Lower Duwamish Waterway Group

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

TECHNICAL MEMORANDUM: COMPILATION OF EXISTING DATA

FINAL

Prepared for

Lower Duwamish Waterway Group

For submittal to:

US Environmental Protection Agency

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Acronyms

AC	activated carbon
AML	Alaska Marine Lines
AOC	Administrative Order on Consent
Boeing	The Boeing Company
COC	contaminant of concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CSO	combined sewer overflow
DDT	dichlorodiphenyltrichloroethane
DL	detection limit
DMMP	Dredged Material Management Program
DOC	dissolved organic carbon
DQO	data quality objective
DSOA	Duwamish sediment other area
EAA	early action area
Ecology	Washington State Department of Ecology
EDD	electronic data deliverable
EIM	Environmental Information Management (Ecology database)
EMPC	estimated maximum potential concentration
ENR	enhanced natural recovery
EPA	US Environmental Protection Agency
EqP	equilibrium partitioning
EQuIS™	Environmental Quality Information System
FOIA	Freedom of Information Act
FS	feasibility study
ID	identification
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
MHHW	mean higher high water
MIT	Massachusetts Institute of Technology

MLK	Martin Luther King
MLLW	mean lower low water
MS	matrix spike
MSD	matrix spike duplicate
MTCA	Model Toxics Control Act
na	not applicable
NPDES	National Pollutant Discharge Elimination System
PAH	polycyclic aromatic hydrocarbon
PBDE	polybrominated diphenyl ether
PBT	persistent, bioaccumulative, toxic
PCB	polychlorinated biphenyl
PE	polyethylene
PEF	potency equivalency factor
PSEMP	Puget Sound Ecosystem Monitoring Program
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RARE	Regional Applied Research Effort
RI/FS	remedial investigation and feasibility study
RL	reporting limit
RM	river mile
SAP	sampling and analysis plan
SERDP	Strategic Environmental Research and Development Program
SPME	solid-phase microextraction
SRM	standard reference material
SVOC	semivolatile organic compound
T-115	Terminal 115
T-117	Terminal 117
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids
TEF	toxic equivalency factor
TEQ	toxic equivalent

TOC	total organic carbon
USACE	US Army Corps of Engineers
VOC	volatile organic compound
WDFW	Washington Department of Fish and Wildlife
Windward	Windward Environmental LLC

1 Introduction

The Lower Duwamish Waterway Group (LDWG) is conducting pre-design studies for the Lower Duwamish Waterway (LDW) in accordance with the third amendment of the Administrative Order on Consent (AOC) (EPA 2016d). The AOC amendment specifies that Task 2 will include a compilation of available relevant data made available after April 2010 (or earlier if associated with early action areas [EAAs] but not already included in the remedial investigation and feasibility study [RI/FS] dataset).[1] In addition, the AOC amendment states that Task 2 would include an assessment of the ongoing US Environmental Protection Agency (EPA) Regional Applied Research Effort (RARE), Massachusetts Institute of Technology (MIT), and enhanced natural recovery (ENR)/activated carbon (AC) pilot studies conducted in the LDW (EPA 2016d). The data compiled for Task 2, as described in this memorandum, were obtained from searches conducted through June 15, 2018.

This technical memorandum presents the data compilation approach (Section 2); data compilation summary for in-waterway data (Section 3); data compilation summary for source control-related data and upstream data (Section 4); and an assessment of the RARE, MIT, and ENR/AC pilot studies (Section 5). Sections 6 and 7 present a summary and references, respectively.

The main text is supplemented by appendices presenting data management rules (Appendix A), detailed results from data quality reviews (Appendix B), and exported data as user-ready Excel tables (Appendix C).

[1] The dataset used in the RI contains data collected through 2006. The dataset used in the FS contains all of the RI data plus any data collected after 2006 and prior to the completion of the draft FS in 2010.

2 Approach

This section presents the approach for the compilation of the Task 2 data, including the scope of data compiled, the data processing methods, and the data quality review procedure.

