of the slope set at the deepest elevation or depth along the interface of the units.

10.2.4.2 Horizontal Dredge Offsets

Section 9 identifies the in-water and shoreline structures that are within or adjacent to an SMA, including structures that will be protected in place and structures that will be removed (and potentially replaced). The dredge design includes horizontal offset requirements for structures based on adjacent required sediment removal elevations/thickness cuts and associated short-term and long-term structure stability. Offset recommendations for structures have been summarized in Section 8 and are shown on the Drawings (Volume III).

10.2.4.3 Dredging Tolerances

The dredge prism includes two components: the required dredge elevation/thickness and the allowable overdredge tolerance. The required dredge elevation/thickness information provided in Table 10-2 represents the removal elevation grades or thicknesses that a contractor will be required to remove all sediment above throughout the RAA subarea. To achieve the required dredge elevation/thickness, an allowable overdredge tolerance, which is an additional depth of sediment below the required dredge elevation/thickness that may be removed, is necessary to account for dredging equipment accuracy, operator skill, and site conditions. The dredge prism design (including allowable overdredge tolerance) reflects the fact that it is not possible/practical for any dredge to excavate to an exactly flat surface.

The contractor will be provided with an allowable overdredge tolerance of 1 foot below the required dredge elevation/thickness. Further criteria for evaluation and acceptance of dredge tolerances during construction are defined in the CQAP. The overdredge tolerance will result in a more constructable dredge surface and may also reduce dredging residuals concentrations because the overdredge layer is composed of lower concentration materials that can mix with the dredged sediment, potentially resulting in an overall lower concentration residual release.

10.2.5 Dredging Production Rates

Dredging production rates (i.e., the volume of in situ dredged material removed on an hourly or daily basis) will vary based on the contractor’s selected equipment and personnel experience, sediment physical characteristics, transport rate of dredged material to landfills, and site constraints, such as nearby vessel traffic and weather conditions. Production rates will be higher in some areas of the upper reach and lower in others, depending on the constraints affecting production, including sediment type (e.g., consolidated vs. unconsolidated), water depths, cut thickness, type of cut (e.g., sloped cut), water quality protection, and presence of debris. Typically, production rates are lower at the start of new construction activities (e.g., beginning of a construction season, or start of a new activity), and then increase over time as the contractor works out efficient methods to accomplish the work. However, weather or access delays, location, adjacent marine traffic, the project’s environmental controls (such as turbidity control requirements and environmental and water quality monitoring), confirmation sampling and resulting potential need to re-dredge some areas, equipment maintenance, and tangential factors (e.g., offload facility production rate) are expected to periodically slow production over relatively short time spans during a typical construction season.

It is estimated that a reasonable mechanical dredging production rate in the upper reach will be approximately 1,100 cy per day in open-water areas, such as the FNC. Dredging production rates are anticipated to be lower for contingency re-dredging, nearshore dredging, and restricted access dredging, which are estimated to range from approximately 500 to 700 cy per day, with an overall site-wide weighted average production rate of 900 cy per day. This overall site-wide weighted average production rate closely mirrors recently experienced production rates for regional remediation dredging in Puget Sound and is also aligned with anticipated daily transloading and dredged material transportation and disposal rates. However, the production rates presented in this Final (100%) RD are higher than the range of production rates presented in the FS (AECOM 2012; ranged from 277 to 781 cy per day), which results in a shorter overall project duration.

To illustrate the calculation to determine a dredging production rate in one site condition, the anticipated daily site-wide weighted average dredging production rate is calculated using the following assumptions:

- Assume contractor uses a mechanical barge-mounted derrick crane.
- Assume derrick crane uses an 8-cy bucket.
- Assume bucket fill factor of 70% (30% of bucket is not filled with sediment).
- Assume dredge cycle time (i.e., one cycle equals the time to lower the bucket to the bottom, close the bucket with dredged material, raise the bucket out of the water, place the dredged material into the barge, and make ready for the next cycle) of 2.4 minutes per cycle.
- Assume contractor works one 10-hour shift per day (i.e., 600 minutes per day).
- Assume average operational "uptime" is 65%. Uptime is the proportion of time that the dredge is actually working. The remainder of the time (i.e., downtime) includes time for maintenance, dredge re-positioning, debris management, shift changes, time needed to periodically switch out the barges used to transport dredged material, inherent delays (i.e., including, but not limited to, commercial shipping and tribal fishing activities within the work site and inclement weather) and other non-dredging work.

Overall Site-Wide Weighted Average Mechanical Dredging Daily Production Rate Equation:

*Production Rate = (bucket size * bucket fill factor) *((total work minutes per day/cycle time in minutes) * %uptime))*

*= (8 cy * 70%) *((600 min/2.4 min) *65%)*

= (900 cy/day)

It is expected that this calculated site-wide weighted average production rate will vary significantly on a daily basis (both lower and higher) due to factors listed previously. However, from a schedule planning perspective, an overall site-wide weighted average production rate of 900 cy per day was assumed to develop the Final (100%) RD construction duration, with a potential range of 500 to 1,100 cy per day depending upon site conditions, resulting in an estimated three construction seasons. Multiple dredges working simultaneously could potentially increase these daily production rates. However, the constraint of offloading and shipment to a commercial landfill is anticipated to govern the maximum amount of material that can be dredged per week.

10.2.6 Transload Facilities

Sediment and debris removed from the upper reach will be loaded onto barges, or directly into trucks during upland excavation activities, and transported to a transload facility where the material will be offloaded from barges and loaded onto trucks and/or railcars for transportation to a permitted disposal facility. Dewatering of the dredged materials will be initially performed on barges. Initial dewatering will be accomplished by gravity separation of sediment solids from the water fraction, with associated filtering (or other necessary treatment to comply with water quality criteria) and return of the water to the LDW.

Once loaded to land at the transload facility, additional dewatering will be performed if determined necessary by the transloading and disposal facilities. Any effluent generated by dewatering at the transload facility will be managed (contained and, if necessary, treated) and disposed of in accordance with the facility's permits and standards for wastewater disposal.

10.2.6.1 Commercial Transload Facilities

The Duwamish Reload Facility at 7400 8th Avenue South, operated by Waste Management, is a transload facility located on the LDW. The facility has water access in Slip 4, at approximately RM 2.8, and has demonstrated a sufficient operational capacity to dewater and stockpile sediment and capture dewatering effluent for the estimated production and offloading rates assumed in the RD. The facility has the capability to offload bulk material from barges and load onto trucks or railcars, and it accepts nonhazardous contaminated soil and special wastes.

Lafarge North America formerly operated a transload facility at 5400 W. Marginal Way with water access at approximately RM 1.0 of the LDW. As of June 21, 2022, Lafarge North America has notified customers that it has terminated its transload operations.

The Duwamish Reload Facility is known to be operating at the time of this Final (100%) RD. Other commercial transload facilities may become available or be identified prior to construction, and the contractor will propose the transload facility in its RAWP subject to approval by the Owner and EPA.

10.2.6.2 Contractor-Provided Transload Facility

A contractor-provided transload facility may be proposed during the contractor's work plan development phase (i.e., contractor's RAWP). The contractor would be required to obtain all necessary permits or substantive equivalence (e.g., solid waste and discharge permits), and the use of a contractor-provided transload facility would be subject to approval by the Owner and EPA. Any off-site facility would need to meet or exceed the substantive requirements associated with operating an on-site facility.

10.2.6.3 Project-Specific Transload Facility

The design team evaluated potential locations for siting a project-specific transload facility. Given the presence of an established commercial transload facility in close proximity to the upper reach, a project-specific facility would need to offer significant advantages to offset the cost and time required to acquire or lease property, obtain necessary solid waste and discharge permits, and develop, equip, and staff the facility. The process for evaluating potential project-specific transload facilities began with identifying criteria for the evaluation and reviewing the local real estate market to identify any properties that met the criteria.

The property would need certain attributes, including the following, to be considered as a potential candidate as a transload facility:

- Location on the water, ideally adjacent to the upper reach
- A dock with space for at least one barge
- Rail and road access
- Location in an industrial or commercial setting without restrictions that would limit 24-hour operations
- Sufficient size to dewater and stockpile sediment and load processed material into trucks or railcars
- Sufficient size to treat dewatered wastewater or pretreat and have sewer connection with adequate capacity to convey.

The review of available properties found that there are no vacant sites on the LDW for sale or lease. The nearest vacant property is two blocks from the water and therefore unsuitable for this purpose, not having water access. One developed property is for sale on the water, but a 60,000-square-foot building that is currently occupied takes up more than half the property. Considering the lack of a suitable property, the expense of acquiring and developing the property as a transload facility, the time required to obtain necessary permits or approvals, and the availability of commercial transload capacity adjacent to the site, a project-specific transload facility is not likely to support transloading for the upper reach. Although the Final (100%) RD costs assume commercial transload, the project-specific transload option has not been ruled out.

10.2.7 Upland Transport and Disposal

Disposal of dredged and excavated materials will be at a permitted landfill. Waste characterization results and acceptable landfills are discussed in this section.

10.2.7.1 Waste Characterization

Based on a site-wide review of bulk chemistry data compared to 20 times the toxicity characteristic regulatory levels, sediments in RAA 22[21] were identified for additional waste characterization. The bulk chemistry data for all other RAAs indicate that the sediment will pass the TCLP. During the Phase III PDI, a composite sample from RAA 22 was analyzed by TCLP for comparison to federal toxicity characteristic regulatory levels and for bulk chemistry for a Washington toxicity dangerous waste determination. The preliminary waste determination is described in Volume II, Part V. Sediment from RAA 22 passed the TCLP. In addition, sediment from RAA 22 was determined not to be toxic dangerous waste per WAC 173-303-100. The contractor is required to coordinate review of the preliminary waste determination and available sediment chemistry data with its approved landfill(s) and, if needed, perform supplemental waste characterization.

Two piles of what appears to be slag and foundry brick were identified in RAA 22.[22] Because these materials are planned to be removed prior to dredging or capping sediment, the slag and other debris were characterized for disposal. Composite samples of this material representative of management units (individual piles) were collected and subjected to analyses for characterization. The following three types of analyses were performed during Phase III PDI on the composite samples to characterize the material:

- Bulk chemistry to determine total concentrations of metals, semivolatile organic compounds, and dioxins and furans for a Washington dangerous waste determination
- Static acute bioassay for a Washington dangerous waste determination
- TCLP for constituents identified in 40 CFR 261.24

Based on the results of the debris testing, the debris was determined not to be toxic dangerous waste per WAC 173-303-100(5)(d), as described in Volume II, Part V.

10.2.7.2 Acceptable Landfills

Several permitted landfills in the Pacific Northwest are approved to dispose of nonhazardous contaminated sediment from Superfund sites. These include the Roosevelt Regional Landfill (owned and operated by Republic Services in Roosevelt, Washington) and the Columbia Ridge Landfill (owned and operated by Waste Management in Arlington, Oregon). Other landfills are also approved

[21] At the time that preliminary waste characterization was conducted, it was unknown whether RAA 18 would be included in the RD. Thus, RAA 18 samples were also included in the characterization. The preliminary waste characterization for RAA 18 will be used to support future integrated sediment and upland cleanup actions in this area.

[22] An additional debris pile is located in RAA 18. This debris pile was also characterized for disposal.

for this waste stream; acceptability criteria vary by facility. The selection of a landfill will be made by the contractor in its RAWP subject to approval by the Owner and EPA. The compliance status of the landfill will be confirmed prior to removing waste from the site in conformance with the Off-Site Rule (40 CFR 300.440). The method of transportation (i.e., truck or rail) may depend on the choice of landfill. Both the Republic Services and Columbia Ridge landfills are served by rail and have dedicated rail unloading facilities. In addition, both landfills have exclusions from the requirements of the Paint Filter Test for dredged material, allowing wet material to be delivered to the landfill.

The ROD anticipated, based on RI/FS data, that material removed from the upper reach will be characterized as nonhazardous waste and not regulated by the Toxic Substances Control Act. The preliminary waste characterization described in Section 10.2.7.1 confirmed that debris to be removed as part of the upper reach design (i.e., in RAA 22), may be managed as nonhazardous waste at the Roosevelt Regional Landfill (owned and operated by Republic Services in Roosevelt, Washington), the Columbia Ridge Landfill (owned and operated by Waste Management in Arlington, Oregon), or another Subtitle D landfill.[23] Final selection of disposal sites will be determined by the contractor subject to approval by EPA.

10.2.8 Post-Dredge Elevation and Chemical Verification

The completeness of dredging will be verified as described in the CQAP (Volume II, Part I), in the post-dredge verification sampling framework and decision flow chart. Progress surveys will verify that the required dredge elevations or thicknesses have been met. In locations where the required dredge elevation/thickness requirements have not been achieved, the contractor will be required to remove additional material to comply with the plans and specification requirements as described in the CQAP.

Once post-dredge elevation requirements are achieved, post-dredge confirmation sampling will occur to characterize the post-dredge surface as described in the CQAP. Based on the sampling results, contingency actions (placement of RMC, contingency re-dredging, or placement of backfill) may be required for residuals management as described in Sections 10.2.9 and 10.2.10.

10.2.9 Residuals Management Approach

Dredging residuals are unavoidable and occur with all types of dredging. The quantity and quality of dredge residuals vary depending on the dredge material properties, presence of debris, and other

[23] Action in RAA 18 is deferred, as discussed in Sections 2.2 and 6.1.3, but the debris in that area has also been determined not to be toxic through this process. Based on the book designation procedure, the sediment in the northern part of RAA 18 may be a WT02 toxic dangerous waste. A bioassay was not performed on sediment because a sample was not available and remedial action in RAA 18 is deferred. Further characterization of sediment in the northern part of RAA 18 may be necessary (as part of the middle or lower reach PDIs) to perform a waste determination.

factors. The residuals management approach differentiates **generated residuals** from **missed inventory**.

- **Generated residuals** refer to the thin layer of disturbed contaminated sediment that are deposited on the post-dredge surface due to material loss during dredging or due to the inability of the dredge to fully remove the material disturbed during the excavation process. This material generally exhibits very high water content and very low shear strength and can be easily mobilized. Additional dredge passes are rarely effective at capturing generated residuals. Generated residuals can be deposited within the dredge prism and on nearby sediments.
- **Missed inventory** refers to unanticipated contaminated sediment within the bottom of an SMA that is below the designed dredging elevation/thickness (i.e., contaminated sediment located deeper than expected). Subject to engineering limitations (e.g., slope and structural stability), missed inventory can often be removed with additional dredge passes.

The purpose of residuals management is to provide a clean post-remedial action surface condition with concentrations that are all below surface RALs. Three techniques will be used to manage dredge residuals: contingency re-dredging, placement of RMC, and placement of backfill. These techniques are discussed in this section and Section 10.2.10. The CQAP includes sampling and response protocols for generated residuals and missed inventory (Volume II, Part I).

10.2.9.1 Contingency Re-Dredging

Contingency re-dredging is additional dredging that may be implemented after the required dredge surface has been achieved, based on results of the post-dredge sediment sampling. Post-dredge sediment sampling will be used to identify areas of missed inventory or high concentrations of generated residuals and to then define a dredge thickness or elevation over a defined area (i.e., the Decision Unit; see the CQAP [Volume II, Part I] for more information). Contingency re-dredging will be directed by the Project Representative. Contingency re-dredging includes an overdredge allowance of 0.5 foot. No contingency re-dredging will be performed in dredge areas that also include subsequent engineered cap material placement to isolate remaining contamination.

10.2.9.2 Residuals Management Cover

RMC can be used to manage generated residuals and limit their movement around the site. The RMC materials are anticipated to blend with the generated residuals and provide a post-remedial action surface condition with concentrations that are below surface RALs. Placing RMC has provided greater certainty in achieving residual performance standards in the case study project sites evaluated in Desrosiers and Patmont (2009) and the USACE technical guidance *The Four R's of Environmental Dredging: Resuspension, Release, Residual, and Risk* (USACE 2008b). The RMC is typically a relatively thin layer (e.g., average 15 cm [6 inches]) of clean sand from local commercial aggregate suppliers.

A targeted placement thickness of 9 inches of RMC (with a 3-inch plus-or-minus vertical placement tolerance) will be placed in all dredge areas that are not backfilled, as shown on the Drawings (Volume III). RMC will also be placed on dredge side slopes to a targeted placement thickness of 24 inches (with a 6-inch plus-or-minus vertical placement tolerance). Additional RMC placement is planned for the perimeter surrounding the dredge area, consisting of two 20-foot-wide[24] perimeter bands. The inner perimeter is the 20-foot width from the top of dredge cut that will automatically receive RMC placement unless constraints from structures or shorelines dictate a narrower band of placement. No sampling will be conducted within the inner perimeter after completion of dredging within an SMA. The outer perimeter is an additional 20 feet outside of the inner perimeter that will be sampled to determine if placement of RMC is necessary. RMC placement on the inner perimeter and outer perimeter (if necessary) will also be placed at a targeted placement thickness of 9 inches with a 3-inch plus-or-minus vertical placement tolerance. For missed inventory, a contingency re-dredging pass will be conducted over a portion of the SMA dredge footprint to remove material above the threshold concentration prior to placement of RMC. Not all dredging areas are expected to require contingency re-dredging.

The dredge residuals management approach (including sampling, reporting, decision logic, and communication) are summarized in the CQAP post-dredge verification sampling framework and decision flow chart presented in Volume II, Part I.

10.2.10 Post-Dredge Backfilling

Backfilling dredged areas with clean material will be required in some dredged areas to restore pre-construction elevations for habitat purposes. Backfill can also serve a residuals management function. Unlike an engineered cap, this backfill layer is not armored to protect it from erosive forces; rather, it is sized, in part, to be generally stable in intertidal areas while balancing the gradation to use materials that are as fine as possible to more closely mimic the sediment that is naturally deposited. Some movement of the backfill material could occur, similar to how natural sediments in the river can move due to erosive forces. Backfill placement will target approximate existing grade above -10 feet MLLW with a 6-inch plus-or-minus vertical placement tolerance, as shown on the Drawings (Volume III). The CQAP includes additional information on placement verification and tolerances (Volume II, Part I). Post-dredge backfill is also used where steeper (2H:1V) temporary dredge cuts need to be restored to a stable (3H:1V) long-term slope, as discussed in Section 8.

All dredge areas located outside of the FNC and above an elevation of -10 feet MLLW are to be backfilled and integrated with habitat material placement in intertidal areas as appropriate.

[24] The downstream inner and outer perimeters are 30 feet for areas along the main flow of the river channel.

Additionally, some areas along EAAs will be backfilled where steeper temporary cuts are made within the EAA so that a stable long-term backfill slope is created.

10.3 Engineered Cap Design

SMA 12B has been identified for an engineered cap, and SMA 5 has been identified for a potential engineered cap. Engineered capping evaluations are presented in Appendices I and J. The need for a cap for SMA 5 would not be confirmed until post-excavation sampling is conducted per the CQAP (Volume II, Part I); thus, the revetment designed for SMA 5, which includes backfill bedding layers and armor rock surface, has been evaluated to confirm that the backfill bedding layers can also function as engineered cap isolation on the sloped portion of the bank, if needed.[25] This evaluation is included in Appendices I and J to avoid needing to conduct cap design analysis during construction after post-excavation bank samples are obtained.

10.3.1 General Cap Design Approach

An engineered cap is designed in accordance with the guidance on cap design set forth by the EPA and USACE (Palermo et al. 1998) and the Interstate Technology and Regulatory Council (ITRC 2014, 2023). These guidance documents provide a generalized approach to designing an in situ cap, including considerations of the following specific design components detailed in Appendices I and J:

- **Chemical Isolation:** Designing a cap chemical isolation layer that attenuates the transport of contaminants through processes such as advection, dispersion/diffusion, bioturbation/bioirrigation, and surface exchange. Contaminant fate and transport modeling is performed to evaluate and design the chemical isolation layer component of a cap.
- **Physical Isolation:** Designing the cap layer thickness and/or material types to prevent direct contact of contaminants with biota and burrowing organisms (bioturbation). Physical isolation also includes developing design criteria to prevent erosion of the cap.
- **Geotechnical:** Confirming that the bearing capacity and shear strength of underlying sediments, and of the cap itself, are sufficient to prevent excessive mixing during construction and slope failure. Geotechnical considerations for capping, including an evaluation of seismic risk, are discussed in Section 8.3.9.

An engineered cap typically consists of an erosion protection layer overlying a chemical isolation layer; however, a cap design may combine the chemical isolation plus erosion protection layer as a single combined layer. For the upper reach, the ROD requires that the top of the cap has suitable

[25] The design detail for the slope is the same, regardless of whether the slope will function as a cap. If a cap is determined not to be necessary, based on post-excavation sampling, there would not be a need for long-term cap monitoring in this location, and the LTMMP would be finalized accordingly, but the design detail would not be revised.

habitat material in clamming areas. Details and results of the cap design evaluations and modeling are provided in Section 10.3.2 and in Appendices I and J.

10.3.2 Cap Design Components

An engineered cap includes components for chemical isolation and erosion protection. The following sections describe evaluations for both of these components.

10.3.2.1 Chemical Isolation Layer

Based on the ROD, there are a total of 42 LDW COCs: 4 COCs based on risk to human health, 40 COCs based on risk to benthic invertebrates, and 1 COC for wildlife (i.e., river otters). The chemical isolation functions of caps for specific locations are designed based on representative COCs at that location. In SMA 5 (RAA 27) and SMA 12B (RAA 14/15/16), total PCB was the only chemical to exceed a RAL. Thus, PCBs were evaluated in Appendix I for SMA 5 and SMA 12B.

Chemical Isolation Layer Design Criteria

The chemical isolation cap layer is designed to meet performance standards within the surface of the cap. Typically caps are designed to be effective at preventing the transport of contaminants to the surface of a cap, resulting in an exceedance of the performance standard within 100 years; for LDW, this would mean designing a cap to reduce risk to human health by preventing chemical concentrations at the surface (0 to 10 cm in both intertidal and subtidal areas and 0 to 45 cm in intertidal areas) from exceeding the surface RAL within 100 years. The chemical isolation analysis was performed to identify the cap thickness and composition (i.e., amendment) needed to meet performance standards for PCBs for 100 years.

Chemical Isolation Layer Design Approach and Results

The one-dimensional model of chemical transport within sediment caps, CapSim (version 3.8; Reible 2017)[26] was used for this evaluation. The model considers the transport of contaminants under the processes of groundwater advection, diffusion/dispersion, bioturbation/bioirrigation, and exchange with the overlying surface water within the sediment cap. As a conservative assumption, the ongoing sedimentation that will occur in most locations has not been considered in the cap design.

The cap model predicts the chemical concentrations that may occur in the surface of a cap over time. This analysis was performed to identify the cap thickness and composition (i.e., amendment) needed to meet performance standards for PCBs for the SMA 5 cap and the SMA 12B cap. PCBs were simulated

[26] A newer version of CapSim is available; however the functionality of the model used in these evaluations has not changed in the newer version; therefore, the results will not be different.

by homolog group to account for the differences in mobility among the homologs, and results were summed to calculate total PCBs in sediment for comparison with RALs.

Results of the cap model evaluation are described in Appendix I. That analysis demonstrated that a minimum chemical isolation layer thickness of 30 cm (12 inches) of sand would be sufficient to meet the PCB RALs for more than 100 years within each cap design area evaluated.

10.3.2.2 Bioturbation

Another consideration in the design of engineered caps is to account for the potential for surficial and deeper-burrowing benthic organisms to burrow (i.e., bioturbation) into the cap and reach the subsurface contaminants. The biological active zone (BAZ) refers to the surface sediment layer where sediments are mixed by the feeding and burrowing behaviors of benthic invertebrates. A bioturbation thickness of 10 cm (4 inches) was used in the cap design where mixing by benthic activity was simulated. Section 2.8.2 of the RI (Windward 2010) concluded that 10 cm (4 inches) can be reasonably applied to the BAZ for the LDW based on an Ecology-led study in 2006 (Ecology 2007) that included 87 sediment profile imaging (SPI) stations within the LDW and 28 SPI stations in the LDW at the Duwamish/Diagonal EAA site under a King County study (Anchor Environmental and King County DNRP 2007):

- **Representativeness of the Benthic Invertebrate Community:** The benthic invertebrate community primarily uses shallower sediment, based on the limited number of voids that have been observed below 10 cm (4 inches); individual benthic invertebrates have been observed at depths of 15 to 20 cm below the sediment surface.
- **Relationship Between Voids and Depth in Sediment:** The number of voids decreases significantly with distance from the sediment surface.
- **Central Tendency of Void Depth:** The mean of the maximum void depths observed in individual profile images was approximately 10 cm (4 inches) with a 95% upper confidence limit of 11 cm (4.5 inches) in subtidal and intertidal areas of the LDW, which was corroborated by the King County study (Anchor Environmental and King County DNRP 2007).
- **Location:** Other than an association with fine-grained sediment, there were no apparent clusters of areas with deeper voids; voids seem to be distributed throughout the RI study area and not related to presence or absence of contamination.

Caps will include an erosion protection layer that will limit the ability of organisms to reach the underlying chemical isolation layer component of the cap, as discussed in Section 10.3.2.3, due to coarser grain size (more difficult burrowing) and thickness (greater than the 10-cm [4-inch] BAZ).[27]

[27] The ROD also requires placement of a 45-cm (1.5-foot) thickness of habitat material at the top of the cap within intertidal clamming areas to provide sufficient thickness for clams to burrow such that the underlying erosion protection and chemical

10.3.2.3 Erosion Protection

Caps are designed to be stable in perpetuity with regard to expected erosive forces. The design of the erosion protection layer includes determining the required cap erosion protection layer grain size and thickness to prevent cap damage from erosive forces and adding an underlying layer of material to prevent the loss of the chemical isolation layer material due to winnowing from between the larger grain-sized erosion protection layer. The top layer of the cap that acts as the erosion protection layer is typically referred to as an armor layer; the material under the armor layer that helps prevent winnowing is referred to as the filter layer. The cap erosion protection design may be able to avoid a discrete filter by integrating filter material both into the armor and chemical isolation layers, which is a common design approach; however, this approach was not used in the erosion protection design for the upper reach.

Erosive forces acting on SMA 5 and SMA 12B were evaluated to design the erosion protection layer. Per the RDWP, the cap has been designed to resist the following erosive forces: hydrodynamic flows, wind-generated waves, vessel propwash, and vessel wakes (Anchor QEA and Windward 2019a). The following sections summarize the erosion protection design presented in Appendix J. Climate change effects (e.g., sea level rise) on erosion protection design are discussed in Section 10.9.

Hydrodynamic Flows

Hydrodynamic flows (i.e., LDW river flow velocities) are a natural cause of potential bed erosion. The FS prepared a STM for the LDW (QEA 2008) and predicted river velocities generated during a 100-year recurrence event. The 100-year flow recurrence is considered a standard design event for cap design, and the LDW STM predicted a maximum near-bed river flow velocity of 1.1 feet per second (ft/s) near the shoreline and a mid-channel velocity of up to 5.8 ft/s. Therefore, the hydrodynamic maximum river flow velocity used in the cap design at SMA 5 is 1.1 ft/s, and a velocity of 5.8 ft/s was used at SMA 12B. For both SMAs the hydrodynamic river flow velocity is higher than the predicted design vessel propwash velocity in the area.

The stable particle sizes to resist the river flow velocities and propwash were evaluated using the methods in Appendix A ("Armor Layer Design") of EPA's *Guidance for In-Situ Subaqueous Capping of Contaminated Sediment* (Palermo et al. 1998). The median stable particle size (D_{50}) to resist the 100-year hydrodynamic flows is 0.1 inch for the SMA 5 cap and 2.3 inches for the SMA 12B cap. As described in the following sections, the median stable particle sizes (D_{50}) for the cap design areas to resist propwash forces are less than 0.25 inch for the sloped bank of SMA 5 and approximately 5 inches for SMA 12B. The reason that the median stable particle size for propwash is larger than for

isolation layers are not disturbed by clam burrowing activity. Neither SMA 12B nor SMA 5 are clamming areas, as discussed further in Section 10.3.2.4; therefore, this layer is not included in the cap design for the upper reach.

river flow, even though the velocity is lower, is that propwash is assumed to be a much more turbulent flow that results in higher bed shear stresses (Appendix J).

Wind-Generated Waves

Wind-generated waves are formed by wind blowing over an unobstructed water surface. Wind-generated waves are formed due to continuous wind blowing in a single direction over long distances (i.e., fetch). The LDW is narrow (between 250 and 450 feet wide); the water surface has obstructions that block the wind at various locations (e.g., South Park Bridge, bends in the waterway, high banks); and the LDW has restricted fetch[28] distances.

Seventy-nine years of wind data were collected from King County International Airport, and an extreme analysis was conducted to find the 100-year wind speeds at various directions. As SMA 12B is below the surf zone, and therefore below wave impacts, only SMA 5 was analyzed. SMA 5 is located at RM 4.0, approximately midway along the upper reach, and is oriented north-northwest to south-southeast; therefore, two fetch distances and orientations were analyzed. The 100-year wind speeds are 53 miles per hour from the north and 62 miles per hour from the south. The fetch from the north is approximately 0.5 mile, and the fetch from the south is approximately 0.6 mile. Given that the waterway is narrow, with a low width-to-length ratio, effective fetch factors were included, which reduce the fetch lengths to 0.2 and 0.3 mile, respectively (Ippen 1966). Using the FNC depth of 26.3 feet at MHHW, maximum wave heights for the 100-year wind speeds are 0.5 foot from the north and 0.7 foot from the south.

Wind-generated wave heights are similar to the predicted possible wake heights caused by transiting vessels (as described in the following section). However, wind-generated waves will be oblique to the cap and have less force impacting the surface layer compared to vessel wakes. Therefore, wind-generated waves will not govern the size of the erosion protection layer aggregate.

Vessel Propwash

In order to evaluate potential erosion forces from vessels transiting the upper reach, design vessels and assumed conservative operating conditions need to be identified. The design vessel selection and operating parameters are described in Appendix J.

Vessel-generated propeller-induced water velocity (i.e., propwash) was evaluated using the methods in Appendix A ("Armor Layer Design") of EPA's *Guidance for In-Situ Subaqueous Capping of Contaminated Sediment* (Palermo et al. 1998). This model considers physical vessel characteristics (e.g., propeller diameter, depth of propeller shaft, and total engine horsepower) and operational and

[28] Fetch refers to the unobstructed overwater distance in the wind direction of interest. Fetch distance can be very long in large open water locations (e.g., oceans) and is very short where land masses and other wind obstructions (e.g., buildings, bridges) limit the ability of wind shear stress to act for sustained distance on the water surface.

site conditions (e.g., applied horsepower and water depth) to estimate propeller-induced bottom velocities at various distances behind the propeller. This model was used to predict the particle size that will be stable when subjected to the steady-state propwash (i.e., the vessel is essentially stationary or maneuvering at a very low speed).

The FS (AECOM 2012) evaluated a range of vessels operating in the LDW. Because the FS evaluations were conducted in 2009, recent vessel data were collected to determine whether different vessel characteristics (size, horsepower) should be considered. Vessel traffic data were obtained through the Automatic Identification System; vessel data are collected by the U.S. Coast Guard through onboard navigation safety devices that transmit and monitor vessel locations and characteristics of large vessels. These data were downloaded via MarineCadastre.gov (BOEM and NOAA 2021). Three representative vessels were analyzed; two tugs and one pleasure craft. The larger vessels are similar in size and horsepower to those considered in the FS. Design vessels are as follows:

1. Capt. Cae Tug
    a. The largest tug to transit the area in 2020 (92 feet long)
2. Westrac II Tug
    a. An average sized tug (74 feet long), selected to represent the more typical tugs that frequent the area; the average length for tugs that transited the area in 2020 was 72 feet
3. Arctic Pride Yacht
    a. One of the largest pleasure vessels to transit the area in 2020 at 126 feet long; there were three larger vessels (up to 150 feet long), but Arctic Pride transited more frequently

Appendix J provides further details of the propwash model design scenarios and inputs. The results of the propwash evaluation for SMA 12B show that resulting bottom velocities (0.8 to 3.2 ft/s) and required median stable particle sizes (0.3 to 4.8 inches) are the governing forces for the design of the erosion protection layer of the cap, based on the design vessels and operating scenarios due to the cap location within the FNC. SMA 5 is much farther from the sail line; therefore, the propwash forces are smaller, requiring an erosion protection layer with a stable median particle size (D_{50}) that is less than 0.25 inch.

Vessel Wakes

Estimates of vessel-induced wave heights (i.e., wakes) were completed through an evaluation of ship traffic patterns within the navigation channel at the cap design area and calculations of vessel wakes based on type of vessel, operational speed, and water depths. The analysis used the Weggel and Sorensen (1986) methodology to predict vessel wakes. The calculated vessel wave heights were assessed for the cap design area using the rubble-mound revetment module (USACE 2004) with the Automated Coastal Engineering System developed by USACE (1992). This module was used to compute the median particle stone size (D_{50}) resistant to the predicted wake height on the steep slope of up to 2H:1V in SMA 5. SMA 12B was not evaluated for vessel wakes because this location is at a depth below wave influences. Based on the analysis of SMA 5, a stable median particle size diameter (D_{50}) of 2.9 inches would withstand vessel wakes within the wake breaking zone.

The resulting stable median particle size[29] (D_{50}) for the wake forces is 2.9 inches for sloped bank of SMA 5. This indicates that geotechnical factors will be more critical for the design of armor in this location, as described in Section 8.3.8.2. An armor thickness of 2 times the median armor diameter is recommended, and an appropriately sized filter under layer is needed between the chemical isolation layer and armor layer.

Erosion Protection Summary

The armor layer material size is controlled by the largest particle size that is stable against a range of erosive forces in the upper reach, including hydrodynamic forces, wind-generated waves, and vessel-generated propwash and wakes. The stable particle sizes (D_{50}) to resist the following forces are as follows:

- **Hydrodynamic Flows:**
  - SMA 12B: 2.3 inches
  - SMA 5: negligible
- **Wind-Generated Waves:**
  - SMA 12B: not applicable, below wave influences
  - SMA 5: similar heights to vessel wakes, but obliquely impacted; therefore, vessel wakes will govern wave forces
- **Vessel Propwash:**
  - SMA 12B: 4.8 inches
  - SMA 5: less than 0.25 inch
- **Vessel Wakes:**
  - SMA 12B: not applicable, below wave influences
  - SMA 5: 2.7 inches

Therefore, within the design area in SMA 5, located in the intertidal zone, the armor layer material size is controlled by the vessel wakes, which results in a D_{50} of 2.7 inches (cobble-sized material) to provide erosion protection to the cap. Within the design area in SMA 12B, located in the FNC, the armor layer material size is controlled by vessel propwash, which results in a D_{50} of 4.8 inches (cobble-sized material) to provide erosion protection to the cap.

[29] To meet the stable median particle size (D_{50}), the Specifications (Volume III) will require a gradation that includes particles that are larger than the D_{50}.

For SMA 12B, a minimum armor thickness of 10 inches is recommended, and a filter with D_{50} of 0.6 inch (gravel to cobble-sized material) will be required. For SMA 5, the armor size needed to construct a stable slope is a larger size than that required for hydrodynamic flows, wind-generated waves, vessel propwash, and vessel wakes. Therefore the SMA 5 amor will consist of the same cobble-sized materials as those used for SMA 12B, with a minimum armor thickness of 12 inches.

10.3.2.4 Habitat Substrate Considerations for Caps

The ROD (EPA 2014) requires placing 45 cm (1.5 feet) of habitat material as the top layer of a cap placed within intertidal clamming areas (shown in ROD Figure 6). The SMA 12B cap is located in the subtidal area of the FNC and does not require habitat material to be placed over the armor layer. The cap design in SMA 5 includes an initial overlay of rounded gravelly sand habitat material equivalent to a 3-inch placement thickness. This layer would also be placed on top of any future armor rock maintenance as well. The habitat layer will not be maintained by renourishment after initial placement because this intertidal area is not a clamming area and is a relatively steep slope that poses a long-term stability challenge for sand and gravel materials. Habitat substrate material type and material sources are discussed further in Section 10.6.

10.3.3 Cap Design Summary

Total design cap thicknesses are based on the thickness of the individual chemical isolation layer, filter, and armor layers of each cap. Minimum thicknesses were determined for each cap layer as described in this section. The Final (100%) RD also includes allowable overplacement for each layer for constructability purposes. Table 10-3 summarizes the cap design thickness for each layer; these exceed the minimum thickness requirements that were developed through the modeling described in this section.

Table 10-3
Cap Design Summary – Design Thickness[1]

Location	Minimum Chemical Isolation Layer Thickness (inches)	Minimum Filter Layer Thickness (inches)	Minimum Erosion Protection Layer Thickness (inches)	Total Minimum Cap Thickness[2] (inches)
SMA 12B	12	6	12	30
SMA 5	12	6	12	30

Notes:
1. The allowable overplacement for the chemical isolation, filter, and armor layers is 6 inches; the total maximum allowable cap thickness is 48 inches (4 feet), if full overplacement occurs.
2. Total minimum cap thickness is calculated assuming no overplacement occurs.

SMA: sediment management area

10.4 Enhanced Natural Recovery Design

The ROD selected ENR as the sediment remedy in Recovery Category 2 or 3 areas where COC concentrations in the top 10 cm are between 1 and 3 times the surface sediment (0 to 10 cm) RALs (depending on area) or where COC concentrations in the top 45 cm are between 1 and 1.5 times the intertidal RALs for the 45-cm interval (EPA 2014). In potential vessel scour areas in Recovery Category 2 or 3 areas, the upper limit for ENR is the same as the subsurface RAL, which means ENR is not an option for a subsurface RAL (i.e., PCBs at 195 mg/kg organic carbon [OC] in the top 60 cm) exceedance at those locations.

ENR includes the placement of a thin cover layer of clean sand to accelerate natural recovery processes. ENR immediately provides a new surface substrate of clean sediments. This cleaner surface material will generally mix with the underlying material through mechanisms such as bioturbation. ENR reduces contaminant concentrations in surface sediments more quickly than would happen by natural sedimentation processes alone. Findings from the ENR/AC Pilot Study Year 3 monitoring report (Wood et al. 2021) indicate that ENR alone (without AC) is effective at reducing bioavailability of PCBs (90% reduction in concentration). The ENR/AC Pilot Study also demonstrated that the ENR remained in place and performed as intended under various physical conditions (e.g., wakes/waves, propwash, bridle chain dragging) over the 3-year study.

The ROD indicated that ENR may be combined with in situ treatment (i.e., the sand substrate may be amended with AC or other sequestering agents to reduce the bioavailability of organic contaminants such as PCBs; EPA 2014). The effectiveness and potential impacts of using in situ treatment or amendment technologies, as well as the areas best suited for these technologies, were evaluated in the ENR/AC Pilot Study. The ENR/AC Pilot Study concluded that adding AC to the ENR layer provided no substantial improvement in PCB bioavailability reduction when compared to ENR alone (Wood et al. 2021). The study also showed that the amount of AC used (2.7% to 4% by weight AC) did not adversely impact benthic communities. AC amendment is not included in ENR as part of the

Final (100%) RD but is considered for area-specific technologies to provide a redundancy in protection for those areas (see Section 10.5 for more details).

Consistent with the ROD and recent Puget Sound projects, ENR will include a layer of clean sand (or other suitable habitat materials) with a targeted placement thickness of 9 inches on in situ sediments (with a 3-inch plus-or-minus vertical placement tolerance). Table 5-1 in Section 5 indicates that ENR technology is assigned to RAAs 7, 10,23, 33, and 36, consisting of a total area of approximately 11,700 square feet. ENR is also the technology selected for RAA 13 (SMA 13). As noted in Table 5-1, the area is located on a steep slope, and coarser material has been selected for use compared to typical material used for ENR on more gentle slopes or in flat areas. For construction simplicity, the amended cover material is specified for this area because of its larger gradation compared to the ENR specification.

10.5 Area-Specific Technology Design

Two area-specific technologies have been defined for the upper reach, including the ENR/AC Pilot Study intertidal plot and amended cover in dredge offset areas.

10.5.1 Area-Specific Technology A: ENR/AC Pilot Plot

Within the ENR/AC Pilot plot, PCB concentrations in some of the sediment samples collected prior to ENR/AC placement were measured to be greater than 3 times the RAL (threshold for ENR); therefore, these area-specific technology locations were further evaluated to assess the long-term performance of the material that was placed to attenuate PCBs and maintain concentrations in the surface of the ENR/AC Pilot plot area (top 10 cm) less than the surface PCB RAL of 12 mg/kg OC. These evaluations, which are documented in Appendix K, show that the 30-cm (1-foot) placed thickness of material is sufficient to meet the surface RAL for more than 100 years.

10.5.2 Area-Specific Technology B: Amended Cover in Dredge Offset Area

Area-Specific Technology B will be applied in localized areas where dredging, capping, or ENR cannot be applied because of structural limitations or ROD requirements (e.g., the ENR upper limit). Area-Specific Technology B will be applied to portions of SMA 7 where dredge offsets are required and the ENR upper limit is exceeded. Capping in these locations would raise grades significantly from pre-construction elevations, which would negatively impact the habitat value and was therefore not considered. These are small, localized areas (representing 0.01% of the surface area of the upper reach SMAs).

10.5.2.1 Modeling Results and Design Requirements

A cover material amended with AC has been evaluated for application in these offset areas to address PCB concentrations greater than the ENR upper limit (greater than 3 times the RAL).

Model-predicted PCB concentrations within the surface of the cover (0 to 10 cm) were compared to the total PCB surface RAL (12 mg/kg OC) throughout the 100-year simulations. Model results indicate that a 12-inch cover with 1% total OC or a 6-inch cover with 1.5% total OC would be sufficient to maintain the PCB concentration in the surface of the cover at values less than the 12 mg/kg OC RAL for more than 100 years for both Darcy flux scenarios (400 and 800 cm per year). Details of this evaluation are described in Appendix K.

The amended cover is designed to be a thin layer (targeted placement thickness of 12 inches with a 3-inch plus-or-minus vertical placement tolerance) of sand/gravel substrate blended with granular activated carbon (GAC) to achieve a minimum of 1% by weight GAC[30] to reduce the bioavailability of PCBs at the surface of the cover over a 100-year period.

10.5.2.2 Application of AC in Dredge Offset Area

Although results of the ENR/AC Pilot Study indicated that ENR with and without GAC performed similarly, the evaluation specific to the Area-Specific Technology B in portions of SMA 7 indicate that a sorptive amendment is required to meet the RALs. This is due to the higher PCB concentrations measured in some of the Area-Specific Technology B areas compared with the ENR/AC Pilot plot PCB concentrations. For comparison, the maximum PCB concentration in sediment prior to placement of the cover in the ENR/AC Pilot plot was 107 mg/kg OC. The two highest concentrations in the Area-Specific Technology B area are 191 mg/kg OC and 214 mg/kg OC. Modeling evaluations detailed in Appendix K show that a cover with an amendment is needed to meet goals in these areas that have higher PCB concentrations.

As described in the previous subsection, a target of 1% GAC is indicated for the placed material layer. The Specifications (Volume III) require a minimum of 2% GAC by weight to account for any potential loss of GAC during placement activities. The Specifications also include a particle size requirement range (200 to 1,000 microns) that matches the material that was used in the ENR/AC Pilot Study; that material was successfully placed and retained. This range includes very small particle sizes, which makes it a mixture of powdered and granular-size activated carbon particles.

The cover material sand substrate gradation is similar to the ENR material that was used for the ENR/AC Pilot Study intertidal plot, which has shown to be stable in similar intertidal conditions and includes a larger fraction of gravel to increase the overall stability of the cover material.

The effectiveness of an amended cover to attenuate contamination within SMA 7 is evaluated in Appendix K, and the physical stability evaluation of the cover material is discussed in Appendix J. The

[30] Although model results indicate that 12 inches of sand/gravel with 1% by weight total OC is needed to maintain PCB concentrations in the surface of the cover at values less than the RAL for more than 100 years, a conservative target of 1% by weight GAC was selected.

gradation of the sand/gravel mixture and the type and dosage of amendment for Area-Specific Technology B are defined in the Specifications (Volume III).

This technology is not intended to provide the physical isolation that an engineered cap would provide. The use of clean sand/gravel will reduce surface concentrations, and the blended amendment will reduce the bioavailability of PCBs. Examples of projects that have successfully used GAC in surficial applications include the ENR/AC Pilot Study (LDW), Slip 4 EAA (LDW), the Y Jetty and Lang Cove Remediation Project (Victoria, British Columbia), and the Former Portland Gas Manufacturing Site cleanup project (Portland, Oregon).

10.6 Material Types and Placement Methods

Material placement types included in this Final (100%) RD include backfill, ENR, RMC, habitat substrate, and engineered cap materials (cap isolation, filter, and armor layers). The anticipated types of material, sources, placement methods, and production rates are discussed in this section.

10.6.1 Material Types

Imported materials used for backfill, RMC, ENR, erosion protection, habitat mix, and area-specific technologies will generally consist of sand and gravel aggregates with limited fines content (percent of material passing the U.S. No. 200 Sieve) and armor rock (cobbles) for erosion protection on steeper slopes such as the shoreline bank at Container Properties (SMA 5). By limiting fines, turbidity will be minimized during material placement.

Table 10-4 provides the characteristics for each of the material types needed for the project. Although armor materials will be angular, gravel and smaller materials intended to support habitat functions will be rounded. Gradation ranges of materials used are provided in the Specifications (Volume III).

Table 10-4
Summary of Material Characteristics

Material Type	Material Description[1]
Habitat substrate	Sand and/or rounded gravel aggregate (also known as "fish mix") will be used in habitat areas, including clam habitat areas.
ENR	Medium- to coarse-grained sand; and gravelly sand at SMA 13 as described in the Specifications
RMC material	Medium- to coarse-grained sand as described in the Specifications
Area-specific technology	Gravelly sand; specific amendments targeted to COC added where needed as described in the Specifications

Material Type	Material Description[1]
Engineered cap armor material	Angular rock armor (cobble/quarry spalls size) as described in the Specifications
Engineered cap filter material	Angular gravel as described in the Specifications
Engineered cap isolation material	Gravelly sand
Backfill material	Gravelly sand or medium- to coarse-grained sand material depending on location, as described in the Specifications

Notes:
1. Material grain size and selected gradations do not vary based on material placement within Recovery Category 1, 2, and 3 areas. A single gradation has been selected to simplify constructability and to be protective in all Recovery Category areas.
COC: contaminant of concern
ENR: enhanced natural recovery
EPA: U.S. Environmental Protection Agency
RMC: residuals management cover

10.6.2 Candidate Source Material Suppliers

Materials will be obtained from established upland borrow sources. There are several regionally available commercial sources of aggregate material (i.e., sand and gravel quarries) that can supply materials for backfill, capping (e.g., sand, gravel, armor), RMC, and ENR (e.g., sand and gravel). Locally available sources of aggregate material include the following:

- Glacier Northwest commercial sources (e.g., Dupont Pioneer Aggregates, White River, Snoqualmie locations in Washington)
- Corliss Resources (Lehigh Hanson), a sand and gravel facility in Sumner, Washington
- Valley View/Dieringer Pit, a sand and gravel pit in Shelton, Washington
- Baydo, a gravel facility in Auburn, Washington
- Johns Prairie Mine, a sand and gravel pit in Shelton, Washington
- Kent-Kangley Pit, a sand and gravel pit in Ravensdale, Washington
- Miles Sand and Gravel, multiple aggregate pit locations in Puget Sound region, Washington

The contractor will ultimately select appropriate material suppliers that can meet the design quantities, delivery schedules, gradations, and chemical quality criteria established for each material type. The specific supplier(s) will be identified as part of the contractor's RAWP, and the Specifications (Volume III) require that each product have construction submittals of test results for acceptance by the Project Representative.

Beneficial use of clean dredged material from off-site non-remediation projects was evaluated as a potential source of backfill, ENR, RMC, and cap attenuation layer materials. Beneficial use of clean dredged material entails significant legal, contracting, logistic, coordination, and timing complications, among other issues, and for recent cleanup projects has been difficult to accomplish. Given the constrained schedule for cleanup in the upper reach; the uncertainty of the timing, quantity, and quality of future dredging project volumes; and the challenges encountered in past projects associated with the perceived risk of using beneficial use sources on cleanup projects, beneficial use of clean dredged material is not considered feasible and is not included in this design.

10.6.3 Source Material Acceptance Criteria

Cap, backfill, ENR, RMC, and habitat materials must be approved for use by the Owner and by EPA; therefore, testing of the borrow source material is required of the contractor to demonstrate that the source materials meet specifications. Chemical criteria, gradation, material properties, and testing requirements are identified in the Specifications (Volume III).

10.6.4 Material Placement Methods

For placement of all imported materials, the Specifications (Volume III) identify performance criteria that the contractor must meet and provide flexibility for the contractor to choose the optimal means and methods that take advantage of its experience and equipment. The contractor will be required to place all materials in a manner that reduces resuspending potentially contaminated bed sediment. Additionally, material will be placed using methods that limit mixing of the placed materials with the bedded sediment. Finally, placement of material will be subject to water quality monitoring.

Exhibit 10-2 depicts in-water placement of clean material using typical marine equipment.

The following methods are considered acceptable placement methods, or combinations of methods, that the contractor may use to limit disturbance of the bottom sediments during material placement operations. The contractor will be allowed to propose alternate placement methods in its RAWP for review and approval by the Owner and EPA:

- Placing cap, backfill, ENR, habitat, and RMC materials with a barge-mounted, crane-operated clamshell or a spreader box ("skip box")
  - The clamshell placement method involves slightly opening the bucket and slowly releasing the sand from the bucket near or slightly below the water surface as the operator moves the bucket in a sweeping motion from side to side. Allowing sands to fall through the water column helps spread out the placed materials, which may help reduce the energy of the placed materials hitting the bed.
- Placing cap, backfill, ENR, habitat, and RMC materials from a barge with a variable-speed telebelt, which would project material over the placement area.
  - This placement method has been demonstrated locally (e.g., at the Todd Shipyard remediation project on Harbor Island, completed in 2006, in underpier areas with limited access for standard marine equipment).