2.1 SCOPE

Three categories of data were compiled for this document:

- In-waterway data – includes sediment, surface water, tissue, porewater, and seep samples collected from within the LDW Superfund site
- Source control-related data – includes storm drain and combined sewer system solids, bank soil, and groundwater from upland areas adjacent to the LDW
- Upstream data – includes surface water (total and dissolved concentrations) and suspended solids from upstream areas in the Green / Duwamish River

The AOC states that only data obtained or made available since April 2010 would be compiled. It was not always possible to determine when the data were obtained or made available; therefore, any data collected in or after 2010 were targeted to ensure that all relevant data not in the RI / FS dataset were included.[2] Any available data that could be obtained by June 15, 2018 were included in the data compilation process.

For groundwater data, the third amendment to the AOC required an update of the groundwater dataset for upland areas following the general approach used in the Phase I RI, compiling data for contaminants of concern (COCs) in the EPA Record of Decision (ROD) (Tables 19 and 20) (EPA 2014b)[3] and for volatile organic compounds (VOCs).

The temporal and spatial scopes of the Task 2 data compilation are summarized in Table 2-1. As discussed in Section 2.2.2, data quality reviews of the compiled data were conducted for the in-waterway data only.

[2] In-waterway data collected prior to 2010 were included in this data compilation if they were not in the RI / FS dataset, including data associated with EAAs.

[3] ROD Tables 19 and 20 are *Cleanup Levels for PCBs, Arsenic, cPAHs, and Dioxins/Furans in Sediment for Human Health and Ecological COCs (RAOs 1, 2 and 4)* and *Sediment Cleanup Levels for Ecological (Benthic Invertebrate) COCs for RAO 3*, respectively.

Table 2-1. Data compilation scope

Medium	Spatial Extent	Date Range	Data Quality Review Required
In-waterway Data			
Sediment[a]	RM 0 to RM 5 of the LDW	collected in or after 2010[b]	yes
Surface water			
Tissue			
Porewater			
Seep			
Upland Data			
Bank soil[c]	RM 0 to RM 5 along the banks of the LDW	collected in or after 2010	no
Storm drain/combined sewer system solids	drainage basins discharging to the LDW		
Groundwater	wells closest to the LDW	most recent data collected	
Upstream Data			
Suspended solids – chemistry and particle size distribution	Green/Duwamish River at Foster Links (RM 10)	collected in or after 2010	no
Surface water			

[a] Subsurface samples are identified as those with a lower depth greater than 15 cm, regardless of the surface depth (e.g., 0-45 cm, 1-2 ft).

[b] May include pre-2010 data from EAA monitoring events not included in the FS.

[c] Samples identified as bank samples or from locations between +4 ft MLLW and +14 ft MLLW (i.e., elevations below MHHW).

EAA – early action area
FS – feasibility study
LDW – Lower Duwamish Waterway
MHHW – mean higher high water
MLLW – mean lower low water
RM – river mile

2.2 DATA PROCESSING

This section discusses the data processing approach. The initial data processing steps included searching for data within the scope of this task and acquiring those data electronically (Figure 2-1). The data were then compiled (i.e., imported) into an Environmental Quality Information System (EQuIS™) database containing the Task 2 data, and data quality reviews were conducted for in-waterway data. Data were then exported from the database into user-ready data tables. These steps are described in more detail below.