- Placing individual engineered cap layers by lowering the cap material close to the sediment bed surface and slowly opening the bucket to provide more accurate placement of each discrete cap layer
- Placing larger armoring layer material from near the sediment bed instead of from the surface of the water column
- On slopes, placing materials from the bottom of the slope and working up the slope to reduce the potential for slope sloughing
- Placing materials using upland earthwork equipment from the shoreline
- In intertidal areas, working at low tides "in the dry" to limit water quality effects and better control placement accuracy

10.6.5 Placement Tolerances and Verification

The Drawings and Specifications (Volume III) specify the required thicknesses of backfill, ENR, RMC, and habitat material layers and overplacement allowances for material placement. Materials may be placed in single lifts for ENR and RMC, and multiple lifts may be needed in backfill and capping areas.

The Specifications (Volume III) require the contractor to perform QC during material placement activities in accordance with the Specifications and the contractor's RAWP (e.g., frequent progress surveys, pre- and post-placement acceptance surveys, bucket maps, quantity documentation, equipment inspection, sampling and analysis to verify imported materials quality). Construction QA will be performed by the Owner to review and accept specified material layer thicknesses. The CQAP describes QA roles and responsibilities, QA activities, and the means and methods that the Owner will use to provide QA during construction to assess compliance with the Specifications. Contractor QA/QC is discussed further in Section 16.

Exhibit 10-2
In-Water Placement of Clean Material Using Typical Marine Equipment

Controlled bucket placement

Variable-speed telebelt placement

10.6.6 Material Placement Production Rates

Similar to dredge production rates presented in Section 10.2.5, material placement production rates (i.e., the volume of material placed on an hourly or daily basis) will vary based on the contractor's selection of equipment, water depth, material types and physical characteristics (e.g., sand, gravel, armor), and site constraints such as nearby vessel traffic and weather conditions. It is estimated that a reasonable mechanical material placement production rate in the upper reach will be approximately 1,100 cy per day in open-water areas, such as the FNC. Material production rates are anticipated to be lower for nearshore and restricted access placement, which are estimated to range from approximately 600 to 700 cy per day. The overall site-wide weighted average placement production rate is estimated to be 900 cy per day.

Similar to estimating dredging production rates, other factors will affect production rates, may increase overall duration, and must be accounted for in the contractor's schedule. These include, for example, QA/QC and Owner acceptance of each layer, water quality protection, scheduled downtime, directed moves to allow safe passage of commercial vessels, inherent delays, maintenance, inclement weather, holidays, or slowdowns due to bottlenecks at other portions of the operation (e.g., material procurement and delivery).

10.7 Monitored Natural Recovery

MNR is the selected remedy for sediment areas outside of the SMA and EAA boundaries that are not remediated through dredging, capping, ENR, or an area-specific technology. The compliance monitoring and decision framework regarding MNR will be developed in the LTMMP (plan outline in Volume II, Part VI). As stated in the ROD, MNR is split into two categories that will be further described in this section: MNR to benthic SCO and MNR below the benthic SCO (EPA 2014).

10.7.1 MNR to Benthic SCO

In MNR areas that exceed the benthic SCO, compliance monitoring of surface sediments (top 10 cm [4 inches]) will be implemented to evaluate whether the Remedial Action Objective (RAO) 3 cleanup levels (benthic SCO criteria) are projected to be achieved.

Sample locations where MNR to benthic SCO may apply were originally presented in the DER (Anchor QEA and Windward 2022a). Table 10-5 and Figure 10-1 provide an updated summary following review of Phase III PDI data. Additional samples have been collected at some of these locations during the Phase III PDI to evaluate how surface sediment COC concentrations are changing over time as projected by natural recovery models (Anchor QEA and Windward 2022b).

MNR to benthic SCO locations will be monitored as part of long-term monitoring. The LTMMP will detail the monitoring requirements and process for addressing these areas if recovery is not achieved.

Table 10-5
Locations with Surface Sediment COC Concentrations > Benthic SCO and < RAL That Are Not Within an SMA

Sample (Year Sampled)	Location	COC	EF Relative to Benthic SCO	EF Relative to RAL (note 1)
LDW20-SS156 (2020)	RM 3.4 in FNC	Mercury	1.1	0.56
LDWSS383 (2020)	West side of Turning Basin	Dibenzofuran	1.3	0.67
LDW21-SS599 (2021)	RM 3.82E	BEHP	1.6	0.79
LDW21-SS625 (2021)	RM 3.92E	BBP	1.4	0.72

Note:

1. The RAL is twice the benthic SCO in Recovery Category 2/3 areas, so the exceedance factor relative to the RAL is one-half that relative to the benthic SCO.

BBP: benzyl butyl phthalate
BEHP: bis(2-ethylhexyl) phthalate
COC: contaminant of concern
EF: exceedance factor
FNC: federal navigation channel
PAH: polycyclic aromatic hydrocarbon
RAL: remedial action level
RM: river mile
SCO: sediment cleanup objectives
SMA: sediment management area

10.7.2 MNR Below Benthic SCO

MNR below benthic SCO areas will be monitored as part of the site-wide monitoring program to track progress toward achieving RAOs 1 and 2. MNR below benthic SCO generally encompasses most areas of the LDW outside the SMAs, and the associated monitoring regime will be presented in the LTMMP.

10.8 No-Rise Evaluation

Per the Federal Emergency Management Agency (FEMA) Region 10 guidance document, *Procedures for "No-Rise" Certification for Proposed Developments in the Regulatory Floodway* (FEMA 2013), the equivalent to a "no-rise" certification is required for the upper reach remedial action using hydraulic analyses to demonstrate substantive compliance with Section 60.3(d)(3) of the National Flood Insurance Program and King County Code Section 21A.24.240 (zero-rise flood fringe). These codes stipulate that any development or alterations to the floodplain must not increase the base flood elevation or energy grade line elevation during the occurrence of the 100-year flood discharge. A FEMA no-rise evaluation (Appendix L) was prepared to support EPA's assessment of ARAR substantive compliance.

Over the length of the upper reach, the total quantity of material dredged will be greater than the total fill quantity placed for backfill, capping, ENR, and RMC. At Final (100%) RD, the estimated total dredging volume (including assumed contingency re-dredging volume) is 132,300 cy; the estimated total placement volume for backfill, capping, ENR (including SMA-c1), amended cover, and RMC is 95,300 cy. Apart from ENR, Area-Specific Technology B, and RMC placement, the remedial approach presented does not incorporate placement of fill to elevations greater than the existing mudline. Thus, the cleanup will result in a net benefit with respect to flood rise because the capacity of the waterway to accommodate flood flows will slightly increase.

ENR placement entails a relatively thin new layer of material that is intended to mimic the natural sedimentation and recovery process that will otherwise occur over time in the same area. The increase in elevation due to ENR placement will result in a riverbed condition that is no different than the long-term, post-construction bed elevation that will naturally proliferate in the same area as incoming sediment is deposited. The same holds true to the strips of RMC around the outside of dredge areas. However, the zero-rise evaluation performed represents the elevation of ENR placement at the time of construction rather than the long-term post-construction bed as a result of natural erosion or sedimentation.

USACE's Hydrologic Engineering Center – River Analysis System (HEC-RAS) hydraulic model was used to evaluate the effect of the remedial action on the 100-year flood elevation. HEC-RAS is the FEMA-accepted modeling tool used for determining the base flood elevations reported in FEMA Flood Insurance Studies. This model was used to estimate the pre-construction and post-construction flood stage elevations in the upper reach.

Anchor QEA acquired from King County the existing FEMA Regulatory HEC-RAS floodplain model (Effective model) for the Green River/Duwamish Waterway developed in 2019. The Effective model was updated with the pre-project existing conditions (existing conditions model), including the existing South Park Bridge and elevation data from the project basemap, as described in Section 2.4.1. Additional cross sections were added to those in the Effective model in the existing conditions and proposed conditions models to capture elevation changes within the Project. The existing conditions model was compared to a proposed conditions model, which reflects the Final (100%) RD dredge, ENR, RMC, backfill, and engineered cap plans. All HEC-RAS models were run with the 100-year flow from the Effective FEMA Flood Insurance Study (FEMA 2020).

Based on the modeled proposed conditions, it is not expected that the RD will result in a predicted increase to the flood levels or energy grade line of the 100-year discharge. Therefore, the remedy, as designed, will not affect the flood risk in the upper reach. Detailed descriptions of model development and results can be found in Appendix L.

10.9 Climate Change Design Considerations

Climate change effects in the greater Puget Sound region and relevant to the LDW include sea level rise, changes in precipitation patterns, and overall hydrological changes. Climate change adaptation generally focuses on evaluating a system's vulnerability to climate change and implementing adaptation measures, when warranted, so that the remedy continues to remain effective at meeting the ROD objectives (EPA 2014). EPA and LDWG have considered climate change design factors as they apply to the LDW since the 2014 ROD. EPA Region 10 hosted the Lower Duwamish Waterway: Climate Change Adaptation Workshop in March 2017, which focused on technical aspects of climate change impacts on sediment cleanup and upland source control at the LDW Superfund Site. Attendees included EPA, LDWG, USACE, Ecology, Duwamish Tribe, NOAA, University of Washington, and others. A full list of attendees and summaries of presentations delivered during the workshop by representatives of government agencies and supporting organizations is presented in the Workshop Summary (EPA 2017a).

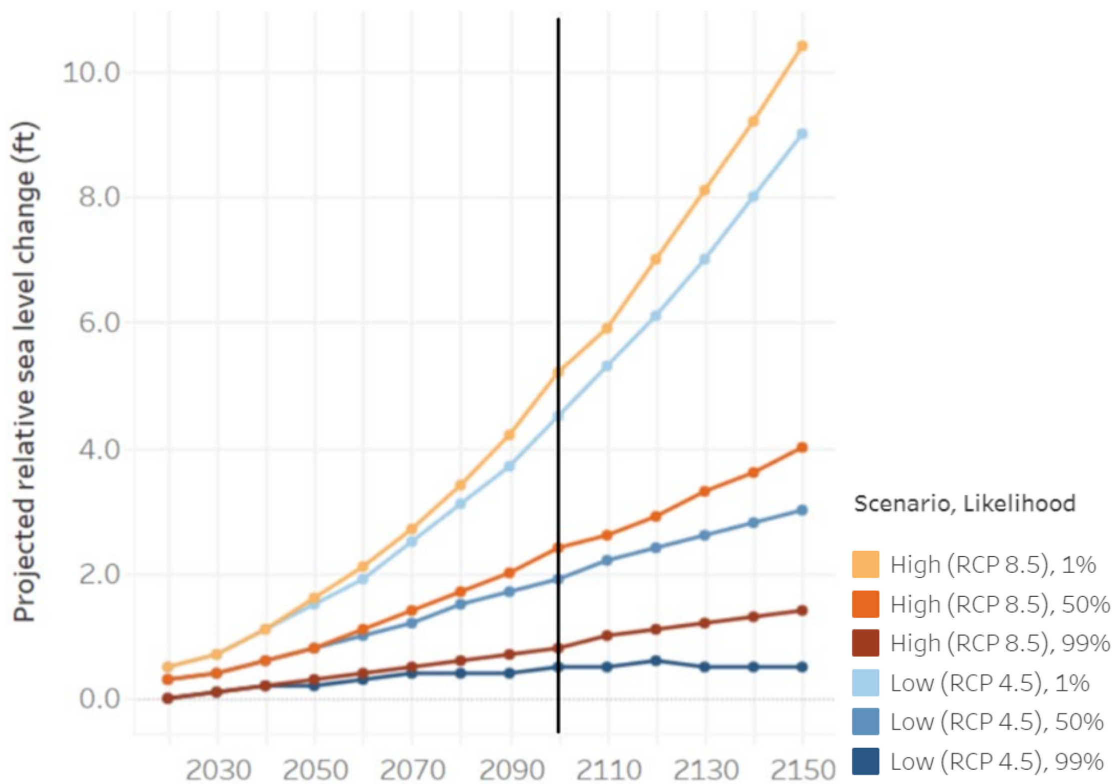
10.9.1 Sea Level Rise

Climate change is expected to increase sea levels over the next few hundred years (CIG/UW 2017). An increase in mean sea level will correspond to an increase in design water levels at the upper reach due to tidal influence; however, not all components of the RD are anticipated to be affected by an increase in design water levels. For example, dredging will not be affected by the increase in long-term water depth because long-term changes in water depth do not influence dredging during the construction phase or the effectiveness of the dredging remedy in the future. Caps and ENR layers are designed assuming the areas are currently submerged under constant or tidal immersion, and deeper water depths in the future would lower the forces on the riverbed, as described in the following paragraphs.

In the future, sea level rise will increase the water depths within the upper reach. The projected changes in sea level have been assessed in accordance with Ecology guidance. A report prepared for the Washington Coastal Resiliency Project (WCRP) in 2018 provided an assessment of projected sea level rise and the associated hazards for Washington State. The WCRP report provides updated projections for sea level rise that are more comprehensive than past estimates, taking into consideration recent research, land movement, and greenhouse gas emissions. Greenhouse gas emission projections depend on a variety of factors related to human behavior. Therefore, probabilistic projections for sea level rise have been made based on both low and high greenhouse gas scenarios.

Climate projections are made for two greenhouse gas emissions scenarios in the WCRP report: Representative Concentration Pathway (RCP) 4.5 and RCP 8.5. RCP 4.5 is a low estimate in which greenhouse gas estimates stabilize by mid-century and decrease thereafter. RCP 8.5 is a high scenario in which there is a continued increase in greenhouse gases until the end of the twenty-first century (Mauger et al. 2015). The Washington Coastal Network used the data presented in Miller et al. (2018) to generate visualization tools to projected sea level rise applicable to various coastlines across Washington. Exhibit 10-3 shows the projected sea level rise for various potential scenarios for the upper reach. The exhibit presents the projects for RCP 4.5 and RCP 8.5 for the 1%, 50%, and 99% likelihood of occurrence. Although there is no industry standard for the application of sea level rise projections, other projects in the Puget Sound have incorporated the 50% central estimate for the design of site elevations. Based on the projections and using the 50% central estimate, the relative sea level is predicted to rise between 1.9 to 2.4 feet by 2100 (black line, Exhibit 10-3; Miller et al. 2018).

Exhibit 10-3
Sea Level Rise Projections for the LDW



Source: https://wacoastalnetwork.com/research-and-tools/slr-visualization/

10.9.2 Hydrodynamics

As described in the RDWP, additional modeling of climate change on future hydrodynamics is not necessary as part of RD (Anchor QEA and Windward 2019a). First, propwash velocities and vessel wakes control cap design because they are much higher than velocities due to river flows or wind-generated waves, including under future sea level rise conditions. Second, ongoing water management practices at the Howard Hanson Dam effectively control most peak river flows in the Duwamish River (USACE 2014).

Propwash forces on the riverbed are expected to be lower with sea level rise due to the larger propeller clearance as water depths increase. The deeper the water depth, the further the propeller is from the riverbed. The further the propeller is from the riverbed, the lower the propwash velocities are on the riverbed. As a result, there will be lower propwash forces in the future as water depths increase. Wake forces are not expected to change with sea level rise because wake heights are not expected to change; however, the wake forces will be experienced at higher elevations on the bank.

USACE evaluated how climate change could impact hydrology and water management operations on the Green River and what adaptations might be feasible at Howard Hanson Dam to accommodate those impacts (USACE 2014). The report concluded that the current water control plan at Howard Hanson Dam is somewhat resilient to climatic shifts and that flexibility inherent in the reservoir regulation could be adapted to further accommodate climate changes.

10.9.3 Sediment Load

Uncertainties in estimates of sediment load were evaluated as part of the RI/FS process. Climate change impacts and land use changes of upstream areas in the Green-Duwamish watershed may affect the relative and total sediment contributions to the LDW. Modeling demonstrated the vast majority of the sediment load is delivered during higher flows (QEA 2008). Therefore, more frequent higher flows in the Green River may result in higher sediment loads in the river and therefore greater rates of net sedimentation throughout the LDW. As a result, the MNR process may be accelerated. The STM indicates that higher flows are not expected to increase overall erosion in the LDW (QEA 2008).

Climate change effects on sediment load do not affect the design of remedial action because the ROD (EPA 2014) defines what remedial technologies are applicable for the present site conditions. Qualitatively, greater net sedimentation rates will accelerate natural recovery processes. No further modeling of these effects on sediment loads is planned due to the infeasibility of predicting changes to sediment load that have many contributory factors (e.g., upland development, agricultural practices, erosion, dam operations, stormwater discharges).

10.9.4 Design for Climate Change Adaptability

As part of the design process, an assessment was performed to evaluate how long-term changes in sea level and corresponding water depths would influence the remedy. The RD allows the remedy to adapt to long-term climate change scenarios. This section presents the assessment for the key design elements and describes how those elements are adaptable to climate change.

10.9.4.1 Dredging Remedial Action Adaptation

Dredging RD footprints (horizontal and vertical extents) are not affected by sea level rise because the dredging minimum removal extents are developed based on the design chemistry dataset, PDI geotechnical engineering data, and engineering considerations, which are based on current, not future, conditions for design.

10.9.4.2 Capping and ENR Remedial Action Adaptation

As part of the cap erosion protection evaluation, potential long-term changes in water depths were assessed. As described in Appendix J, the caps are expected to be stable under long-term water level changes. Future sea level rise conditions are not expected to increase the stable sediment size required for the cap armor stone to resist propwash or wind- and vessel-generated wave forces. As the depths within the waterway will increase, it is anticipated that bottom velocities from propwash forces will decrease in a future climate change scenario, resulting in a decrease in needed stable sediment size. However, there is uncertainty in future flow and sediment transport into the LDW due to a variety of factors that could include future dam changes for fish passage, future dredging, and climate-related changes in hydrodynamics. This uncertainty will be a factor that helps inform the interpretation of long-term monitoring, remedy protectiveness, and time frames for natural recovery. Monitoring for potential climate change affects will be addressed in the LTMMP.

The armor layer design on the slope at SMA 5 extends to the top of bank around elevation +20, which is more than 8 feet above the current MHHW elevation and well in excess of the 50% central estimate sea level rise prediction.

Vessel wake heights are not expected to increase with the addition of sea level rise to the waterway because travel speeds are expected to remain similar to current day, and the relative change in water depth is not expected to substantively change the types of vessels that transit the LDW. Therefore, required stable sediment sizes for future sea level rise conditions are not expected to increase. However, with sea level rise, higher bank elevations will be subject to wakes. Thus, where banks are to be capped, the cap will extend to existing top of bank using a substrate that will resist current-day and future vessel wakes considering higher water levels.

ENR remedial action is also not expected to be impacted by future sea level rise for the same reasons as capping remedial action.

Climate change could impact groundwater seepage rates, which in turn can affect performance of the chemical isolation layer. Increased precipitation has been shown to occur as short but intense rain events, and this precipitation enters waterbodies as runoff, rather than by infiltration into the ground (ITRC 2023). As reported by EPA (2022), flooding has become more frequent in the Pacific Northwest. Flooding increases the water depths and therefore decreases the seepage rate. Decreases in seepage rates in the future could result in improved cap performance compared with the design.

10.9.4.3 Habitat Elevations Adaptation

Habitat restoration elevations per the ROD state that habitat areas (above -10 feet MLLW or as determined by EPA) will be restored to their pre-dredging elevations by backfilling dredged areas with habitat suitable materials (ROD Section 13.2.1.1 [EPA 2014]). Increase in water depths due to sea level rise would not impact the RD because the required backfilling will be performed in habitat areas. Sea level rise would essentially raise the MHHW elevation. Such changes in habitat will occur globally, and potential future mitigation actions are outside the scope of the CERCLA action.

10.9.4.4 Bank Stability Adaptation

Remedial actions that affect bank areas will be designed to address long-term bank stability, including geotechnical stability and bank erosion stability. From a climate change adaptation standpoint, the top elevation of bank armoring in SMA 5 is above the predicted sea level rise elevation in year 2100 and will provide stability and erosion protection as described in Section 10.9.4.2.

10.10 Maintenance, Monitoring, and Institutional Controls

Maintenance and monitoring will be implemented in accordance with the LTMMP (outline included in Volume II, Part VI), and institutional controls in accordance with the Sediment Remedy Institutional Controls Implementation and Assurance Plan (ICIAP; outline included in Volume II, Part VII). Per AOC4, this Final (100%) RD includes revised outlines of the LTMMP and Sediment Remedy ICIAP that have been annotated with additional details on the proposed approaches.

The Implementing Entity, working under a forthcoming Consent Decree or other enforcement mechanism, will finalize and implement the LTMMP and Sediment Remedy ICIAP after construction is completed. It is expected that the LTMMP and Sediment Remedy ICIAP will be subsequently amended to include site-specific requirements for each reach following construction.

The purpose of the LTMMP is to assess the following:

- Remedy performance compared to the ROD criteria
- Compliance with ARARs
- Integrity of the remedial actions
- Develop information for EPA’s periodic reviews of the remedy

The LTMMP will describe performance standards, sampling (type, density, and frequency), interim benchmarks (if applicable), and associated follow-up or response actions. The LTMMP will be developed in accordance with *Guidance for Management of Superfund Remedies in Post Construction* (EPA 2017b). The LTMMP will include both LDW-wide monitoring elements as well as elements specific to the remedy in the upper reach (including EAAs),[31] such as specific monitoring requirements for caps, ENR, and MNR to benthic SCO.

The purpose of the Sediment Remedy ICIAP is to identify the institutional controls necessary to protect the physical integrity of remedial actions. The Sediment Remedy ICIAP will include an evaluation of the most appropriate institutional, proprietary controls and location-specific use restrictions needed to support long-term effectiveness of the remedial action, consistent with Section 13.2.4 of the ROD (EPA 2014). The Sediment Remedy ICIAP will be developed in accordance with *Institutional Controls: A Guide to Planning, Implementing, Maintaining, and Enforcing Institutional Controls at Contaminated Sites* (EPA 2012a) and *Institutional Controls: A Guide to Preparing Institutional Controls Implementation and Assurance Plans at Contaminated Sites* (EPA 2012b).

For the protection of risks to human health from resident seafood consumption, EPA and Public Health Seattle-King County established a community-based Duwamish Healthy Seafood Consumption Institutional Control Program for the LDW Superfund Site (Public Health Seattle and King County 2019). To avoid redundancy, the Sediment Remedy ICIAP will refer to the Duwamish Seafood Consumption ICIAP for institutional controls related to reducing risk from consuming contaminated resident seafood from the LDW and thus will not be repeated in the Sediment Remedy ICIAP. The Implementing Entity will complete and implement the Sediment Remedy ICIAP after construction is completed, such that the ICIAP accurately reflects the details of the constructed remedy.

[31] As noted in Footnote a. of Table 23 of the ROD (EPA 2014), recovery categories were not previously assigned to the EAAs. EPA has requested that recovery categories be assigned to EAAs for the purposes of long-term monitoring decisions. As such, the areas have been split into Recovery Category 1 and Recovery Category 2/3 based on the results of the STM (Figure 10-2). The other lines of evidence in ROD Table 23 cannot be applied to the EAAs at this time.

11 Environmental Protection During Construction

This section describes environmental protection considerations and requirements during construction, such as any controls that will be employed to comply with ARARs and reduce environmental impacts (in accordance with Sections 13.2.5 and 13.2.8 of the ROD [EPA 2014]).

11.1 Water Quality Effects During Construction

Dredging and material placement will generate short-term turbidity caused by resuspended sediments in the water column as well as some release of COCs associated with the sediment and porewater; causes of sediment resuspension are described in this section. Compliance with water quality criteria and anticipated monitoring are also discussed.

11.1.1 Water Quality Criteria

The contractor is responsible for providing QC of its work, as well as adhering to environmental protection criteria in the Specifications (Volume III). These include the performance standards for complying with applicable and relevant state water quality criteria (WAC 173-201A-210). This includes required limits measured in the water column for turbidity, dissolved oxygen, pH, and temperature and for select COC criteria (e.g., PCBs). Dredging impacts on water quality are typically assessed by complying with the provisions of EPA's CWA Section 404 ARAR Memorandum (Section 3.4). The CWA Section 404 ARAR Memorandum provisions will be based on state turbidity water quality standards, which are at WAC 173-201A-210(1)(e) for waters designated as "excellent" marine quality. Of the water quality parameters, turbidity is typically the limiting factor that may affect the contractor's operations. Expected turbidity criteria of the CWA Section 404 ARAR Memorandum are that in-water construction activities do not increase the in-water turbidity, measured as nephelometric turbidity units (NTU), more than 5 NTU above background (or 10% above background if background is 50 NTU or higher). Compliance is typically measured at the edge of the designated mixing zone (e.g., 150 feet away from the work activity at the compliance point). The CWA Section 404 ARAR Memorandum will specify the detail of any chemical monitoring required during the remedial action.

For contaminants in sediment targeted for dredging that could enter the water column due to resuspension, the acute and chronic criteria for protection of aquatic life in marine water are the applicable water quality criteria. Applicable water quality criteria are the Washington State standards (WAC 173-210A-240, Table 240) for protection of aquatic life and are listed in the WQMP (Volume II, Part I, Appendix A).

The CWA Section 404 ARAR Memorandum is typically finalized following approval of the 100% design and will specify details of any chemical monitoring required during the remedial action. A WQMP is provided as Appendix A of Volume II, Part I, which was developed in consultation with EPA to reflect the likely requirements of the CWA Section 404 ARAR Memorandum. The WQMP will be updated by the Implementing Entity, as required prior to the start of construction to reflect the final CWA Section 404 ARAR Memorandum requirements.

Measurement of water quality will be by the Owner, as described in Section 11.1.5.

11.1.2 Sediment Resuspension During Dredging

Dredging of contaminated sediments results in temporary water quality effects during construction. Therefore, significant effort has been made to understand and limit water quality effects during remediation (e.g., *The Four Rs of Environmental Dredging: Resuspension, Release, Residual, and Risk* [USACE 2008b]). As a result, there is an established set of tools commonly used for analyzing water quality effects during sediment remediation and typical approaches employed for managing those effects.

USACE developed the DREDGE Model (Hayes and Je 2000) to help predict the effects of dredging on contaminant concentrations within the water column. The details of this analysis are provided in Appendix M and summarized here.

Two sets of input parameters were developed. Acute water quality criteria were compared to potential short-term (i.e., 1-hour; 24-hour for PCBs) effects based on an assumed maximum hourly dredging production rate of 180 cy per hour and maximum sediment concentrations in core data. Chronic water quality criteria were compared to potential longer term (i.e., 4-day; 24-hour for PCBs) effects based on an average dredging production rate of 1,000 cy per day and mean sediment concentrations in core data. During dredging for both scenarios, 3% of the dredged material volume was assumed to be resuspended into the water column. The ambient river flow and tidal velocities within LDW vary; however, a range of potential river flow velocities was evaluated to represent average flow conditions in the river. The maximum and mean concentrations of modeled COCs are summarized in Appendix M. The maximum sediment PCB concentration (6,680 micrograms per kilogram) used for modeling and comparison to acute water quality criteria is the maximum vertically weighted average concentration of all cores within dredge areas.

In summary, based on site-specific model inputs to the DREDGE Model, no acute or chronic water quality chemical criteria exceedances are predicted for COCs at the compliance point of 150 feet or greater from the work zone during dredging activities.

11.1.3 Dredge Return Water

Remedial activities will consist of mechanically dredging contaminated sediment and placing the dredged materials onto a haul barge. Dredging results in the bucket capturing both sediment and added site water, especially when environmental buckets are used. A bucket fill factor was assumed to be 70%, which means that the dredging captures 3 parts water for every 7 parts of sediment.

Excess water from the haul barge, which is generated from the captured water and porewater from sediment as the sediments dewater on the barge, is typically separated from the dredged material on the barge. The segregated water is then filtered to remove suspended solids by pumping the water, or passively draining the water, through a filter media (e.g., geotextile fabric) and then returned back to the receiving water within the dredging work zone. This is referred to as dredge return water. Water quality from the entire dredging operation (including both the direct effects of the dredging and the release of the dredge return water) will be monitored under the WQMP (Volume II, Part I, Appendix A) and need to comply with appropriate quality standards at the approved points of compliance (Section 11.1.1). Visual observations, real-time water quality measurement results (e.g., turbidity levels) and chemistry results (when required) will be collected in accordance with the WQMP, and the contractor will be required to modify its operations as needed to comply with the requirements of the CWA 401 Water Quality Certification by enhancing the filtration or otherwise treating the return water. If barge dewatering occurs at a different location than the dredging operation, separate water quality monitoring will be conducted at that different location.

For design purposes, potential water quality effects during barge dewatering were estimated by calculating the dissolved contaminant concentrations in the dredge return water based on sediment bulk chemistry and equilibrium partitioning theory and assuming that porewater in the sediment fully mixes with the captured water. This is a very conservative assumption because sediment porewater is mostly retained within the sediment matrix and will not fully mix with the added captured water. This assumed "fully mixed" water concentration is then used as the dredge return water concentration, and the dredge return water load is assumed to be based on the volume of the captured water. The effects within the area of mixing were calculated based on the procedures in *Evaluation of Dredged Material Proposed for Discharge in Water of the U.S. – Testing Manual,* Appendix C (USACE 1998) and are presented in Appendix M.

In summary, no acute or chronic water quality exceedances are predicted for COCs at the edge of the designated mixing zone (assumed to be 150 feet or greater) from the dredging and barge discharge activities. Actual compliance with water quality criteria will be measured during construction, as described in Section 11.1.5.

11.1.4 Sediment Resuspension During Material Placement

Material placement activities will result in short-term, localized sediment resuspension, and therefore, turbidity. Turbidity has been observed during clean material placement even when materials with very low fines content have been used. This turbidity will be transient and generated by clean aggregate material, mostly from the finer fractions of the clean aggregate material as it descends through the water. However, some resuspension of the bed sediment could occur depending upon the contractor's placement method. Sediment resuspension during material placement may also result from propwash disturbance from marine equipment and attendant vessels (e.g., tugboats).

Disturbance of the existing bed sediments during material placement is commonly managed by specifying limits on the initial lift thickness of placed materials (if needed), to avoid bearing capacity failure of the sediments (Section 8), as well as requiring placement techniques that spread the placed material.

Experience in Puget Sound has shown that a common cause of turbidity exceedances is suspension of fines in clean materials being placed (for cap, ENR, etc.) even after BMPs are employed. Turbidity from clean fines in the placement materials will be reduced by limiting the fines content (material smaller than the U.S. No. 200 sieve) in the materials placement specification, for protection of water quality. The method for achieving compliance with the gradation specification (e.g., washing) will be determined by the material supplier, and the contractor will be required to demonstrate compliance with gradation requirements with testing results.

However, some fines are always present, and the need to evenly spread the placement material will result in the resuspension of the clean fines. Because these types of turbidity exceedances are localized and short term, and because the import material is clean (i.e., import material must comply with strict limits on COC content), it is generally recognized that the net benefit provided by placing clean material as backfill, ENR, cap, or habitat substrate outweighs the short-term effects of localized turbidity exceedances.

Many of the other resuspension mechanisms mentioned previously will be limited through BMPs (Section 11.2).

11.1.5 Water Quality Monitoring During Construction

As part of the CQAP, a WQMP is provided as Appendix A of Volume II, Part I. The WQMP describes the monitoring program intended to provide QA that the contractor's operations are in compliance with water quality criteria and to identify conditions potentially requiring corrective measures in response to water quality observations. The WQMP describes the monitoring methodology and equipment, monitoring locations (e.g., compliance, and background stations), water quality criteria (listed in Section 11.1.1), monitoring frequency and schedule, and potential response and corrective actions in the event of a water quality exceedance. The WQMP also identifies communication and response protocols with EPA. Water quality monitoring results will be reported in meetings with EPA, the Owner, and the contractor regularly during construction, and any response actions will be subject to EPA approval.

11.2 Construction Best Management Practices

BMPs are management practices that are determined to be effective, practical, and sustainable means of achieving an environmental performance objective. The Specifications (Volume III) identify specific performance criteria for environmental protection (e.g., water quality criteria). BMPs will be used to meet those performance criteria during construction and to limit, to the extent practicable, potential adverse construction impacts and the magnitude of residual contamination. BMPs encompass operational and engineering controls to help reduce the environmental impacts of construction. Although operational controls include actions or modifications that can be applied by the contractor to the standard operational practices of the equipment being used for construction activities, engineering controls are equipment, barriers, and containment measures specified by the design and based on site-specific conditions that could be deployed.

This section describes construction BMPs that may be implemented by the contractor during the dredging, barge dewatering, haul barge filling and in-water transportation, transloading, upland transportation, disposal, and material placement (e.g., backfill, ENR, RMC, Area-Specific Technology B [amended cover], and engineered capping) operations or other associated construction activities. The contractor may propose additional construction BMPs in its RAWP, subject to review and approval by EPA and the Owner.

Additional BMPs specific to quality-of-life considerations are provided in Section 11.3.

11.2.1 Operational Controls to Reduce Sediment Resuspension

Operational controls are the procedures that a contractor implements to prevent or reduce potential sediment resuspension. Potential water quality effects from sediment resuspension associated with in-water work are expected to be temporary and located at or close to the point of disturbance. Water quality monitoring has been conducted during the construction of the EAAs and many similar regional sediment remediation projects. The most common water quality issue observed has been occasional exceedances of turbidity criteria, either during dredging or placement of clean materials (e.g., ENR, Area-Specific Technology B [amended cover], backfill, RMC, or engineered capping).

Operational controls are one approach to reduce potential sediment resuspension and include actions or modifications that can be applied by the dredging/placement operator to its standard operational practices to help reduce the potential environmental impacts of the dredging/placement operations (USACE 2008a). Operational controls to reduce sediment resuspension can include a broad array of methods; however, prescriptive requirements may not prove effective because equipment types and dredging methods will vary. Establishing performance criteria for water quality and allowing some degree of flexibility to the contractor in using operational controls allows it to customize its operations to effectively meet the performance standards.

The following standard operational control requirements to reduce sediment resuspension have been incorporated into the Specifications (Volume III):

- Removal of large to medium-sized debris, if practicable, will be required prior to dredging in known debris areas (Exhibit 11-1 depicts typical debris encountered prior to dredging). Debris caught in dredging equipment can cause additional resuspension and release of contaminated sediments. Note that this operational control is not appropriate for buried debris below the mudline; debris removal itself generates turbidity. Practicability of debris removal will depend on field conditions.

Exhibit 11-1
Debris Removal Prior to Dredging

- Multiple bites by the dredge bucket on the sediment bed before ascending to the surface will be prohibited so that bed disturbance by the bucket is reduced.
- "Sweeping" (i.e., dragging a bucket or beam) or leveling of the sediment bed by pushing bottom sediments around with the dredge bucket to knock down high spots to achieve required dredge elevations will be prohibited. Instead of leveling to remove high spots, the contractor may be required to make an additional dredging pass to remove any high spots that are identified during post-construction surveys. Note that leveling may be an appropriate step for fill placement to create habitat surfaces that are relatively leveled and within the appropriate elevation range. Leveling clean fill materials to reduce low spots can improve the performance of specific habitat types. The contractor may propose to level the placement

surfaces (e.g., SMA 5 cap) for work conducted above the water line; such a proposal will be subject to Owner approval.

- Interim underwater stockpiling of dredge material will be prohibited (i.e., taking small dredge cuts and temporarily stockpiling material at the mudline in a mound to allow the dredge operator to grab a fuller bucket). Such action could create a pile of loose sediment that can easily be resuspended.
- Overfilling of conventional clamshell and environmental buckets will be prohibited. When the dredge bucket penetrates into soft sediment, there is the potential for the bucket to penetrate beyond the designed digging depth of the bucket. If the bucket is overfilled, a portion of the dredged material cannot be contained within the bucket and may be lost and resuspended in the water column as the bucket is raised. If bucket overloading is observed, measures will be taken to reduce this potential (e.g., decrease the maximum cut depth).
- Selection of the appropriate dredge bucket for site-specific conditions will be required (i.e., soft sediment versus debris or hard digging), such as using an environmental (closed) bucket where unconsolidated sediments exist and using a different (e.g., digging) bucket in areas where an environmental bucket cannot fully close or cannot penetrate the sediment.
- Specific dredging procedures (e.g., shallow top-to-bottom cuts) will be specified to prevent the potential for slope failures and slope movement that would cause sediment resuspension.
- All barges handling dredged materials will be required to be properly outfitted to filter dredge return water.
- All barges transporting dredge materials will be certified as sealed (watertight) and seaworthy by a marine inspector prior to barge use.
- Uneven filling and overfilling of barges beyond the top of the side rails will be prohibited to prevent spillage from barges.

Additional BMPs to reduce sediment resuspension that may be employed as needed to manage water quality and meet turbidity criteria include the following:

- The rate of dredge bucket descent and ascent may be slowed; however, this BMP needs to be carefully implemented based on the physical characteristics of the sediments being removed (e.g., soft sediments versus hard digging, presence of debris, water depths) because limiting the velocity of the descending bucket in dredge operations may reduce the volume of sediment that is picked up by the bucket, thus requiring multiple bites to remove the project sediment and increasing the overall project duration and associated duration of short-term water quality effects.
- After placing dredged sediment into the haul barge, the opened bucket may be held above the barge for a short period of time to allow residual materials from the bucket to fall into the barge.

- After placing dredged sediment into the haul barge, the bucket may be opened and closed over the haul barge to shake and remove loose residual materials from the bucket to the extent possible before lowering into the water.
- Use of the lowest feasible power for tug operations will be recommended during barge relocation, movement for maritime traffic, as well as when changing dredge/material barges, to reduce sediment resuspension.

Operational controls that are overly restrictive will reduce production rates and may increase the overall project duration, which would increase the duration for potential short-term environmental impacts. Thus, the advantages of applying operational controls need to be considered in light of this reduction in efficiency and appropriately balanced to support environmental protectiveness (USACE 2008a).

Implementation of operational controls during construction will be performed by the contractor. The Owner will verify that specified operational controls are adhered to, and the contractor will employ additional BMPs and/or engineering controls (Section 11.2.2) as needed to manage water quality impacts. Changes to operational or engineering controls during the project will be in coordination with EPA.

11.2.2 Engineering Controls (Specialized Equipment)

11.2.2.1 Environmental (Closed) Buckets

For mechanical dredging, this technology consists of specially constructed dredging buckets designed to reduce the loss of dredged materials from the bucket during dredging, when used properly and in the appropriate site conditions. Environmental buckets are discussed in Section 10.2.1.

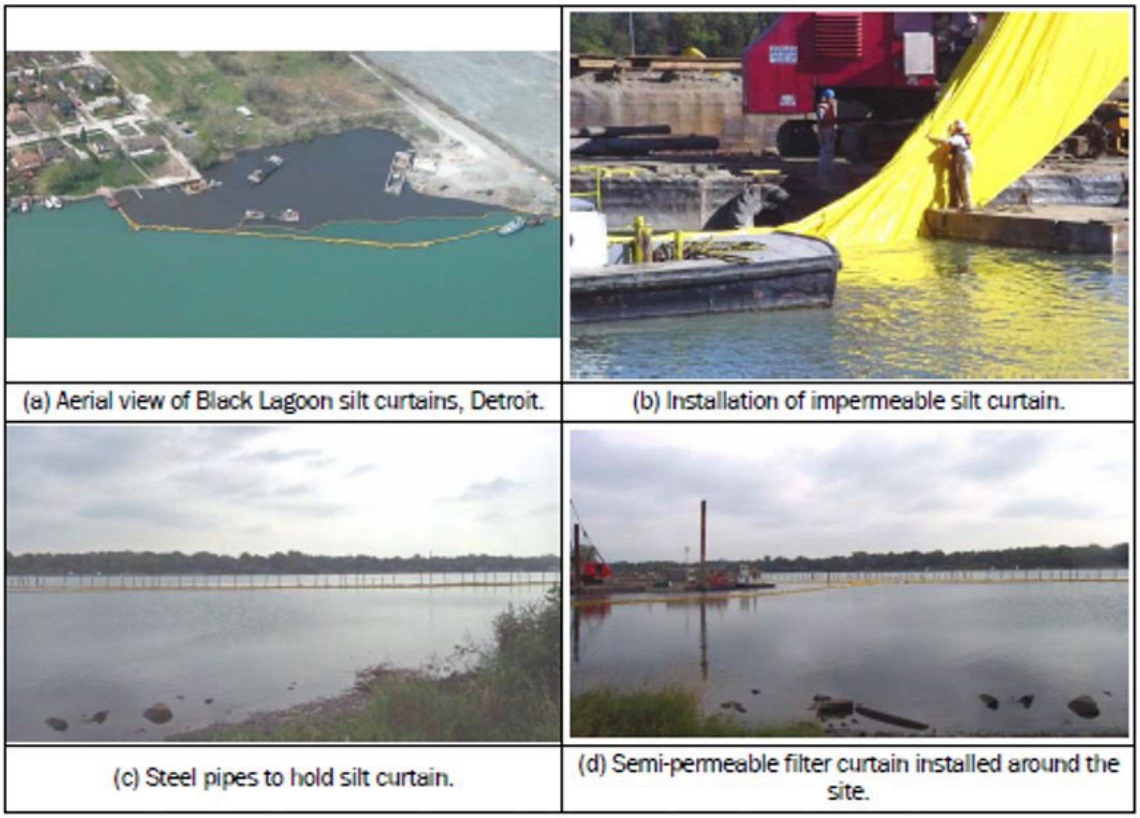
Environmental buckets are specified as the primary technology to be used for dredging to reduce sediment resuspension, but the Specifications (Volume III) allow the contractor to use other buckets (e.g., digging buckets, rehandling buckets) as site conditions warrant to achieve both the required dredging elevations and thicknesses and to meet environmental protection criteria (e.g., water quality criteria).

11.2.2.2 Silt Curtains

A silt curtain is a potential engineering control that can be considered for reducing the size of turbidity plumes in the water column. A silt curtain is a constructed floating physical barrier that is positioned around the marine equipment (or the immediate area of dredging/placement) to reduce suspended sediment transport that is generated during dredging or placement operations. Silt curtains do not treat sediment resuspension or turbidity; rather, they direct and restrict the movement of the resuspended sediment and associated contamination to a smaller area

(USACE 2008a). Exhibit 11-2 depicts a typical silt curtain installation. Silt curtains are typically constructed of flexible, reinforced geotextile material with flotation elements in the upper hem and ballast material in the lower hem.

Exhibit 11-2
Examples of Silt Curtain Installation (Black Lagoon, Detroit River, Michigan)



(a) Aerial view of Black Lagoon silt curtains, Detroit.

(b) Installation of impermeable silt curtain.

(c) Steel pipes to hold silt curtain.

(d) Semi-permeable filter curtain installed around the site.

Source: USACE (2008a)

Because they are mostly impermeable, silt curtains are easily affected by tides and currents, and their effectiveness can be adversely impacted by high current velocities, moderate to large wave conditions, propwash from work tugs, or large tidal variation. Silt curtains are more effective on projects where they are not opened and closed to allow equipment access to work areas. For more complex site configurations, larger-sized dredge areas, and active vessel traffic, silt curtains need to be frequently moved, repositioned, and re-anchored, thereby reducing effectiveness and overall dredging production rates and increasing the duration of construction and overall short-term impacts from the dredging operations (EPA 2005). Typical silt curtain systems interfere with vessel navigation, so they are usually not used in active navigation channels.

Traditional silt curtain barrier controls are designed to provide either containment of the full depth or partial depth of the water column. Partial-depth curtains are more typically applied when there is a tidal range to prevent the curtain from sitting on the bottom where the curtain could cause resuspension and/or be buried under sediment requiring constant maintenance. Full-depth curtains are either anchored directly into the mudline along a fixed alignment or affixed to installed vertical pilings or other existing in-water infrastructure. Similarly, partial-depth curtains can also be anchored or affixed to pilings or in-water infrastructure and extended from the mudline upward into the water column, or they can be deployed from the surface of the water with a series of floats and bottom weights to extend the curtain to the target depth. Partial-depth curtains can be less effective than full-length curtains because the curtain does not extend the full depth of the water column, allowing passage of water and suspended solids below the curtain extent, in effect redirecting suspended sediments near the bottom.

Another type of silt curtain configuration is "moon pools," which are mobile containment systems that move with the dredging equipment. However, unlike anchored silt curtains that remain in one location until the whole system is uninstalled and reinstalled in a new location, the moon pool system is designed to be mobile by attaching the system directly to the dredge barge so that it is always centered over the immediate dredging area. The moon pool system normally consists of a partial depth silt curtain attached to a rigid framework of interlocking floats, enclosing a variable dimension dredging area depending on site-specific characteristics. The moon pool silt curtains can be designed to be permeable or impermeable and, in some cases, comprise a curtain that is both permeable and impermeable. Depending on the size of the moon pool and hydrodynamics in the dredge area, steel spuds may be used to secure and stabilize the inner curtain. The contractor will be required to use a rigid-frame silt curtain (moon pool) system when dredging in SMA 12B, which is adjacent to the T-117 habitat area, as an additional protective measure.

Use of a silt curtain system was evaluated for the LDW upper reach. The upper reach is a tidally influenced site with a large tide range (approximately 11 feet between MLLW and MHHW). The upper reach also experiences a variety of hydrodynamic and wave forces from river flow, wind-generated waves, and vessel propwash and wakes. Vessels routinely use the upper reach for navigation, and USACE maintains the FNC and Turning Basin for active vessel use. Because of these factors, silt curtains have typically not been used for sediment remediation projects in the LDW because they could interfere with navigation, would not be capable of being full-length due to tidal range, and would be anticipated to increase the duration of remedial construction without effectively reducing movement of resuspended sediments.

In general, the required use of environmental buckets and contractor operational controls is considered more effective to reduce sediment resuspension than deployment of a silt curtain. A contractor may choose to use silt curtains as a supplemental tool when localized site conditions allow them to be implemented. Therefore, silt curtains are specified in the Specifications as an engineering control for the contractor to have available on site from the beginning of construction so that they can be employed as a potential corrective measure (in response to water quality criteria exceedances during dredging and, if appropriate, during placement activities) if the contractor's primary resuspension controls are not effective for the localized site conditions. Site-specific conditions will affect whether silt curtains are feasible at any given location. The Specifications require the contractor to meet performance requirements for water quality and will generally not identify the contractor's specific equipment, means, and methods to meet environmental protection compliance. The contractor may propose to use silt curtains in a configuration of its choice if it considers silt curtains to be an effective BMP.

11.2.3 Additional Environmental Controls

Available additional environmental controls associated with barge dewatering, haul barge filling and overwater transportation, transloading, transportation to an upland facility, spillage prevention, and decontamination of equipment are described in the following sections.

11.2.3.1 BMPs During Barge Dewatering

For dredge sediment dewatering occurring on haul barges, the dredge return water will be allowed to be discharged back into the LDW within or near the active dredging work zone. The contractor will be required to equip the barges with appropriate BMPs (e.g., filtering all water prior to discharge to remove suspended solids from the dredge return water) to maintain compliance with water quality criteria. The Specifications require filter media to include an AC component, such as an AC-impregnated permeable geotextile or combined GAC/sand filter.

11.2.3.2 BMPs During Haul Barge Filling and Overwater Transportation

BMPs that will be required to reduce the potential for spillage of dredged material during haul barge filling and overwater transportation include the following:

- Haul barges will be loaded evenly to maintain barge stability.
- Haul barges will be filled to below the top of the side rails to reduce the potential for spillage or overflow.
- Once the barge is loaded and stabilized, it will be inspected for sediment adhered to the outside of the barge that could fall off the barge during transport. Contractor personnel will conduct a visual inspection around the entire barge deck area to remove such sediment before moving the barge out of the dredging site.
- With the exception of dredge return water drainage ports, haul barges will be watertight during all operations, and no dredge return water will be allowed to discharge into the LDW in transit to the transload facility.

11.2.3.3 BMPs During Dredged Material Transfer and Transportation to Disposal Facility

BMPs are required to reduce the potential loss of dredged material during transfer of dredged materials off the barge (at the transload facility) or from a temporary upland stockpile area (if intertidal sediment and shoreline bank soil excavation occurs, needing an onshore management area). BMPs are also required during transport of dredged/excavated material to the approved disposal facility. Such BMPs include the following:

- To prevent dredged material spillage when transloading materials between the haul barge and transload facility, spill aprons will be set up and used to direct bucket spillage back into the barges or onto the uplands and not into the LDW.
- Inside the transload facility, material captured by spill aprons will land on secondary containment areas outside the area typically traveled by trucks or railcars to avoid tracking material on tires or wheels.
- The bucket swing path from the haul barge to the upland transload facility will not be allowed to occur over open water. The contractor will need to swing the offloading bucket over either the derrick barge or a "spanning" barge that will capture any spillage from the offloading bucket.
- All haul trucks and railcars (e.g., containers or gondolas) will be required to be lined, covered, and secured for upland transportation. Visual monitoring will be performed by the contractor to determine if the transport of dry dredged/excavated materials creates dust or leakage.
- When wet materials are transported over land, haul trucks or railcar containers will be lined or sealed to reduce the chance of sediment or water release during transport.
- For dredge material transfer from a temporary upland stockpile area, truck loading will occur within the transfer area, and the trucks will be decontaminated and inspected within a designated contained footprint before they leave the transfer area.
- Trucks or railcars will not be overloaded to prevent loss due to spilling (minimum freeboard height of 6 or 36 inches, respectively, will be required to be maintained).
- Truck loading areas will be swept frequently to reduce the probability of truck tires tracking contaminated materials outside of the loading areas.
- The trucks, truck loading area, and the access route will be visually inspected to confirm there is no loss of material from the trucks prior to releasing the truck from the transload facility to public roads.
- Tires and truck or railcar bodies will be cleaned to remove sediment, if necessary, before leaving the site (e.g., dry brushing and tire/wheel washing).
- Containment areas will be designed so that fluids from the transloading operations can be collected separately from other site stormwater.
- The fluid collected from transloading operations will be disposed of with the other waste generated from the site (included with the sediment for disposal); sampled, treated, and

discharged in accordance with approved permits of the transload facility; or disposed at a permitted commercial facility.

Exhibit 11-3 depicts examples of offloading/transloading operational controls.

Exhibit 11-3
Examples of Offloading and Transloading Operational Controls

Use of spill apron

Contained landside facility

Spanning barge

Loading of sediment into lined containers

Operations may need to be limited or suspended in the event of high river flows, storms, or high wave conditions at the transload facility that may impact the ability to moor haul barges safely and effectively, transload materials from the haul barges, or prevent potential discharge of dredged materials to the LDW. There is no specific condition (e.g., specific river velocity) that will trigger this contingency because it is impossible to predict the exact set of conditions that would impair operations. However, if conditions appear to pose a threat to meeting environmental protection goals at the transload facility, transload operations will be suspended until conditions improve.

11.2.3.4 BMPs for Oil and Other Hazardous Substance Spillage Prevention and Control

For compliance with the National Contingency Plan, the Oil Pollution Prevention regulation (40 CFR I), and the Oil and Hazardous Substance Spill Prevention and Response (RCW 90.56), the contractor will be required to prepare and implement a Spill Prevention, Control, and Countermeasure Plan (to be submitted as part of the RAWP), have a spill kit available during all on-water construction activities, and have a marine spill response contractor on call. BMPs to prevent and control spills of oil and other hazardous substances that will be required include the following:

- The use of environmentally sensitive hydraulic fluids (readily or inherently biodegradable) will be specified for hydraulic lines and systems of all compatible equipment associated with in-water work to minimize the potential impacts of leaking hydraulic fluids on the aquatic environment.
- The contractor will contain all visible floating oils with booms, dikes, oil-absorbent pads, or other appropriate means and remove from the water prior to discharge into state waters.
- The contractor will immediately contain all visible oils on land using dikes, straw bales, or other appropriate means and remove using sand, ground clay, sawdust, or other absorbent material, and properly dispose.
- The contractor will temporarily store waste materials in drums or other leak-proof containers after cleanup and during transport to disposal.
- The contractor will dispose waste materials off property at an approved and permitted disposal facility and obtain certificates of disposal.
- Dredge vessel personnel will be trained in hazardous material handling and spill response and will be equipped with appropriate response tools, including oil-absorbent booms or pad, an oil-skimming system, oil-absorbent material, sandbags, oil dry-all gloves, and plastic bags. If a spill occurs, spill cleanup and containment efforts will begin immediately and will take precedence over normal work.
- The National Response Center (1-800-424-8802), the Washington Emergency Management Division (1-800-258-5990 OR 1-800-OILS-911), and U.S. Coast Guard (206-217-6002) will be notified immediately if a spill occurs.
- The contractor will inspect fuel hoses, oil or fuel transfer valves and fittings, lubrication equipment, hydraulically operated equipment, and oil drums on a regular basis for drips, leaks, or signs of damage and maintain and store properly to prevent spills into the surface water.

11.2.3.5 Decontamination of Construction Equipment

Decontamination of the dredge and haul barges will be done at the completion of the remedial activities and between construction seasons. The haul barges will be swept and pressure-washed (including all portions of the barge where sediment is visually present) such that no sediment or dredge return water is released to the LDW. The remaining sediment and water inside the barge will be managed for off-site disposal, as described in Section 10.2.7.

At the completion of the dredging work and prior to any material placement, the dredging buckets will be pressure-washed over the last haul barge, and the wash water will be managed for off-site disposal consistent with the barge dewatering effluents. Similarly, the dredged material haul barges will be decontaminated prior to any other use.

After all construction activities are completed, all marine and offloading equipment that handled contaminated dredged material will be required to be decontaminated.

11.3 Quality-of-Life Considerations

This section describes the activities and measures that will be taken to reduce the effects of remedial construction activities on the local community. Although much of the construction will be accomplished with water-based equipment (which is regularly employed throughout the LDW for other industrial activities), the uplands in the vicinity of the upper reach have mixed industrial, commercial, and residential uses (Section 2.3.5). Therefore, the residents in the adjacent neighborhoods, liveaboards in marinas, marine users on the LDW, motorists on roads shared with project truck traffic, and workers could potentially be affected.

Any quality-of-life concerns that arise from the community during construction are identified and communicated with the mechanisms described in the Community Outreach and Communications Plan (Volume II, Part VIII), which describes the communication/response plan to the community. In addition, the Community Impacts Mitigation Plan (see Volume II, Part VIII for more information) will present the identified actions to reduce potential impacts on the community (e.g., residents, businesses, fishers, waterway users) from the remedy implementation.

Specified requirements and BMPs are discussed in the following sections. As community concerns are identified during construction, the concerns will be reviewed with EPA and the contractor, and the procedures below may be modified, as practicable, to address the concern.

11.3.1 Air, Noise, and Light Quality

As part of the Specifications (Volume III), the contractor is required to comply with performance requirements for quality-of-life criteria (i.e., air, noise, and light).

11.3.1.1 Air Quality

Compliance with federal, state, and local air quality standards (Clean Air Act [42 USC 7401-7671q; 40 CFR 50], Washington Clean Air Act [RCW 70.94; WAC 173-400], and Regulation I of the Puget Sound Clean Air Agency [Sections 9 and 15]) will be required during construction activities to protect the surrounding community from diminished air quality.

Air quality performance requirements to be met during construction are defined in the Specifications (Volume III), following the air emission standards defined in EPA's Tier System[32] for fossil fuel consumption, to help reduce engine emissions from construction equipment.[33]

Examples of BMPs that are required to limit air quality impacts include the following:

- Engine idling restrictions for all construction equipment
- Changes in driving techniques (such as avoiding rapid acceleration, braking, and excessive speeds)

In addition, dust particles and odors from the project activities will be required to be controlled at all times (including weekends and hours when work is not in progress). Federal and state air quality requirements also establish requirements for dust control. Dust and odor management requirements include the following measures as applicable:

- Wetting of excavation areas, unpaved traffic lanes, and soil stockpiles if needed for dust control
- Covering truck loads to prevent the escape of dust-bearing materials
- Covering stockpiles with plastic sheeting when loading and stockpiling activities are not occurring (i.e., inactive for a specified period of time) or if nuisance odors are encountered prior to transportation off site
- Cleaning of vehicles leaving the site to remove dirt or dust from wheel treads and exterior
- Using work site controls such as ceasing above-water excavation during high winds or limiting the number and size of excavations open at one time
- Covering roadways and parking areas (located to the extent possible away from residences) with asphalt, concrete, or gravel
- Sweeping any paved on-site truck routes, loader paths, loading and stockpiling areas, daily during dry weather, at a minimum

The contractor's RAWP will be required to identify air quality prevention, mitigation, and control measures to be implemented during construction activities for federal and state criteria compliance.

11.3.1.2 Noise

Construction noise will be generated from both in-water and upland sources (dredging and excavation of banks and shoreline) in an already industrial waterway; however, the receiving properties will be residential (including upland and marina liveaboard residents), commercial, and industrial. The Specifications (Volume III) require the contractor to comply with noise requirements for the cities of Seattle and Tukwila and unincorporated King County areas when working close to

[32] https://www.epa.gov/emission-standards-reference-guide

[33] The EPA emission standards for each tier are specific to the type of equipment (on-road vehicles, non-road equipment/engines), the year of manufacture, and the engine power. See Appendix N for more detailed information on EPA's Tier System.

residential areas (upland and liveaboard) adjacent to the project site perimeter to limit the extent of potential noise impacts to the community.

All local ordinances (Seattle Municipal Code Chapter 25.08, Tukwila Municipal Code Chapter 8.22, and King County Title 12.86) establish equally stringent maximum permissible sound levels from industrial sound sources to a receiving property (residential at daytime or nighttime, commercial, or industrial), as listed in Table 11-1. For example, the contractor will be required to meet a 60-A-weighted decibel (dB[A]) limit for noise generation during daytime (between the hours of 7:00 a.m. and 10:00 p.m. on weekdays), applicable from an industrial source to a residential receiving property. In addition, all local ordinances allow a 25-dB(A) addition for construction activities by heavy equipment (e.g., dredging, shoreline/bank excavation), making the maximum permissible sound level at the receiving residential property 85 dB(A) but during a shorter working period (between the hours of 7:00 a.m. and 7:00 p.m. on weekdays).

Table 11-1
Maximum Permissible Sound Levels from All Local Ordinances

District of Sound-Producing Source	Maximum Permissible Sound Levels in District of Receiving Property[1]			
	Residential, During Daytime	Residential, During Nighttime	Commercial	Industrial
Industrial	60 dB(A)[2]	50 dB(A)	65 dB(A)[2]	70 dB(A)[2]
Construction Equipment at 50-foot Distance from Equipment (whichever is further), During Daytime Only[3]	An additional noise allowance of 25 dB(A)	N/A	An additional noise allowance of 25 dB(A)	An additional noise allowance of 25 dB(A)

Notes:
Maximum permissible sound levels applicable to sound sources within the limits of the cities of Seattle and Tukwila and unincorporated King County areas.
1. The maximum permissible noise level is applied to a minimum measurement interval of 1 minute for a constant sound source or a 1-hour measurement for a non-continuous sound source.
2. Daytime is defined as the most stringent daytime period among all local ordinances, set to be between 7:00 a.m. and 10:00 p.m. on weekdays and between 9:00 a.m. and 10:00 p.m. on weekends and legal holidays.
3. For construction equipment, daytime is reduced to be between 7:00 a.m. and 7:00 p.m. on weekdays and between 9:00 a.m. and 7:00 p.m. on weekends and legal holidays. This definition is also applicable to construction equipment used on public projects per SMC 25.08.425.

dB(A): A-weighted decibel
N/A: not applicable
SMC: Seattle Municipal Code

Additional specific maximum permissible sound levels and working hours associated with various types of impact equipment used in construction sites and for short-duration construction activities (up to 1 hour) are described in Seattle Municipal Code Chapter 25.08.425C and Tukwila Municipal Code Chapter 8.22.

In general, noise-generating construction activities will be limited to normal working hours (between the hours of 7:00 a.m. and 7:00 p.m. for weekdays and 9:00 a.m. and 7:00 p.m. for weekends and legal holidays) to the extent possible to reduce potential noise impacts to the community. Seattle Municipal Code, Tukwila Municipal Code, and King County Title 12 noise ordinances set lower sounds levels for any work conducted outside of these hours.

Noise performance requirements to be met during construction are defined in the Specifications (Volume III) based on the most stringent noise ordinance. Examples of BMPs that may be used to prevent and mitigate noise impacts to the community include the following:

- Reduce vehicle speeds when transiting near residential areas (if applicable).
- Phase work with construction equipment that generates noise.
- Turn off engines when equipment is inactive for a period of time.
- Potentially limit work hours or certain construction activities in locations near residential or liveaboard occupancy.

11.3.1.3 Light

It is anticipated that artificial lighting may be required for construction work conducted during winter season (before sunrise [with work starting at 7 a.m.] and after the sun sets at approximately 4:30 p.m.), to accommodate activities during low tides or to facilitate meeting the construction schedule (i.e., progress of activities within the in-water work window). The Specifications (Volume III) require the contractor to comply with light requirements for the cities of Seattle and Tukwila (Seattle Municipal Code Chapter 23.50.046 and Tukwila Municipal Code Chapter 18.044.050) when working close to residential areas (upland and marina liveaboard) and commercial/industrial areas, adjacent to the project site perimeter, to limit the extent of potential light impacts to the community. Light performance BMPs are defined in the Specifications; e.g., the contractor may be required to use light shrouds or barriers to help direct light into the work areas, re-sequence work during the day (if feasible), or reposition lighting equipment to avoid directing light outside of the immediate work area.

11.3.2 Equipment and Material Transportation Through Residential Areas

The majority of dredged and excavated sediments will be barged and offloaded at permitted commercial and/or contractor-provided transload facilities for loading onto trucks or railcars for final disposal. Similarly, imported materials for cap and ENR are anticipated to be delivered by barge.

However, to a limited extent, transportation of equipment and materials may be necessary through or near residential areas, causing short-term impacts to the community. Examples would be excavation of certain bank areas using land-based equipment or placement of materials from shoreline access points. The contractor may propose different access locations in its RAWP to conduct material placement, beyond work in SMAs 5 and 13, and the locations will be subject to approval by the Owner.

To the extent feasible, such transportation will be limited to larger arterial roadways that support similar types of traffic. As described in Section 10.2.6, the upper reach project will rely on either established commercial transload facilities or a contractor-provided transload facility with road and/or rail connections designed to support commercial traffic. Candidate truck haul routes (if anticipated to be needed) are provided in the Drawings (Volume III). The contractor will identify any additional potential haul routes in the RAWP, and these haul routes will be subject to approval by the Owner and EPA. Haul routes will be reviewed in coordination with EPA to confirm that they are configured in a manner to reduce impacts to residential neighborhoods to the extent practicable.

11.3.3 Construction Work Hours

The anticipated in-water work hours for the contractor will be from 7 a.m. to 7 p.m., Monday to Friday, and from 9 a.m. to 7 p.m. on Saturdays, for a 6-day-per-week work schedule. In-water work during the nighttime or on Sundays and legal holidays may be required to conduct bank excavation activities due to the timing of low tides or to do occasional work proposed by the contractor to meet the construction schedule and support progress of activities within the in-water work window (see Section 13 for details on the in-water work window). EPA coordination and approval will be required for these events. In addition, any in-water work that is conducted during weekends or nighttime will be subject to additional restrictions, as previously described.

11.4 Green Remediation

According to the EPA Office of Solid Waste and Emergency Response *Superfund Green Remediation Strategy* (EPA 2010), "green remediation is generally recognized as a major step in maximizing the environmental outcome of a contaminated land cleanup" by incorporating specific strategies into remedial actions that reduce their environmental footprint to achieve greater net environmental benefits. A *Green Remediation Evaluation and Implementation Approach* (Appendix N) has been developed for the upper reach remedy to evaluate impacts of remedy construction activities, including sediment dredging and excavation, debris removal, sediment offload/transload, sediment upland transportation and off-site disposal, material placement, and structural work.

11.4.1 Green Remediation Objectives and Approach

As described in the RDWP (Anchor QEA and Windward 2019a), the purpose of the *Green Remediation Evaluation and Implementation Approach* is to accomplish the following:

- Establish the project's environmental footprint for the sediment remedy presented in the BODR through the five core elements identified in the *Superfund Green Remediation Strategy* (EPA 2010): air, water, materials and waste, energy, and land and ecosystems.
- Identify potential applicable greener construction activities, technologies, and practices that could be applied to the extent practicable during the sediment remedy implementation

(e.g., dredging, sediment transloading, transportation, and disposal, material placement, habitat restoration, and structural work) in an effort to reduce the project's environmental footprint (consistent with the EPA Region 10's *Clean and Green Policy* [EPA 2009]) while still achieving the ROD RAOs and protectiveness requirements in a timely manner.

The five core elements identified in the *Superfund Green Remediation Strategy* (EPA 2010) and used for the *Green Remediation Evaluation and Implementation Approach* (Appendix L) are summarized as follows:

- **Air and Atmosphere:** Reduce emissions of air pollutants, including greenhouse gases.
- **Water:** Reduce water use and protect water quality.
- **Energy:** Reduce energy use and support the use of renewable energy.
- **Materials and Waste:** Reduce waste generation and the use of virgin materials.
- **Land and Ecosystems:** Protect land resources and ecosystems near the site.

The *Methodology for Understanding and Reducing a Project's Environmental Footprint* (EPA 2012c) was used in Appendix N to develop the framework for conceptually quantifying the environmental footprint associated with remedial actions (cleanup activities), understanding the remedy components with the greatest influence, and determining key green remediation metrics for each of these green remediation core elements. Additional EPA green remediation guidance and policy documents were also reviewed and considered in the application of sustainable cleanup activities, technologies, and practices to a greener and sustainable upper reach sediment remedy to the extent practicable (Appendix N).

11.4.2 Construction Activities Required for the Sediment Remedy

Construction activities associated with the upper reach remedy are the baseline for determining the project's environmental footprint to comprehensively include the work required to be implemented, understand the sediment remedy components with the greatest influence, and appropriately represent the environmental impacts and effects the project may generate on the environment. It is important to note that the construction activities and the development of the environmental footprint presented in Appendix N are based on Final (100%) RD criteria and assumptions. However, the quantification of the Final (100%) RD environmental footprint is a high-level, conceptual evaluation, based on current available design information advanced from the Pre-Final (90%) RD, assumed contractor equipment, and past engineering experience with similar projects.

The anticipated construction activities needed to implement the sediment remedy can be classified as primary (major construction activities) and secondary (minor construction activities). Both of these are conducted either within or outside of the project site but directly contribute to the project's environmental footprint. Additional activities, referred to as ancillary, are other activities that are indirectly required or associated with the sediment remedy implementation but are sourced elsewhere and not dependent on the remedy itself; therefore, they are not considered applicable activities to the project.

The detailed construction activities associated with the upper reach sediment remedy for the purposes of the green remediation evaluation are described in Appendix N.

11.4.3 Application of Green Remediation into Remedial Design

Consistent with the 2012 *Methodology for Understanding and Reducing a Project's Environmental Footprint* (EPA 2012c), green remediation metrics are designed to accomplish the following: "1) reflect parameters that a remedy project team has a relatively direct ability to change; and 2) encourage practices that would result in favorable changes to the metric values" (EPA 2012c). The following metrics were evaluated in Appendix N for the five green remediation core elements associated with the upper reach sediment remedy:

- **Core Element 1 – Air Emissions:** Air emissions were calculated for eight air constituents: hydrocarbons, volatile organic compounds, carbon monoxide, nitrogen oxides, particulate matter less than 10 and 2.5 microns in diameter (PM_{10} and $PM_{2.5}$, respectively), sulfur dioxide, and carbon dioxide. [34]
- **Core Element 2 – Use of Water:** Consumption of water during construction activities (such as dust control, equipment decontamination, and additional uses at transloading facilities) was considered.
- **Core Element 3 – Use of Materials and Waste Generation:** Raw materials (imported sand, gravelly sand, and gravel for backfill, RMC, ENR, GAC, and capping activities), recycled materials, and waste materials (dredge sediment, debris, removed piles/structural items) associated with the upper reach sediment remedy were quantified.
- **Core Element 4 – Use of Energy:** Total fuel-based energy consumption (diesel fuel) to power engines and equipment, facilitate transport activities, and run operations associated with the upper reach sediment remedy implementation were accounted for.
- **Core Element 5 – Protection of Land and Ecosystems:** A qualitative assessment on safeguarding land/ecosystems and site preparation/land restoration was conducted.[35]

These metrics establish the project's conceptual Final (100%) RD environmental footprint based on the anticipated cleanup construction activities so that the most applicable greener construction activities, technologies, and practices, through BMPs, can be identified for the Specifications and applied to the extent practicable to reduce the impacts of the sediment remedy. Appendix N presents a comprehensive list of potential BMPs that might be applicable to the five core elements in

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[34] Carbon dioxide is also a key greenhouse gas, along with methane and nitrous oxide which are the largest greenhouse gas contributors. Appendix N, however, accounts for methane and nitrous oxide in the carbon dioxide equivalent total.

[35] Specific design measures to offset aquatic habitat modifications that may be incorporated into the LDW upper reach sediment remedy to the extent practicable are presented in Section 11.6, in compliance with CWA Section 404 and Section 7 of the ESA.

relation to the upper reach sediment remedy and its anticipated construction activities, consistent with the BODR and the Final (100%) RD.

Applicable specific BMPs are incorporated into the project Specifications, which are presented with the Final (100%) RD deliverable (Volume III). In particular, to reduce diesel emissions, the Specifications require the contractor to use engines for primary construction activities such as dredging, offloading, and material transportation that are certain tiers (engine types defined in the Clean Air Act) and to meet a goal based on the percentage of hours operating at specified engine tiers. The engine requirements for the upper reach remediation are more stringent than what is required at most marine construction projects. The Specifications also have BMP requirements for the other core elements that help facilitate a greener remedy.

The contractor will have inherent motivation to select other specific BMPs listed in Appendix N in cases where such BMPs will increase efficiency and reduce cost.

11.5 Habitat Considerations and Evaluation

Habitat within the LDW will be considered and evaluated during all phases of RD. As described in Section 2.3.11, existing habitat types in the LDW based on elevation ranges include the following:

- **Deep Subtidal:** Deeper than -10 feet MLLW
- **Shallow Subtidal:** -10 feet MLLW to -4 feet MLLW
- **Lower Intertidal:** -4 feet MLLW to +4 feet MLLW
- **Upper Intertidal:** +4 feet MLLW to +11.3 feet MLLW
- **Riparian:** Above MHHW (+11.3 feet MLLW)

These different habitat types provide specific functions to aquatic species, and the value of each habitat type differs depending on the functions provided. The most valuable habitat is provided in the Upper Intertidal, Lower Intertidal, and Shallow Subtidal zones (i.e., -10 feet MLLW and higher), as detailed in Section 11.5.3.1.

The ROD defines “habitat areas” as all areas with elevations between -10 feet MLLW and the MHHW elevation of +11.3 feet MLLW to provide design requirements for remedial activities that occur within those elevations (EPA 2014). As such, the RD considers and applies the habitat specific ROD design requirements to remedial activities that occur within the ROD-defined “habitat areas.” Additionally, the impact of remedial activities to all habitat types, including the ROD-defined “habitat areas,” has been evaluated to comply with Section 404 of the CWA (see the CWA Section 404(b)(1) analysis in Appendix C) and Section 7 of the ESA (see the *Biological Assessment* [BA] in Appendix E). The results of the habitat evaluation (Appendix E, Attachment E.6) determine if the remedial activities are expected to improve or degrade habitat conditions relative to existing conditions.

The remainder of this section includes details about the following:

- Approach for addressing potential impacts of remedial activities on habitat
- Design considerations for the ROD-defined "habitat areas"
- Description of the habitat evaluation that was used to assess remedial impacts to all habitat types, including the ROD-defined "habitat areas"

11.5.1 Approach

The approach to considering and evaluating habitat during the RD is as follows:

- Identify areas where remedial activities are expected to occur in ROD-defined "habitat areas" (EPA 2014) and consider the ROD habitat design requirements during RD for these areas (Section 11.5.3).
- Determine a method for evaluating potential remedial impacts to all habitat types, including ROD-defined "habitat areas" (Section 11.5.3).
- Demonstrate that the remedial activities are consistent with CWA Section 404(b)(1) and Section 7 of the ESA, including consistency with the USACE and EPA approach for avoiding, minimizing, or, when adverse impacts are unavoidable, mitigating for adverse impacts to the aquatic environment. This demonstration is summarized in Section 11.5.3 and documented in more detail in the habitat evaluation that is included as Attachment E.6 to the BA (Appendix E) and the CWA Section 404(b)(1) analysis (Appendix C). The results of the habitat evaluation are used to support the evaluation of threatened and endangered species in the BA.

11.5.2 Design Considerations for Remedial Activities in ROD-Defined "Habitat Areas"

Figure 11-1a shows where remedial activities are expected to occur within ROD-defined "habitat areas" (EPA 2014). Figure 11-1b includes the following information important for understanding existing conditions and the context of the ROD-defined "habitat areas":

- Potential clamming areas, as described in Section 2.3.11
- Existing restoration areas, as described in Section 2.3.11
- Shoreline condition
- Existing bank vegetation

The ROD identifies the following design elements that should be considered during RD for remedial activities that occur within the ROD-defined "habitat areas":

- Restore pre-dredge elevations using suitable habitat materials. Different substrate types are naturally present throughout the upper reach in various habitat types, which are used by a variety of species.

- Specify substrate in the RD that balances targeted functions (providing substrate that is as similar as possible to pre-construction conditions) and constructability/environmental protection during construction (minimizing fines content to reduce turbidity to the extent practicable).
- Coordinate with EPA during RD to evaluate proposed habitat substrate, recognizing that the post-construction surface substrate will equilibrate over time to the naturally deposited sediment grain size regardless of the selected substrate.
- Use suitable habitat material as the uppermost layer of backfill and caps and for ENR.
- For caps in intertidal clamming areas, include a minimum 45-cm (1.5-foot) clam habitat layer.

Material types that will be used for engineered caps, ENR, RMC, and backfill placement are described in Section 10.6.1 and Table 10-4.

The design elements to backfill dredged habitat areas with appropriate material and place appropriate material over cap armor and as ENR material have been incorporated into the RD with the exception of the cap at SMA 5, which is a relatively steep intertidal slope that is not a clamming area and where the full 45-cm thickness of habitat material would not be stable; in this location, a thinner sand and gravel overlay will be used to help fill interstitial armor spaces. Using these strategies, the remediation is expected to avoid the need for mitigation. This expectation has been confirmed by implementing the habitat evaluation described in Section 11.5.3.

11.5.3 Habitat Evaluation

An evaluation of potential impacts to all habitat types, including ROD-defined "habitat areas" (EPA 2014) from implementation of remedial activities has been conducted to comply with CWA Section 404 and Section 7 of the ESA. This habitat evaluation is described in detail in Attachment E.6 and updated in Attachment E.8 of Appendix E (BA). Overall, the habitat evaluation steps included the following:

- Establish existing habitat conditions.
- Establish post-remediation habitat conditions.
- Conduct a quantitative habitat evaluation for remedial activities included in the Puget Sound Nearshore Calculator (PSNC).
- Conduct a semi-quantitative evaluation for remedial activities not included in the PSNC.

Mitigation for the LDW CERCLA cleanup may be required to offset unavoidable adverse impacts to habitat, but this will be evaluated across all reaches (upper, middle, and lower) of the LDW. The design for the upper reach seeks to maintain net habitat value and avoid the need for mitigation to the extent possible. Additionally, it is anticipated that the future design for the middle and lower reaches will also seek to avoid the need for mitigation to the extent possible, which will be confirmed by conducting the same habitat evaluation for the middle and lower reaches as the RD progresses for those reaches. The resulting habitat impacts or benefits will be determined for each reach. The intent of this approach is to use potential habitat gains generated in one reach to offset potential losses estimated in another reach, such that there is no net habitat loss for the LDW as a whole, and thus, mitigation will be unnecessary. If it is determined that mitigation is needed after considering all three reaches of the LDW, a Compensatory Mitigation Plan will be included in the RD submittals for the lower reach, and temporal impacts between remediation and the restoration of habitat will be accounted for.

A summary of the quantitative and semi-quantitative methods that were used for the evaluation along with a summary of the results are described in the following sections.

11.5.3.1 Quantitative Evaluation: Puget Sound Nearshore Calculator

The PSNC uses Habitat Equivalency Analysis (HEA) and the Nearshore Habitat Values Model (NHVM) to evaluate the following: 1) habitat impacts resulting from nearshore projects that decrease habitat function; and 2) habitat benefits, which are associated with projects that increase nearshore habitat function (Ehinger et al. 2023). HEA is an accounting technique for calculating the replacement of lost ecological services (defined as functions and values that a habitat provides) resulting from an impact (NOAA 1995; Ray 2009). It is a generalized method that can be used in any type of habitat, including freshwater rivers and streams, salt marshes, seagrass beds, and coral reefs. The accounting metric used in HEA is discounted service acre-years (DSAYs), which is a measure of the resource service flows provided by various habitats over time.

The NHVM defines habitat values in terms of physical and biological functions of salmonid critical habitat as defined in 50 CFR 226.212 (Ehinger et al. 2023). As described in the BA (Appendix E), elements of salmonid critical habitat include the unobstructed migratory corridor, cover and primary production, sediment quality and quantity, and water quality. The NHVM defines habitat values for four major elevation zones including the Riparian Zone, the Upper Shore Zone, the Lower Shore Zone, and the Deep Shore Zone, which are used in the PSNC. More information on HEA and the NHVM can be found in the PSNC User Guide (Ehinger et al. 2023).

The PSNC is available at the NMFS Puget Sound Nearshore Habitat Conservation Calculator website as an Excel workbook (NOAA 2023). The PSNC was used to evaluate the following activities: riparian disturbance and replanting in SMA 5; debris removal in SMA 9; waterward reinforcement of an existing bulkhead in SMA 9; piling removal and replacement in SMAs 1, 2, 5, and 7; and creosote-treated piling removal in SMAs 2, 5, and 7.

The results of the PSNC portion of the habitat evaluation are reported in DSAYs, where a DSAY represents the value of all the ecosystem services provided by 1 acre of habitat over 1 year. A negative DSAY indicates a habitat impact; a positive DSAY indicates a habitat benefit. The habitat evaluation compared baseline habitat conditions to the post-remediation habitat conditions for activities including pile installation and removal, creosote-treated piling removal, bulkhead reinforcement, debris removal, and riparian disturbance and replanting. These activities are reported as habitat impacts and benefits (debits and credits). The project is expected to result in habitat impacts of -0.37 DSAY related to piling installation, waterward shoring reinforcement of an existing bulkhead in SMA 9, and riparian disturbance in SMA 5. The project is expected to result in habitat benefits of 0.48 DSAY related to piling and creosote removal, debris removal in SMA 9, and planting of vegetation in SMA 5. Overall, project remediation activities are expected to result in a net habitat benefit of 0.10 DSAY.

11.5.3.2 Semi-Quantitative Habitat Evaluation

As described in the Salish Sea Nearshore Programmatic Biological Opinion (NOAA 2022), methods of removing or isolating contaminated sediments from aquatic habitats (e.g., dredging, excavation, capping) that are performed, ordered, or sponsored by government agency with established legal or regulatory authority are not included in the PSNC. Therefore, a semi-quantitative habitat evaluation was performed for this category of remedial activities by comparing the existing habitat conditions to the expected post-remediation habitat conditions. The semi-quantitative evaluation was used in the BA (Appendix E) as a systematic way to determine the level of habitat benefit or habitat impact related to remedial activities not considered in the PSNC. Habitat categories in the semi-quantitative evaluation were defined by elevations referenced to MLLW based on the bathymetric and topographic data collected as part of the Phase I and II PDIs. Habitat categories used for the habitat evaluation included the following:

- **Deep Subtidal:** Deeper than -10 feet MLLW
- **Shallow Subtidal:** Between -10 and -4 feet MLLW
- **Lower Intertidal:** Between -4 and +4 feet MLLW
- **Upper Intertidal:** Between +4 and +11.3 feet MLLW
- **Riparian[36]:** Above +11.3 feet MLLW

The semi-quantitative habitat evaluation of sediment chemical remediation activities, including dredging and capping, shows that no changes in habitat type (e.g., from intertidal to Shallow Subtidal) are expected in 98% of the SMAs. Changes in habitat elevation and/or degradation status[37] are expected to occur in a total of 0.33 acre in SMAs 1, 3, and 9. A change from Degraded Upper Intertidal to Degraded Lower Intertidal in SMA 9 is related to removal of delineated debris piles. Because these areas are adjacent to a bulkhead wall, they are still considered degraded habitat after debris removal. However, the benefit related to the debris pile removal is quantified by the PSNC, as previously described. Removal of scattered riprap and debris in SMA 3 from dredging will result in a

[36] Riparian is assumed to extend 400 feet upland or until a paved surface and is not expected to be impacted by remediation construction.

[37] Degradation refers to habitat with overwater structures, riprap and/or debris, or that is adjacent to a bulkhead wall.

habitat change from Degraded Upper Intertidal to Upper Intertidal. Removal of scattered riprap and debris in SMA 1 from dredging will result in habitat changes from Degraded Upper and Lower Intertidal to Upper and Lower Intertidal. In the engineered cap area in SMA 5, the existing substrate consists of riprap and debris within the cap area. Because the surface substrate in this area would be riprap armor, there is no change in substrate type post-remediation. In the engineered cap area in SMA 12B, riprap armor will also be placed in a Deep Subtidal area that is expected to quickly fill in with native material and cover the riprap. As such, no permanent change in substrate type is expected in this area. The semi-quantitative habitat evaluation results indicate that there will be project-related habitat benefits from debris/riprap removal. These benefits would be in addition to benefits quantified with the PSNC and the expected permanent benthic habitat, sediment quality, and water quality improvements from sediment chemical remediation.

Consideration of both the PSNC calculations and the semi-quantitative evaluation of sediment remediation areas shows that conservation offsets (i.e., mitigation) are not expected for the upper reach of the LDW. There is expected to be up to 0.10 DSAY of project-related habitat benefit and net improvement of nearshore habitat functions and values to ESA-listed species and their designated critical habitat related to the project.

11.6 Buried Contamination Protectiveness Evaluation

EPA’s 2014 ROD anticipates that subsurface buried contamination will safely remain in some areas where it would not be subject to future release, subject to the specific criteria defined in the ROD. EPA’s determination was based on a variety of analyses in the FS, including the potential for exposure by scour from river flows and vessels (Appendix C of the FS; AECOM 2012). Buried contamination protectiveness evaluations were conducted to demonstrate that the sediment overlying buried contamination is sufficient to prevent the buried contamination from migrating to the surface through dissolved phase transport at some point in the future. These evaluations are summarized in the following paragraphs and are detailed in Appendix K.

Buried contamination is defined as the presence of COC concentrations greater than the surface RAL that are buried by 60 cm (2 feet) or greater of sediment with concentrations less than surface RALs in subtidal areas or by 45 cm (1.5 feet) or greater of sediment with concentrations less than the surface RALs in the intertidal zone. Areas and COCs meeting this definition of buried contamination in the upper reach are limited to PCBs, with the lone exception of arsenic in RAA 18 (SMA 10), for which remediation was deferred due to source control sufficiency (see Section 6.1.3) and not included in the upper reach design. Therefore, this buried contamination evaluation for the upper reach focused on PCBs. Modeling was performed to evaluate whether buried concentrations of PCBs in RAA 14/15/16 (SMA 12B) and between RAAs 4/5/6 (SMA 14D) and RAA 12 (SMA 14A), and PCB concentrations representative of potential buried contamination adjacent to RAAs 1/2/3 (SMAs 17 and 18) and 14/15/16 (SMA 12B), have the potential to recontaminate surface sediments to a concentration greater than the RAL (i.e., 12 mg/kg OC for PCBs) in the future (i.e., over a 100-year simulation) through dissolved phase transport driven by groundwater seepage (as well as diffusion or dispersion and bioturbation).

Specific cores modeled for buried contamination included the highest buried concentration found in the upper reach in order to assess whether any buried contamination would pose a risk in the future. Locations 554 (located between RAAs 4/5/6 [SMA 14D] and 12 [SMA 14A]) and 572 (located within RAA 14/15/16 [SMA 12B]) and generalized core profiles were developed using maximum and average concentrations from cores within RAAs 1/2/3 (SMAs 17 and 18) and 14/15/16 (SMA 12B). The details of the buried contamination modeling approach and results are presented in Appendix K.

Model-predicted concentrations of PCBs in the top 10 cm of the sediment were compared to the surface RAL to evaluate whether buried contamination migration could result in surface RAL exceedances in the surface sediment within 100 years. Model results in Appendix K show that PCB concentrations in the top 10 cm of the sediment are predicted to remain less than the surface RAL of 12 mg/kg OC for more than 100 years in all cases. Sedimentation was ignored in this evaluation. The addition of new material depositing on the surface creates additional thickness over which the PCBs attenuate. A sensitivity analysis showed that the inclusion of sedimentation results in lower concentrations at the surface when compared with the base case modeling results and confirmed that the modeling approach is conservative. In addition, a sensitivity analysis was performed to determine a maximum theoretical buried PCB concentration that could remain buried without creating an exceedance in surface sediments. This analysis determined that PCB concentrations beneath the surface could be significantly greater than the modeled maximum concentration found in the upper reach (10 to 3,000 times greater depending on Darcy flux input assumed) before creating an exceedance in surface sediments.

Because PCBs partition relatively strongly to sediments, they do not migrate quickly through the sediments in the dissolved phase; therefore, contamination that is buried beneath cleaner sediment remains buried, particularly if there is net sedimentation, as is the case in many locations in the LDW. Although the PCBs are predicted to migrate upward to some extent, the transport is not significant enough to affect the surface sediments, as shown in Appendix K; therefore, as shown by the sensitivity analyses presented in Appendix K, PCB-containing sediments buried by 30 cm or greater of sediment that meets the PCB RAL are predicted to be protectively contained.

12 Site Access

Property acquisition, site access agreements, leases, or easements may be needed at properties where remedial activities will be implemented or for off-site staging areas that may be required for the contractor's material, equipment staging, and shoreline access during construction. Agreements may also be needed when remedial activities have the potential to disrupt commercial businesses. Coordination with property owners or lessees will continue to occur after RD to accommodate construction near infrastructure and in shoreline areas where upland equipment access is required. Depending on the owner, the nature and duration of the access, and the resulting remedy, written agreements or other legal documentation (e.g., leases, easements, deed restrictions) may be required. Section 12.1 identifies the property locations and owners where site access agreements are anticipated to be necessary. A *Permitting and Site Access Plan* has been prepared as part of this Final (100%) RD as Volume II, Part II.

12.1 Site Access Considerations

The upper reach consists mostly of publicly owned and managed aquatic land (Port of Seattle and State of Washington) but includes some privately owned submerged portions of adjacent upland parcels. Access agreements with the Port of Seattle and the State of Washington were not needed for sampling during the PDI activities and assumed not to be necessary for construction activities for Port-managed portions of the LDW Superfund Site. For work on State Owned Aquatic Lands (i.e., SMA 1), WDNR has indicated that an aquatic lands use authorization will be needed and will be authorized via right of entry as long as institutional controls (ICs) will not be required. No current design elements (i.e., engineered caps) are included on State Owned Aquatic Lands in the current upper reach RD; therefore, no ICs are anticipated, and access should be authorized via right of entry.

For construction, it is anticipated that access to waterway and upland properties owned by LDWG parties will be readily approved and site access agreements with adjacent property owners will be attainable if needed to facilitate remedy construction. Access agreements are anticipated to be required with private owners of waterway or adjacent property if such areas are determined necessary to accomplish remedy construction. A summary of anticipated site access need by SMA is provided in Table 12-1. Although Table 12-1 reflects the design team's assessment of potential access needs, the contractor may propose an alternate approach that entails access from the upland or may propose to accomplish all work from the water, even for locations listed as "Upland Access Anticipated" in the table. The contractor will be responsible for obtaining any additional access agreements necessary to support its approach if proposed off-site facilities require such agreements.

Construction along the bank at Container Properties (SMA 5) is expected to need more significant coordination and access than most shoreline locations. Access to accomplish bank excavation from the land side and for loading and off-site transportation of excavated soils will need to be obtained.

Coordination for site access at Container Properties has occurred throughout the design process and will continue through construction.

Table 12-1
Anticipated Site Access Needs by SMA

SMA	Property Owner and Adjacent Property Owner (if applicable)[1]	Access Agreement Needed?[2]	Upland Site Access Anticipated?
1	WDNR; Boeing	Yes	No
2	Port of Seattle	No	No
3	Port of Seattle; Boeing	Yes	No
4	Boeing	Yes	No
5	Container Properties LLC	Yes	Yes
6	Container Properties LLC	Yes	No
7	Port of Seattle; CenterPoint Properties	Yes	Yes
8	Port of Seattle; Boeing	Yes	No
9	Port of Seattle; CenterPoint Properties	Yes	No
11	Port of Seattle; Boeing	Yes	No
12	Port of Seattle	No	No
13	Port of Seattle; South Park Marina Ltd	Yes	Yes
14	Port of Seattle; King County	No[3]	No
15	Port of Seattle	No	No
16	Port of Seattle	No	No
17	Port of Seattle	No	No
18	Port of Seattle	No	No

Notes:

1. For areas located within the LDW (which is managed by Port of Seattle up to the Turning Basin and WDNR south of the Turning Basin), the secondary property owner listed is the adjacent upland property. Adjacent property owners are listed when the SMA is within 50 feet of the property.
2. It is assumed that properties will require an access agreement when the SMA is within 50 feet of the property.
3. King County owns the South Park Bridge, which crosses the waterway. Although an access agreement is not needed for remediation in SMAs adjacent to the bridge, it is expected that some notification will be required to inform King County Roads prior to remedial construction.

LDW: Lower Duwamish Waterway
SMA: sediment management area
WDNR: Washington State Department of Natural Resources

12.2 Permitting for Site Improvements

No site improvement work that requires permitting is anticipated to be implemented as part of the project. Examples would include developing new buildings not located within or adjacent to the LDW Superfund Site to support construction management or transloading operations at a LDWG-provided upland staging area.

13 Preliminary Construction Sequencing and Schedule

13.1 Construction Sequencing

Cleanup construction activities will be sequenced to accommodate logistics and reduce the risk of contaminant release, generally beginning with contaminated debris removal (e.g., demolition and removal of creosote-treated materials) followed by intertidal excavation and subtidal dredging. Capping, backfill, and RMC will be sequenced to occur after dredging (including any potential contingency re-dredging) within each SMA is completed to limit residual contamination and reduce risk of recontamination of previously cleaned up areas. In general, work will be required to start at the upstream end of the upper reach and work downstream to reduce risk of recontamination of cleaned up areas. Construction and post-construction monitoring and institutional controls will be implemented to verify the protectiveness of the remedy.

Certain sequencing requirements will be specified (e.g., Owner approval of dredge areas prior to any backfilling; access time periods for specific properties). However, the specific sequencing of the construction will be defined in the contractor's RAWP to allow the contractor to consider its specific construction equipment, means and methods, and production rates in order to develop an effective sequence to do the work within the timing restrictions required by the Specifications (Volume III). Also, the contractor's sequencing will be dependent on (among other things) access agreements with property owners/users and the transloading proposed by the contractor. Assuming commercial transloading at the facility identified in Section 10.2.6.1, construction sequencing is anticipated to be generally as follows:

1. Development and approval of contractor's RAWP
2. Notifications to property owners, Tribes, public, U.S. Coast Guard, and any agency-required notifications completed in accordance with ARARs and permits
3. Mobilization and setup of temporary facilities, including transloading area
4. Procurement and testing of clean placement materials
5. Pre-construction survey
6. Pre-construction conditions inspection and documentation of structures (photographs/video)
7. Boundary (public access) area documentation sampling (pre-construction)
8. Removal of piling and debris from dredge areas
9. Dredging and excavation (generally upstream to downstream), including in-water transport, transload, upland transport, and disposal of dredged materials at an approved disposal facility
10. Dredging acceptance surveys and re-dredging, if determined to be necessary based on post-dredge survey results
11. Post-dredge confirmation sampling and contingency re-dredging actions, if needed
12. Material placement: backfilling, RMC placement, ENR placement, amended cover placement, and capping

13. Post-placement acceptance surveys and additional placement to achieve required placement thicknesses/elevations, if needed
14. Pre-final and final inspections
15. Corrective measures (if needed)
16. Demobilization and site cleanup
17. Post-construction documentation and close out procedures

Multiple activities may occur concurrently, such as dredging in downstream areas while material placement is occurring in upstream areas where dredging has been verified to be complete. The contractor will maintain an up-to-date detailed schedule of activities in accordance with the Specifications (Volume III). Following construction of the upper reach, institutional controls will be enacted, and certain components of long-term monitoring will begin.

13.2 Construction Schedule

Remedial construction of the upper reach will proceed following source control sufficiency determinations, as described in the RDWP (Anchor QEA and Windward 2019a). In-water construction activities will occur during in-water work windows designated for the LDW (to be determined by EPA but anticipated to be from approximately October 1 through February 15 or an approved extension) that will be set to protect threatened and endangered species under the ESA. Construction activities will be coordinated with the Muckleshoot Indian Tribe and Suquamish Tribe to reduce impacts on tribal fishers. Remedial construction for the upper reach is anticipated to require three construction seasons based on the Final (100%) RD quantities and production rates for dredging (Section 10.2.5) and quantities and production rates for material placement (Section 10.6.6), as defined by the in-water work windows. The overall production rate can be affected by the off-site disposal rate, and the contractor will need to coordinate with the disposal transportation provider(s) to plan truck and rail capacity. Assumed production rates used in the design reflect similar production rates observed during past sediment remediation projects in the region and therefore likely account for the risks associated with potential off-site disposal bottlenecks such as rail capacity.

The conceptual preliminary construction schedule shown in Figure 13-1 identifies the major phases of construction for the project at Final (100%) RD and associated estimated durations of major construction activities (i.e., dredging, material placement, structural work); durations were estimated based on construction production rates for similar work at other sites, conversations with local experienced remediation contractors, assumptions regarding contractor and crew and equipment resources that may be dedicated to the project, and engineering best professional judgment. A specific-project sequencing (by construction season) will be developed by the contractor in its RAWP and will describe anticipated start/finish dates of all construction activities associated with each SMA.

A typical sequence of construction activities within each SMA will be as follows:

- Required dredging/excavation: approximately 1 to 30 days, depending on the size of the SMA
- Verification of required dredging/excavation through bathymetric/topographic surveys: 1 day
- Collection and analysis of post-dredge construction sediment samples and contingency re-dredging decision-making (conducted by the Owner): approximately 15 days
- Contingency re-dredging (if required): approximately 1 to 5 days
- Material placement (backfill material, RMC, engineered caps): approximately 1 to 25 days, depending on the size of the SMA

The Specifications will require the contractor to start RMC and backfill material placement in each SMA within a specific timeline, unless otherwise approved by the Owner, after the Project Representative provides them with approval to proceed with the work.

14 Quantity Calculations and Engineer's Cost Estimate

This section provides information on quantity calculations and the Engineer's Cost Estimate for the Final (100%) RD.

14.1 Quantity Calculations

Quantity calculations for dredging and material placement (including backfill, RMC, ENR, Area-Specific Technology B [amended cover], and engineered caps materials) are discussed in the following paragraphs and summarized in Table 14-1.

Dredge volumes were calculated for each SMA with AutoCAD Civil3D software based on the design dredge plan (i.e., dredge prism) included on the Drawings (Volume III). The dredge prism volume is measured by developing a triangulated irregular network (TIN) surface of the required dredge prism (including side slopes) and calculating the cut and fill quantities between the dredge prism TIN surface and the TIN surface of the recent bathymetric and topographic survey basemap. The volume of the overdredge allowance was computed by using the area of the dredge prism boundary, including side slopes, and multiplying that area by the 1-foot overdredge allowance.

Following the completion of all required dredging, the RD has assumed that one additional contingency re-dredging pass will be conducted over a portion of the SMA dredge footprint to remove generated dredge residuals above a threshold concentration (as described in the CQAP post-dredge confirmation sampling plan; Volume II, Part I) and remove missed inventory. For costing purposes, as described in Appendix O, the RD assumes that 15% of the required dredge area will be re-dredged by 1 foot (which includes 6 inches of overdredge allowance) to address generated residuals, and 20% of the required dredge area will be re-dredged by 2.5 feet (which includes 6 inches of overdredge allowance) to remove missed inventory.

RMC, ENR, and Area-Specific Technology B (amended cover) material placement quantities were developed using the Final (100%) RD assumed targeted placement thicknesses up to the maximum vertical placement tolerances (see Sections 10.2.9.2, 10.4, and 10.5.2.1) over each respective placement area (generated via AutoCAD). Capping material quantities were developed using the Final (100%) RD assumed minimum placement thicknesses, plus the maximum overplacement allowances over each respective placement area (generated via AutoCAD).

In addition, the following assumptions have been used for costing purposes in Appendix O:

- RMC placement:
  - RMC is to be placed over 100% of the dredge areas that do not receive backfill, in specific SMAs (as shown on the Drawings [Volume III]).

  - The RMC placement footprint also includes dredge-cut side slope areas (top to toe of dredge cut daylight).
    - Per Section 10.2.9 of this BODR, additional RMC placement outside of the dredge areas will occur as follows:
    - Inner perimeter RMC will be automatically placed within a perimeter surrounding the dredge area (generally 20 feet wide in the upstream and cross-channel directions and 30 feet wide in the downstream direction from top of dredge cut daylight) without the need for post-dredge construction sediment sampling.
    - Outer perimeter RMC consists of RMC placed within an assumed 25% of a perimeter (generally 20 feet wide in the upstream and cross-channel directions and 30 feet wide in the downstream direction) outside of and surrounding the inner RMC perimeter. Perimeter sediment sampling within the outer perimeter will be performed to determine whether there is a need for RMC placement in the outer perimeter.
- ENR is to be placed in specific SMAs (as shown on the Drawings [Volume III]). ENR quantity assumes a placement footprint that includes a 10-foot buffer around the planned ENR placement area.
- As Area-Specific Technology B, amended cover is to be placed in limited portions of SMA 7; as noted in Section 10.4, the ENR in SMA 13 will use amended cover material, so it is included here for costing purposes. Amended cover is intended to address areas that are adjacent to existing structures or armored slopes, where dredge offsets are required, and where the ENR upper limit is exceeded (as shown on the Drawings [Volume III]). GAC is assumed to be mixed in at 2.0% by dry weight (to achieve a minimum 1.0% dosage; see Section 10.5.2 of this BODR and Appendix K).
- Engineered cap is to be placed within two SMAs: SMA 12B and SMA 5, as shown on the Drawings (Volume III). The engineered caps will consist of three layers: a chemical isolation layer (gravelly sand material), a filter layer (gravel material), and an erosion protection layer (quarry spalls); see Section 10.3.3.