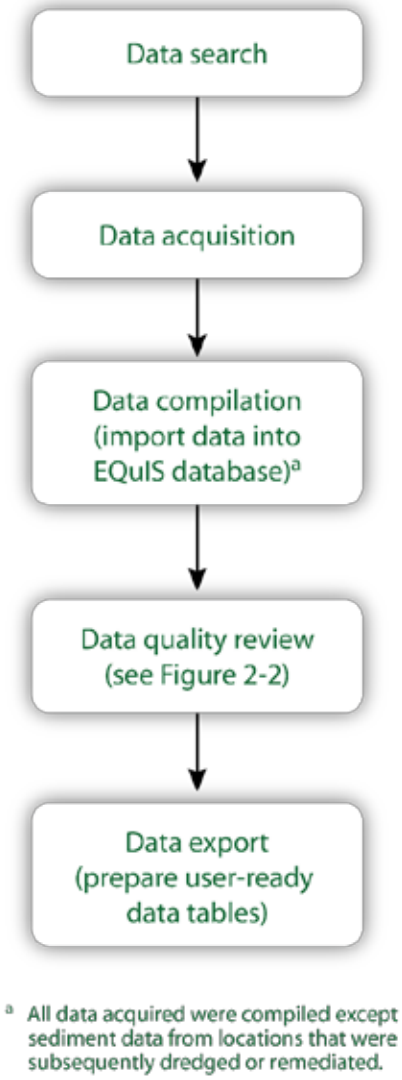


Figure 2-1.Task 2 data compilation process

2.2.1 Data search and acquisition

A search was conducted to identify studies that collected data within the scope of this data compilation (Table 2-1). The data search process consisted of four components:

- A request to LDWG for data from studies they have conducted
- A search of the Washington State Department of Ecology (Ecology) Environmental Information Management (EIM) database

- A review of the database compiled by AECOM,[4] which includes studies conducted or made available after the FS and before the November 2014 LDW ROD
- A request to Ecology and EPA for data from relevant studies that are not available in the EIM database

The EIM search tools and queries used to identify studies for the different types of sample areas and media included:

- Polygon search[5] between River Mile (RM) 0 and RM 5 of the LDW to identify studies with in-waterway samples, with the query limited to sediment, surface water, tissue, seep, and porewater
- Polygon search between RM 0 and RM 5 of the LDW to identify studies with bank samples, with the query limited to soil
- Polygon search of the upland area surrounding RM 0 to RM 5 of the LDW to identify studies with groundwater samples, with the query limited to groundwater
- Polygon search between RM 5 and RM 10 of the Green / Duwamish River to identify studies with upstream samples, with the query limited to surface water and suspended solids
- Search within the King County boundary to identify combined sewer system and storm drain samples collected by any party in King County, with the query limited to solids samples with media types including the words "sediment," "CSO,[6]" "CSS,[7]" or "stormwater"

A detailed review was then conducted to eliminate specific data from the initial search that were outside of the scope of Task 2, as summarized in Table 2-1. For combined sewer system and storm drain solids, only locations within the outfall basins defined in the RI were included (Map 2-1). Bank soil data were included only if it was clear from the study title (or data report, if available) that the samples were part of a bank soil investigation between RM 0 and RM 5.

For groundwater data, wells from all relevant studies were mapped, and a detailed review was conducted to identify those wells located nearest the LDW (Maps 2-2 through 2-6). For each of the wells located nearest the LDW, the range of sampling dates associated with each location was assessed to determine the most recent sampling event. Since many wells are sampled on a quarterly or semiannual basis, and analyses

[4] AECOM conducted the LDW Feasibility Study on behalf of LDWG.
[5] The polygon search tool enables a line to be drawn around an area for spatial selection of data.
[6] CSO for combined sewer overflow.
[7] CSS for combined sewer system.

may vary from one sampling event to the next, all samples collected within the most recent sampling year were identified for import.

Data for in-waterway sediment, bank soils, and groundwater were also excluded if they had been collected from locations that were subsequently remediated or dredged.

2.2.2 Data quality review

The data quality review process consisted of an evaluation of data quality objectives (DQOs) that were established in the RI/FS (Windward 2010) to determine data acceptability, followed by a more detailed review of data that met the DQOs (Figure 2-2). Per the AOC, only the in-waterway data were subject to a data quality review (Table 2-1), results of which were used to determine whether data were acceptable for all uses or for conditional use only. Data quality reviews were not conducted for source control-related data and upstream data; in the database, these data are flagged for conditional use only.

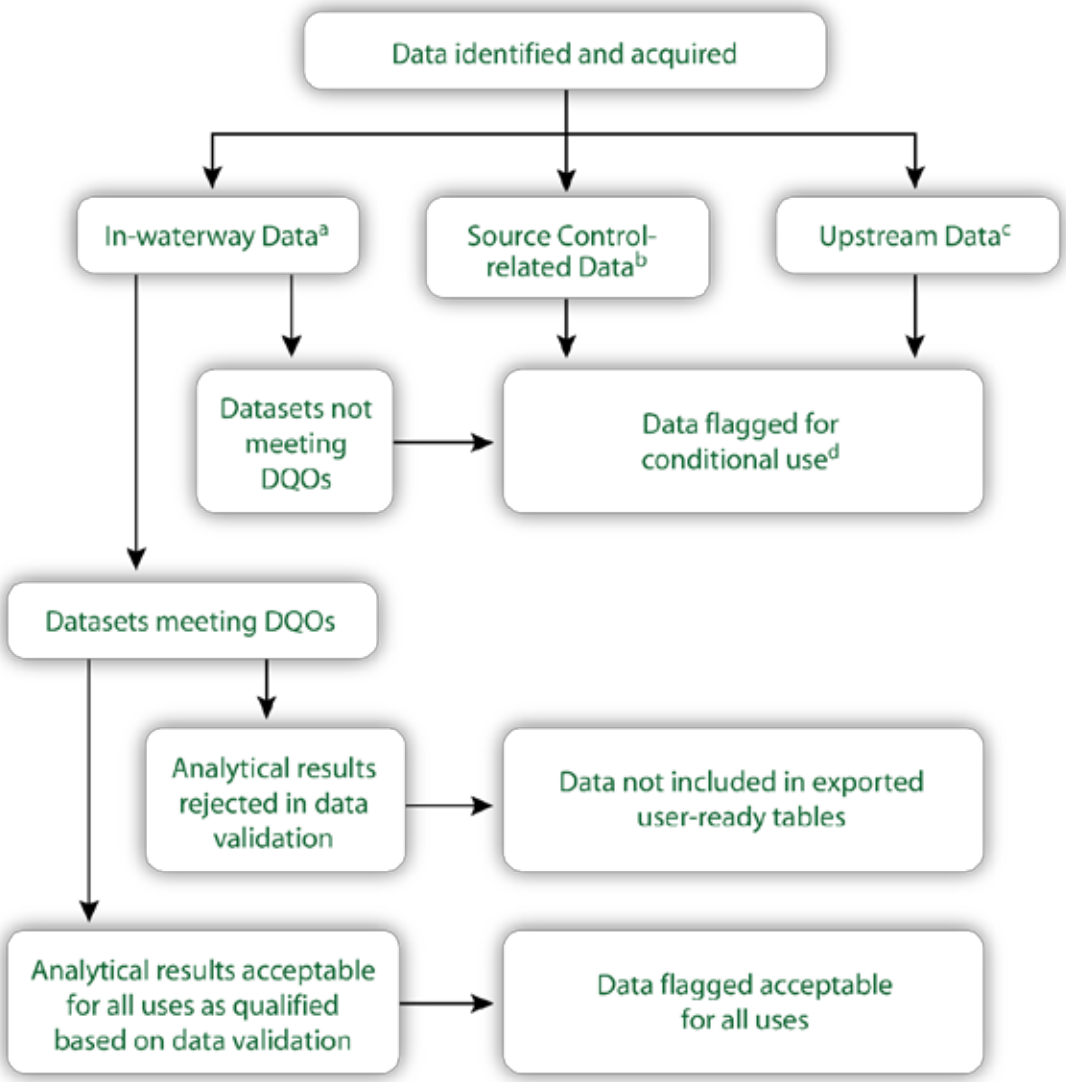


Figure 2-2. Data quality review process

2.2.2.1 DQOs

DQOs were established to determine whether chemistry data reviewed as part of Task 2 could be considered acceptable for all uses. Table 2-2 lists the DQOs, categorized by the level at which each DQO would be applied: event, sample, or result. A DQO applied at the result level could cause a result record to be qualified for a particular chemical but not for other chemicals analyzed during the same study. These DQOs are equivalent to

those established for the RI/FS (Windward 2010), with the exception of the event date. The data for the RI/FS included any data collected since 1990 and has been revised for this task to include any data collected since the RI/FS.