Backfill placement is intended to restore habitat areas to pre-construction elevations and to flatten temporary steeper dredge cuts (e.g., along the Boeing Plant 2 EAA). All dredge areas located outside of the FNC and above elevation -10 feet MLLW are assumed to be backfilled and integrated with habitat material placement in intertidal areas as appropriate, as shown on the Drawings (Volume III; see also Section 10.2.10 of the BODR). Backfill volumes are dependent on the final dredge cut surface and may not exactly match the pre-dredge elevations due to equipment placement accuracy and geotechnical properties of the placement materials. Therefore, for Final (100%) RD, the backfill volume for each SMA was calculated by developing a backfill TIN surface with AutoCAD Civil3D software, based on backfill design placement elevations and grades, as well as the final design dredge plan to be backfilled (back from the overdredge allowance surface). The backfill design considers how to balance achieving the ROD requirement to restore habitat areas to pre-dredge elevations using imported backfill materials that may somewhat differ from the pre-dredge substrate. The backfill volume also accounts for the upper end of the vertical placement tolerance.

Table 14-1
Summary of Final (100%) RD Volumes

Description	Volume (cy)
Required Dredge Volume	100,500
Overdredge Allowance Volume	22,300
Contingency Re-Dredging Volume	9,500
Total Dredge Volume	132,300
Backfill Volume	57,600
RMC + Inner/Outer Perimeter RMC Volume	25,200
ENR Volume	400
Area-Specific Technology B – Amended Cover Volume	300
Engineered Cap Volume (SMA 5)	3,700
Engineered Cap Volume (SMA 12B)	8,000
Total Placement Volume	95,200

Notes:
1. Volumes are rounded to the nearest hundred. See Appendix O for detailed dredging and material placement quantities.
ENR placement volume does not include the volume associated with SMA-c1 (cPAH-only area, which adds approximately 100 cy; see Appendix F).ENR: enhanced natural recovery
RD: remedial design
RMC: residuals management cover
SMA: sediment management area

14.2 Engineer's Cost Estimate

A Final (100%) RD Engineer's Cost Estimate (Appendix O) was prepared based on the design information provided on the Drawings (Volume III). It builds upon the Pre-Final (90%) RD Opinion of Probable Cost to refine costing of the footprints of remediation and updates in the remedial approach, where needed.

The total project cost includes costs for direct construction tasks (i.e., all construction activities anticipated to be conducted by the contractor), indirect construction tasks (i.e., additional QA activities that are necessary to the project but are performed by parties other than the contractor), and additional construction oversight tasks (by EPA).

Costs were developed using both parametric and bottom-up costing approaches. Parametric costing was based on review of historical cost estimates for 10 similar sediment remediation projects completed locally (in the Seattle area) and regionally (in the Pacific Northwest). In bottom-up costing, the large project was broken down into a number of smaller components, and costs were specifically derived for each of these smaller work components based on engineering cost guidance. By comparing bottom-up costs with parametric cost information (if projects reviewed contained similar quantities and/or conditions as the upper reach), along with engineering best professional judgment, "probable" unit costs were then derived.

Costs developed for direct and indirect construction tasks and additional construction oversight tasks include the following components:

- Direct construction costs:
  - Mobilization and demobilization
  - Site preparation
  - Surveys
  - Structural work
  - Dredging and excavation
  - Transloading, upland transportation, and disposal
  - Material placement
  - Environmental controls
  - Planting preparation, landscaping, and 1-year maintenance in SMA 5
- Indirect construction costs:
  - Project management
  - Engineering support services
  - Construction quality assurance
    - Construction management (inspection and oversight)
    - Environmental compliance monitoring (including confirmation sediment sampling and contingency action determination, environmental monitoring during construction [water quality, air/noise/light], and inadvertent discovery monitoring)
  - Site access agreements and temporary leases
  - Community outreach and communications
- Additional construction oversight costs:
  - EPA oversight

General and specific RD costing assumptions are detailed in Appendix O and in the cost estimate workbook (Appendix O, Attachment O.1).

The total Final (100%) RD probable cost for LDW upper reach implementation is $66.6 million. Costs are presented in present-day U.S. dollars (i.e., 2023), with sales tax (10.25%[38]) and contingency (25.0%, applied to the total direct and indirect construction costs and to the additional construction oversight costs). Contingency percentage was selected to represent potential cost risks associated with the level of information available and engineering best professional judgment.

[38] Although the upper reach SMAs fall into both the Cities of Seattle and Tukwila jurisdictions, for the purposes of the engineer's cost estimate, sales tax is included at 10.25% (to account for Washington State [6.5%] and the City of Seattle [3.75%] taxes), as a conservative assumption for Final (100%) RD; sales tax for the City of Tukwila is 10.1%.

15 Construction Contracting Strategy

RD for the upper reach is being completed by LDWG under AOC4. Remedy construction will be implemented under a future Consent Decree or other enforcement mechanism by the Implementing Entity (details to be determined; see Section 1.4).

The Implementing Entity will assign the responsibility of construction contracting to an experienced construction management firm or one of its members (Owner). The public or private nature of the organization will dictate the type of construction contract that will be used, the format of the Drawings and Specifications, and the specific legal arrangements between the selected contractor and the Implementing Entity. For this Final (100%) RD submittal, King County standards have been used for purposes of structuring the technical Specifications.

15.1 Remediation Contractor Selection

The Implementing Entity will establish contractor selection criteria. The Implementing Entity will also develop its preferred contracting approach, including number of contracts, breakdown of work between contracts (if multiple contracts are used), insurance and bonding requirements, and contract administration processes. If the Implementing Entity contains one or more public entities, certain requirements will govern contractor selection in accordance with established public works contracting law.

15.2 Construction Quality Assurance Contract

An experienced construction management team will be formed to conduct construction QA activities independent of the contractor. The details for the field inspection and monitoring and construction QA scope of work are described in Section 16.3 and in Volume II, Part I (CQAP). The Implementing Entity will identify the Owner, who will be responsible for execution of the construction contract and for construction QA activities.

15.3 Designer

Anchor QEA is the Designer for the LDW upper reach and will provide consultation and observations during construction to assist with implementation of the remedial action in conformance with the EPA-approved design documents, review of product approvals, request for information or clarifications, and acceptable design modifications as approved by EPA.

15.4 Number of Construction Contracts

The Implementing Entity may determine that it could be advantageous to engage in more than one agreement with different remediation contractors. Advantages of such an approach could include easier cost allocation or tracking, improved project sequencing, and greater depth of resources to complete remedial construction. Challenges associated with multiple contractors could include conflicts between overlapping contractor schedules or sequence, potentially blurry lines of responsibility, increased bottlenecks at key project pinch points (e.g., transloading and disposal), and greater construction contract administration overhead. On balance, the challenges of using a multiple-contractor approach are likely to outweigh the potential benefits, and it is expected that the Implementing Entity will most likely not split the remedial construction of the upper reach into multiple construction contracts. However, some elements of the work (such as planting) will require specialty contractor expertise that may require splitting these work elements into a separate construction agreement.

16 Contractor Quality Control and Construction Quality Assurance

A critical part of successful sediment remediation projects is to require that the contractor has a robust QC plan to manage its work in a manner that complies with all requirements identified in the Drawings and Specifications (Volume III) and with all federal, state and local regulations. This section describes how QA/QC will be implemented during remedy construction.

16.1 Pre-Construction Activities

Following the construction contract award, the Owner will direct the selected contractor to develop a RAWP as a pre-construction submittal that will describe specific means and methods the contractor will use to implement the remediation construction activities. The design Specifications identify the components of the RAWP for which the contractor is responsible.

The contractor will also be required to develop an Emergency Response Plan documenting the procedures to be followed in the event of an accident or emergency during remedial construction. The Emergency Response Plan itself will be a component of the contractor's RAWP. Key components that will be required in the contractor's RAWP include the following:

- Project Work Plan, including the following: 1) a description of construction elements, including proposed means and methods; and 2) an equipment and personnel list, including project organization chart and reporting responsibilities
- Initial Project Schedule
- Site-Specific Health and Safety Plan, including an Emergency Response Plan
- Surveying and Positioning Control Plan, including surveyor certifications (bathymetric and topographic)
- Material Placement Plan, including materials submittals per Specifications (e.g., material testing results)
- Dredging and Excavation Plan
- Transloading, Upland Transportation, and Disposal Plan, including proposed transload and disposal facility names, locations, and certification
- Water Quality Protection Plan
- Water Management Plan
- Erosion and Sediment Control Plan
- Stormwater Pollution Prevention Plan
- Spill Prevention, Control, and Countermeasure Plan
- Air Pollution and Odors Control Plan
- Noise Control Plan
- Light Control Plan

- Personnel and Equipment Decontamination Plan
- Traffic Control Plan
- Green Remediation Plan
- Vessel Management Plan
- Demolition Plan
- Construction Quality Control Plan
- Temporary Facilities and Control Plan
- Notifications Plan
- Instrumentation and Monitoring Plan
- Site Clearing and Management Plan
- Temporary Irrigation Plan
- Examples of progress reporting forms
- Change order forms and process

The RAWP will be reviewed and approved by the Owner and EPA.

16.2 Contractor's Quality Control

The contractor's QC refers to the procedures, actions, and documentation performed and produced by the contractor to demonstrate the contractor has met the project requirements as detailed in an approved RAWP and other Owner/EPA-approved pre-construction submittals, as well as the Drawings and Specifications (Volume III). Construction QC (e.g., daily progress surveys, equipment inspection, sampling and analysis to verify import materials quality) will be the responsibility of the construction contractor, in accordance with the Specifications and the contractor's RAWP. The Specifications require the selected contractor to prepare a Construction Quality Control Plan as part of the RAWP.

16.3 Construction Quality Assurance

Construction QA refers to the procedures and actions performed by the Owner to confirm that the contractor is complying with all project requirements and to also provide QA related to the remedy performance. The Owner will oversee the entire construction QA program, in coordination with the Project Representative, and will be responsible for implementing the QA program during construction. The CQAP provided in Volume II, Part I, describes QA roles and responsibilities, QA activities conducted during pre-construction, construction, and post-construction, and the means and methods that the Owner and its consultant will use to provide QA during construction to oversee and track the contractor's work, monitor environmental compliance, and assess compliance of the remedial action with the Specifications (Volume III).

16.3.1 Construction Inspection and Engineering Support

The Owner will provide construction inspection (in-field activities) and engineering support (office support activities) to oversee the contractor's activities. The Owner will assign a Project Representative to lead the construction management team to oversee the contractor's work and help administer the construction contract. Construction management team responsibilities include construction administration, on-site inspection, review of submittals, design interpretation and developing response actions, and communication and coordination with the selected contractor and EPA.

16.3.2 Environmental Controls and Monitoring

The Owner will provide environmental monitoring and reporting to EPA for all environmental ARARs compliance requirements, such as water quality monitoring. The CQAP includes environmental monitoring plans and response actions (i.e., how modifications to the construction procedures will be directed, as necessary, in response to monitoring data).

16.3.3 Remedial Action Performance Monitoring

The Owner, in coordination with the Implementing Entity, will provide remedial action performance monitoring, specifically to assess the post-dredge sediment surface quality to evaluate whether the post-dredge surface concentrations are below surface RALs (0 to 10 cm [0 to 4 inches]). The CQAP describes the post-dredge confirmation sampling and decision framework for contingency action(s) resulting from confirmation sampling test results.

17 Work by Others

Work by others (bank or in-water construction activities, such as permitted maintenance dredging or nearshore upland cleanup activities) within the limits of the upper reach may take place leading up to or during the anticipated construction duration. Upper reach construction activities conducted by others could modify existing conditions. Therefore, as described in the RDWP (Anchor QEA and Windward 2019a) and within this BODR, any planned or completed construction activities within the upper reach starting in 2019 (representing the upper reach RD notice to proceed) through the anticipated RD completion in 2023 are currently being tracked.

Appendix P summarizes the status of in-water and bank construction activities occurring adjacent to the SMAs; anticipated changes in structures and in-water, bank, and upland areas; and probability of impact to specific SMA remedy design. Construction activities have been documented by reviewing the *Lower Duwamish Waterway Source Control Status Report 2020* (Ecology 2022b), accessing the *Water Quality Permitting and Reporting Information System (PARIS*), and through previous communications with water-dependent users (as part of the *Water User Survey and Assessment of In-Water Structures – Data Report;* Integral et al. 2018) and coordination with upland property owners.

Should non-remediation-related construction take place between EPA approval of the Final (100%) RD and anticipated start of remedial construction, the Implementing Entity will review the new conditions and revise the Drawings and Specifications (Volume III) if necessary.

18 References

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Figures

Prepared by ClaireC, 1/19/2024; W:\Projects\Duwamish AOC4\GIS\Maps and Analyses\Remedial Design\BODR\Fig 02-1 7059 Vicinity map.mxd

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N
0 0.5 1 Miles
0 1 2 Kilometers

Figure 2-1. LDW Superfund Site vicinity map

100% Remedial Design Basis of Design Report for the LDW Upper Reach JANUARY 16, 2024

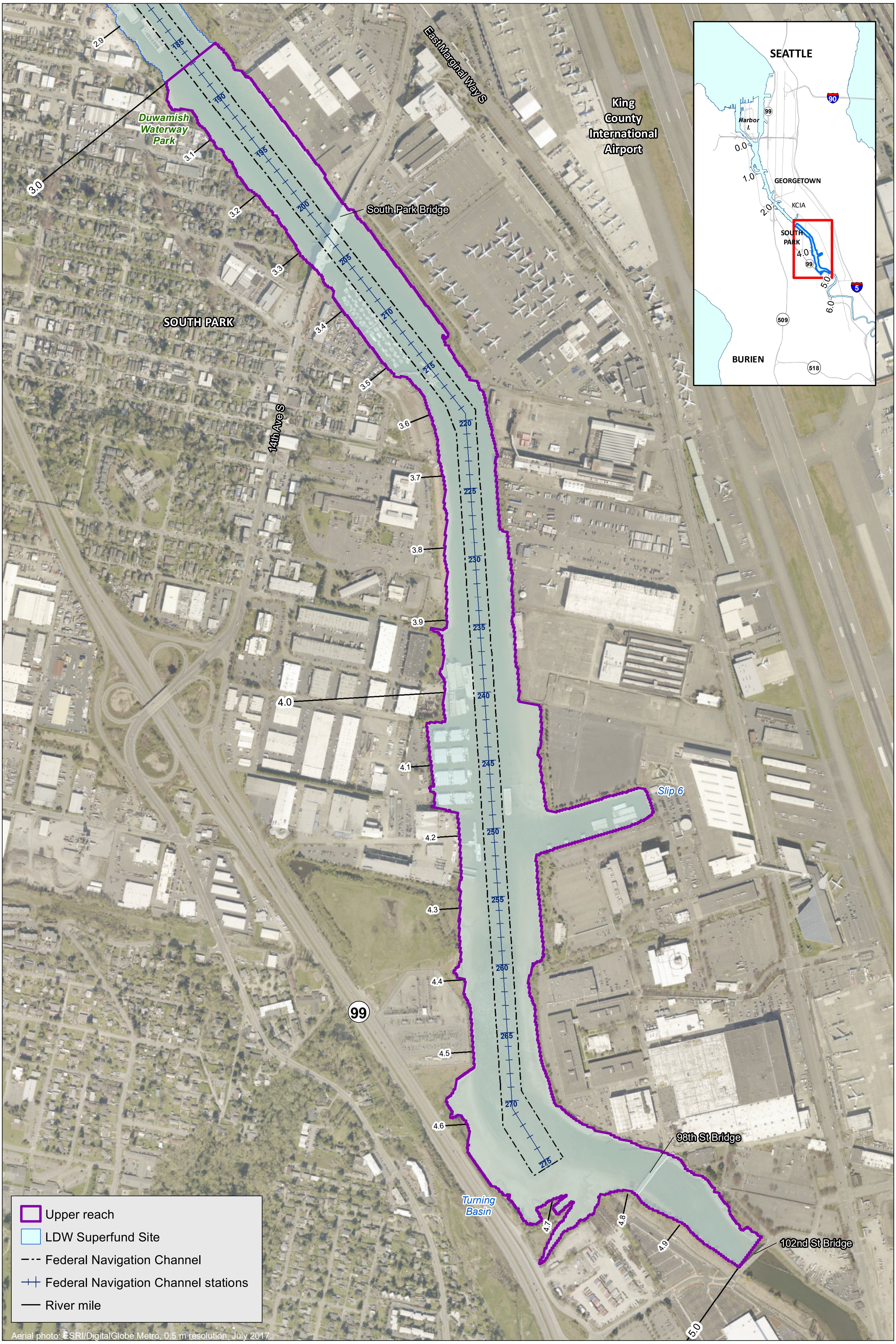

Figure 2-2. Upper reach vicinity map

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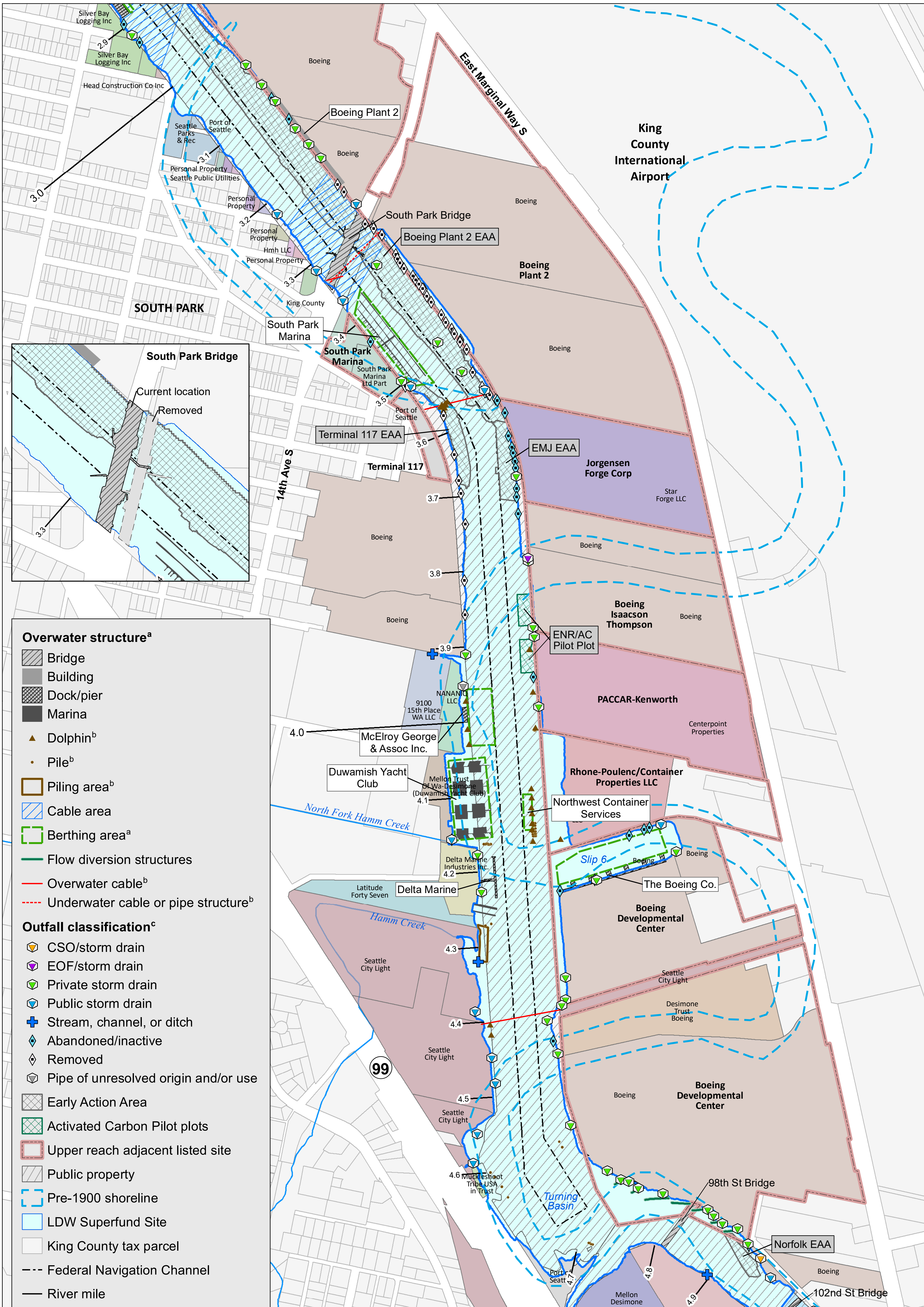

[a] Source: Waterway User Survey and Assessment of In-Water Structures - Data Report (Integral et al. 2018)
[b] Source: Lower Duwamish Waterway Final Feasibility Study (AECOM 2012)
[c] Outfalls based on the Ecology 2020 survey as amended by LDWG as of September 19, 2022. Pending final approval by LDWG, EPA, and Ecology.

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Figure 2-3. Infrastructure, early action areas, upland sites, and land ownership

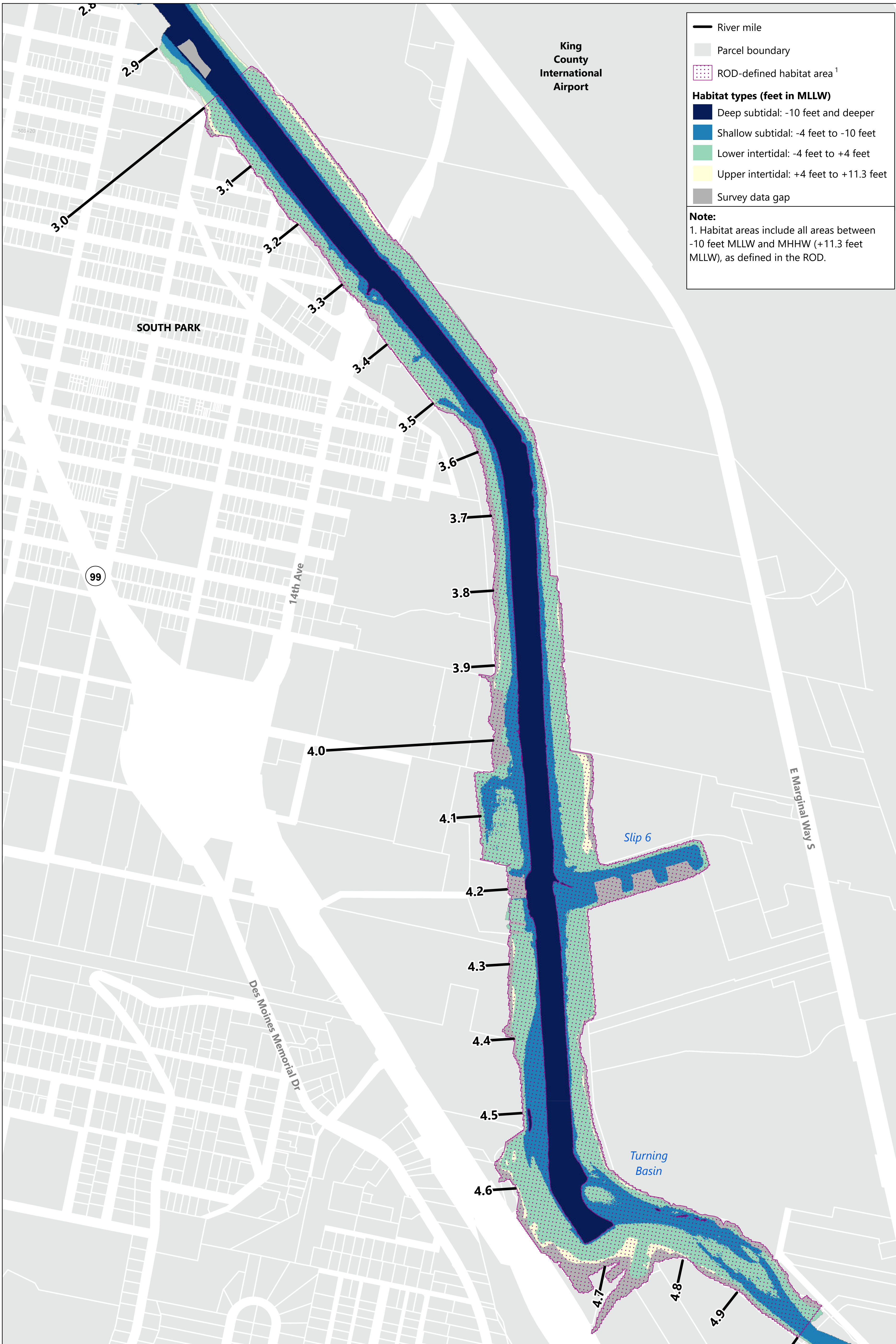

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Figure 2-4a. Existing habitat types and ROD-defined habitat areas

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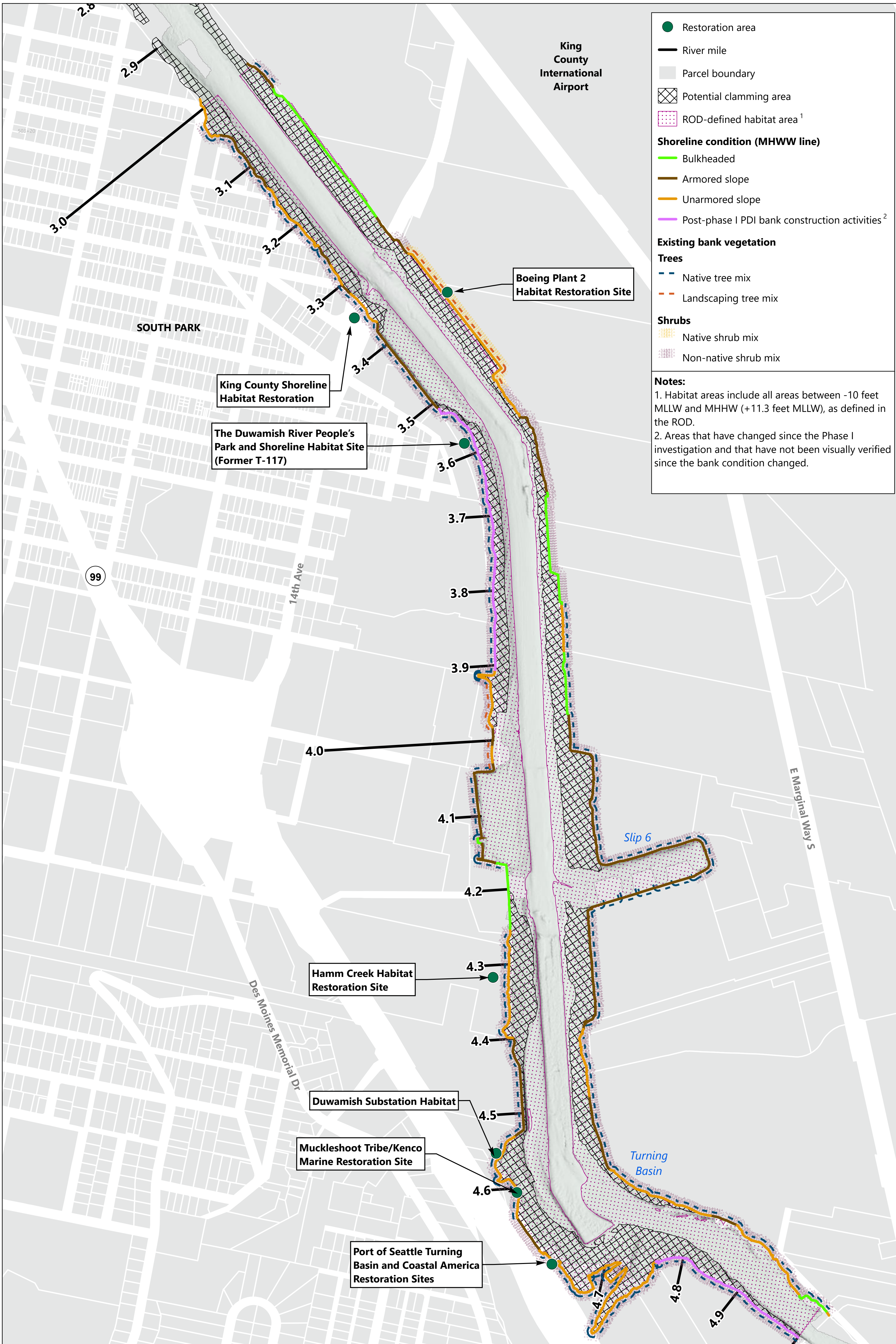
JANUARY 16, 2024

Prepared by jlarson, 12/14/2023; \\orcas\GIS\Jobs\KingCounty_0067\LDW\Maps\Reports\BasisDesignReport\LDW_BDR_100pct.aprx



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0 650 1,300 Feet

0 100 200 Meters

N

Figure 2-4b. Existing clamming areas, restoration areas, and shoreline conditions

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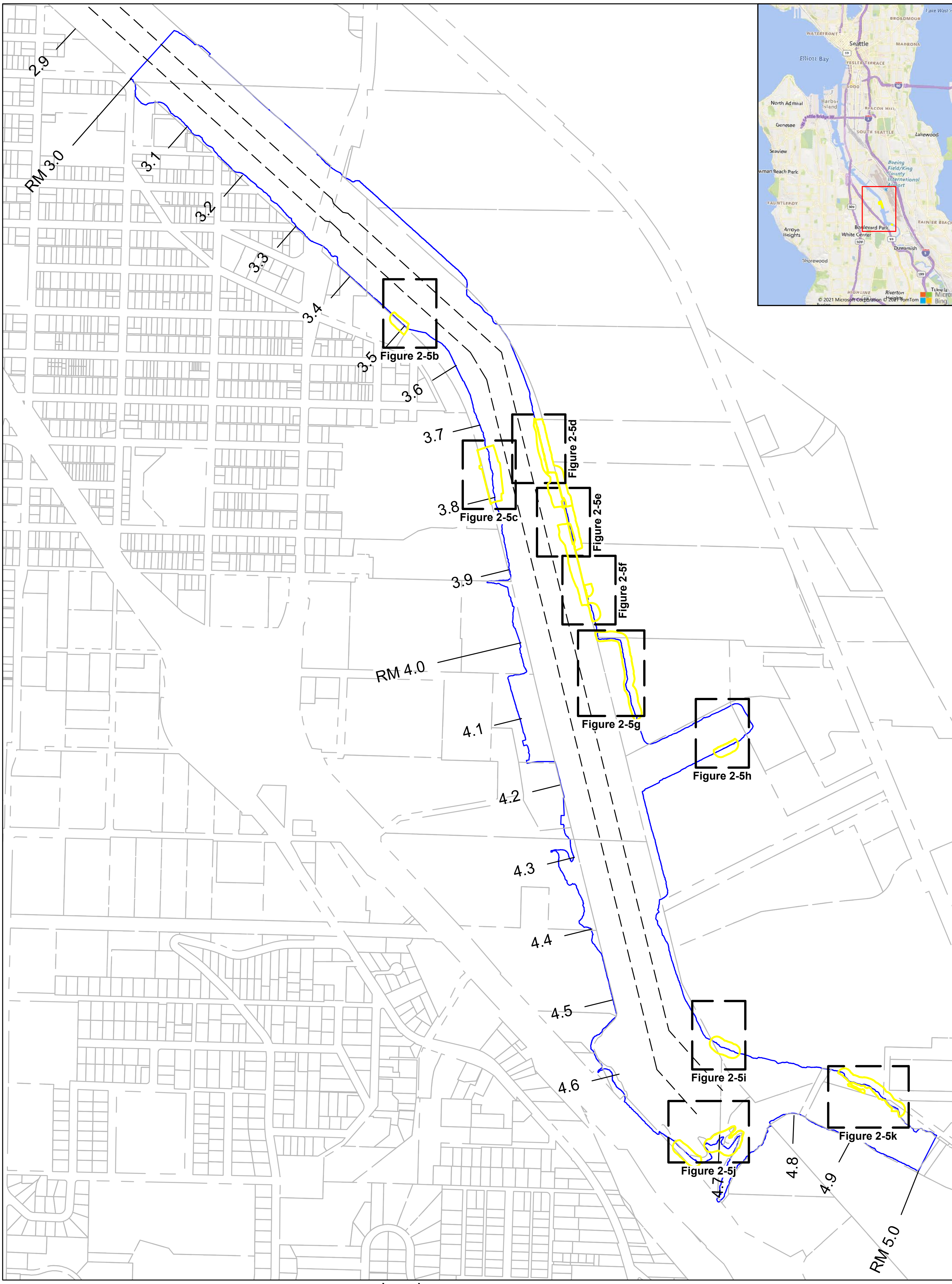
JANUARY 16, 2024

Prepared by jlarson, 12/14/2023; \\orcas\GIS\Jobs\KingCounty_0067\LDW\Maps\Reports\BasisDesignReport\LDW_BDR_100pct.aprx



Source: Topographic survey by True North Land Surveying, Inc. performed between June 30, 2021, and August 10, 2021. Additional survey by True North performed on October 5 and 6, 2022. Bathymetric survey by Northwest Hydro performed between April 18, 2019, and May 15, 2019. Additional survey by Northwest Hydro performed June 2020. LiDAR survey from Puget Sound LiDAR Consortium dated 2016. Composite data updated December 2020 and November 2022.

Horizontal Datum: Washington State Plane, North Zone, North American Datum of 1983/91, U.S. Survey Feet; WSDOT MON GP17005-176 & GP17005-181

Vertical Datum: Mean Lower Low Water (MLLW), MLLW converted from NAVD88 (NAVD88 + 2.34' to MLLW)

Legend:

- Federal Navigation Channel
- 250+00 Channel Centerline
- LDW Upper Reach Approximate Boundary
- Topographic Survey Area
- Figure Extents

N

0 700 Feet

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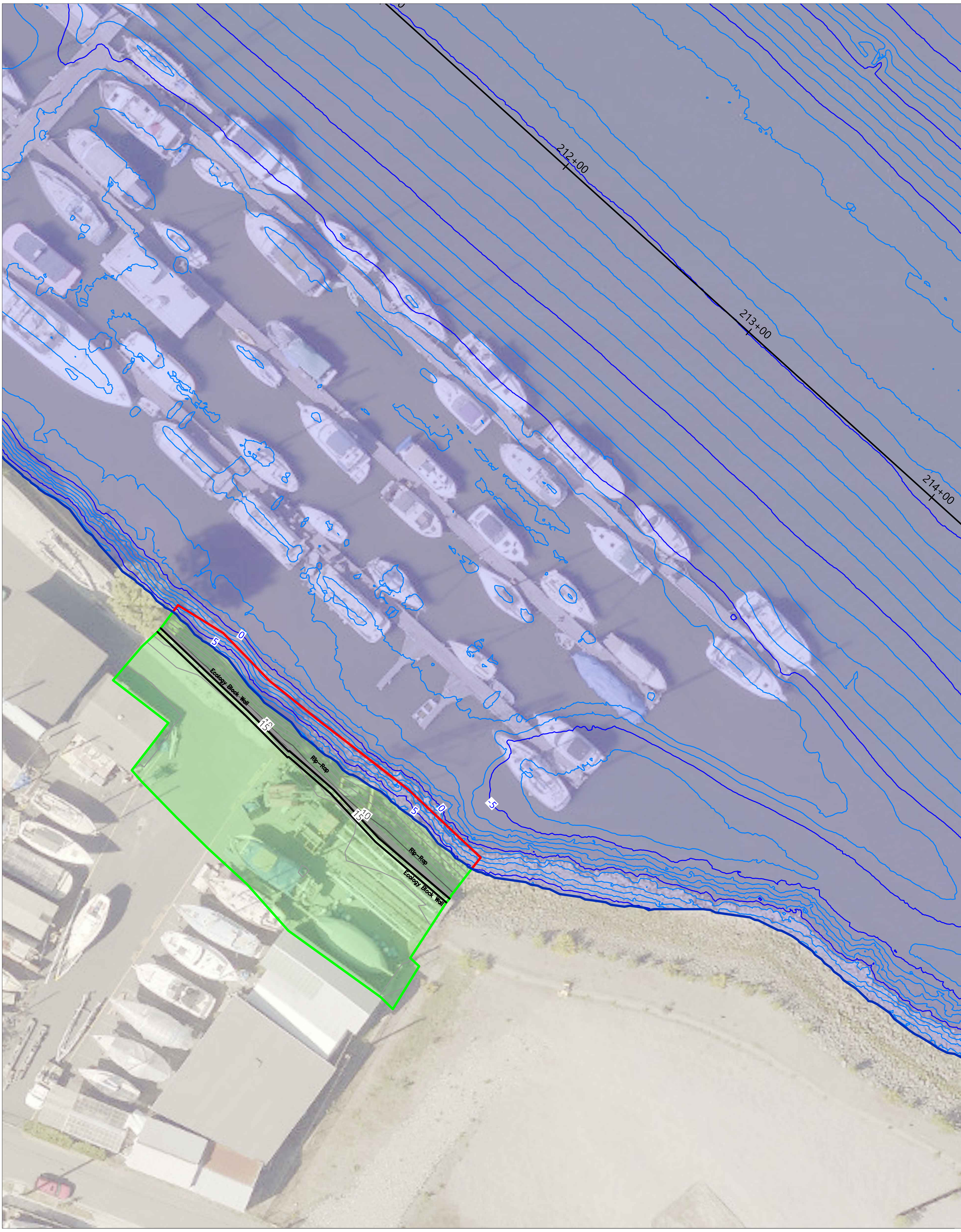
Figure 2-5a. Bathymetric/topographic survey merging overview

100% REMEDIAL DESIGN BASIS OF DESIGN REPORT FOR THE LDW UPPER REACH

JANUARY 16, 2024

Jan 22, 2024 10:40am tgriga \\galia\CAD\Projects\0067-King County\LDW Upper Reach Engineering Services\0067-RP-031 Survey Merge Overview.dwg Figure 2-5a



Source: Topographic survey by True North Land Surveying, Inc. performed between June 30, 2021, and August 10, 2021. Additional survey by True North performed on October 5 and 6, 2022. Bathymetric survey by Northwest Hydro performed between April 18, 2019, and May 15, 2019. Additional survey by Northwest Hydro performed June 2020. LiDAR survey from Puget Sound LiDAR Consortium dated 2016. Composite data updated December 2020 and November 2022.
Horizontal Datum: Washington State Plane, North Zone, NAD83 (2011), U.S. Survey Feet; WSDOT MON GP17005-176 & GP17005-181
Vertical Datum: Mean Lower Low Water (MLLW), MLLW converted from NAVD88 (NAVD88 + 2.34' to MLLW)

Legend:

- 2019/2020 Northwest Hydro bathymetric survey extent
- 2021/2022 True North bank topographic survey extent (not shown where bathymetric survey overrides topo)
- Area where bathymetric survey overrides topographic survey
- Bathymetric survey contours (1' & 5' intervals)
- Topographic survey contours (1' & 5' intervals)

N
0 40
Feet

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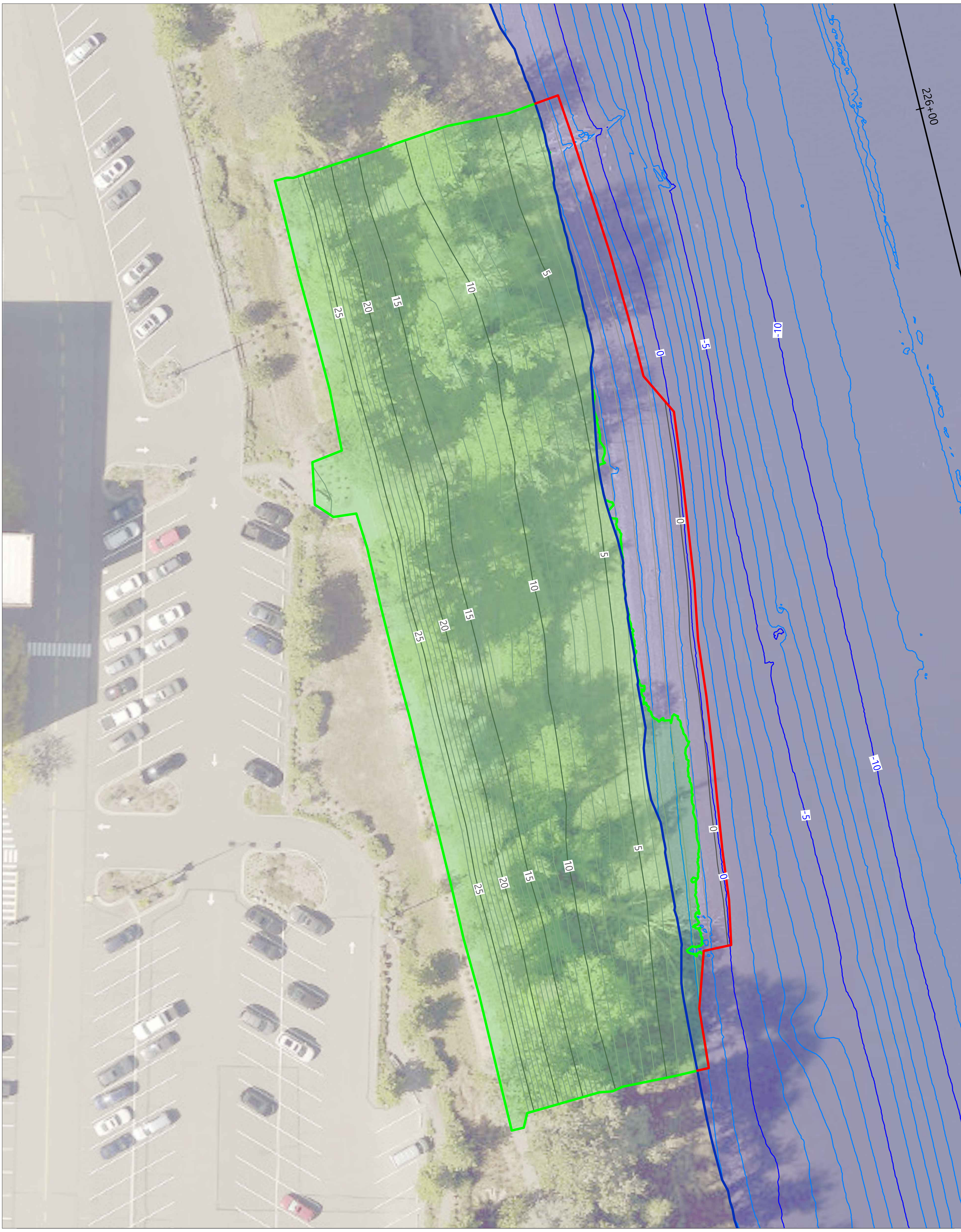
Figure 2-5b. Bathymetric/topographic merging plan

100% REMEDIAL DESIGN BASIS of DESIGN REPORT FOR THE LDW UPPER REACH JANUARY 16, 2024

Jan 22, 2024 10:54am tgriga \\gala\CAD\Projects\0067-King County\LDW Upper Reach Engineering Services\0067-RP-028 BODR Bathy Bank Topo Merge.dwg Figure 2-5b



Source: Topographic survey by True North Land Surveying, Inc. performed between June 30, 2021, and August 10, 2021. Additional survey by True North performed on October 5 and 6, 2022. Bathymetric survey by Northwest Hydro performed between April 18, 2019, and May 15, 2019. Additional survey by Northwest Hydro performed June 2020. LiDAR survey from Puget Sound LiDAR Consortium dated 2016. Composite data updated December 2020 and November 2022.
Horizontal Datum: Washington State Plane, North Zone, NAD83 (2011), U.S. Survey Feet; WSDOT MON GP17005-176 & GP17005-181
Vertical Datum: Mean Lower Low Water (MLLW), MLLW converted from NAVD88 (NAVD88 + 2.34' to MLLW)

Legend:

- 2019/2020 Northwest Hydro bathymetric survey extent
- 2021/2022 True North bank topographic survey extent (not shown where bathymetric survey overrides topo)
- Area where bathymetric survey overrides topographic survey
- Bathymetric survey contours (1' & 5' intervals)
- Topographic survey contours (1' & 5' intervals)

N

0 40

Feet

Figure 2-5c. Bathymetric/topographic merging plan

100% Remedial Design Basis of Design Report for the LDW Upper Reach

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Jan 22, 2024 10:54am tgriga \\gaia\CAD\Projects\0067-King County\LDW Upper Reach Engineering Services\0067-RP-028 BODR Bathy Bank Topo Merge.dwg Figure 2-5c

Source: Topographic survey by True North Land Surveying, Inc. performed between June 30, 2021, and August 10, 2021. Additional survey by True North performed on October 5 and 6, 2022. Bathymetric survey by Northwest Hydro performed between April 18, 2019, and May 15, 2019. Additional survey by Northwest Hydro performed June 2020. LiDAR survey from Puget Sound LiDAR Consortium dated 2016. Composite data updated December 2020 and November 2022.
Horizontal Datum: Washington State Plane, North Zone, NAD83 (2011), U.S. Survey Feet; WSDOT MON GP17005-176 & GP17005-181
Vertical Datum: Mean Lower Low Water (MLLW), MLLW converted from NAVD88 (NAVD88 + 2.34' to MLLW)

Legend:

- 2019/2020 Northwest Hydro bathymetric survey extent
- 2021/2022 True North bank topographic survey extent (not shown where bathymetric survey overrides topo)
- Data gap filled via interpolation
- Area where bathymetric survey overrides topographic survey
- Bathymetric survey contours (1' & 5' intervals)
- Topographic survey contours (1' & 5' intervals)

N

0 40
Feet

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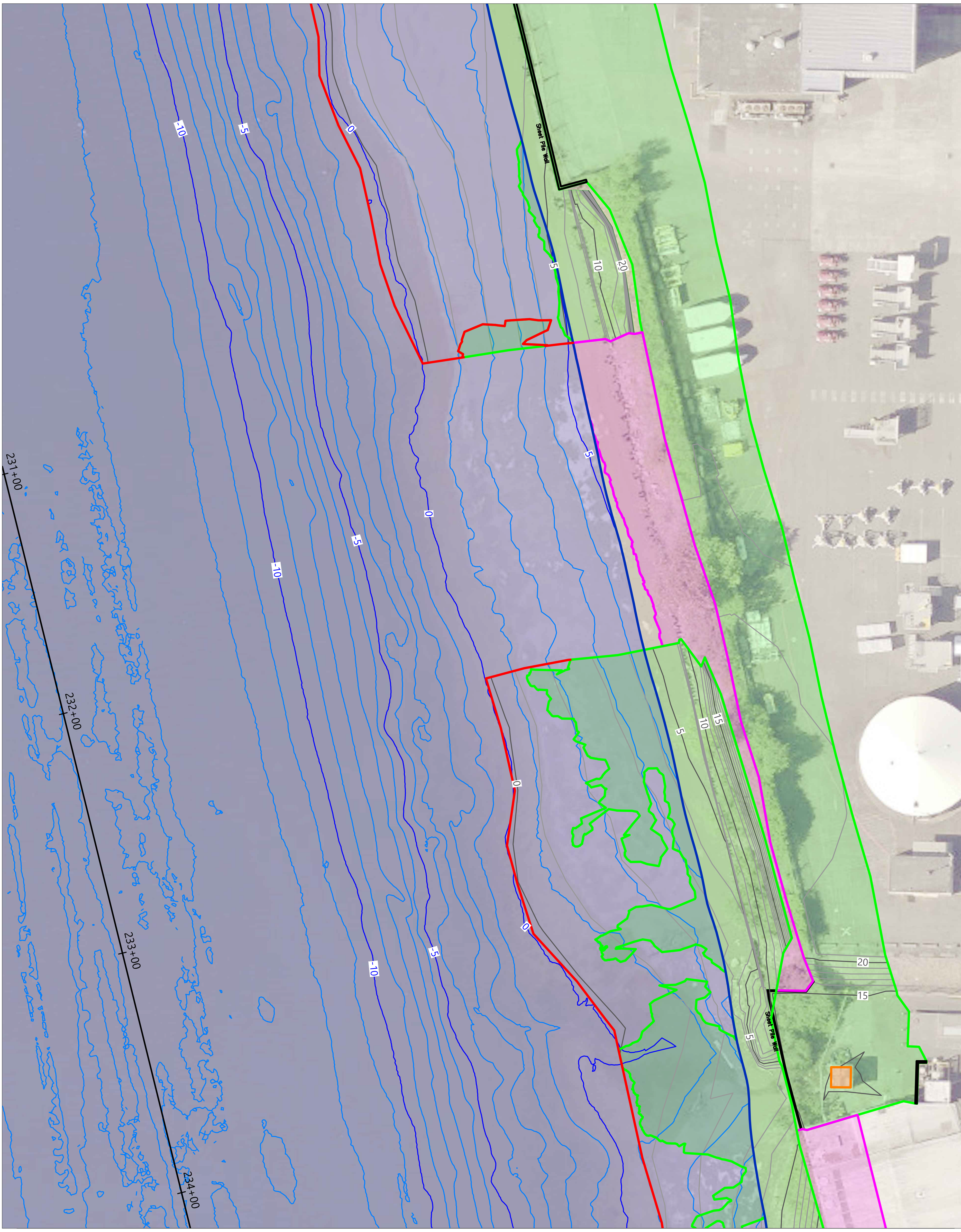
Figure 2-5d. Bathymetric/topographic merging plan

100% REMEDIAL DESIGN BASIS of DESIGN REPORT FOR THE LDW UPPER REACH **JANUARY 16, 2024**



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Horizontal Datum: Washington State Plane, North Zone, NAD83 (2011), U.S. Survey Feet; WSDOT MON GP17005-176 & GP17005-181
Vertical Datum: Mean Lower Low Water (MLLW), MLLW converted from NAVD88 (NAVD88 + 2.34' to MLLW)

Legend:

- 2019/2020 Northwest Hydro bathymetric survey extent
- 2021/2022 True North bank topographic survey extent (not shown where bathymetric survey overrides topo)
- 2016 Puget Sound LiDAR Consortium Survey LiDAR data (used to fill in gap between bathymetric and topographic surveys)
- Data gap filled via interpolation
- Area where bathymetric survey overrides topographic survey
- Bathymetric survey contours (1' & 5' Intervals)
- Topographic survey contours (1' & 5' Intervals)