Table 2-2. DQOs for chemistry data to be considered acceptable for all uses

Level	DQO
Event	Hard copy or original electronic copy of data report must be available.
	Field coordinates (or a description of compositing methodology, if applicable) must be available.
	Data must have been collected in or after 2010, unless associated with an EAA and not previously in the RI/FS database.
	Information on sampling methods must be available.
	Existence and location of supporting documentation (i.e., analytical raw data, chain-of-custody forms, and sample handling descriptions) must be known.
Sample	Sediment sample depth must be identified.
	Sample type must be clearly identified (i.e., field-collected samples must be distinguishable from laboratory replicate and other QC samples).
Result	Data validation qualifiers must be present or derivable from laboratory qualifiers or QA information, and must be applied in a manner consistent with EPA functional guidelines (EPA 2011 for dioxin/furan methods; 2016a for high resolution methods; 2016b for inorganic methods; 2016c for organic methods)[a]
	Each result must have a laboratory-generated form (usually referred to as a Form 1).
	For non-detects, reporting limits and appropriate qualifiers must be given.
	Data for individual components must be available for recalculating analytical sums (e.g., total PCBs or total PAHs).
	Analytical methods must be identified.

[a] References to EPA's most recently published guidelines are presented here; previously published versions would be applicable to data validated prior to these dates.

DQO – data quality objective
EAA – early action area
EPA – US Environmental Protection Agency
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RI/FS – remedial investigation and feasibility study
QA – quality assurance
QC – quality control

2.2.2.2 Detailed data quality review

In-waterway data that met the DQOs summarized in Table 2-2 were reviewed to evaluate the level of data validation conducted and to note any significant analytical issues that would limit the data usability. Documents reviewed include available laboratory, data validation, and data summary reports.[8] The detailed data quality review process also included the identification of sampling objectives, sampling dates, sample collection methods, sampling depth for sediment and surface water samples, number of samples, number of field duplicates, chemicals analyzed, analytical methods,

[8] If data are summarized in a draft data report and data meet DQOs (e.g., data validation complete), they were included without conditional use flags.

analytical laboratory, and data validator. In addition, data validation reports were reviewed for significant analytical issues (i.e., rejected results).

For most datasets reviewed, the level of data validation was identified by the data validator for each study using the stages defined in EPA's *Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use* (EPA 2009). If an EPA data validation stage was identified in the data validation report, it was noted as part of the data quality review process for this task. If the reports for a particular dataset did not specify an EPA stage of data validation, Windward reviewed the validation methods and classified the data validation according to the corresponding or equivalent EPA validation stage. For data validated by King County, Windward applied data qualifiers based on the results of the King County data validation summary.

EPA data validation requirements depend on the project needs, so EPA guidance lists validation checks that should be included in each level of validation (i.e., Stages 1-4) (EPA 2009; Table 2-3). Stage 1 involves review of the data package for completeness, Stage 2 adds a compliance review, Stage 3 consists of calculation checks, and Stage 4 evaluates instrument outputs. Validation checks are intended for use in conjunction with the EPA national functional guidelines for data review (EPA 2011 for dioxin / furan methods; 2016a for high resolution methods; 2016b for inorganic methods; 2016c for organic methods) (EPA 2016a, b, c). Each subsequent stage builds upon the previous (e.g., Stage 3 includes the checks for Stages 1 and 2) and Stage 4 provides the most comprehensive level of data review.

Table 2-3. EPA-recommended validation checks

Validation Check	Validation Stage				
	1	2A	2B	3	4
Sample collection and laboratory receipt documentation reported	X	X	X	X	X
Correct analytical methods performed and dates reported	X	X	X	X	X
Correct analytes and laboratory qualifiers reported	X	X	X	X	X
Reporting limits reported and below requested RLs	X	X	X	X	X
Basic evaluation of results reported (e.g., to analytical method or contract requirements)	X	X	X	X	X
Requested sample handling and preparation methods performed and dates reported		X	X	X	X
Analytical and field QC data and acceptance criteria reported		X	X	X	X
Requested spikes added and frequency of QC samples appropriate		X	X	X	X
Holding times evaluated		X	X	X	X
Calibration data (e.g., initial and continuing calibration verifications and blanks) reported and frequency appropriate			X	X	X
Instrument performance checks and instrument QC samples reported and appropriate			X	X	X
Instrument response data for all instrument, laboratory, and field QC samples reported				X	X

Validation Check	Validation Stage				
	1	2A	2B	3	4
Recalculation and compliance check of initial calibration curve, opening and/or closing continuing calibration verification and blank, percent ratios for each tune, instrument performance checks, and retention time windows, as applicable				X	X
Instrument response checked against minimum response requirements				X	X
Recalculation of reported results, laboratory QC, and spike recoveries from instrument response				X	X
Instrument outputs (e.g., chromatograms and background/interference corrections) reported					X
Sample results, including non-detects and tentatively identified analytes, checked against instrument output for correct identification and quantification					X

QC – quality control
RL – reporting limit

2.2.3 Data import and reduction

Data identified and acquired from the search process described in Section 2.2.1 were compiled (i.e., imported) into an EQuIS™ database. In order to import the data, an electronic data deliverable (EDD) compatible with EQuIS™ was created for each study. The following steps were conducted to prepare these EDDs:

- Confirmation of proper identification of field and lab quality control (QC) samples (when possible)
- Confirmation of consistent reporting of detection limits
- Standardization of method names, chemical names, and units
- Addition of custom sample parameters capturing data quality review components (e.g., data quality review status, validation status)
- Addition of custom location parameters capturing spatial details (e.g., river mile, outfall basin)

Data were then exported from EQuIS™ as user-ready datasets (see Appendix C).[9] The data management rules used for each location group and media type are presented in Appendix A. These rules are the same as those used in the RI/FS (Appendix E of Windward 2010) with the exception of rules for selecting the preferred result when there were multiple results for a single sample using different analytical methods. In the RI/FS, the preferred result was selected primarily based on a comparison of the detection status, reporting limits, and data qualifiers between the methods. The revised rules select the result based on a preference for method, as described in Appendix A.

[9] The Task 1 work plan included a data management plan describing how the data from the RI/FS and Task 2 datasets can be integrated (Windward and Integral 2017).

The final qualifiers of the results in the user-ready data tables are the interpretive qualifiers based on the laboratory qualifiers and the data validation qualifiers.

Because the data validation guidance from EPA for dioxins and furans and polychlorinated biphenyl (PCB) congeners changed in 2013 (EPA 2014a), some of the PCB congener and dioxin/furan results were validated using the old rule and some were validated using the new rule. Before 2013, results with estimated maximum potential concentration (EMPC) laboratory qualification were qualified as non-detected results and U-qualified. Post-2013, the guidance requires the EMPC-qualified results above the reporting limit (RL) to be treated as estimated and J-qualified. The EMPC results below the RL are qualified as non-detected results and U-qualified.

In cases where EMPC-qualified results had no validation qualifier, the EMPC-qualified results were qualified based on the most recent guidance when there was sufficient information to support the qualification. If there was not sufficient information available, the EMPC-qualified results were qualified as non-detects and were U-qualified. The treatment of EMPC qualified data has a minimal impact on the calculation of dioxin and furan toxic equivalents (TEQs) and total PCB concentrations as the sum of PCB congeners.

3 Data Compilation Summary – In-waterway Data

This section summarizes in-waterway data compiled (i.e., imported into EQuIS™), including sediment, surface water, tissue, porewater, and seep data collected from the LDW between RM 0 and RM 5 in or after 2010. Sediment data collected within EAAs were also included if collected prior to January 2010, not in the RI/FS dataset, and not from locations that had been subsequently remediated or dredged.

Eighty-eight in-waterway datasets were compiled into the Task 2 database (Table 3-1): 55 surface sediment datasets, 14 subsurface sediment datasets, 4 surface water datasets, 2 tissue datasets, 8 porewater datasets, and 5 seep datasets. Of the compiled datasets, DQOs were only provisionally met for nine of the surface sediment datasets; eight of the subsurface sediment datasets; one of the surface water datasets; five of the porewater datasets; four of the seep datasets; and all of the tissue datasets. Sampling locations for the compiled in-waterway data are shown on separate maps for surface sediment (Map 3-1), subsurface sediment (Map 3-2), surface water (Map 3-3), tissue (Map 3-4), porewater (Map 3-5), and seeps (Map 3-6). User-ready tables with exported in-waterway data are included in Appendix C. Data that only provisionally met DQOs are flagged for conditional use only in the user-ready data tables.