N

0 40
Feet

Figure 2-5e. Bathymetric/topographic merging plan

100% Remedial Design Basis of Design Report for the LDW Upper Reach

JANUARY 16, 2024

Windward environmental LLC
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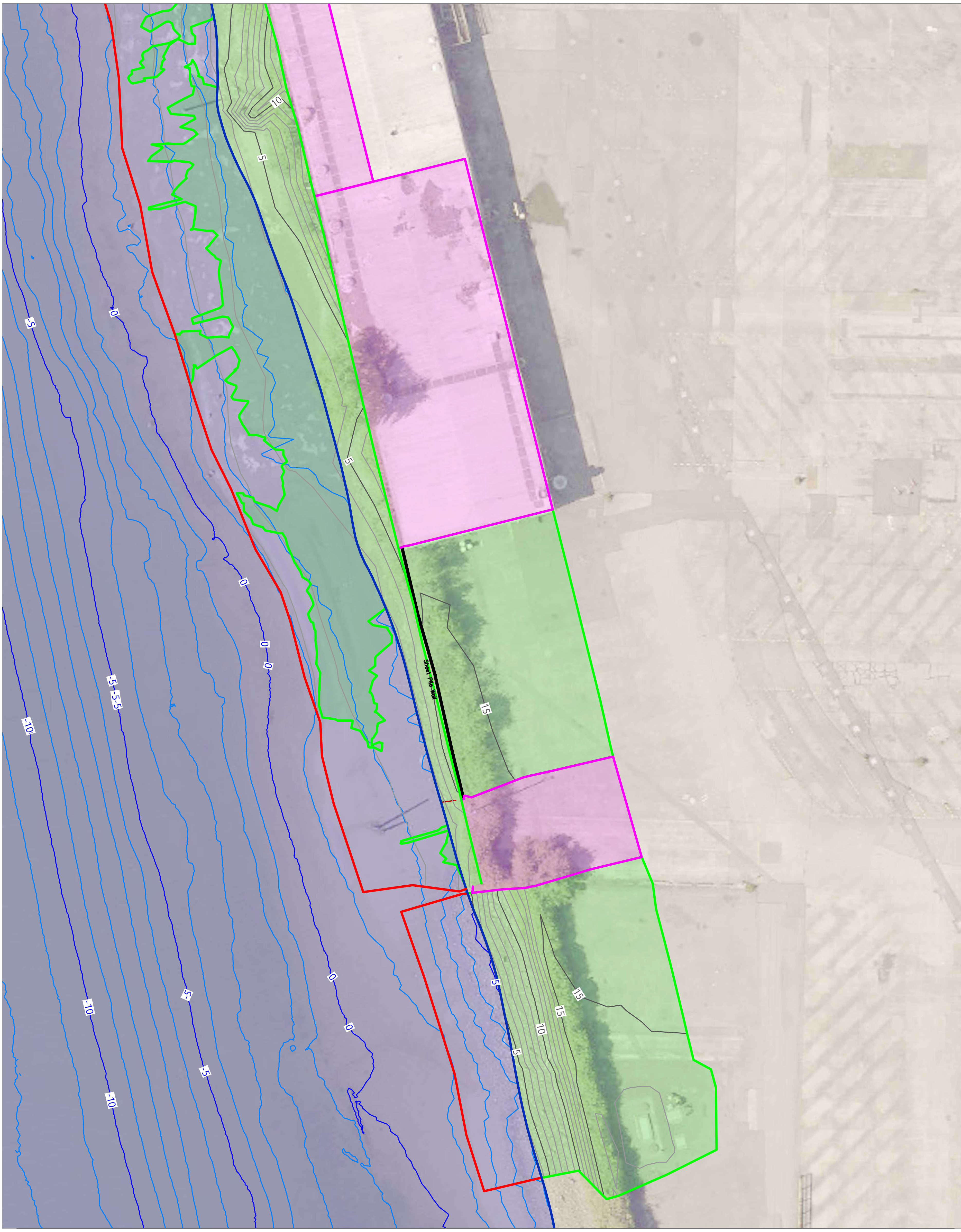

Source: Topographic survey by True North Land Surveying, Inc. performed between June 30, 2021, and August 10, 2021. Additional survey by True North performed on October 5 and 6, 2022. Bathymetric survey by Northwest Hydro performed between April 18, 2019, and May 15, 2019. Additional survey by Northwest Hydro performed June 2020. LiDAR survey from Puget Sound LiDAR Consortium dated 2016. Composite data updated December 2020 and November 2022.
Horizontal Datum: Washington State Plane, North Zone, NAD83 (2011), U.S. Survey Feet; WSDOT MON GP17005-176 & GP17005-181
Vertical Datum: Mean Lower Low Water (MLLW), MLLW converted from NAVD88 (NAVD88 + 2.34' to MLLW)

Legend:

- 2019/2020 Northwest Hydro bathymetric survey extent
- 2021/2022 True North bank topographic survey extent (not shown where bathymetric survey overrides topo)
- 2016 Puget Sound LiDAR Consortium survey LiDAR data (used to fill in gap between bathymetric and topographic surveys)
- Area where bathymetric survey overrides topographic survey
- Bathymetric survey contours (1' & 5' intervals)
- Topographic survey contours (1' & 5' intervals)

N

0 40
Feet

\\gaia\CAD\Projects\0067-King County\LDW Upper Reach Engineering Services\0067-RP-028 BODR Bathy Bank Topo Merge.dwg Figure 2-5f

Jan 22, 2024 11:00am tgriga

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Figure 2-5f. Bathymetric/topographic merging plan

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Source: Topographic survey by True North Land Surveying, Inc. performed between June 30, 2021, and August 10, 2021. Additional survey by True North performed on October 5 and 6, 2022. Bathymetric survey by Northwest Hydro performed between April 18, 2019, and May 15, 2019. Additional survey by Northwest Hydro performed June 2020. LiDAR survey from Puget Sound LiDAR Consortium dated 2016. Composite data updated December 2020 and November 2022.
Horizontal Datum: Washington State Plane, North Zone, NAD83 (2011), U.S. Survey Feet; WSDOT MON GP17005-176 & GP17005-181
Vertical Datum: Mean Lower Low Water (MLLW), MLLW converted from NAVD88 (NAVD88 + 2.34' to MLLW)

Legend:

- 2019/2020 Northwest Hydro bathymetric survey extent
- 2021/2022 True North bank topographic survey extent (not shown where bathymetric survey overrides topo)
- Data gap filled via interpolation
- Area where bathymetric survey overrides topographic survey
- Bathymetric survey contours (1' & 5' intervals)
- Topographic survey contours (1' & 5' intervals)

N

0 50
Feet

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Figure 2-5g. Bathymetric/topographic merging plan

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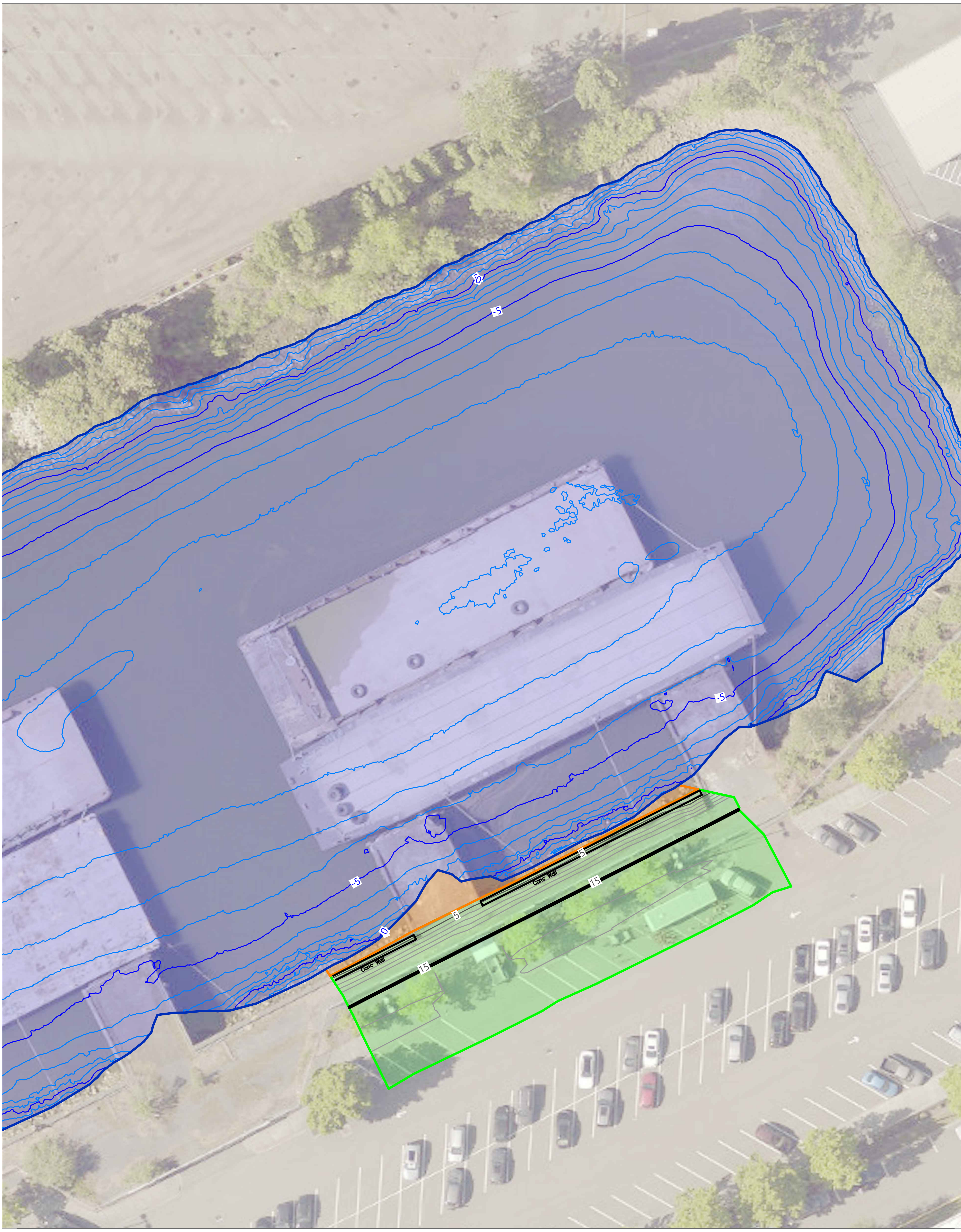
Jan 22, 2024 11:01am tgriga \\gaia\CAD\Projects\0067-King County\LDW Upper Reach Engineering Services\0067-RP-028 BODR Bathy Bank Topo Merge.dwg Figure 2-5g



Source: Topographic survey by True North Land Surveying, Inc. performed between June 30, 2021, and August 10, 2021. Additional survey by True North performed on October 5 and 6, 2022. Bathymetric survey by Northwest Hydro performed between April 18, 2019, and May 15, 2019. Additional survey by Northwest Hydro performed June 2020. LiDAR survey from Puget Sound LiDAR Consortium dated 2016. Composite data updated December 2020 and November 2022.
Horizontal Datum: Washington State Plane, North Zone, NAD83 (2011), U.S. Survey Feet; WSDOT MON GP17005-176 & GP17005-181
Vertical Datum: Mean Lower Low Water (MLLW), MLLW converted from NAVD88 (NAVD88 + 2.34' to MLLW)

Legend:

- 2019/2020 Northwest Hydro bathymetric survey extent
- 2021/2022 True North bank topographic survey extent (not shown where bathymetric survey overrides topo)
- Data gap filled via interpolation
- Area where bathymetric survey overrides topographic survey
- Bathymetric survey contours (1' & 5' intervals)
- Topographic survey contours (1' & 5' intervals)

N

0 40

Feet

Figure 2-5h. Bathymetric/topographic merging plan

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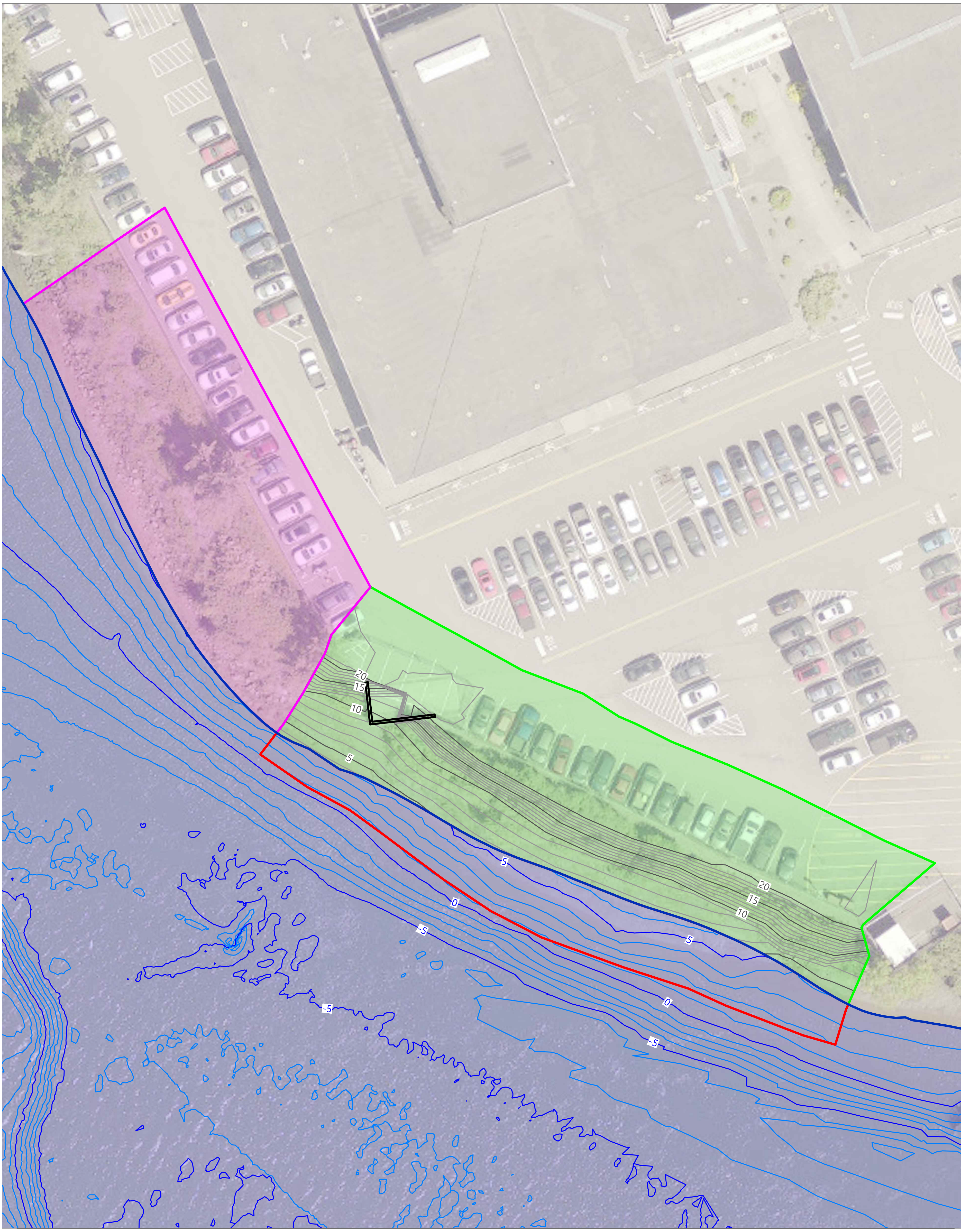
\\gala\CAD\Projects\0067-King County\LDW Upper Reach Engineering Services\0067-RP-028 BODR Bathy Bank Topo Merge.dwg Figure 2-5h

Jan 22, 2024 11:01am tgriga



Source: Topographic survey by True North Land Surveying, Inc. performed between June 30, 2021, and August 10, 2021. Additional survey by True North performed on October 5 and 6, 2022. Bathymetric survey by Northwest Hydro performed between April 18, 2019, and May 15, 2019. Additional survey by Northwest Hydro performed June 2020. LiDAR survey from Puget Sound LiDAR Consortium dated 2016. Composite data updated December 2020 and November 2022.
Horizontal Datum: Washington State Plane, North Zone, NAD83 (2011), U.S. Survey Feet; WSDOT MON GP17005-176 & GP17005-181
Vertical Datum: Mean Lower Low Water (MLLW), MLLW converted from NAVD88 (NAVD88 + 2.34' to MLLW)

Legend:

- 2019/2020 Northwest Hydro bathymetric survey extent
- 2021/2022 True North bank topographic survey extent (not shown where bathymetric survey overrides topo)
- 2016 Puget Sound LiDAR Consortium survey LiDAR data (used to fill in gap between bathymetric and topographic surveys)
- Area where bathymetric survey overrides topographic survey
- Bathymetric survey contours (1' & 5' intervals)
- Topographic survey contours (1' & 5' intervals)

N

0 40
Feet

Jan 22, 2024 11:01am tgriga \\gaia\CAD\Projects\0067-King County\LDW Upper Reach Engineering Services\0067-RP-028 BODR Bathy Bank Topo Merge.dwg Figure 2-5i

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Figure 2-5i. Bathymetric/topographic merging plan

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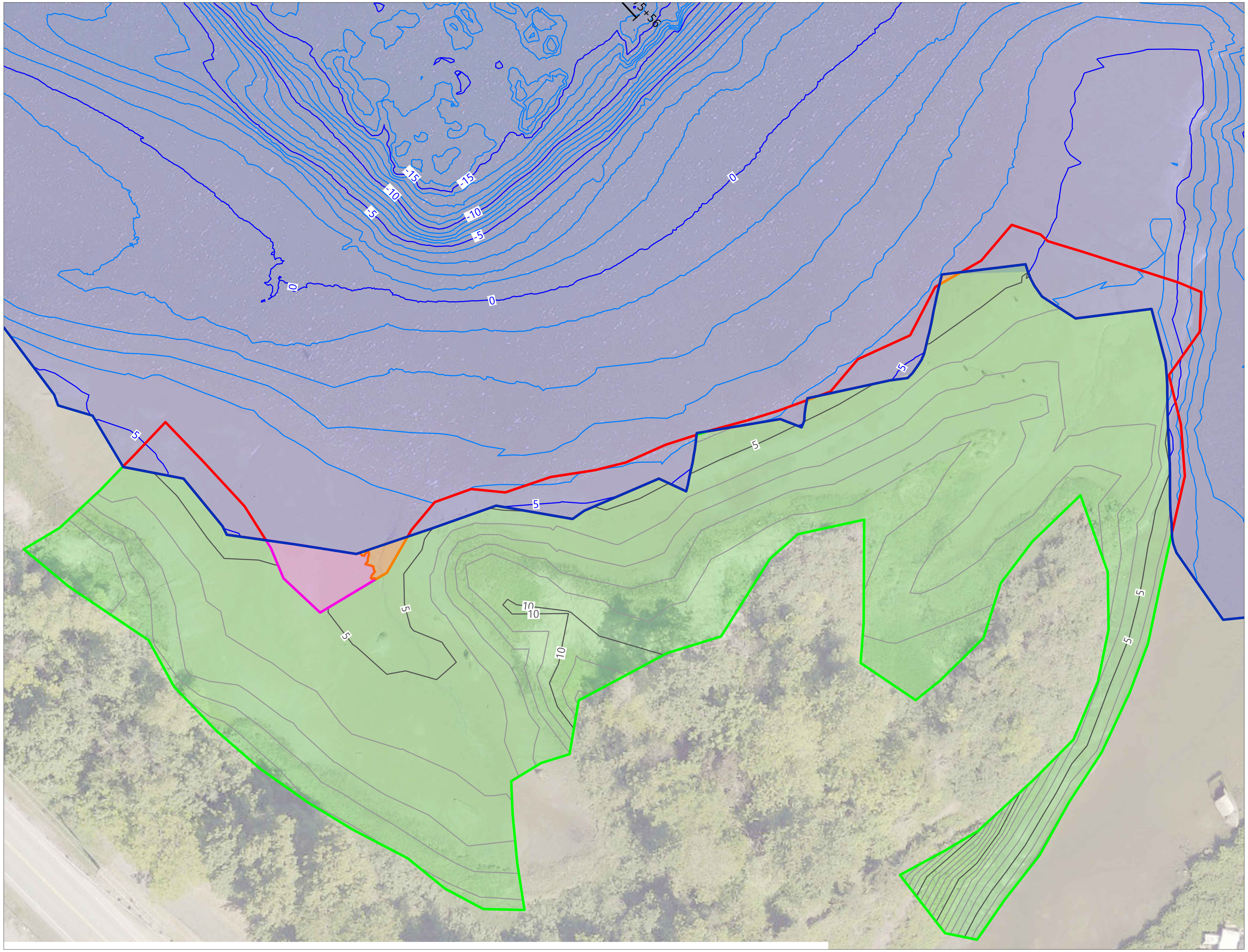

Legend:

- 2019/2020 Northwest Hydro bathymetric survey extent
- 2021/2022 True North bank topographic survey extent (not shown where bathymetric survey overrides topo)
- 2016 Puget Sound LiDAR Consortium Survey LiDAR data (used to fill in gap between bathymetric and topographic surveys)
- Area without PDI survey data filled via interpolation
- Area where bathymetric survey overrides topographic survey
- Bathymetric survey contours (1' & 5' intervals)
- Topographic survey contours (1' & 5' intervals)

Source: Topographic survey by True North Land Surveying, Inc. performed between June 30, 2021, and August 10, 2021. Additional survey by True North performed on October 5 and 6, 2022. Bathymetric survey by Northwest Hydro performed between April 18, 2019, and May 15, 2019. Additional survey by Northwest Hydro performed June 2020. LiDAR survey from Puget Sound LiDAR Consortium dated 2016. Composite data updated December 2020 and November 2022.
Horizontal Datum: Washington State Plane, North Zone, NAD83 (2011), U.S. Survey Feet; WSDOT MON GP17005-176 & GP17005-181
Vertical Datum: Mean Lower Low Water (MLLW), MLLW converted from NAVD88 (NAVD88 + 2.34' to MLLW)

N

0 50
Feet

Figure 2-5j. Bathymetric/topographic merging plan

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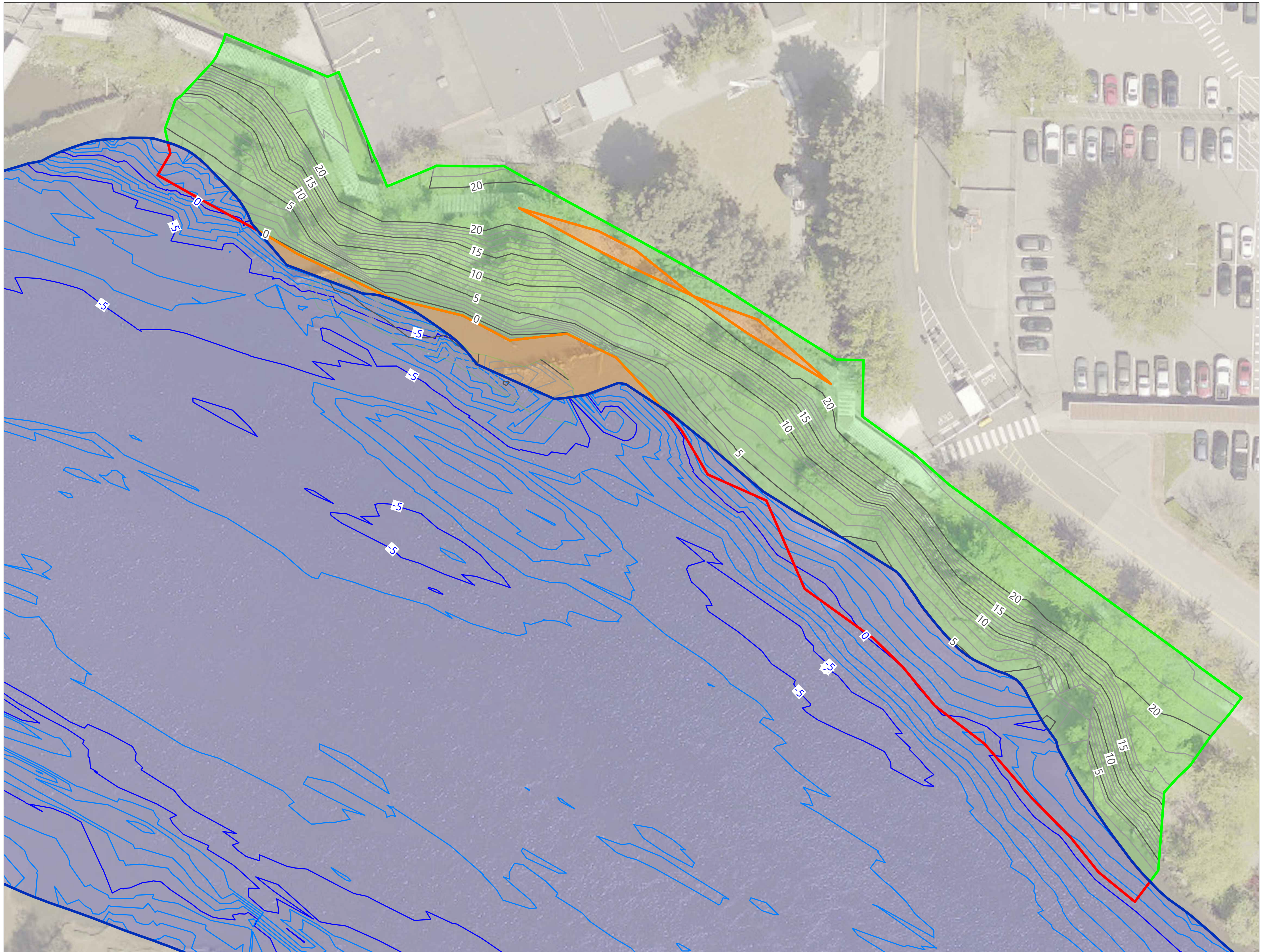

Legend:

- 2019/2020 Northwest Hydro bathymetric survey extent
- 2021/2022 True North bank topographic survey extent (not shown where bathymetric survey overrides topo)
- Area without PDI survey data filled via interpolation
- Area where bathymetric survey overrides topographic survey
- Bathymetric survey contours (1' & 5' intervals)
- Topographic survey contours (1' & 5' intervals)

Source: Topographic survey by True North Land Surveying, Inc. performed between June 30, 2021, and August 10, 2021. Additional survey by True North performed on October 5 and 6, 2022. Bathymetric survey by Northwest Hydro performed between April 18, 2019, and May 15, 2019. Additional survey by Northwest Hydro performed June 2020. LiDAR survey from Puget Sound LiDAR Consortium dated 2016. Composite data updated December 2020 and November 2022.
Horizontal Datum: Washington State Plane, North Zone, NAD83 (2011), U.S. Survey Feet; WSDOT MON GP17005-176 & GP17005-181
Vertical Datum: Mean Lower Low Water (MLLW), MLLW converted from NAVD88 (NAVD88 + 2.34' to MLLW)

N

0 50
Feet

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Figure 2-5k. Bathymetric/topographic merging plan

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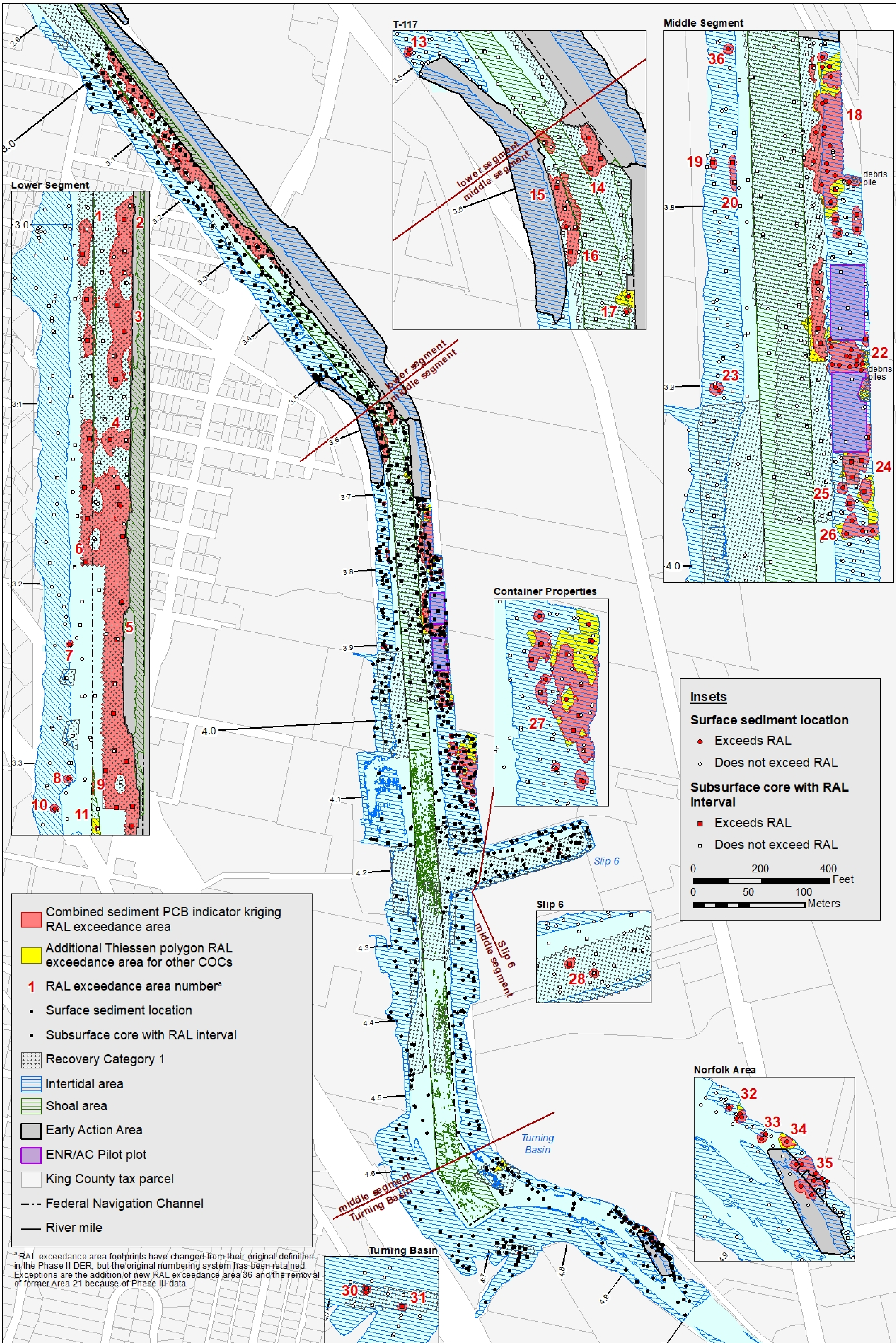
\\gala\CAD\Projects\0067-King County\LDW Upper Reach Engineering Services\0067-RP-028 BODR Bathy Bank Topo Merge.dwg Figure 2-5k
Jan 22, 2024 11:02am tgriga



Prepared by ClaireC, 1/19/2024; \\mink\company\Projects\Duwamish AOC4\GIS\Maps and Analyses\Remedial Design\BODR\Fig 04-1a 7216 Combined PhII REAs w ThPolys.mxd

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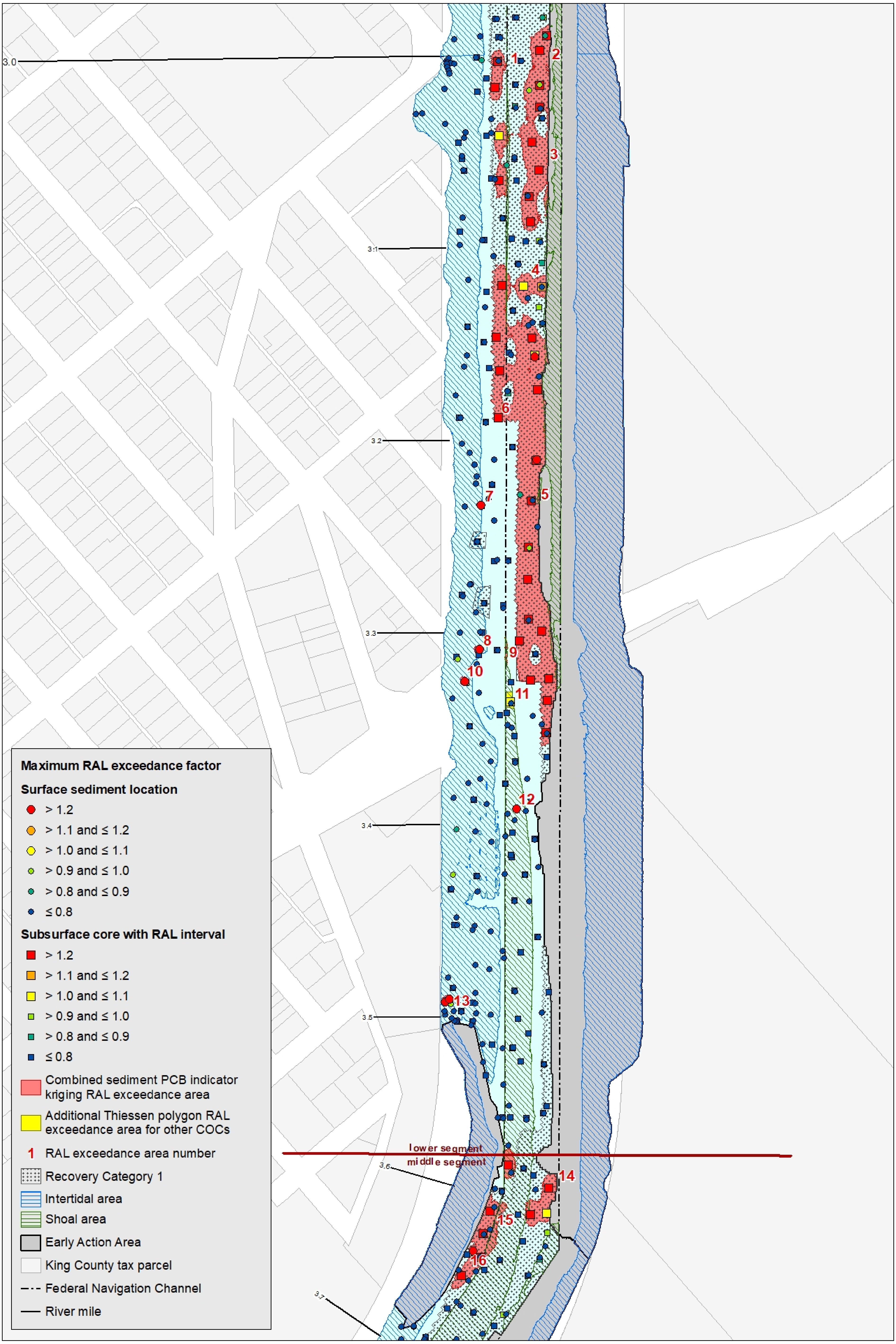
N

0 500 1,000 Feet

0 200 400 Meters

Figure 4-1a. Total PCB combined surface and subsurface sediment indicator kriging interpolation with Thiessen polygons for other COCs



Prepared by ClaireC, 1/19/2024; \\mink\company\Projects\Duwamish AOC4\GIS\Maps and Analyses\Remedial Design\BODR\Fig 04-1b 7216 Combined PhII REAs w Near RALS 1.mxd

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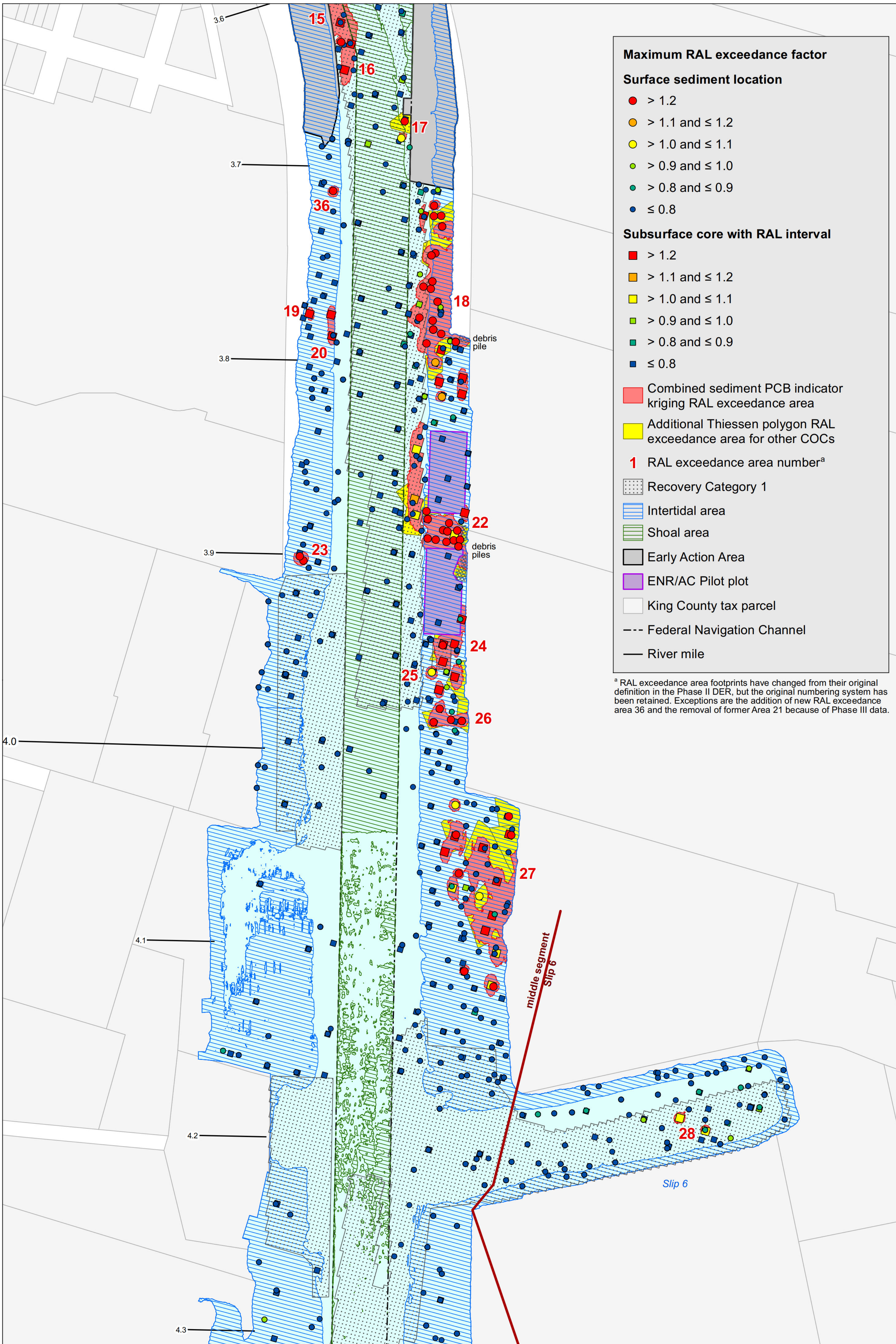
Figure 4-1b. Combined RAL exceedance areas (PCB interpolation and Thiessen polygons for other COCs) with RAL exceedances, RMs 3.0 to 3.7



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N
0 200 400 Feet
0 50 100 Meters

Figure 4-1c. Combined RAL exceedance areas (PCB interpolation and Thiessen polygons for other COCs) with RAL exceedances, RMs 3.7 to 4.3

100% Remedial Design Basis of Design Report for the LDW Upper Reach — January 16, 2024

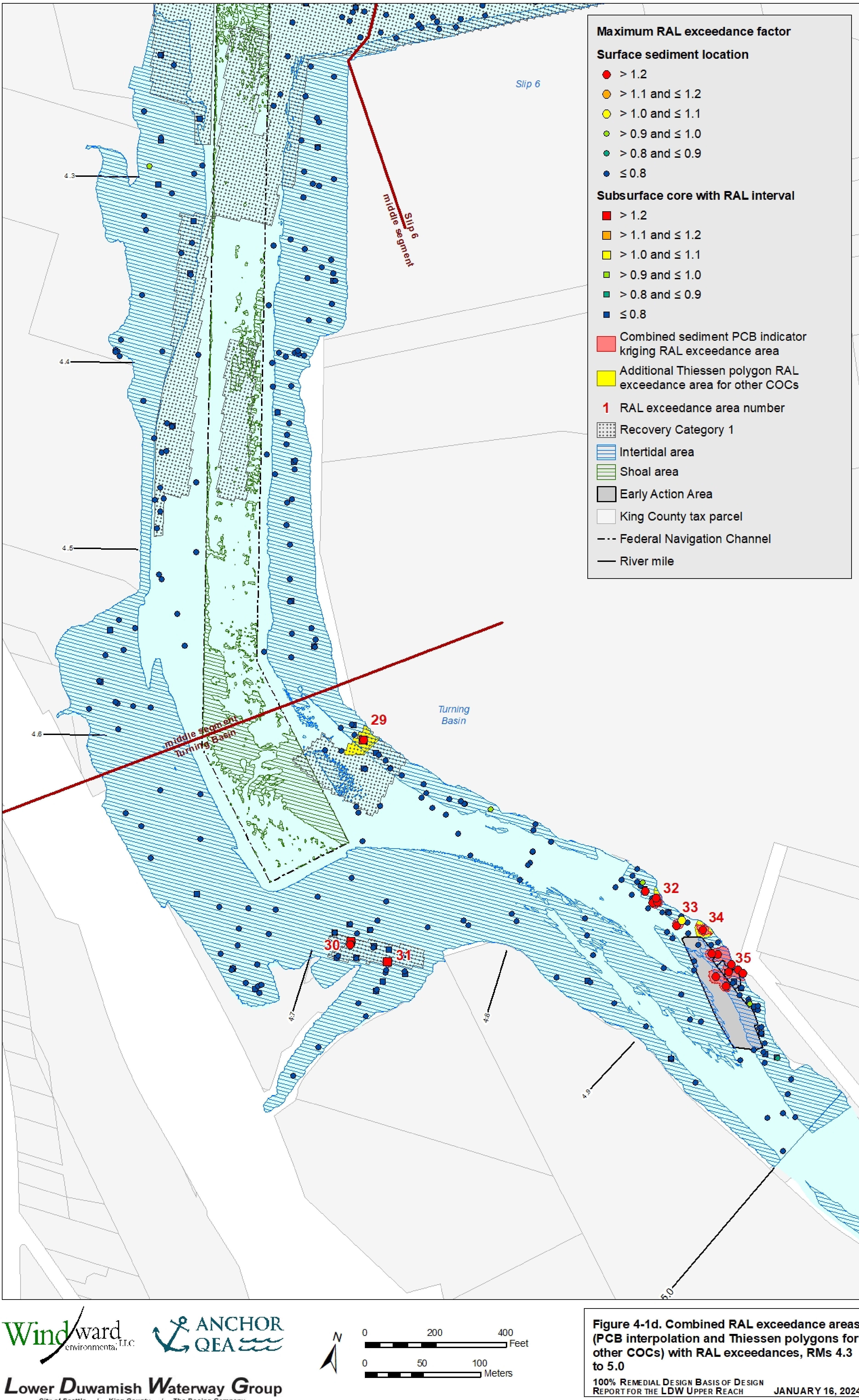

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Figure 4-1d. Combined RAL exceedance areas (PCB interpolation and Thiessen polygons for other COCs) with RAL exceedances, RMs 4.3 to 5.0

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JANUARY 16, 2024

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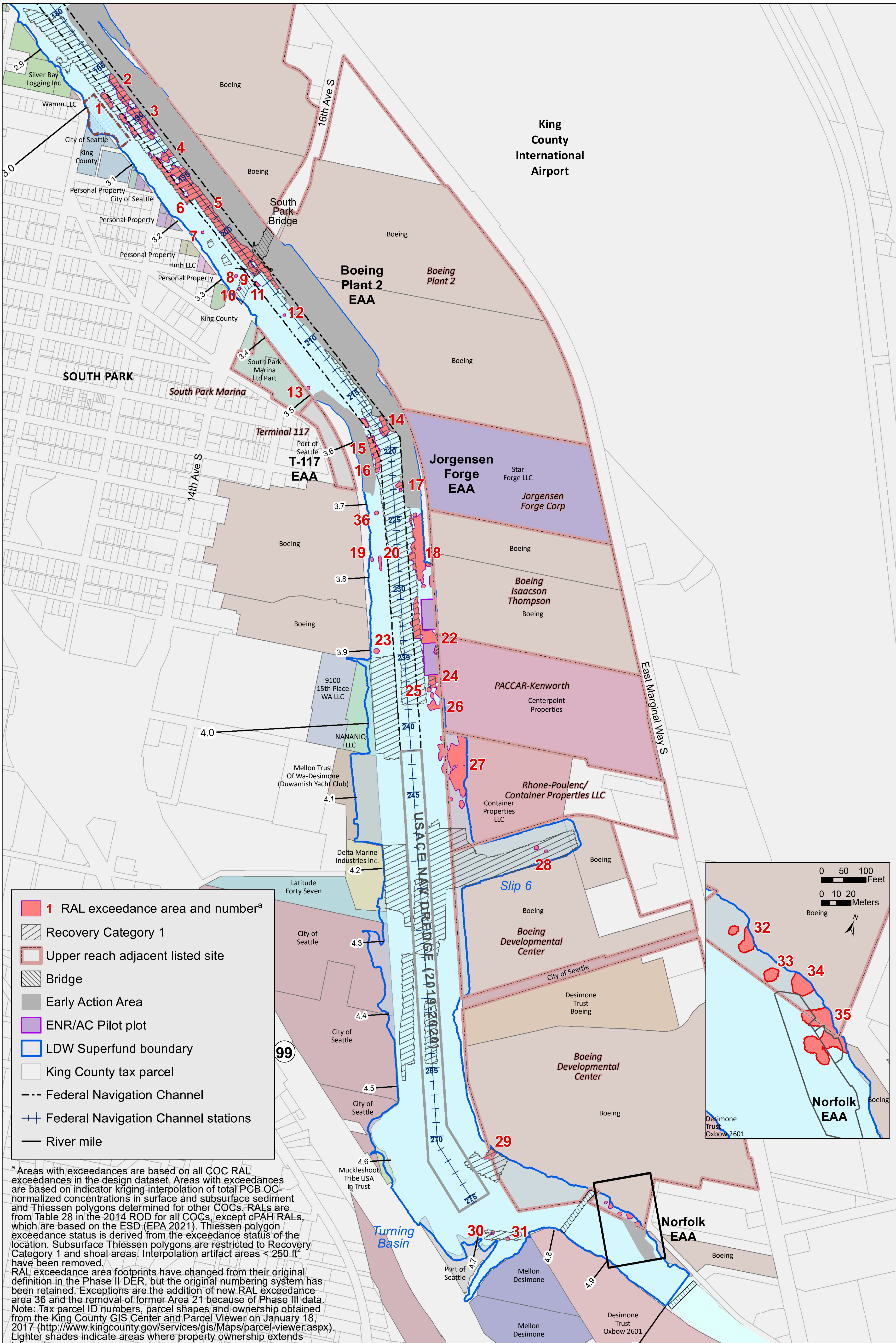

[a] Areas with exceedances are based on all COC RAL exceedances in the design dataset. Areas with exceedances are based on indicator kriging interpolation of total PCB OC-normalized concentrations in surface and subsurface sediment and Thiessen polygons determined for other COCs. RALs are from Table 28 in the 2014 ROD for all COCs, except cPAH RALs, which are based on the ESD (EPA 2021). Thiessen polygon exceedance status is derived from the exceedance status of the location. Subsurface Thiessen polygons are restricted to Recovery Category 1 and shoal areas. Interpolation artifact areas < 250 ft^2 have been removed.
RAL exceedance area footprints have changed from their original definition in the Phase II DER, but the original numbering system has been retained. Exceptions are the addition of new RAL exceedance area 36 and the removal of former Area 21 because of Phase III data.
Note: Tax parcel ID numbers, parcel shapes and ownership obtained from the King County GIS Center and Parcel Viewer on January 18, 2017 (http://www.kingcounty.gov/services/gis/Maps/parcel-viewer.aspx). Lighter shades indicate areas where property ownership extends into water.

0 500 1,000 Feet
0 200 400 Meters

Figure 4-2. RAL exceedance areas in the upper reach

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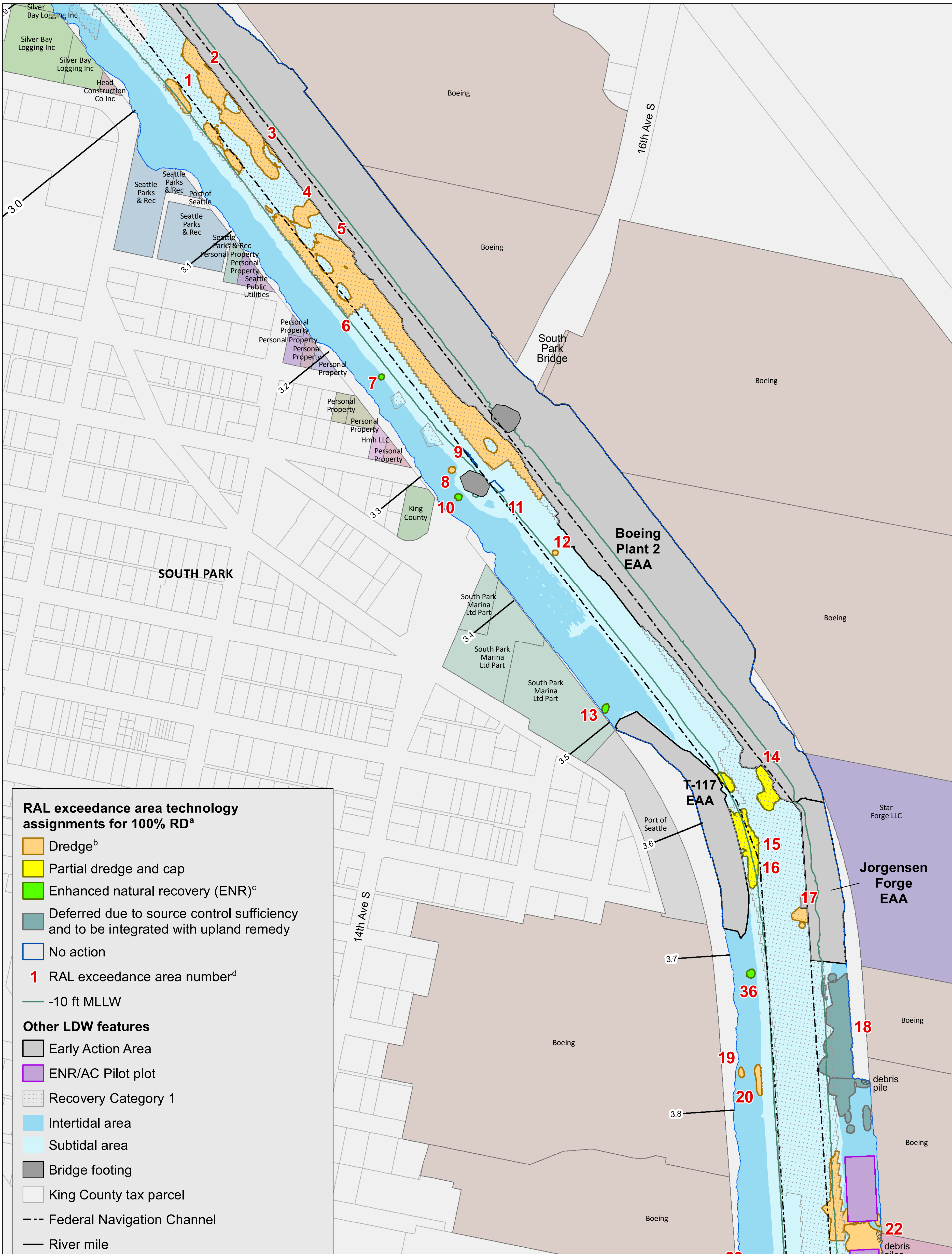
Prepared by ClaireC, 1/19/2024; W:\Projects\Duwamish AOC4\GIS\Maps and Analyses\Remedial Design\BODR\Fig 04-2 7259 Prelim RAL exceedance areas wPropOwnership.mxd



[a] ROD Table 28 is the source of RALs for COCs that were used to calculate exceedance areas, except for cPAHs which use the cPAH ESD RALs (EPA 2021). PDI data are compared to the ROD cPAH RALs in Appendix B. Technology assignment options were based on ROD Figure 19 and revised Figure 20 as detailed in Section 5.
[b] Dredged areas will be backfilled in habitat areas (i.e. -10 ft MLLW and above per ROD footnote 24).
[c] ENR placement will occur in dredging offsets from structures and over armored slopes within RAL exceedance areas, as described in Table 5-1 and depicted on the preliminary drawings.
[d] RAL exceedance area footprints have changed from their original definition in the Phase II DER, but the original numbering system has been retained. Exceptions are the addition of new RAL exceedance area 36 and the removal of former Area 21 because of Phase III data.

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N
0 250 500 Feet
0 100 200 Meters

Figure 5-1a. Technology assignment by RAL exceedance area, RMs 3.0 to 4.0

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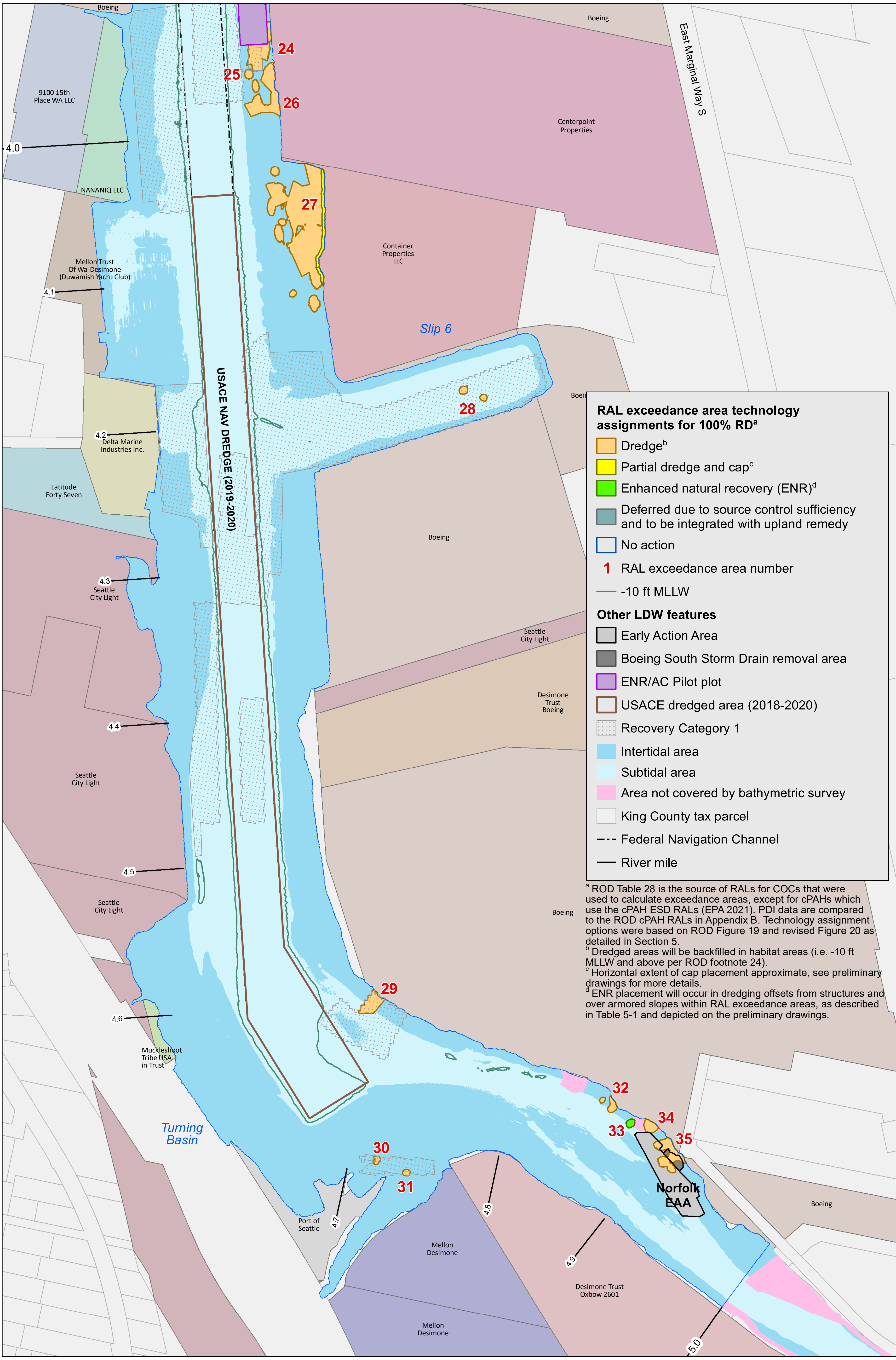
Prepared by ClaireC, 1/19/2024; W:\Projects\Duwamish AOC4\GIS\Maps and Analyses\Remedial Design\BODR\Fig 05-1a 7392 REA tech assignments RM 3-4.mxd



[a] ROD Table 28 is the source of RALs for COCs that were used to calculate exceedance areas, except for cPAHs which use the cPAH ESD RALs (EPA 2021). PDI data are compared to the ROD cPAH RALs in Appendix B. Technology assignment options were based on ROD Figure 19 and revised Figure 20 as detailed in Section 5.

[b] Dredged areas will be backfilled in habitat areas (i.e. -10 ft MLLW and above per ROD footnote 24).

[c] Horizontal extent of cap placement approximate, see preliminary drawings for more details.

[d] ENR placement will occur in dredging offsets from structures and over armored slopes within RAL exceedance areas, as described in Table 5-1 and depicted on the preliminary drawings.

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Figure 5-1b. Technology assignment by RAL exceedance area, RMs 4.0 to 5.0

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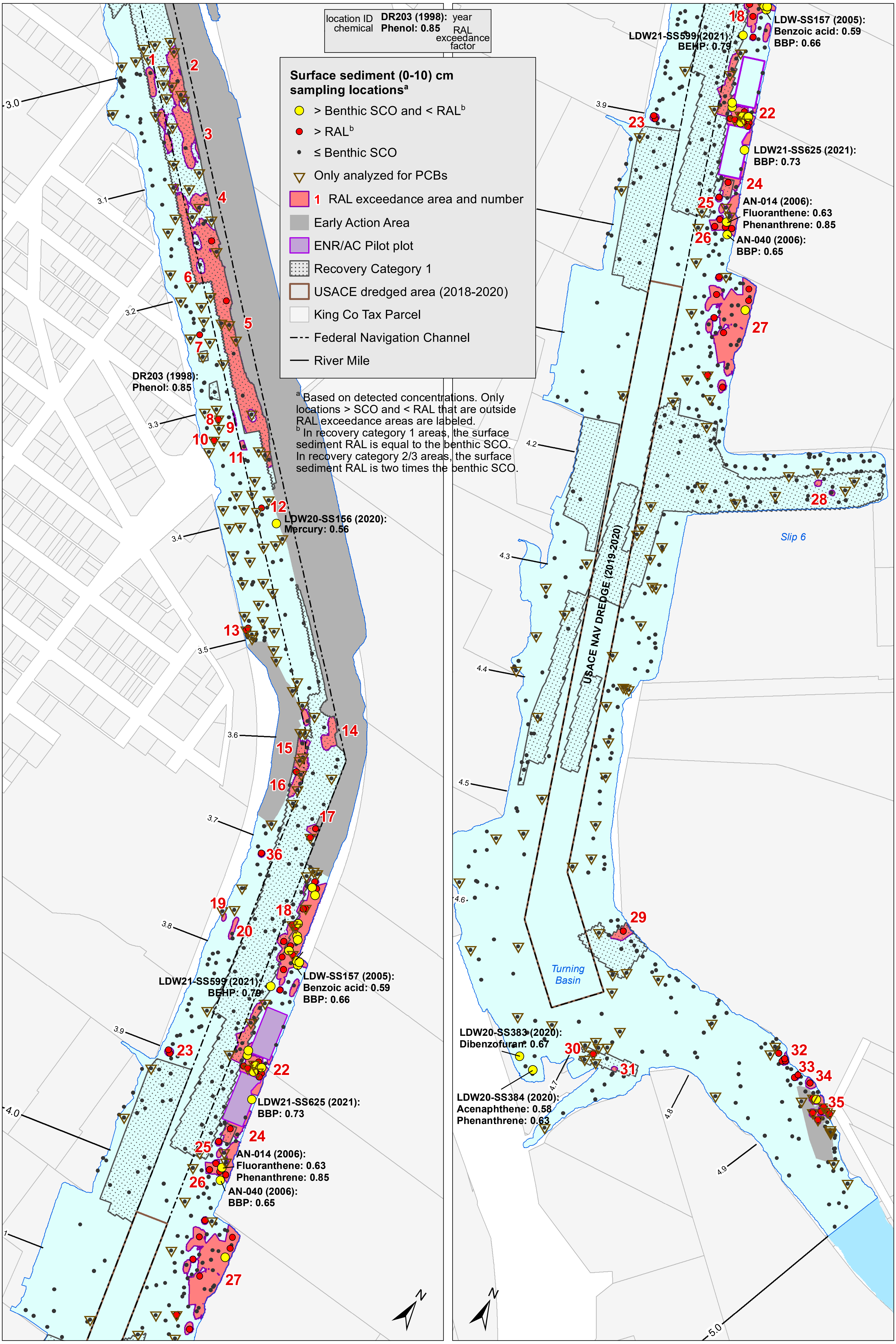

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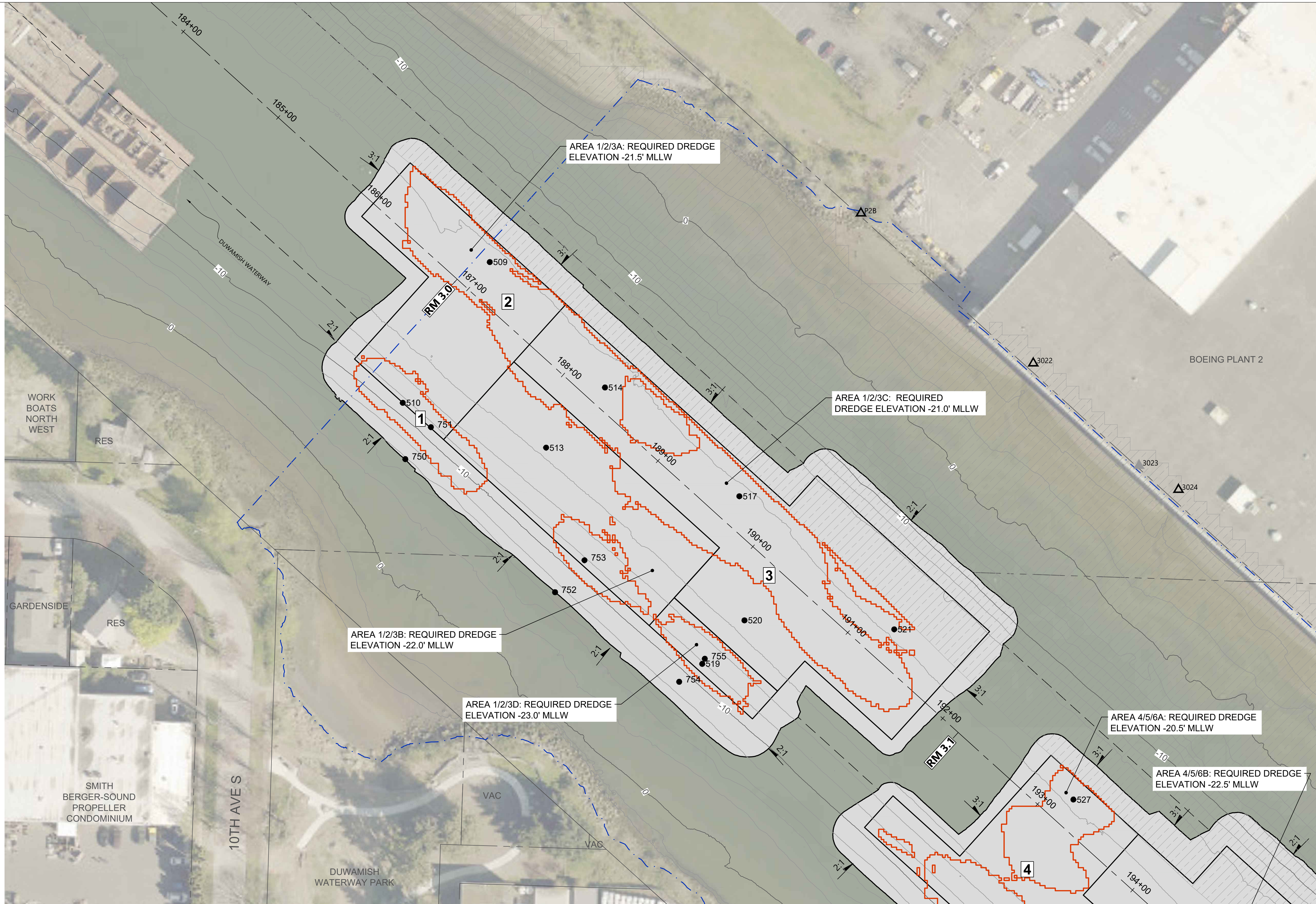
0 500 1,000 Feet
0 100 200 Meters
Scale is the same for each inset map

Figure 5-2. Locations in the upper reach with surface sediment concentrations > benthic SCO and < RAL



LEGEND:

- USACE CHANNEL CENTERLINE AND STATIONING
- FEDERAL NAVIGATION CHANNEL
- RM 3.0 RIVER MILE LABEL
- EARLY ACTION AREA
- LDW UPPER REACH APPROXIMATE BOUNDARY
- KING COUNTY SHORELINE HABITAT RESTORATION APPROXIMATE EXTENTS
- 2018 BATHYMETRIC CONTOURS (2' & 10' INTERVALS)
- OUTFALL LOCATION (ACTIVE)
- OUTFALL LOCATION (ABANDONED/INACTIVE)
- OUTFALL LOCATION (REMOVED)
- EXISTING PILE (APPROXIMATE LOCATION)
- EXISTING DOLPHIN (APPROXIMATE LOCATION)
- VERTICAL SAMPLE LOCATION
- 2 RAL EXCEEDANCE AREA NUMBER
- RAL EXCEEDANCE AREA (5/26/23)
- REMEDIAL ACTION AREA: DREDGING

N

0 40 80

SCALE IN FEET

NOTES:

1. HORIZONTAL DATUM: WASHINGTON STATE PLANE NORTH ZONE, NAD83 (2011), U.S. SURVEY FEET
2. VERTICAL DATUM: MLLW
3. AERIAL IMAGE BY ESRI

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Figure 6-1a. RAA development (RMs 2.93 to 3.15)

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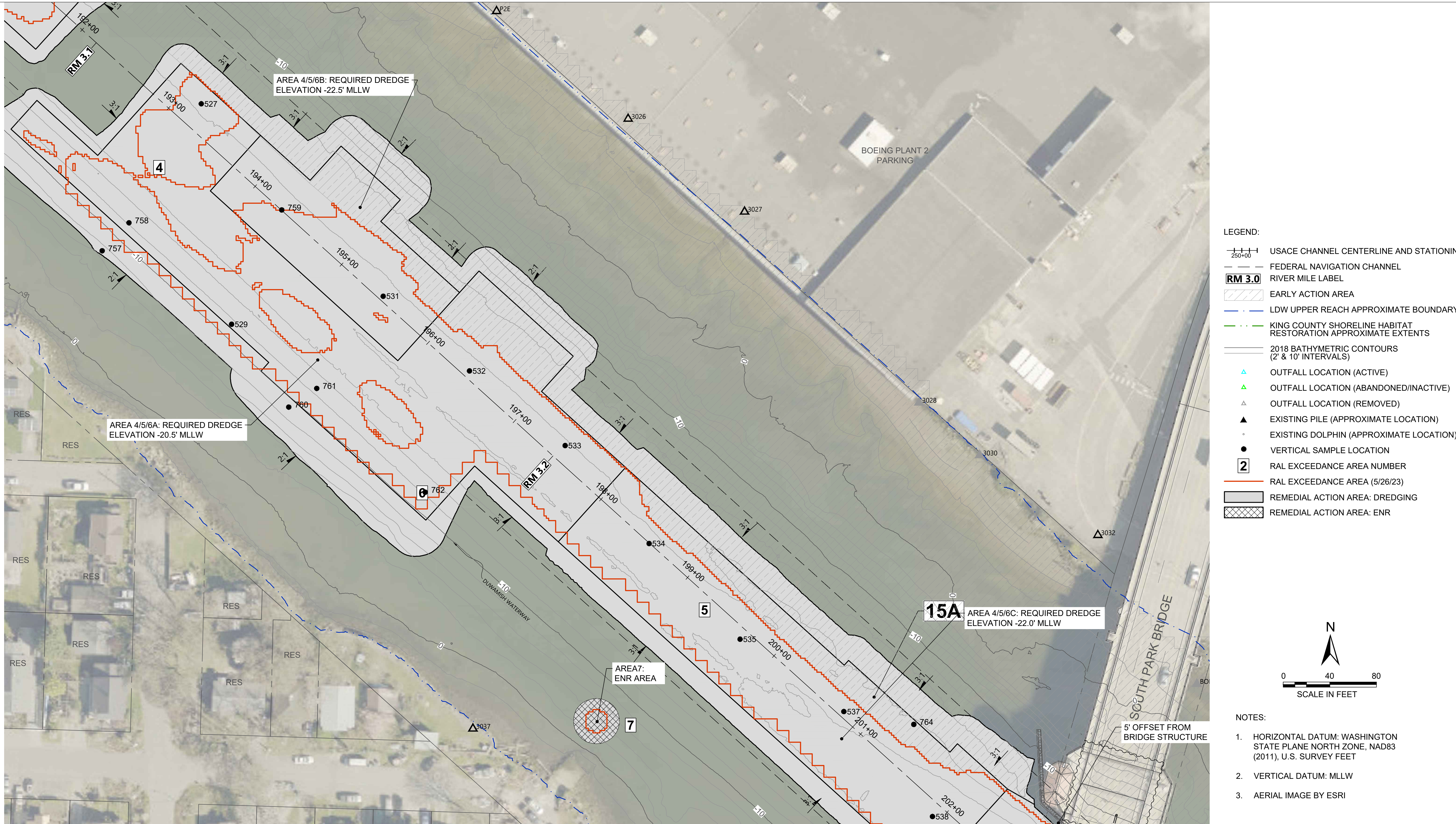
Jan 22, 2024 10:14am tgriga \\gala\CAD\Projects\0067-King County\LDW Upper Reach Engineering Services\0067-RP-034 LDWUR BODR Dredge.dwg Figure 6-1a



NOTES:

1. HORIZONTAL DATUM: WASHINGTON STATE PLANE NORTH ZONE, NAD83 (2011), U.S. SURVEY FEET
2. VERTICAL DATUM: MLLW
3. AERIAL IMAGE BY ESRI

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Figure 6-1b. RAA development (RMs 3.09 to 3.29)

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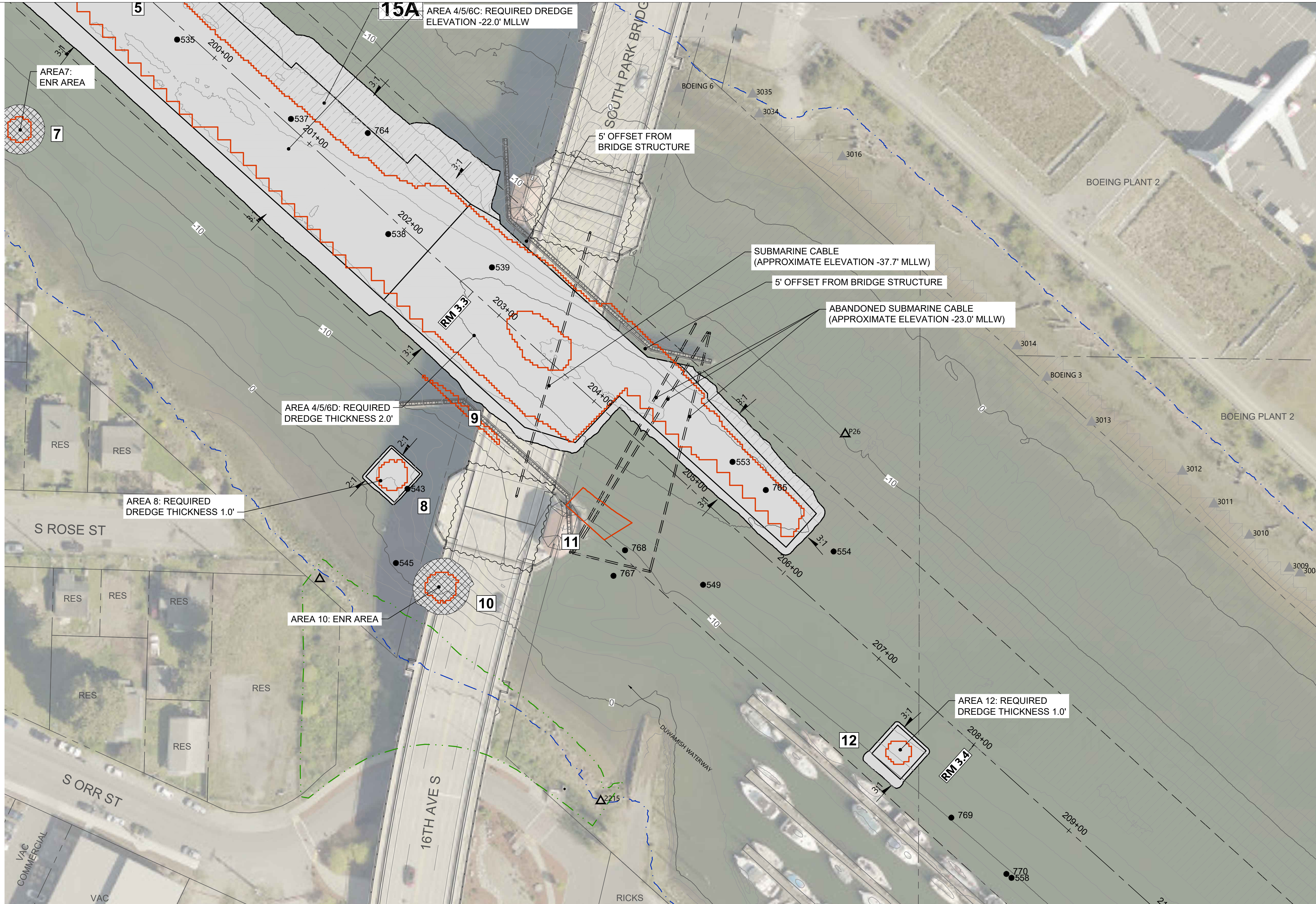

LEGEND:

- USACE CHANNEL CENTERLINE AND STATIONING (250+00)
- FEDERAL NAVIGATION CHANNEL
- RM 3.0 — RIVER MILE LABEL
- EARLY ACTION AREA
- LDW UPPER REACH APPROXIMATE BOUNDARY
- KING COUNTY SHORELINE HABITAT RESTORATION APPROXIMATE EXTENTS
- 2018 BATHYMETRIC CONTOURS (2' & 10' INTERVALS)
- OUTFALL LOCATION (ACTIVE)
- OUTFALL LOCATION (ABANDONED/INACTIVE)
- OUTFALL LOCATION (REMOVED)
- EXISTING PILE (APPROXIMATE LOCATION)
- EXISTING DOLPHIN (APPROXIMATE LOCATION)
- VERTICAL SAMPLE LOCATION
- 2 — RAL EXCEEDANCE AREA NUMBER
- RAL EXCEEDANCE AREA (5/26/23)
- REMEDIAL ACTION AREA: DREDGING
- REMEDIAL ACTION AREA: ENR

N

0 40 80

SCALE IN FEET

NOTES:

1. HORIZONTAL DATUM: WASHINGTON STATE PLANE NORTH ZONE, NAD83 (2011), U.S. SURVEY FEET
2. VERTICAL DATUM: MLLW
3. AERIAL IMAGE BY ESRI

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Figure 6-1c. RAA development (RMs 3.23 to 3.44)

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Jan 22, 2024 10:16am tgriga \\gala\CAD\Projects\0067-King County\LDW Upper Reach Engineering Services\0067-RP-034 LDWUR BODR Dredge.dwg Figure 6-1c

LEGEND:

- USACE CHANNEL CENTERLINE AND STATIONING (250+00)
- FEDERAL NAVIGATION CHANNEL
- RM 3.0 RIVER MILE LABEL
- EARLY ACTION AREA
- LDW UPPER REACH APPROXIMATE BOUNDARY
- KING COUNTY SHORELINE HABITAT RESTORATION APPROXIMATE EXTENTS
- 2018 BATHYMETRIC CONTOURS (2' & 10' INTERVALS)
- OUTFALL LOCATION (ACTIVE)
- OUTFALL LOCATION (ABANDONED/INACTIVE)
- OUTFALL LOCATION (REMOVED)
- EXISTING PILE (APPROXIMATE LOCATION)
- EXISTING DOLPHIN (APPROXIMATE LOCATION)
- VERTICAL SAMPLE LOCATION
- 2 RAL EXCEEDANCE AREA NUMBER
- RAL EXCEEDANCE AREA (5/26/23)
- REMEDIAL ACTION AREA: DREDGING
- REMEDIAL ACTION AREA: ENR

N

0 20 40

SCALE IN FEET

NOTES:

1. HORIZONTAL DATUM: WASHINGTON STATE PLANE NORTH ZONE, NAD83 (2011), U.S. SURVEY FEET
2. VERTICAL DATUM: MLLW
3. AERIAL IMAGE BY ESRI

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Figure 6-1d. RAA development (RMs 3.49 to 3.56)

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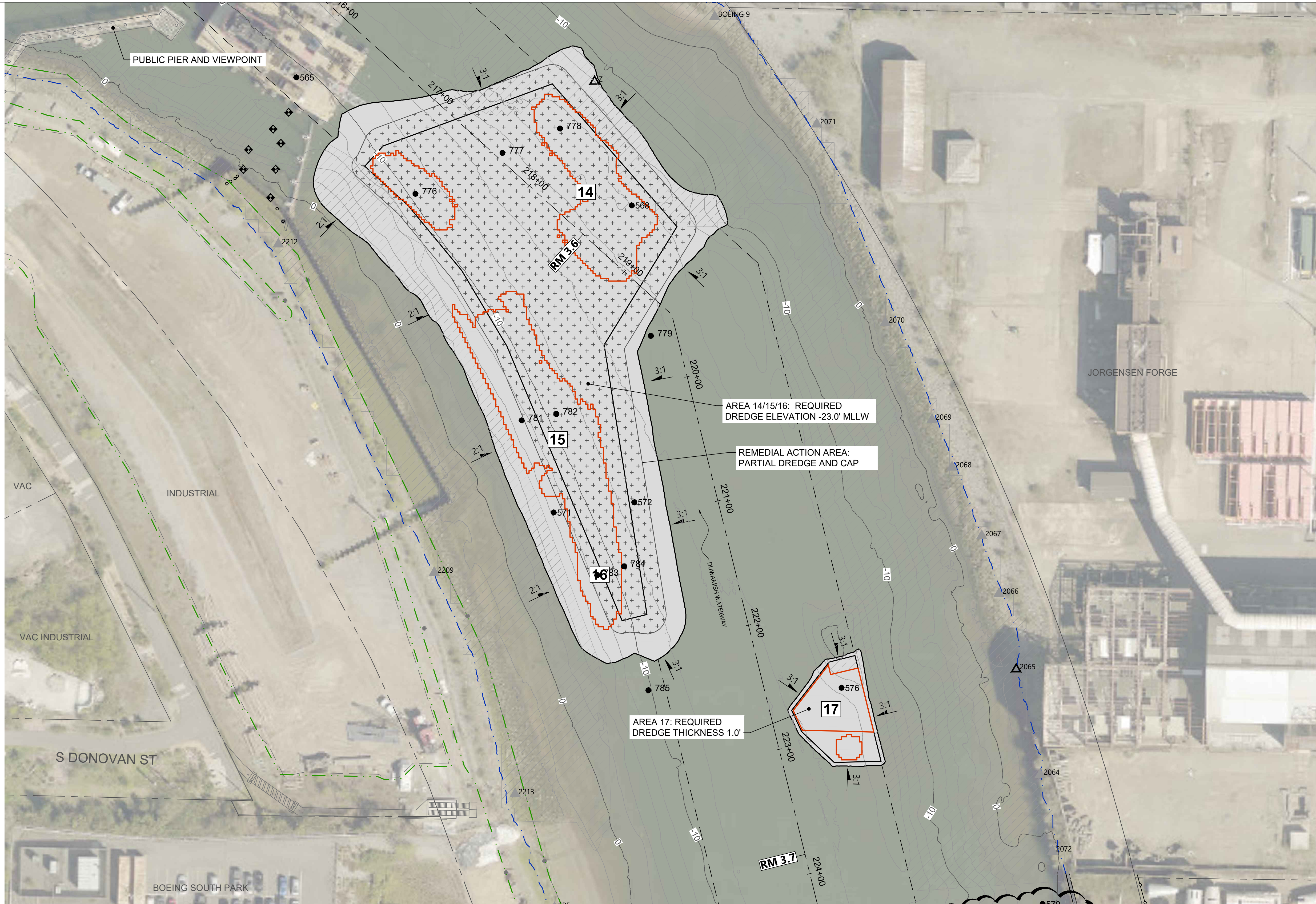

LEGEND:

- USACE CHANNEL CENTERLINE AND STATIONING (250+00)
- FEDERAL NAVIGATION CHANNEL
- RM 3.0 RIVER MILE LABEL
- EARLY ACTION AREA
- LDW UPPER REACH APPROXIMATE BOUNDARY
- KING COUNTY SHORELINE HABITAT RESTORATION APPROXIMATE EXTENTS
- 2018 BATHYMETRIC CONTOURS (2' & 10' INTERVALS)
- OUTFALL LOCATION (ACTIVE)
- OUTFALL LOCATION (ABANDONED/INACTIVE)
- OUTFALL LOCATION (REMOVED)
- EXISTING PILE (APPROXIMATE LOCATION)
- EXISTING DOLPHIN (APPROXIMATE LOCATION)
- VERTICAL SAMPLE LOCATION
- 2 RAL EXCEEDANCE AREA NUMBER
- RAL EXCEEDANCE AREA (5/26/23)
- REMEDIAL ACTION AREA: DREDGING
- REMEDIAL ACTION AREA: PARTIAL DREDGE AND CAP

N

0 40 80
SCALE IN FEET

NOTES:

1. HORIZONTAL DATUM: WASHINGTON STATE PLANE NORTH ZONE, NAD83 (2011), U.S. SURVEY FEET
2. VERTICAL DATUM: MLLW
3. AERIAL IMAGE BY ESRI

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Figure 6-1e. RAA development (RMs 3.54 to 3.71)

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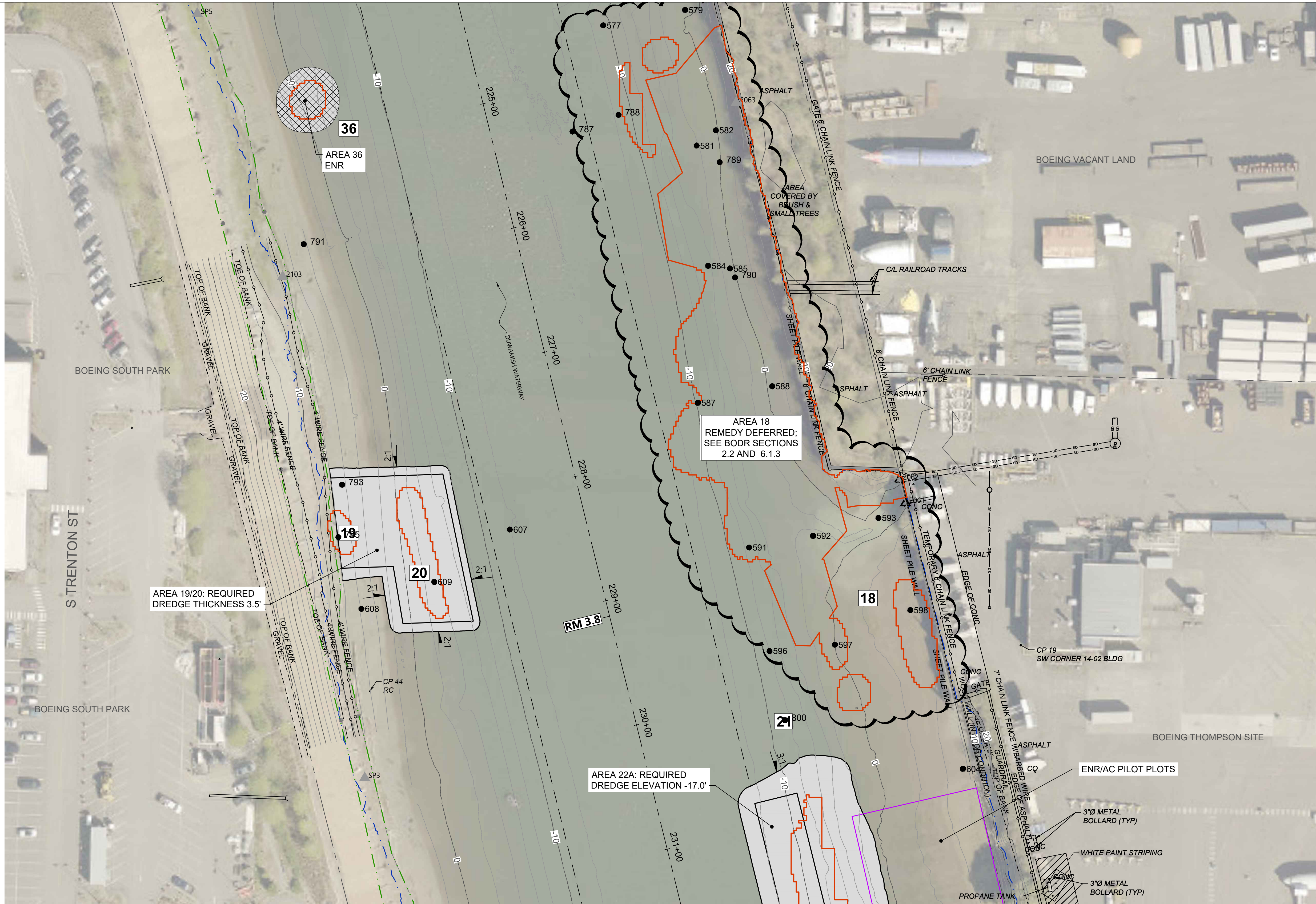
Jan 22, 2024 10:17am tgriga \\gala\CAD\Projects\0067-King County\LDW Upper Reach Engineering Services\0067-RP-034 LDWUR BODR Dredge.dwg Figure 6-1e



LEGEND:

- USACE CHANNEL CENTERLINE AND STATIONING (250+00)
- FEDERAL NAVIGATION CHANNEL
- RM 3.0 RIVER MILE LABEL
- EARLY ACTION AREA
- LDW UPPER REACH APPROXIMATE BOUNDARY
- KING COUNTY SHORELINE HABITAT RESTORATION APPROXIMATE EXTENTS
- 2018 BATHYMETRIC CONTOURS (2' & 10' INTERVALS)
- OUTFALL LOCATION (ACTIVE)
- OUTFALL LOCATION (ABANDONED/INACTIVE)
- OUTFALL LOCATION (REMOVED)
- EXISTING PILE (APPROXIMATE LOCATION)
- EXISTING DOLPHIN (APPROXIMATE LOCATION)
- VERTICAL SAMPLE LOCATION
- 2 RAL EXCEEDANCE AREA NUMBER
- RAL EXCEEDANCE AREA (5/26/23)
- REMEDIAL ACTION AREA: DREDGING
- REMEDIAL ACTION AREA: ENR

N

0 40 80

SCALE IN FEET

NOTES:

1. HORIZONTAL DATUM: WASHINGTON STATE PLANE NORTH ZONE, NAD83 (2011), U.S. SURVEY FEET
2. VERTICAL DATUM: MLLW
3. AERIAL IMAGE BY ESRI

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Figure 6-1f. RAA development (RMs 3.73 to 3.84)

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JANUARY 16, 2024

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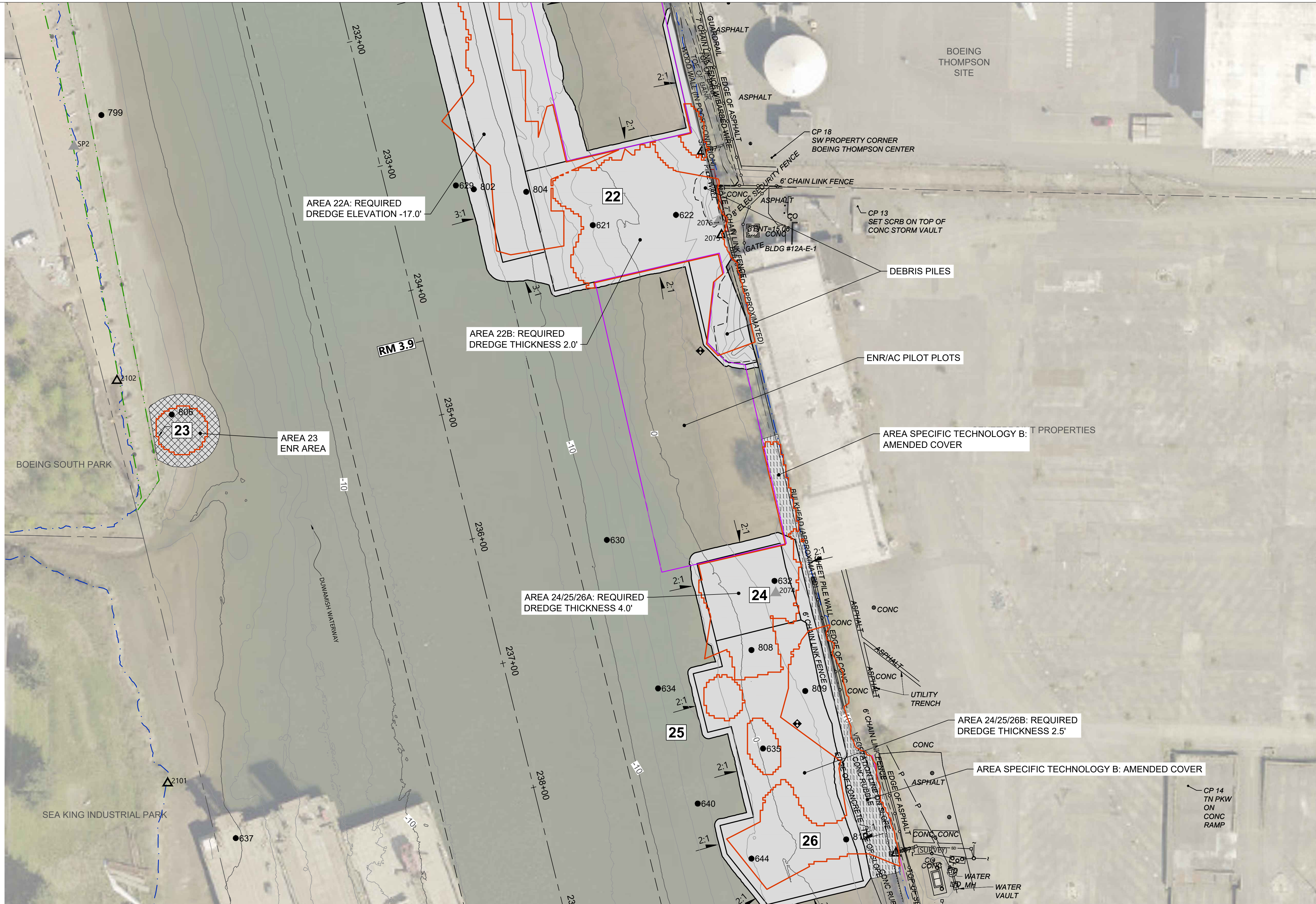

LEGEND:

- USACE CHANNEL CENTERLINE AND STATIONING (250+00)
- FEDERAL NAVIGATION CHANNEL
- RM 3.0 — RIVER MILE LABEL
- EARLY ACTION AREA
- LDW UPPER REACH APPROXIMATE BOUNDARY
- KING COUNTY SHORELINE HABITAT RESTORATION APPROXIMATE EXTENTS
- 2018 BATHYMETRIC CONTOURS (2' & 10' INTERVALS)
- OUTFALL LOCATION (ACTIVE)
- OUTFALL LOCATION (ABANDONED/INACTIVE)
- OUTFALL LOCATION (REMOVED)
- EXISTING PILE (APPROXIMATE LOCATION)
- EXISTING DOLPHIN (APPROXIMATE LOCATION)
- VERTICAL SAMPLE LOCATION
- 2 — RAL EXCEEDANCE AREA NUMBER
- RAL EXCEEDANCE AREA (5/26/23)
- REMEDIAL ACTION AREA: DREDGING
- REMEDIAL ACTION AREA: ENR
- REMEDIAL ACTION AREA: AREA-SPECIFIC TECHNOLOGY

N

0 40 80

SCALE IN FEET

NOTES:

1. HORIZONTAL DATUM: WASHINGTON STATE PLANE NORTH ZONE, NAD83 (2011), U.S. SURVEY FEET
2. VERTICAL DATUM: MLLW
3. AERIAL IMAGE BY ESRI.

\\gaia\CAD\Projects\0067-King County\LDW Upper Reach Engineering Services\0067-RP-034 LDWUR BODR Dredge.dwg Figure 6-1g

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Figure 6-1g. RAA development (RMs 3.85 to 3.99)

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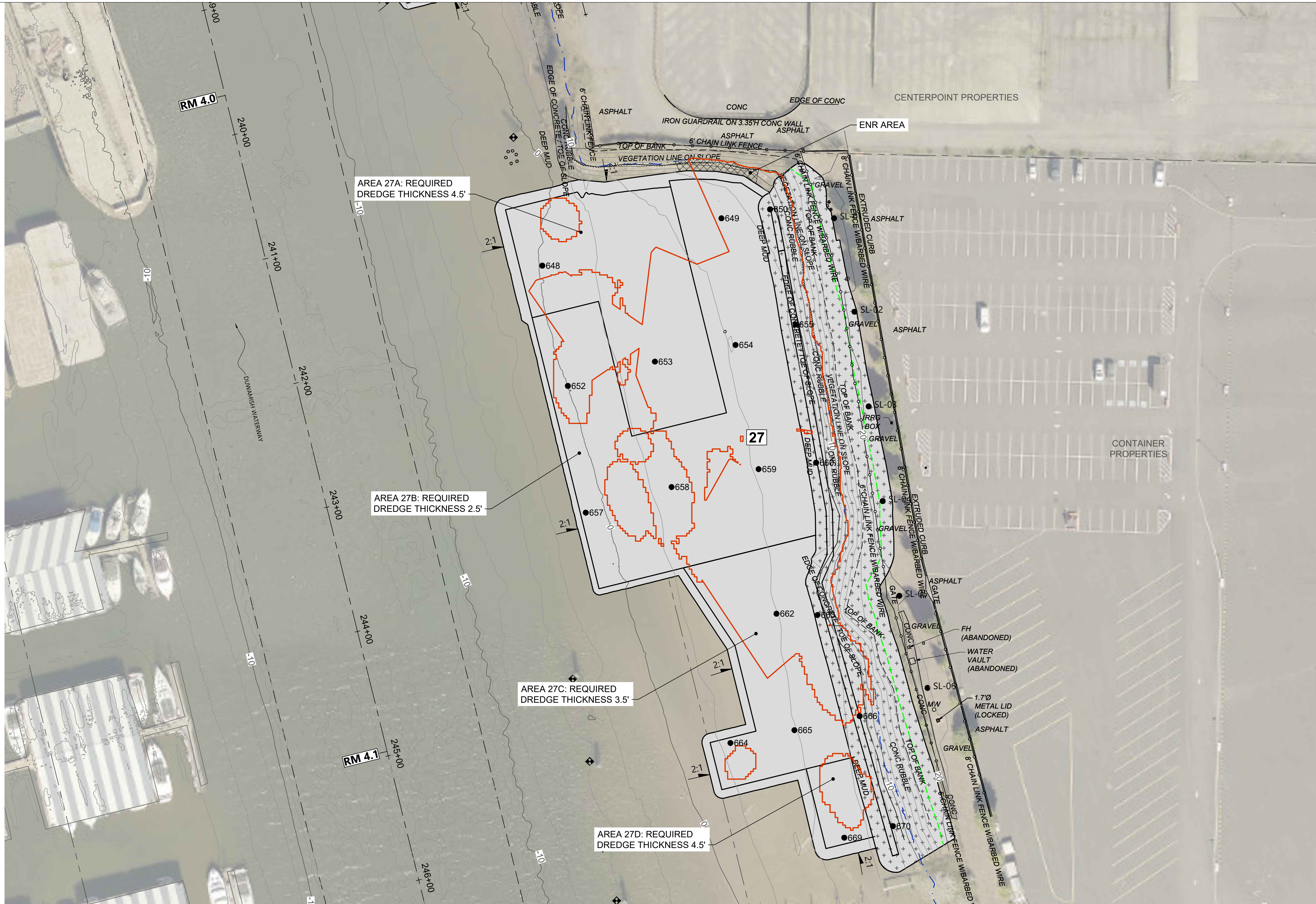

LEGEND:

- USACE CHANNEL CENTERLINE AND STATIONING (250+00)
- FEDERAL NAVIGATION CHANNEL
- RM 3.0 RIVER MILE LABEL
- EARLY ACTION AREA
- LDW UPPER REACH APPROXIMATE BOUNDARY
- KING COUNTY SHORELINE HABITAT RESTORATION APPROXIMATE EXTENTS
- 2018 BATHYMETRIC CONTOURS (2' & 10' INTERVALS)
- OUTFALL LOCATION (ACTIVE)
- OUTFALL LOCATION (ABANDONED/INACTIVE)
- OUTFALL LOCATION (REMOVED)
- EXISTING PILE (APPROXIMATE LOCATION)
- EXISTING DOLPHIN (APPROXIMATE LOCATION)
- VERTICAL SAMPLE LOCATION
- 2 RAL EXCEEDANCE AREA NUMBER
- RAL EXCEEDANCE AREA (5/26/23)
- REMEDIAL ACTION AREA: DREDGING
- REMEDIAL ACTION AREA: ENR
- REMEDIAL ACTION AREA: ENGINEERED CAP

N

0 40 80

SCALE IN FEET

NOTES:

1. HORIZONTAL DATUM: WASHINGTON STATE PLANE NORTH ZONE, NAD83 (2011), U.S. SURVEY FEET
2. VERTICAL DATUM: MLLW
3. AERIAL IMAGE BY ESRI

\\gala\CAD\Projects\0067-King County\LDW Upper Reach Engineering Services\0067-RP-034 LDWUR BODR Dredge.dwg Figure 6-1h

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Figure 6-1h. RAA development (RMs 3.98 to 4.13)

LEGEND:

- USACE CHANNEL CENTERLINE AND STATIONING (250+00)
- FEDERAL NAVIGATION CHANNEL
- RM 3.0 RIVER MILE LABEL
- EARLY ACTION AREA
- LDW UPPER REACH APPROXIMATE BOUNDARY
- KING COUNTY SHORELINE HABITAT RESTORATION APPROXIMATE EXTENTS
- 2018 BATHYMETRIC CONTOURS (2' & 10' INTERVALS)
- OUTFALL LOCATION (ACTIVE)
- OUTFALL LOCATION (ABANDONED/INACTIVE)
- OUTFALL LOCATION (REMOVED)
- EXISTING PILE (APPROXIMATE LOCATION)
- EXISTING DOLPHIN (APPROXIMATE LOCATION)
- VERTICAL SAMPLE LOCATION
- 2 RAL EXCEEDANCE AREA NUMBER
- RAL EXCEEDANCE AREA (5/26/23)
- REMEDIAL ACTION AREA: DREDGING

N

0 20 40

SCALE IN FEET

NOTES:

1. HORIZONTAL DATUM: WASHINGTON STATE PLANE NORTH ZONE, NAD83 (2011), U.S. SURVEY FEET
2. VERTICAL DATUM: MLLW
3. AERIAL IMAGE BY ESRI

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Figure 6-1i. RAA development (RMs 4.14 to 4.23)

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JANUARY 16, 2024

LEGEND:

- USACE CHANNEL CENTERLINE AND STATIONING (250+00)
- FEDERAL NAVIGATION CHANNEL
- RM 3.0 — RIVER MILE LABEL
- EARLY ACTION AREA
- LDW UPPER REACH APPROXIMATE BOUNDARY
- KING COUNTY SHORELINE HABITAT RESTORATION APPROXIMATE EXTENTS
- 2018 BATHYMETRIC CONTOURS (2' & 10' INTERVALS)
- OUTFALL LOCATION (ACTIVE)
- OUTFALL LOCATION (ABANDONED/INACTIVE)
- OUTFALL LOCATION (REMOVED)
- EXISTING PILE (APPROXIMATE LOCATION)
- EXISTING DOLPHIN (APPROXIMATE LOCATION)
- VERTICAL SAMPLE LOCATION
- 2 — RAL EXCEEDANCE AREA NUMBER
- RAL EXCEEDANCE AREA (5/26/23)
- REMEDIAL ACTION AREA: DREDGING

N

0 20 40

SCALE IN FEET

NOTES:

1. HORIZONTAL DATUM: WASHINGTON STATE PLANE NORTH ZONE, NAD83 (2011), U.S. SURVEY FEET
2. VERTICAL DATUM: MLLW
3. AERIAL IMAGE BY ESRI

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Figure 6-1j. RAA development (RMs 4.57 to 4.66)

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Jan 22, 2024 10:21am tgriga \\gaia\CAD\Projects\0067-King County\LDW Upper Reach Engineering Services\0067-RP-034 LDWUR BODR Dredge.dwg Figure 6-1j

LEGEND:

- USACE CHANNEL CENTERLINE AND STATIONING (250+00)
- FEDERAL NAVIGATION CHANNEL
- RM 3.0 — RIVER MILE LABEL
- EARLY ACTION AREA
- LDW UPPER REACH APPROXIMATE BOUNDARY
- KING COUNTY SHORELINE HABITAT RESTORATION APPROXIMATE EXTENTS
- 2018 BATHYMETRIC CONTOURS (2' & 10' INTERVALS)
- OUTFALL LOCATION (ACTIVE)
- OUTFALL LOCATION (ABANDONED/INACTIVE)
- OUTFALL LOCATION (REMOVED)
- EXISTING PILE (APPROXIMATE LOCATION)
- EXISTING DOLPHIN (APPROXIMATE LOCATION)
- VERTICAL SAMPLE LOCATION
- 2 — RAL EXCEEDANCE AREA NUMBER
- RAL EXCEEDANCE AREA (5/26/23)
- REMEDIAL ACTION AREA: DREDGING
- REMEDIAL ACTION AREA: ENR

N

0 20 40

SCALE IN FEET

NOTES:

1. HORIZONTAL DATUM: WASHINGTON STATE PLANE NORTH ZONE, NAD83 (2011), U.S. SURVEY FEET
2. VERTICAL DATUM: MLLW
3. AERIAL IMAGE BY ESRI

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Figure 6-1k. RAA development (RMs 4.64 to 4.76)

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JANUARY 16, 2024

LEGEND:

- USACE CHANNEL CENTERLINE AND STATIONING (250+00)
- FEDERAL NAVIGATION CHANNEL
- RM 3.0 RIVER MILE LABEL
- EARLY ACTION AREA
- LDW UPPER REACH APPROXIMATE BOUNDARY
- KING COUNTY SHORELINE HABITAT RESTORATION APPROXIMATE EXTENTS
- 2018 BATHYMETRIC CONTOURS (2' & 10' INTERVALS)
- OUTFALL LOCATION (ACTIVE)
- OUTFALL LOCATION (ABANDONED/INACTIVE)
- OUTFALL LOCATION (REMOVED)
- EXISTING PILE (APPROXIMATE LOCATION)
- EXISTING DOLPHIN (APPROXIMATE LOCATION)
- VERTICAL SAMPLE LOCATION
- 2 RAL EXCEEDANCE AREA NUMBER
- RAL EXCEEDANCE AREA (5/26/23)
- REMEDIAL ACTION AREA: DREDGING
- REMEDIAL ACTION AREA: ENR

N

0 20 40

SCALE IN FEET

NOTES:

1. HORIZONTAL DATUM: WASHINGTON STATE PLANE NORTH ZONE, NAD83 (2011), U.S. SURVEY FEET
2. VERTICAL DATUM: MLLW
3. AERIAL IMAGE BY ESRI

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Figure 6-1l. RAA development (RMs 4.84 to 4.95)

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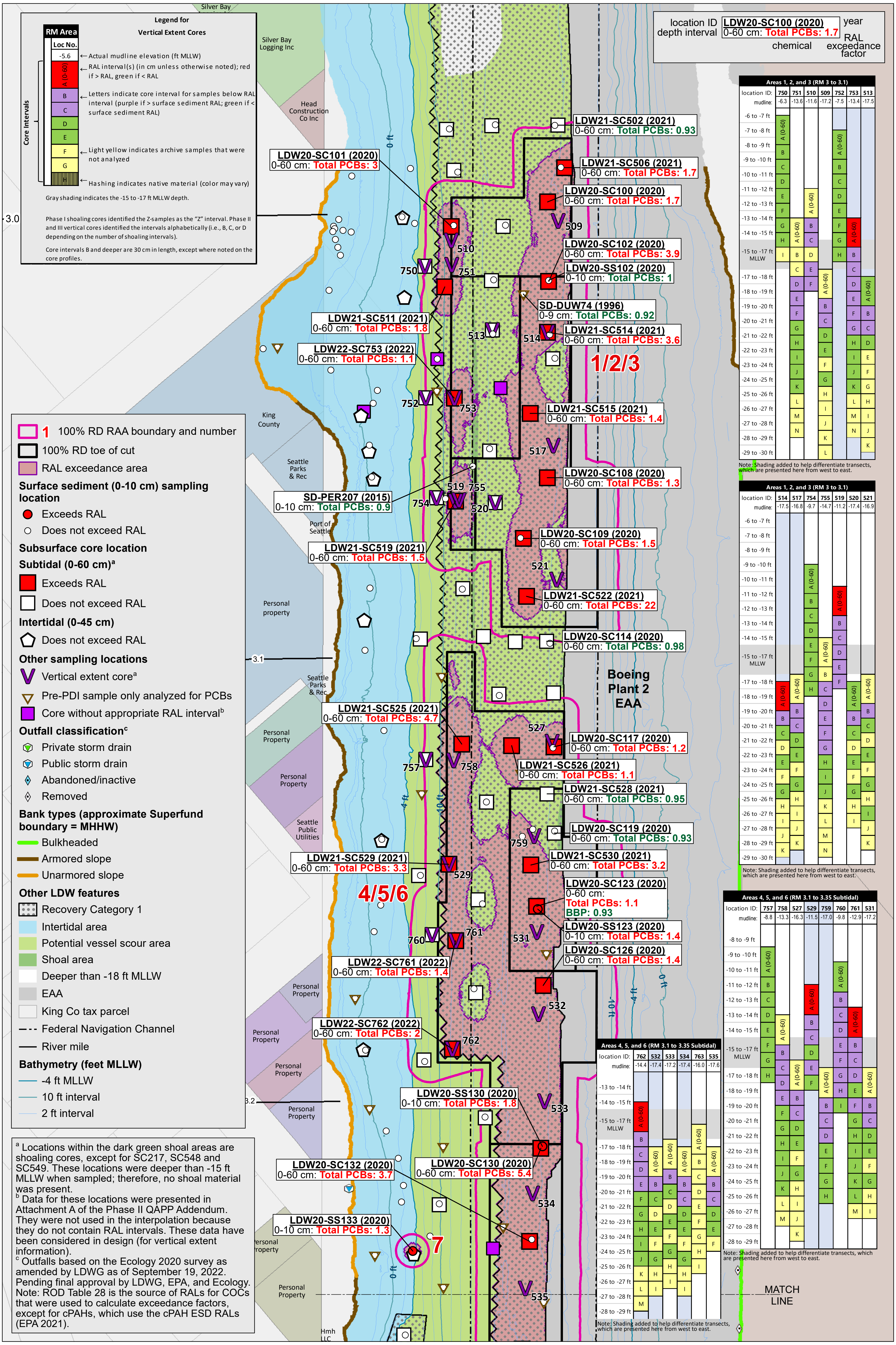

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Figure 6-2a. RAA boundaries, RAL exceedance areas, RAL exceedance locations, and vertical extent data from RMs 3.0 to 3.2

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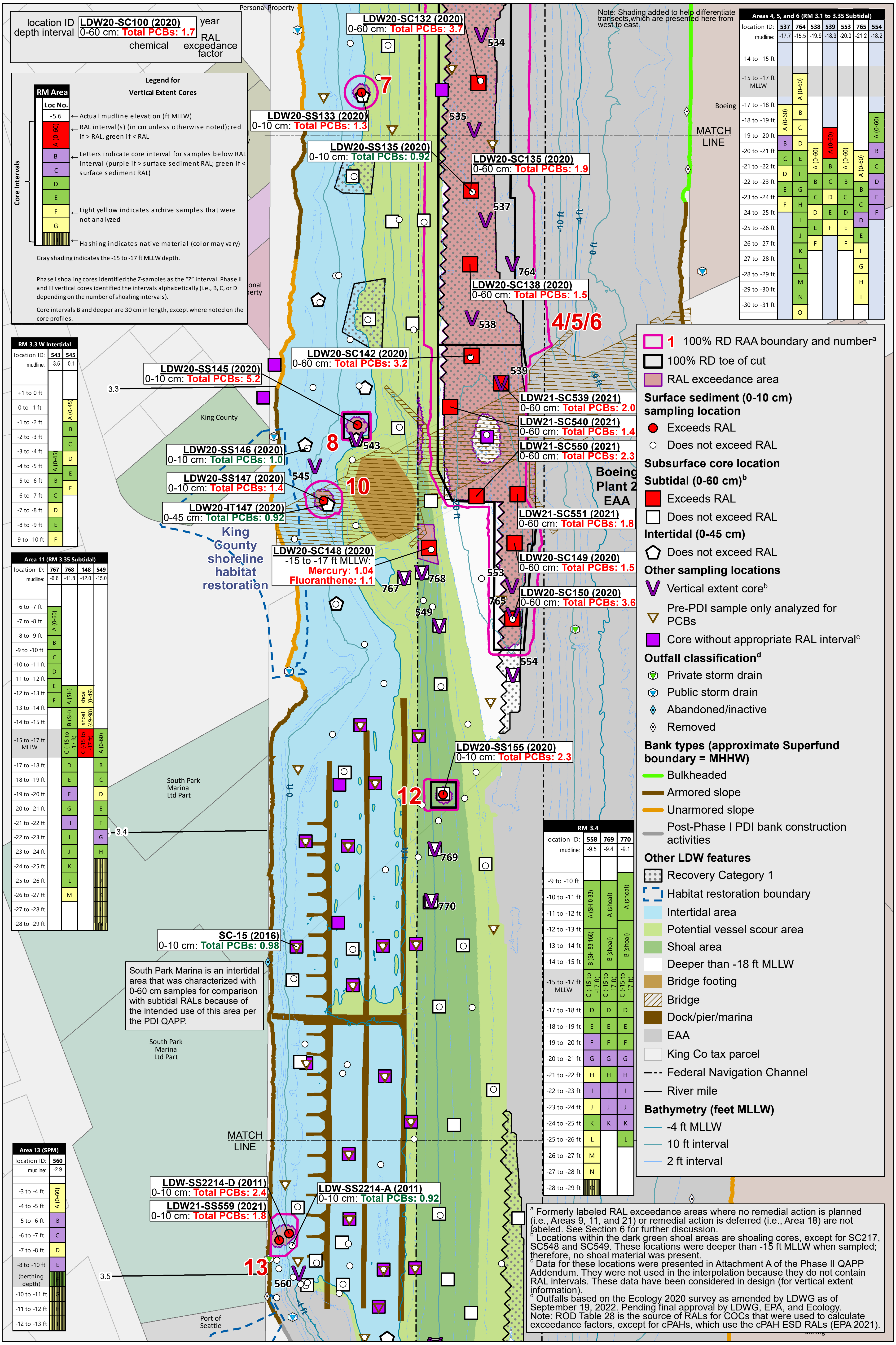

[a] Formerly labeled RAL exceedance areas where no remedial action is planned (i.e., Areas 9, 11, and 21) or remedial action is deferred (i.e., Area 18) are not labeled. See Section 6 for further discussion.
[b] Locations within the dark green shoal areas are shoaling cores, except for SC217, SC548 and SC549. These locations were deeper than -15 ft MLLW when sampled; therefore, no shoal material was present.
[c] Data for these locations were presented in Attachment A of the Phase II QAPP Addendum. They were not used in the interpolation because they do not contain RAL intervals. These data have been considered in design (for vertical extent information).
[d] Outfalls based on the Ecology 2020 survey as amended by LDWG as of September 19, 2022. Pending final approval by LDWG, EPA, and Ecology.
Note: ROD Table 28 is the source of RALs for COCs that were used to calculate exceedance factors, except for cPAHs, which use the cPAH ESD RALs (EPA 2021).

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Figure 6-2b. RAA boundaries, RAL exceedance areas, RAL exceedance locations, and vertical extent data from RMs 3.2 to 3.5

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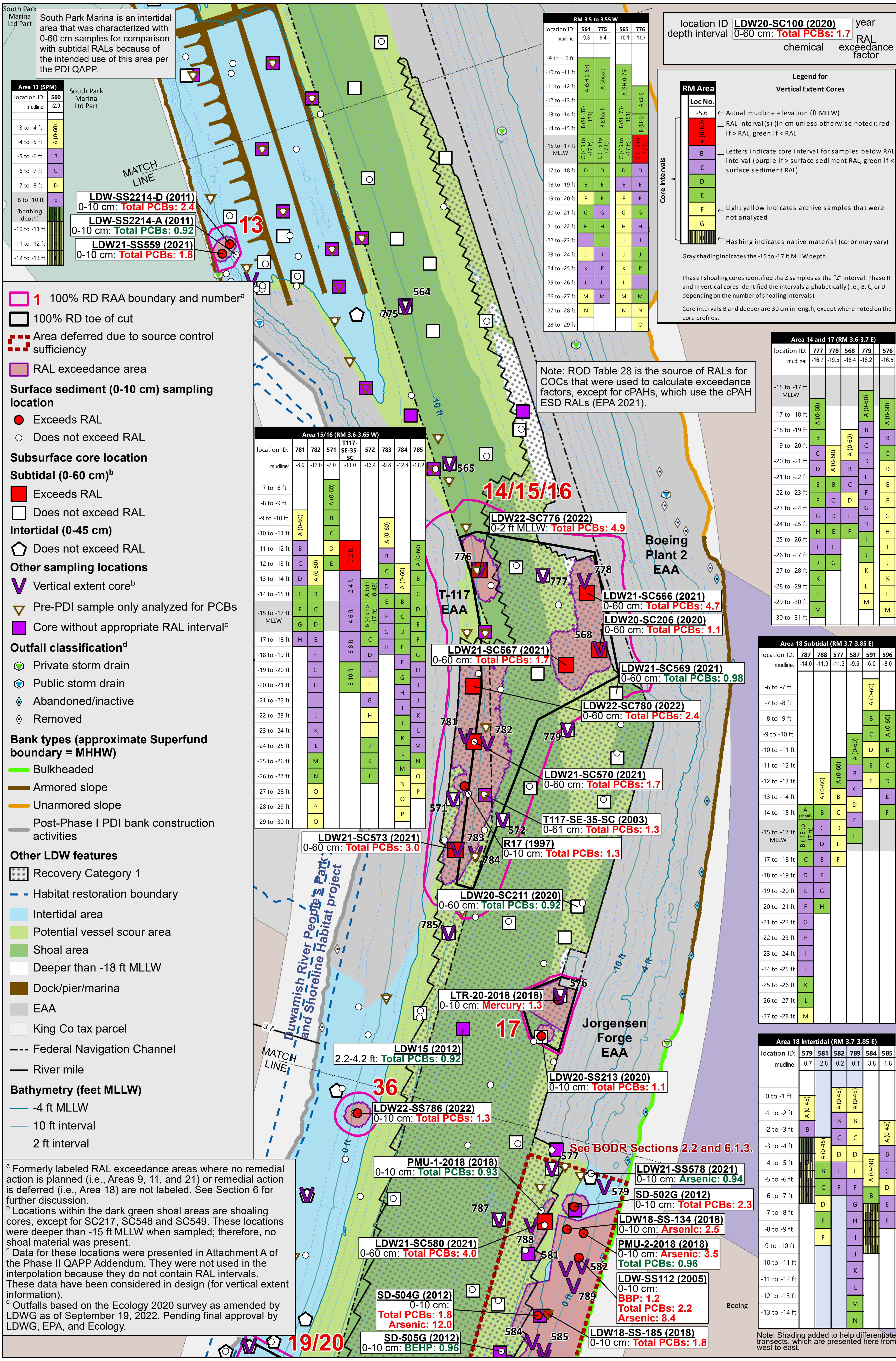

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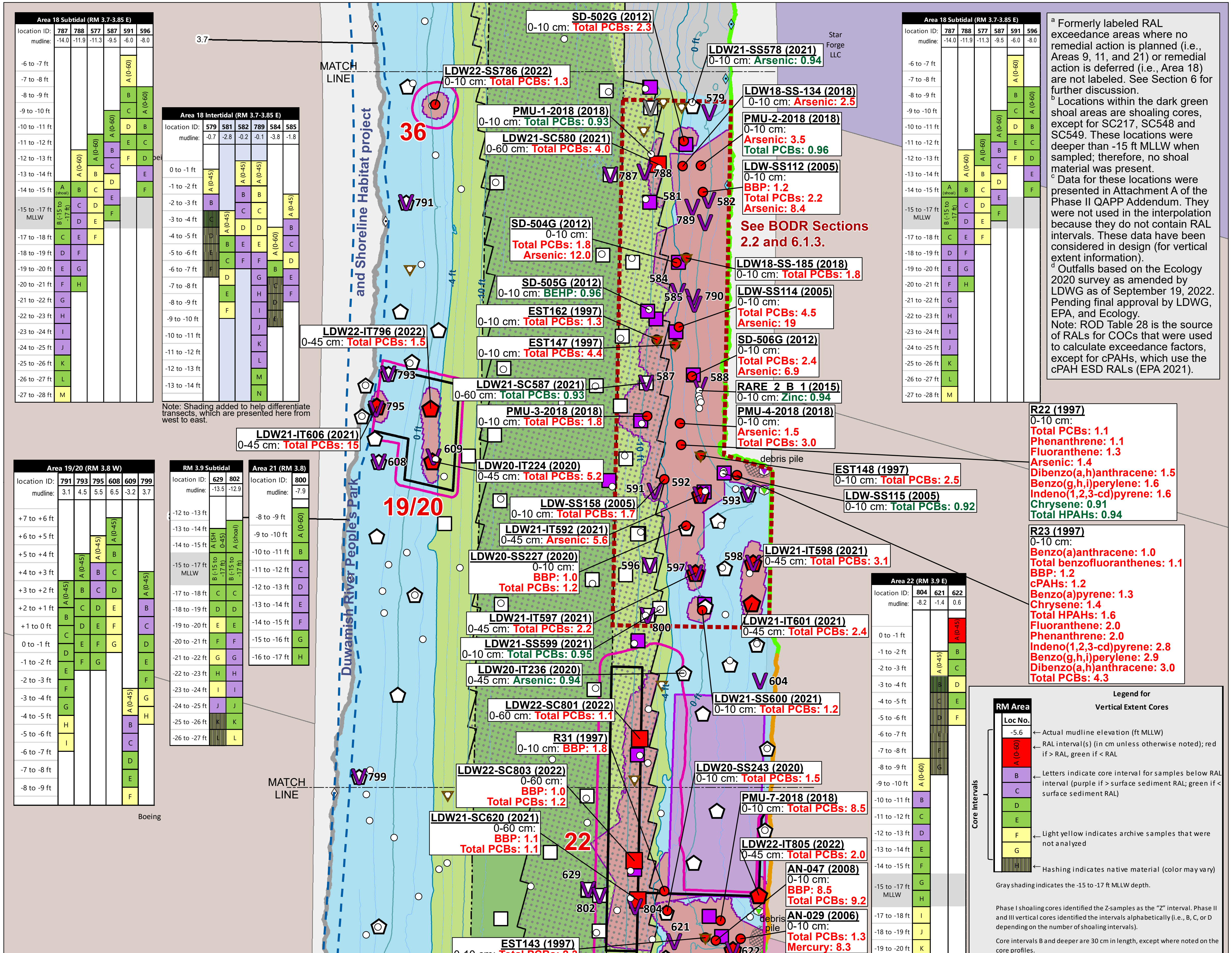
0 100 200 Feet
0 25 50 Meters

Figure 6-2c. RAA boundaries, RAL exceedance areas, RAL exceedance locations, and vertical extent data from RMs 3.5 to 3.7

100% Remedial Design Basis of Design Report for the LDW Upper Reach JANUARY 16, 2024



[a] Formerly labeled RAL exceedance areas where no remedial action is planned (i.e., Areas 9, 11, and 21) or remedial action is deferred (i.e., Area 18) are not labeled. See Section 6 for further discussion.
[b] Locations within the dark green shoal areas are shoaling cores, except for SC217, SC548 and SC549. These locations were deeper than -15 ft MLLW when sampled; therefore, no shoal material was present.
[c] Data for these locations were presented in Attachment A of the Phase II QAPP Addendum. They were not used in the interpolation because they do not contain RAL intervals. These data have been considered in design (for vertical extent information).
[d] Outfalls based on the Ecology 2020 survey as amended by LDWG as of September 19, 2022. Pending final approval by LDWG, EPA, and Ecology.
Note: ROD Table 28 is the source of RALs for COCs that were used to calculate exceedance factors, except for cPAHs, which use the cPAH ESD RALs (EPA 2021).

1 100% RD RAA boundary and number[a]
100% RD toe of cut
Area deferred due to source control sufficiency
RAL exceedance area

Surface sediment (0-10 cm) sampling location
- Exceeds RAL
- Does not exceed RAL

Subsurface core location

Subtidal (0-60 cm)[b]
- Exceeds RAL
- Does not exceed RAL

Intertidal (0-45 cm)
- Exceeds RAL
- Does not exceed RAL

Other sampling locations
- Vertical extent core[b]
- Vertical archive
- Pre-PDI sample only analyzed for PCBs
- Core without appropriate RAL interval[c]

Outfall classification[d]
- EOF/storm drain
- Private storm drain
- Abandoned/inactive
- Removed

Bank types (approximate Superfund boundary = MHHW)
- Bulkheaded
- Unarmored slope
- Post-Phase I PDI bank construction activities

Other LDW features
- Recovery Category 1
- Habitat restoration boundary
- Intertidal area
- Potential vessel scour area
- Shoal area
- EAA
- ENR/AC Pilot plot
- King Co tax parcel
- Federal Navigation Channel
- River mile

Bathymetry (feet MLLW)
- -4 ft MLLW
- 10 ft interval
- 2 ft interval

N
0 100 200 Feet
0 25 50 Meters

Figure 6-2d. RAA boundaries, RAL exceedance areas, RAL exceedance locations, and vertical extent data from RMs 3.7 to 3.85

100% REMEDIAL DESIGN BASIS OF DESIGN REPORT FOR THE LDW UPPER REACH JANUARY 16, 2024

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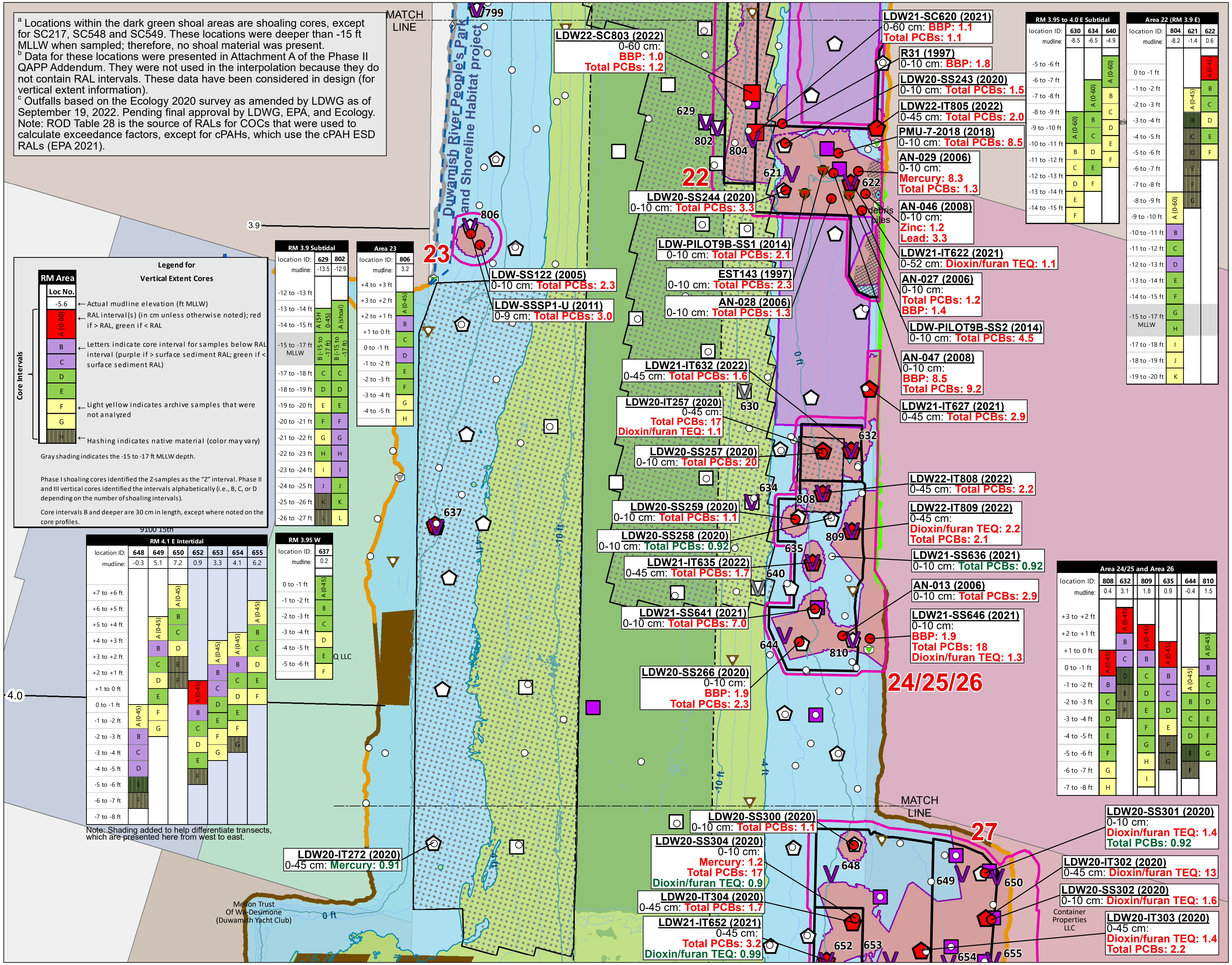

1 100% RD RAA boundary and number
100% RD toe of cut
RAL exceedance area

Surface sediment (0-10 cm) sampling location
- Exceeds RAL
- Does not exceed RAL

Subsurface core location

Subtidal (0-60 cm)[a]
- Exceeds RAL
- Does not exceed RAL

Intertidal (0-45 cm)
- Exceeds RAL
- Does not exceed RAL

Other sampling locations
- Vertical extent core[a]
- Vertical archive
- Pre-PDI sample only analyzed for PCBs
- Core without appropriate RAL interval[b]

Outfall classification[c]
- Private storm drain
- Stream, channel, or ditch
- Abandoned/inactive
- Removed
- Pipe of unresolved origin and/or use

Bank types (approximate Superfund boundary = MHHW)
- Bulkheaded
- Armored slope
- Unarmored slope
- Post-Phase I PDI bank construction activities

Other LDW features
- Recovery Category 1
- Habitat restoration boundary
- Intertidal area
- Potential vessel scour area
- Shoal area
- Dock/pier/marina
- ENR/AC Pilot plot
- King Co tax parcel
- Federal Navigation Channel
- River mile

Bathymetry (feet MLLW)
- -4 ft MLLW
- 10 ft interval
- 2 ft interval

N
0 100 200 Feet
0 25 50 Meters

Figure 6-2e. RAA boundaries, RAL exceedance areas, RAL exceedance locations, and vertical extent data from RMs 3.85 to 4.05

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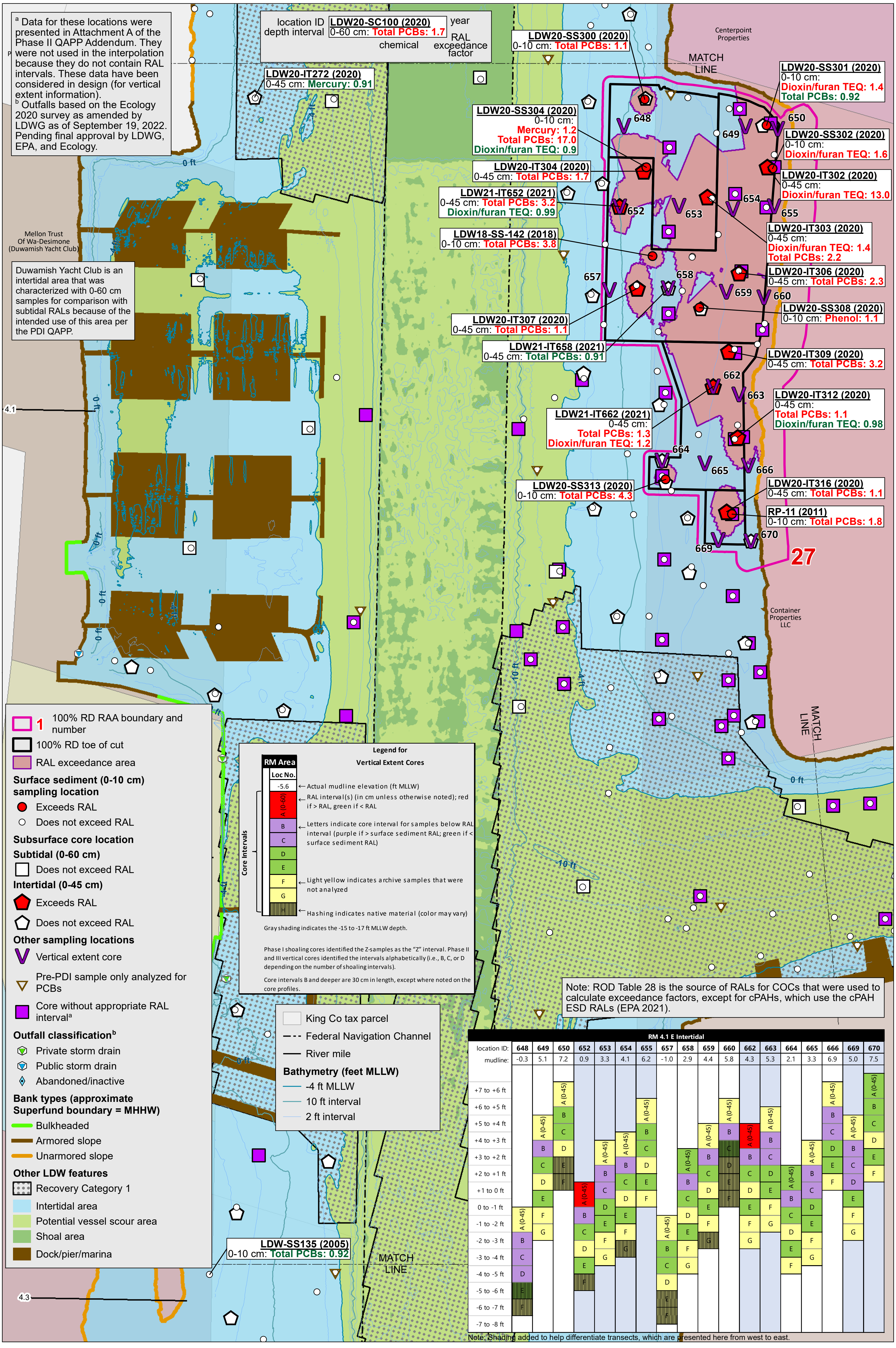

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N

0 100 200 Feet

0 25 50 Meters

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Figure 6-2f. RAA boundaries, RAL exceedance areas, RAL exceedance locations, and vertical extent data from RMs 4.05 to 4.3

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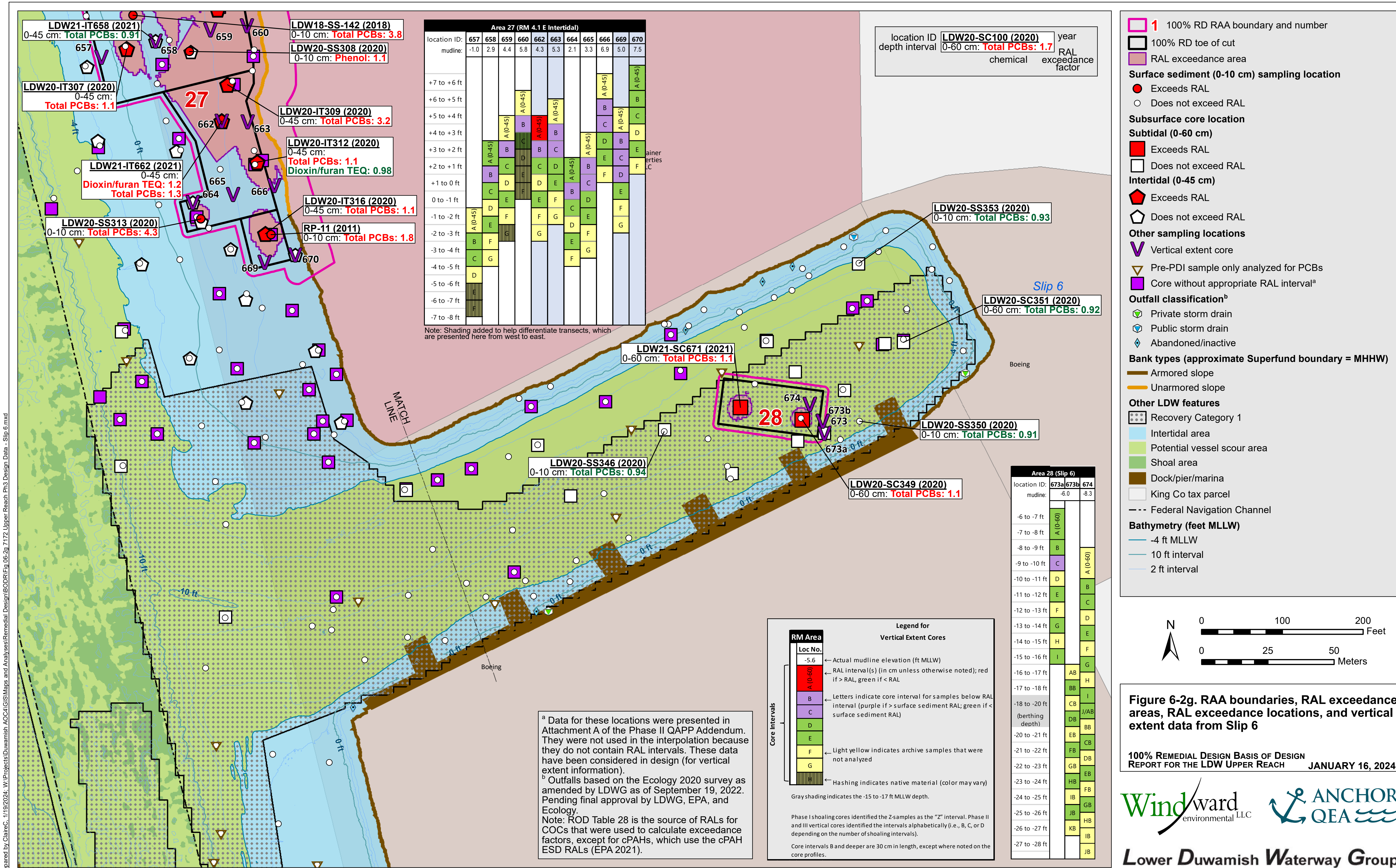

Figure 6-2g. RAA boundaries, RAL exceedance areas, RAL exceedance locations, and vertical extent data from Slip 6

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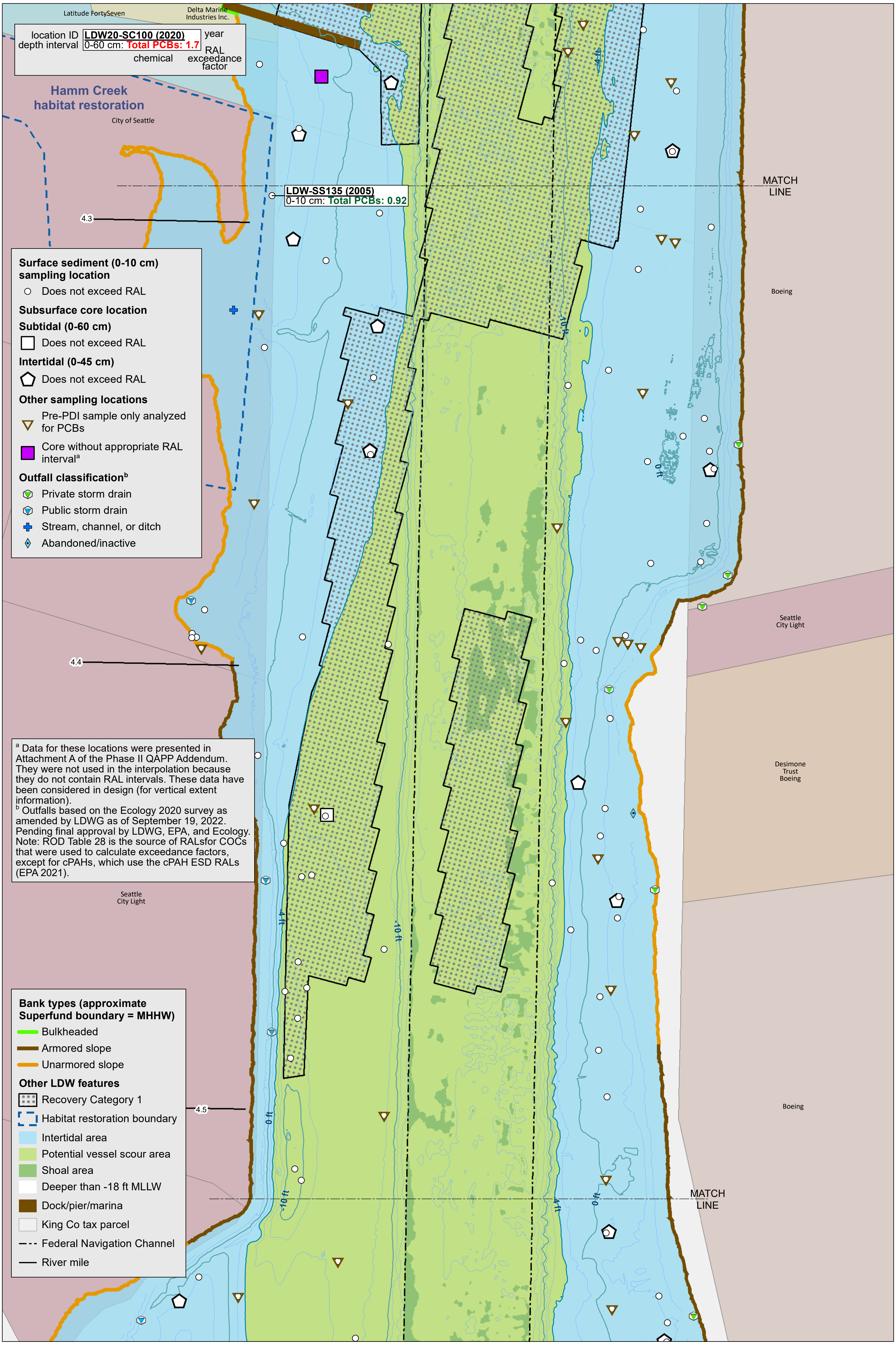

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Figure 6-2h. RAA boundaries, RAL exceedance areas, RAL exceedance locations, and vertical extent data from RMs 4.3 to 4.55

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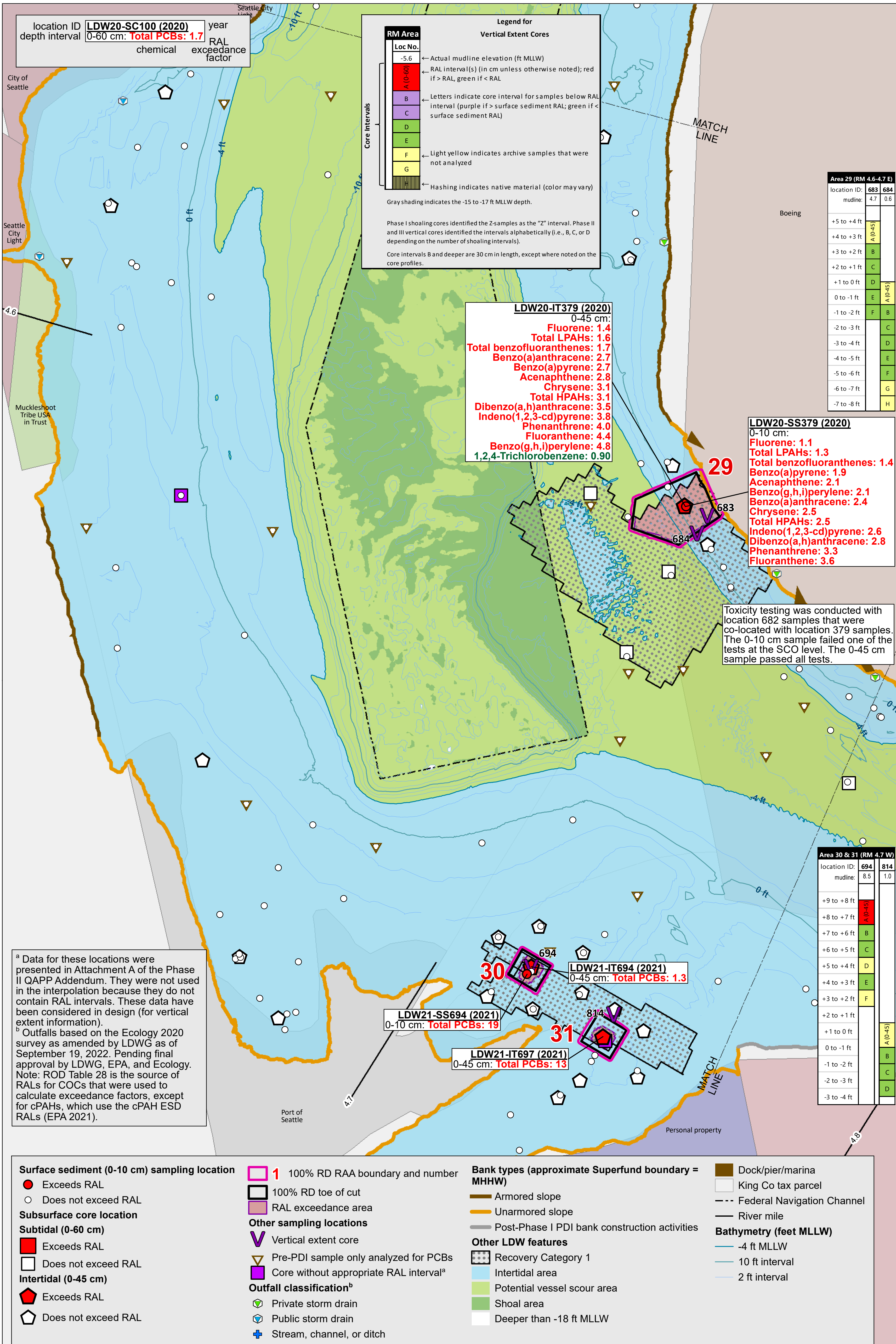

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Figure 6-2i. RAL exceedance areas from RM 4.55 to RM 4.8 with RAL exceedances and vertical extent data in the design dataset

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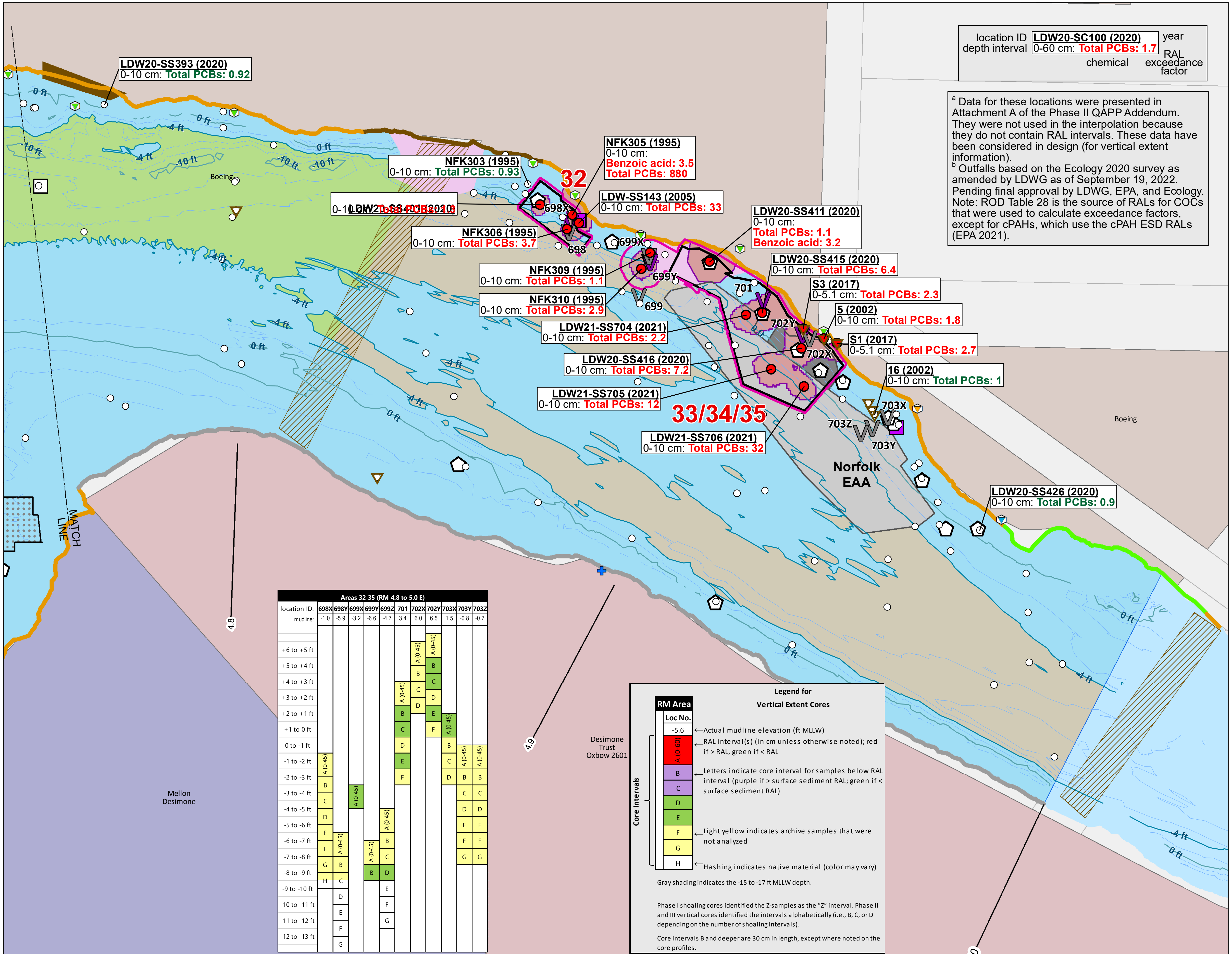

[a] Data for these locations were presented in Attachment A of the Phase II QAPP Addendum. They were not used in the interpolation because they do not contain RAL intervals. These data have been considered in design (for vertical extent information).
[b] Outfalls based on the Ecology 2020 survey as amended by LDWG as of September 19, 2022. Pending final approval by LDWG, EPA, and Ecology.
Note: ROD Table 28 is the source of RALs for COCs that were used to calculate exceedance factors, except for cPAHs, which use the cPAH ESD RALs (EPA 2021).

1 100% RD RAA boundary and number
100% RD toe of cut
RAL exceedance area

Surface sediment (0-10 cm) sampling location
- Exceeds RAL
- Does not exceed RAL

Subsurface core location

Subtidal (0-60 cm)
- Does not exceed RAL

Intertidal (0-45 cm)
- Does not exceed RAL

Other sampling locations
- Vertical extent core
- Vertical archive
- Pre-PDI sample only analyzed for PCBs
- Core without appropriate RAL interval[a]

Outfall classification[b]
- CSO/storm drain
- Private storm drain
- Public storm drain
- Stream, channel, or ditch
- Abandoned/inactive

Bank types (approximate Superfund boundary = MHHW)
- Bulkheaded
- Armored slope
- Unarmored slope
- Post-Phase I PDI bank construction activities

Other LDW features
- Recovery Category 1
- Bridge
- Dock/pier/marina
- Intertidal area
- Potential vessel scour area
- Subtidal with no subsurface RAL
- Area not covered by bathymetric survey
- Boeing South Storm Drain removal area
- EAA
- King Co tax parcel
- River mile

Bathymetry (feet MLLW)
- -4 ft MLLW
- 10 ft interval
- 2 ft interval

N
0 100 200 Feet
0 25 50 Meters

Figure 6-2j. RAL exceedance areas from RMs 4.8 to 5.0 with RAL exceedances and vertical extent data in the design dataset

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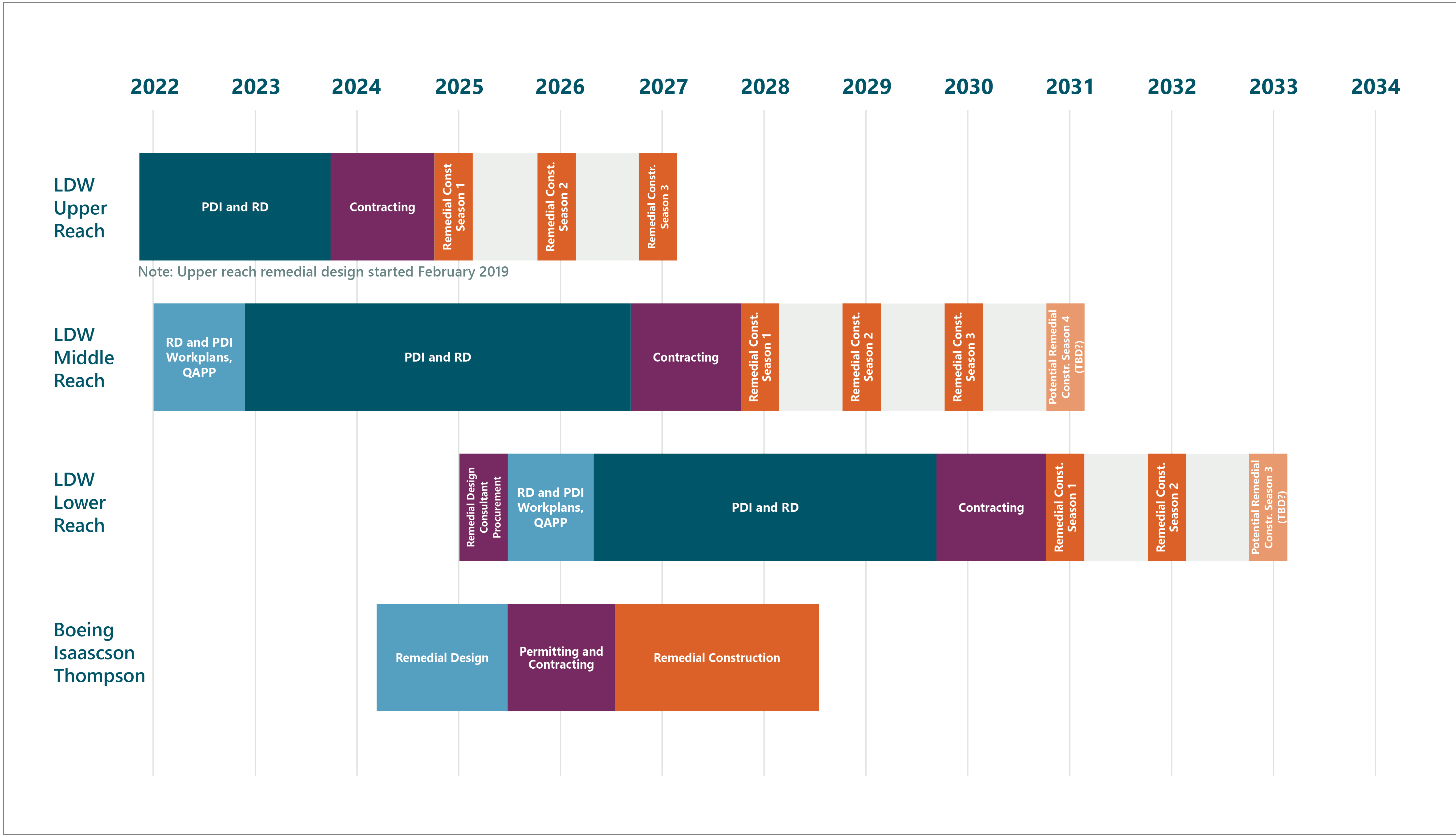

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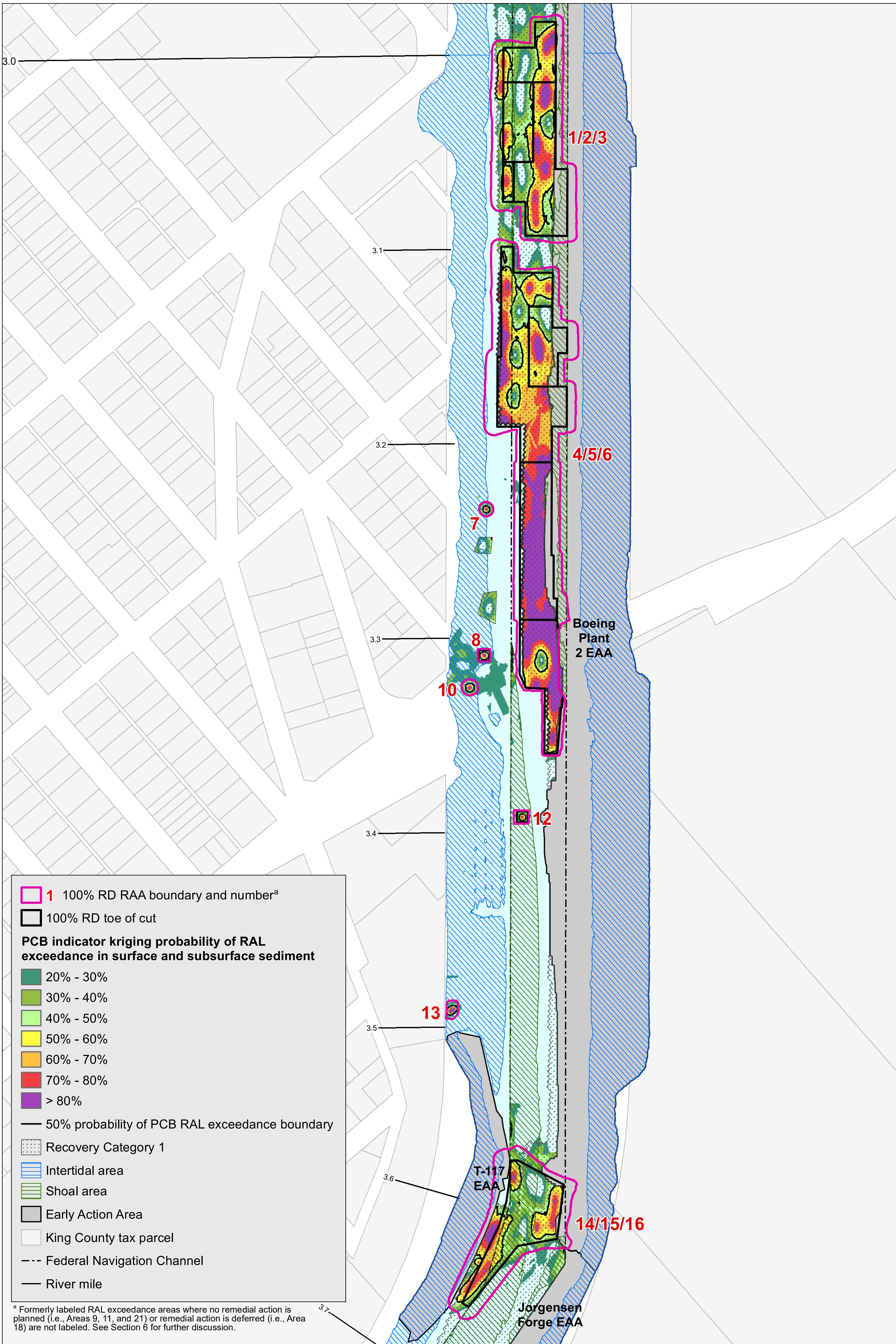
Figure 6-3. Comparison of anticipated LDW Superfund and Boeing Isaacson Thompson cleanup timelines



Prepared by ClaireC, 1/19/2024; W:\Projects\Duwamish AOC4\GIS\Maps and Analyses\Remedial Design\BODR\Fig 06-4a 7216 Combined PhII IK wRAAs - RM 3.0 to 3.7.mxd

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N
0 200 400 Feet
0 50 100 Meters

Figure 6-4a. Total PCB combined surface and subsurface sediment indicator kriging interpolation with RAA boundaries, RMs 3.0 to 3.7

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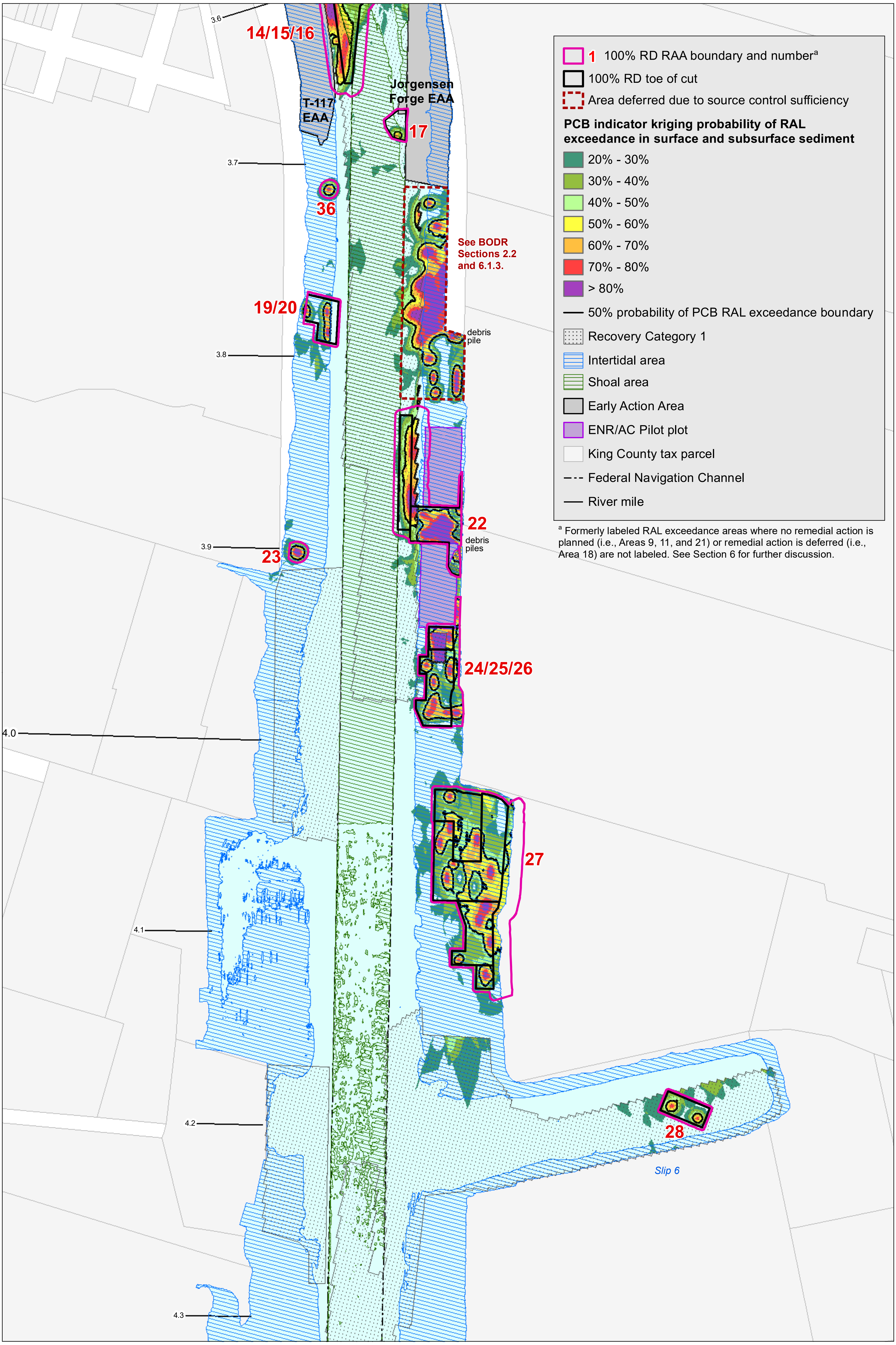

Prepared by craigh, 1/19/2024; W:\Projects\Duwamish AOC4\GIS\Maps and Analyses\Remedial Design\BODR\Fig 06-4b 7216 Combined PhII IK wRAAs - RM 3.7 to 4.3.mxd

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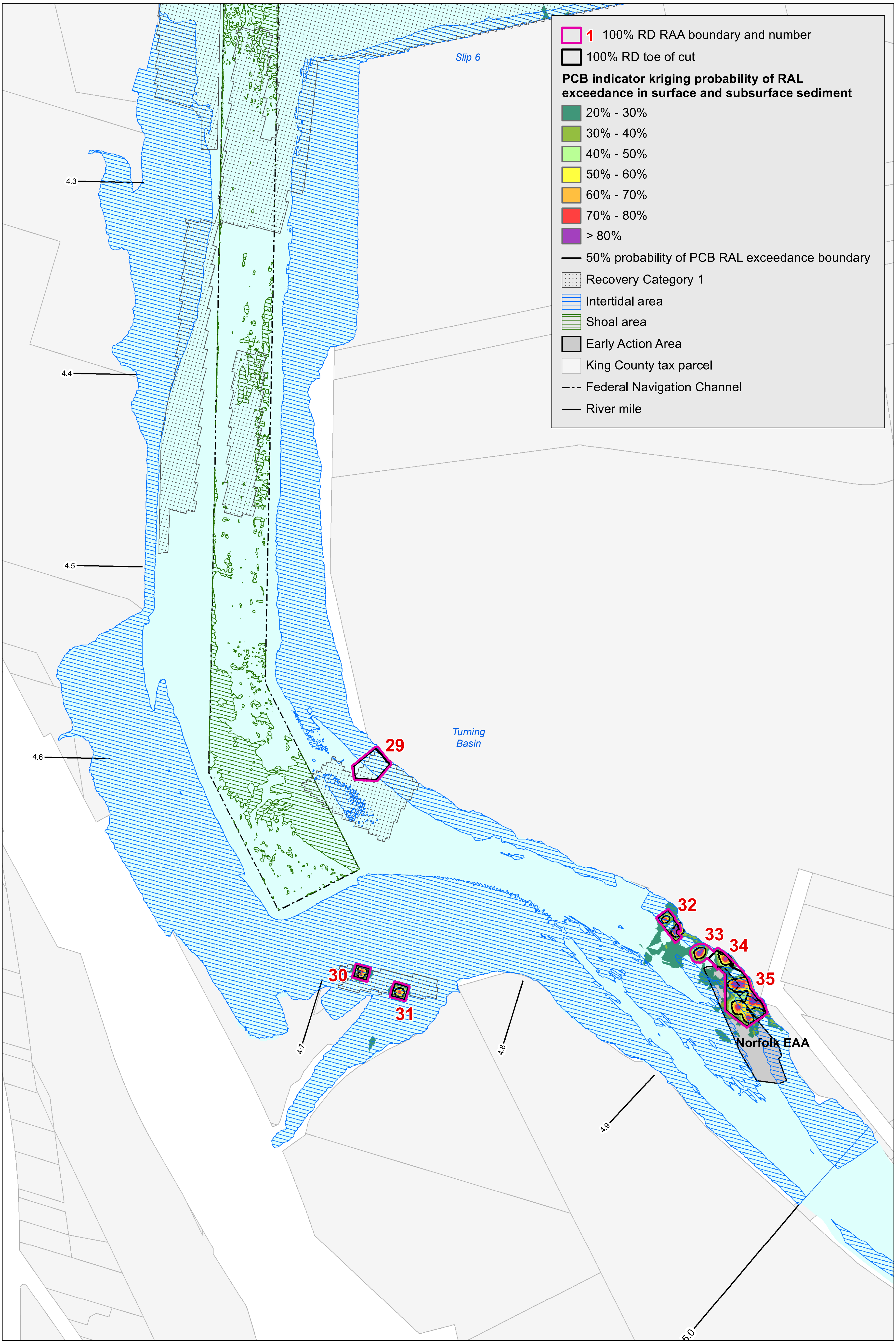
Figure 6-4b. Total PCB combined surface and subsurface sediment indicator kriging interpolation with RAA boundaries, RMs 3.7 to 4.3



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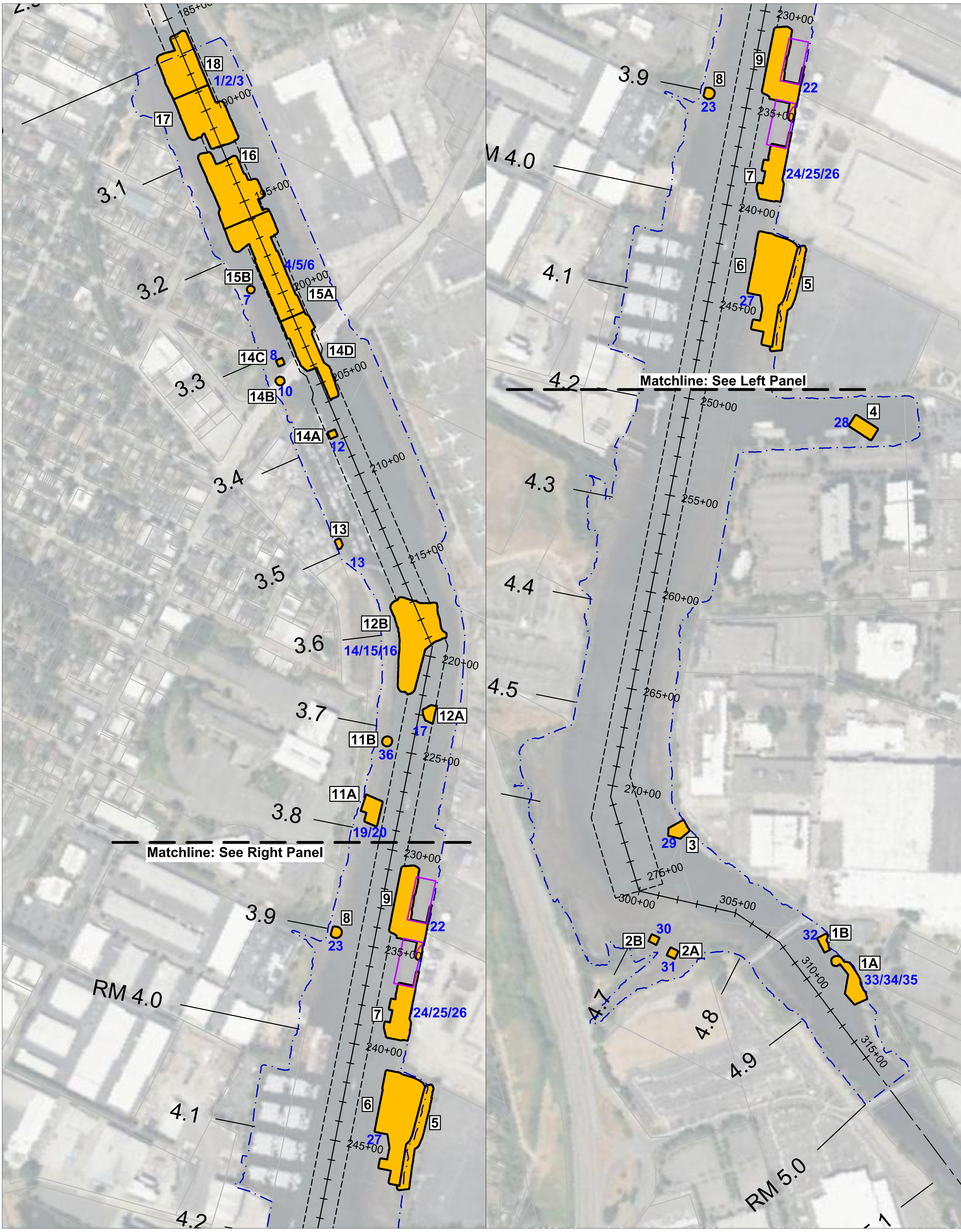
N

0 200 400 Feet

0 50 100 Meters

Figure 6-4c. Total PCB combined surface and subsurface sediment indicator kriging interpolation with RAA boundaries, RMs 4.3 to 5.0



Horizontal Datum: Washington State Plane, North Zone, North American Datum of 1983/91, U.S. Survey Feet; WSDOT MON GP17005-176 & GP17005-181

Vertical Datum: Mean Lower Low Water (MLLW), MLLW Converted from NAD88 (NAVD88 + 2.34' to MLLW)

Legend:

- Federal Navigation Channel
- Channel Centerline (250+00)
- LDW Upper Reach Approximate Boundary
- ENR/AC Pilot Plot Boundary
- Remedial Action Area Boundary
- 1/2/3 Remedial Action Area Numbers
- Sediment Management Area Boundary
- 17 Sediment Management Area Number

N

0 500 Feet

\\gaia\CAD\Projects\0067-King County\LDW Upper Reach Engineering Services\0067-RP-038 LDWUR BODR SMA.dwg Figure 7-1

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Figure 7-1
SMAs and RAAs

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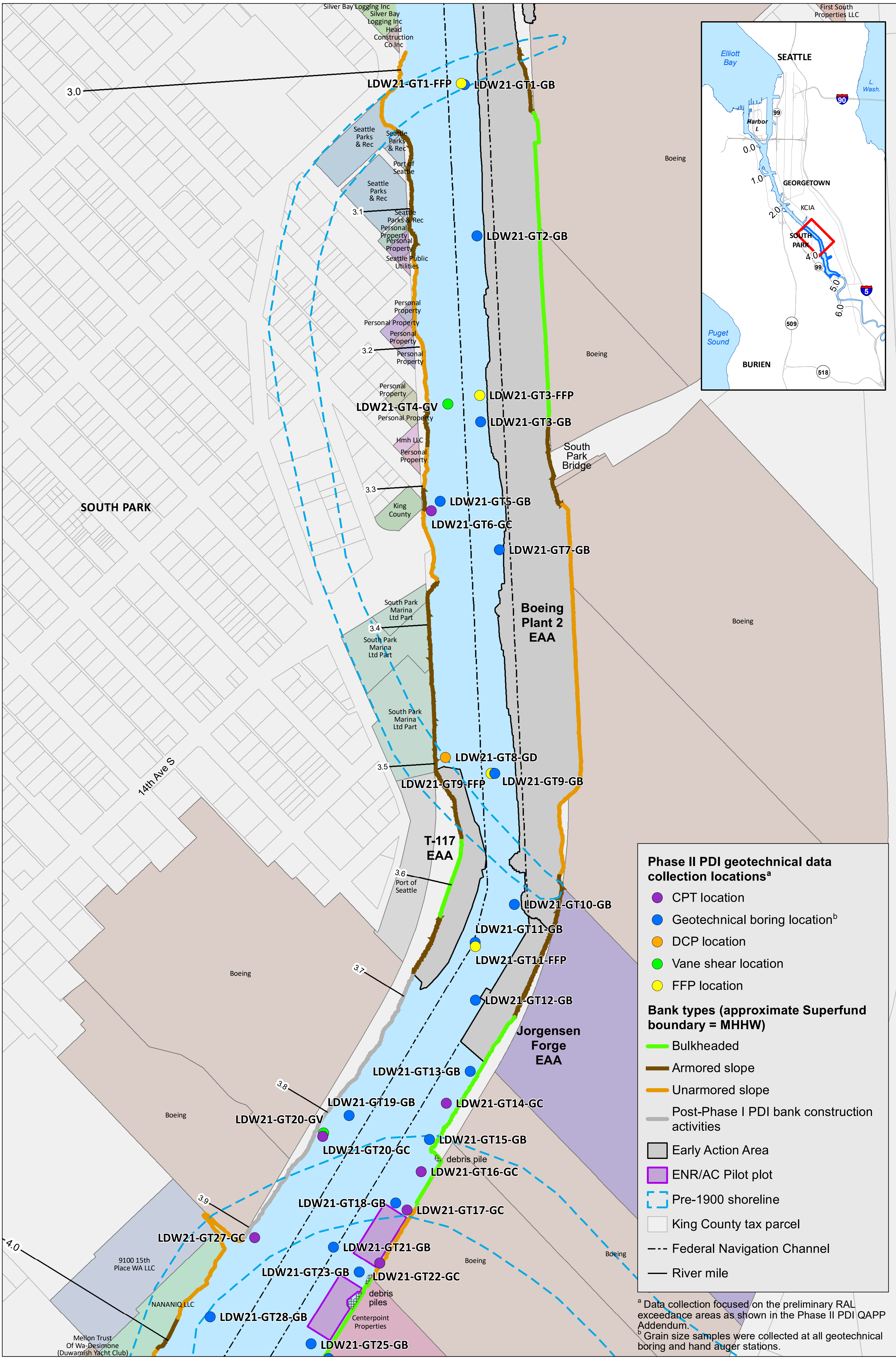

[a] Data collection focused on the preliminary RAL exceedance areas as shown in the Phase II PDI QAPP Addendum.
[b] Grain size samples were collected at all geotechnical boring and hand auger stations.

0 250 500 Feet
0 100 200 Meters

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Figure 8-1a. Phase II PDI geotechnical data locations, RMs 3.0 to 4.0

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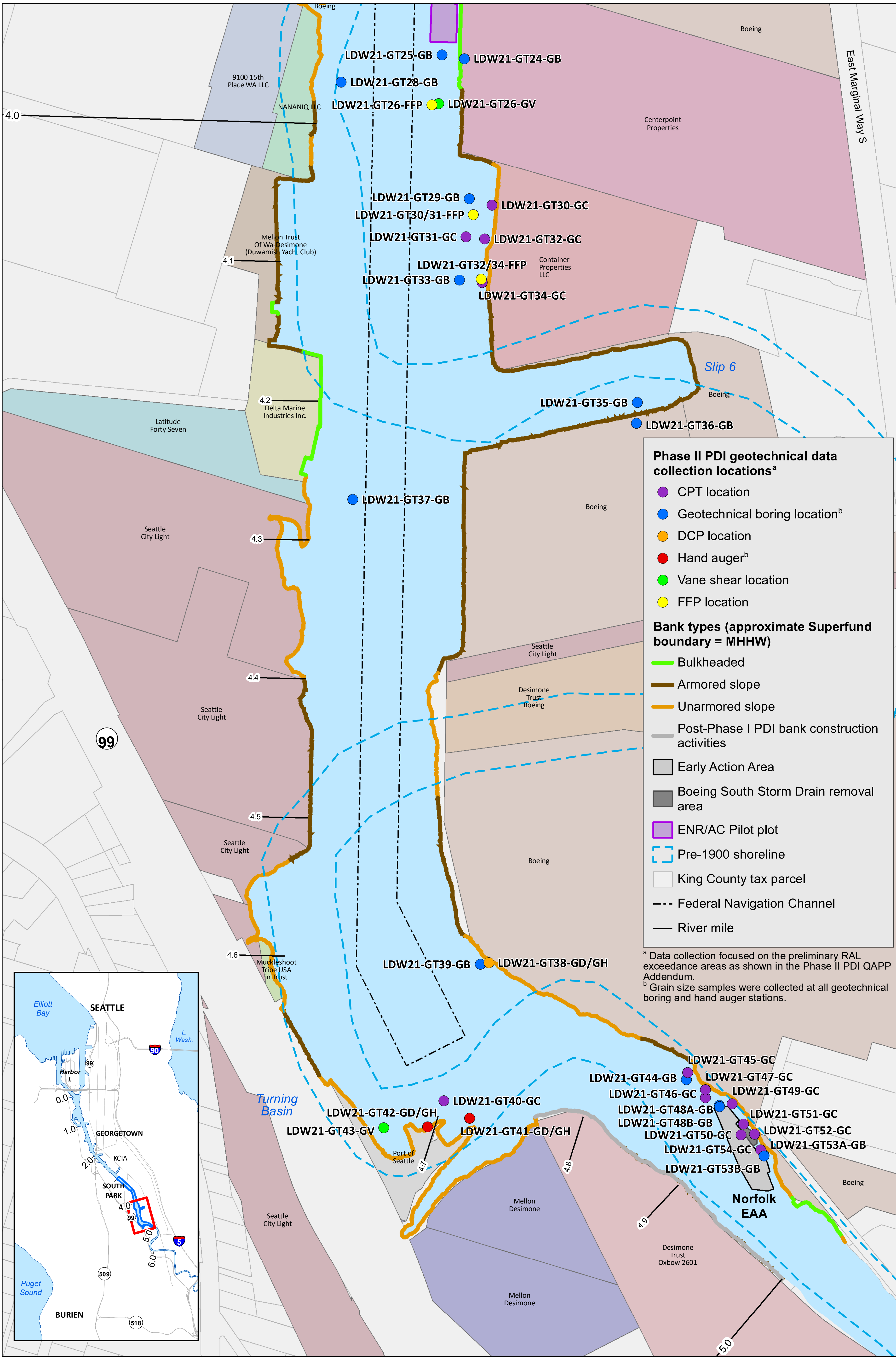

Prepared by ClaireC, 1/19/2024; W:\Projects\Duwamish AOC4\GIS\Maps and Analyses\Remedial Design\BODR\Fig 08-1b 7281 PhII PDI Geotech locations RM4-5.mxd

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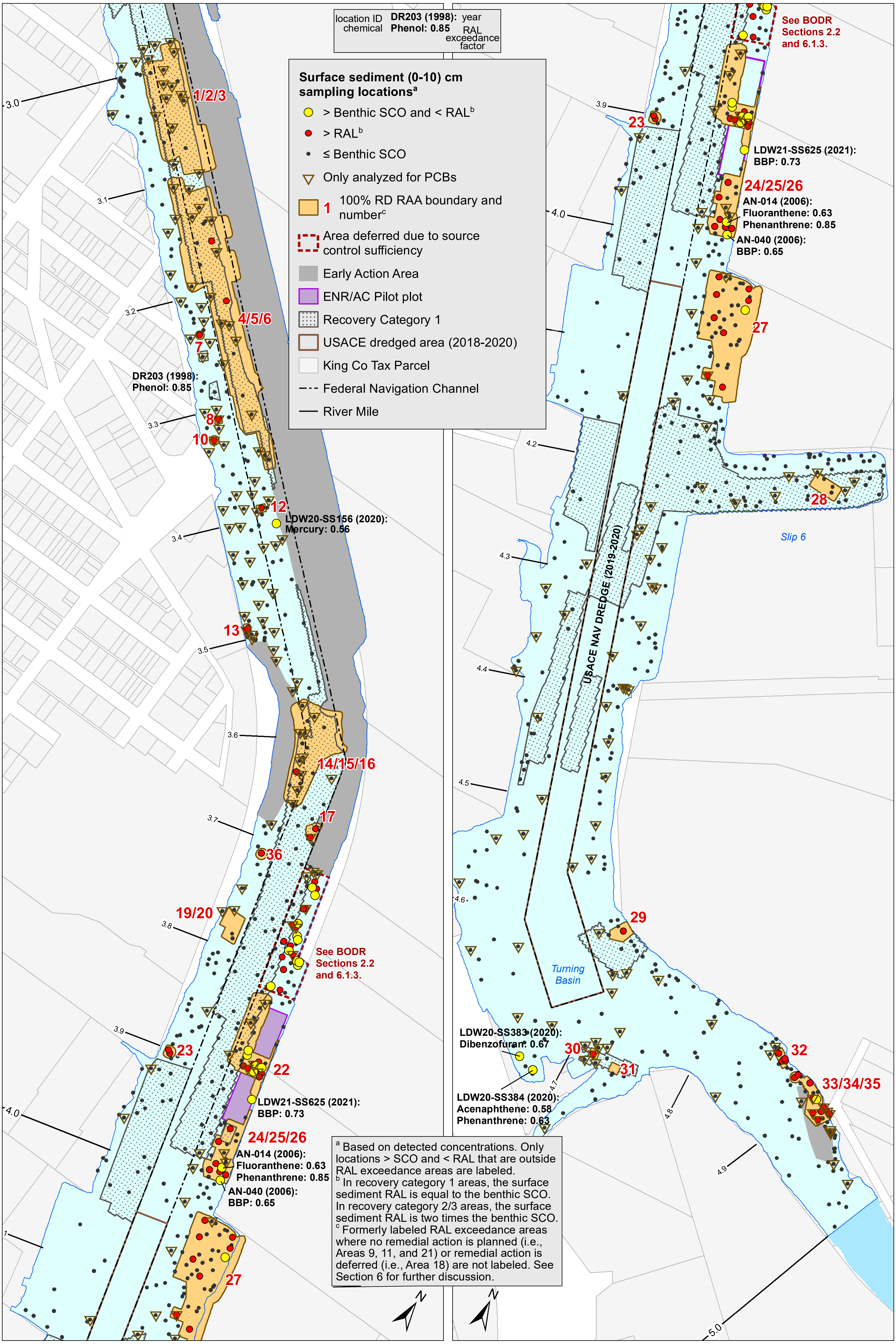
Figure 8-1b. Phase II PDI geotechnical data locations, RMs 4.0 to 5.0



0 500 1,000 Feet

0 100 200 Meters

Scale is the same for each inset map

Figure 10-1. MNR to benthic SCO locations compared with RAAs

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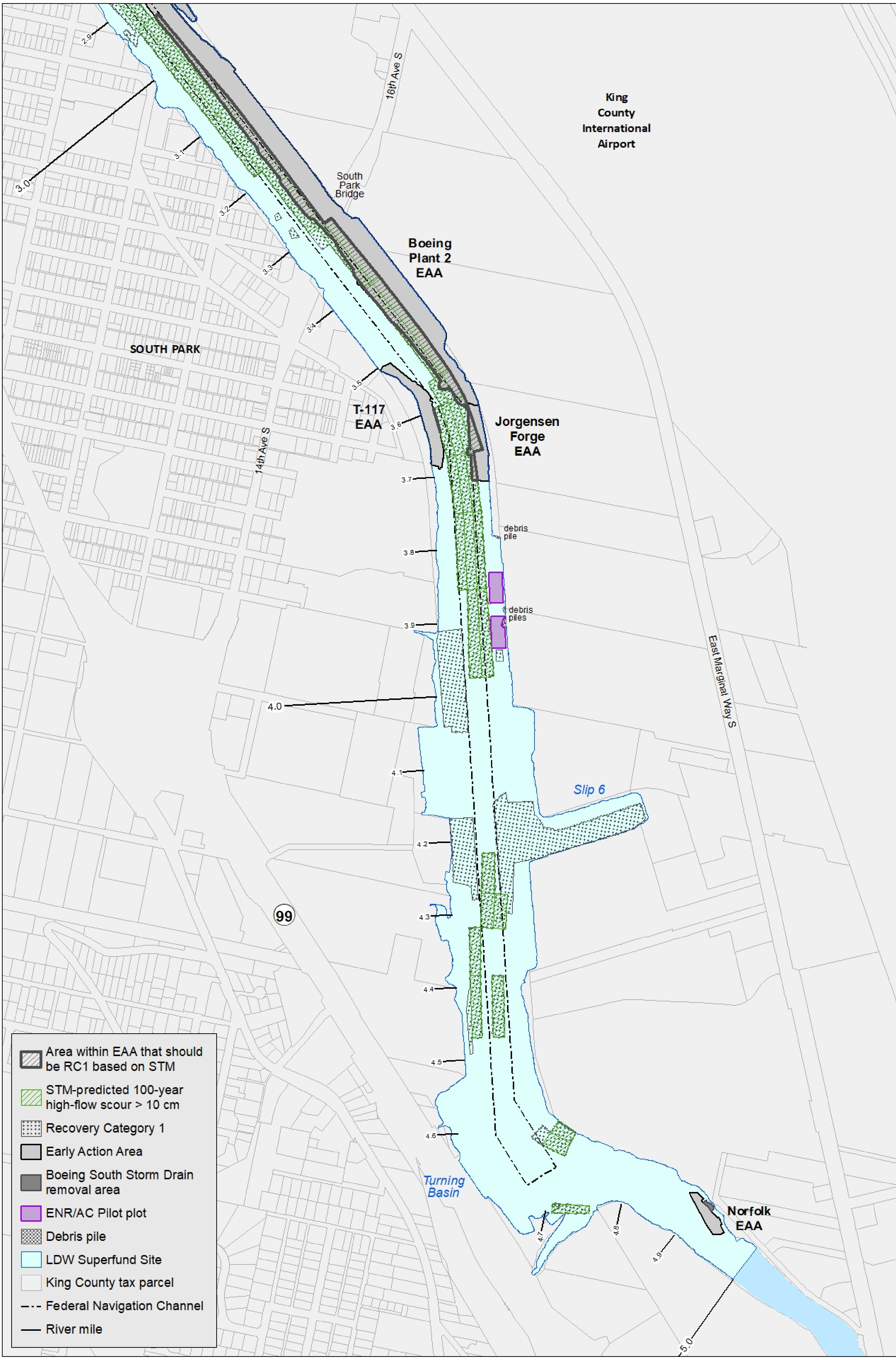

N
0 500 1,000 Feet
0 200 400 Meters

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Figure 10-2. Recovery Category 1 areas and Early Action Areas

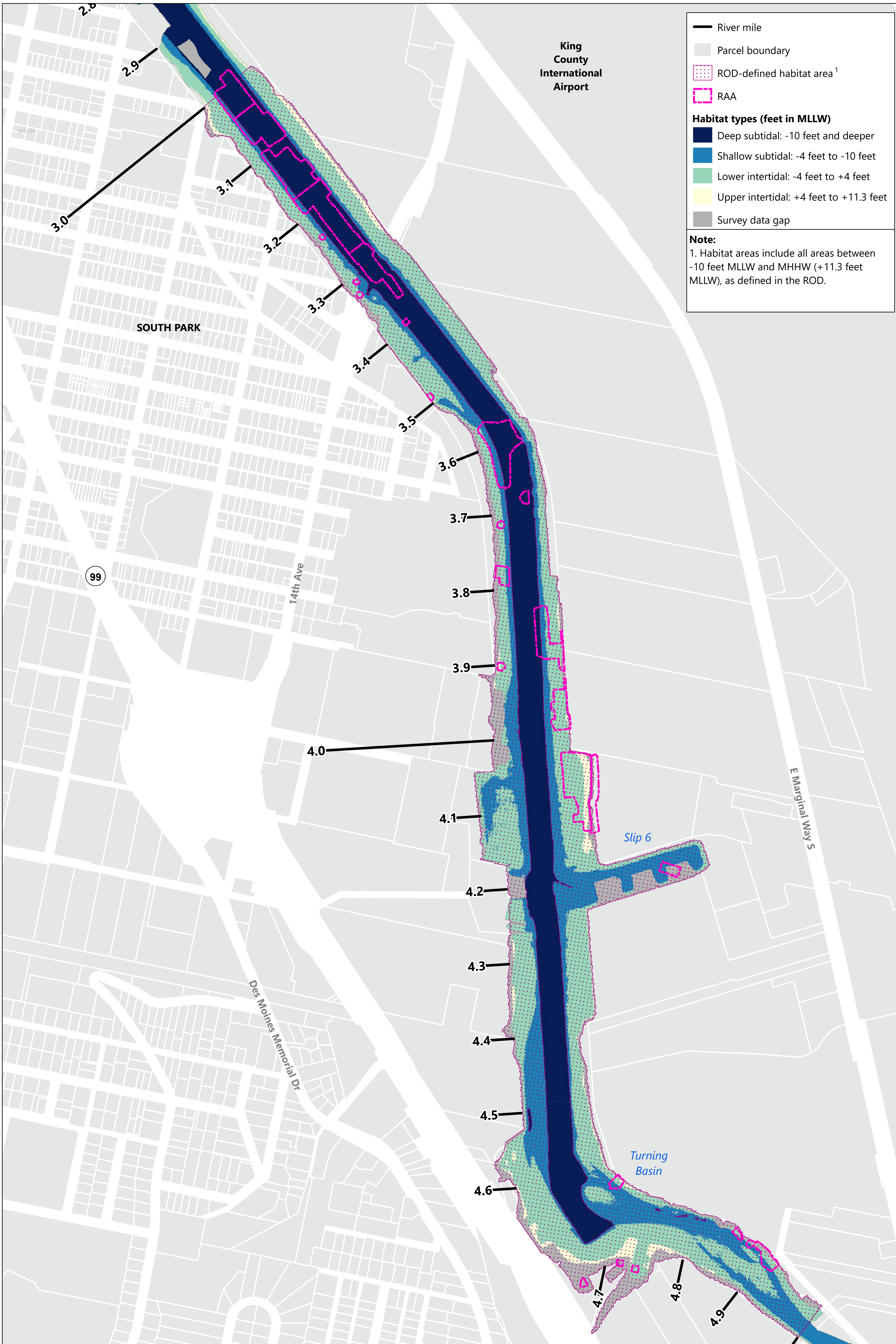

Figure 11-1a. Habitat types and ROD-defined habitat areas that overlap with RAAs

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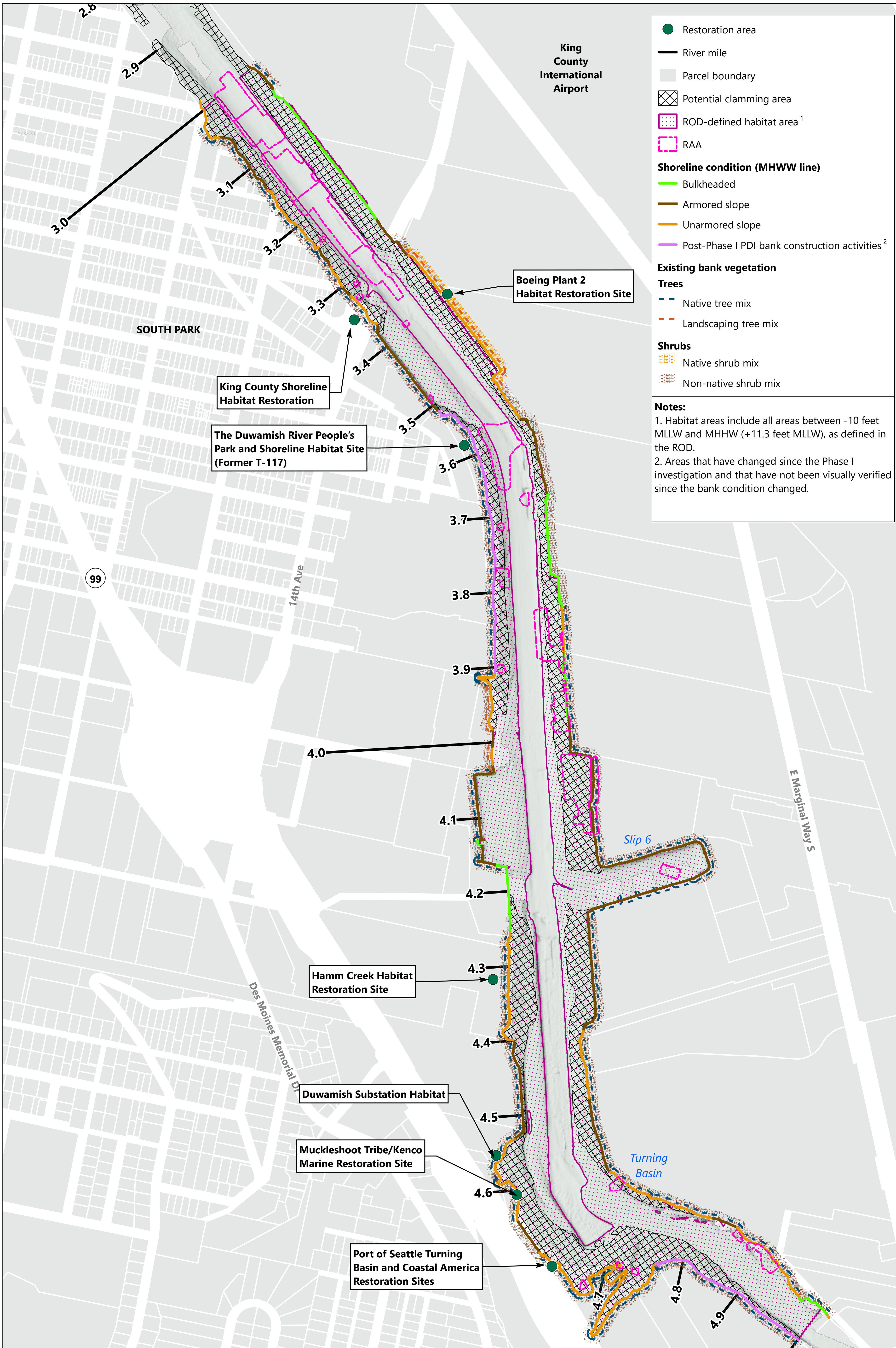

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0 650 1,300 Feet

0 100 200 Meters

N

Figure 11-1b. Clamming areas and shoreline conditions that overlap with RAAs

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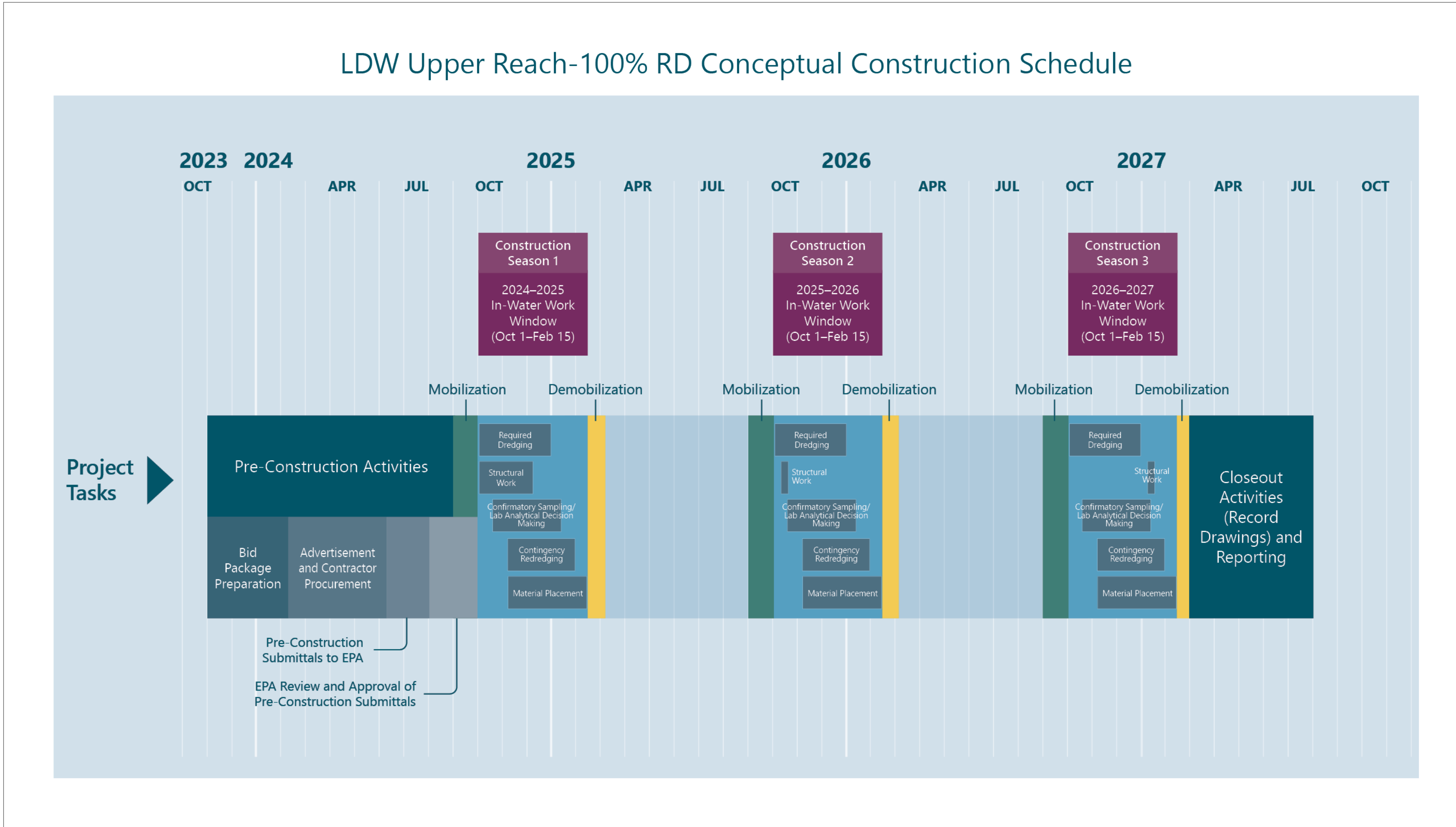

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Figure 13-1. LDW Upper Reach 90% Remedial Design Conceptual Construction Schedule

100% REMEDIAL DESIGN BASIS OF DESIGN REPORT FOR THE LDW UPPER REACH

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