Table 3-1. In-waterway data included in data compilation

Sampling Event	Sampling Year	No. of Samples	DQOs Met?	Study Client	Reference[a]
Surface Sediment (lower depth ≤ 15 cm)					
AML under-pier sampling	2015	3	provisional[b]	na	EIM (2016) (AMLPFM15)
Boeing Development Center					
South storm drain outlet 2010	2010	3	yes	Boeing	CALIBRE (2011)
South storm drain outlet 2011	2011	3	yes	Boeing	CALIBRE (2012)
South storm drain outlet 2012	2012	3	yes	Boeing	CALIBRE (2013)
South storm drain outlet 2013	2013	3	yes	Boeing	CALIBRE (2014)
South storm drain outlet 2014	2014	3	yes	Boeing	CALIBRE (2015)
South storm drain outlet 2015	2015	3	yes	Boeing	CALIBRE (2016)
Boeing Plant 2					
Perimeter monitoring - pre-dredge 2012 (event 1)	2012	46	yes	Boeing	AMEC (2013)

Sampling Event	Sampling Year	No. of Samples	DQOs Met?	Study Client	Reference[a]
Perimeter monitoring - end of season 2013 (event 2)	2013	43	yes	Boeing	AMEC (2013)
Perimeter monitoring - pre-dredge 2013 (event 3)	2013	38	yes	Boeing	DOF et al. (2014)
Perimeter monitoring - end of season 2014 (event 4)	2014	38	yes	Boeing	DOF et al. (2014)
Perimeter monitoring - pre-SW bank excavation 2014 (event 5)	2014	18	yes	Boeing	AMEC Foster Wheeler et al. (2016)
Perimeter monitoring - pre-dredge 2014 (event 6)	2014	56	yes	Boeing	AMEC Foster Wheeler et al. (2016)
Perimeter monitoring - end of season 2015 (event 7)	2015	56	yes	Boeing	AMEC Foster Wheeler et al. (2016)
Post-construction surface sediment monitoring year 0	2015	36	yes	Boeing	AMEC Foster Wheeler et al. (2016)
Post-construction surface sediment monitoring year 1	2016	36	yes	Boeing	Amec Foster Wheeler (2016)
Additional Duwamish sediment other area backfill sampling	2017	97	yes	Boeing	Amec Foster Wheeler and DOF (2017)
Crowley Marine Services Inc. 8th Ave S	2013-2014	23	provisional[b]	na	EIM (2016) (FS1940187)
Duwamish Diagonal					
2010 monitoring	2010	23	yes	King County	King County (2015)
2011 monitoring	2011	23	yes	King County	King County (2016a)
2012 monitoring	2012	22	yes	King County	King County (2016a)
Duwamish Shipyard, Inc. Phase 1 RI, sediments	2011	12	provisional[b]	Duwamish Shipyard, Inc.	EIM (2016) (AQDSI2011Sed)
Duwamish Shipyard, Inc. supplemental (Phase 2) RI	2013	18	provisional[b]	Duwamish Shipyard, Inc.	EIM (DSIP2RI)
Glacier Northwest - Reichhold, Inc. RI/FS	2012	20	provisional[b]	na	EIM (FS23881883-RI)
Industrial Container Services WA LLC (EAA 2 - Lower Duwamish)	2012, 2014	38	provisional[b]	Industrial Container Services WA LLC	EIM (FS2154)
Isaacson-Thompson RI sediment	2012	15	yes	Boeing	Landau (2014)

Sampling Event	Sampling Year	No. of Samples	DQOs Met?	Study Client	Reference[a]
Jorgensen backfill samples - pre-DSOA dredge	2014	6	yes	Boeing	AMEC Foster Wheeler et al. (2016)
Jorgensen backfill samples - post-DSOA dredge	2015	7	yes	Boeing	AMEC Foster Wheeler et al. (2016)
King County CSO 2011 sediment characterization	2011	6	yes	King County	King County (2012)
LDW ENR/AC Pilot Study					
Candidate Plot Sampling	2014	48	yes	LDWG	LDWG (2015)
Candidate Plot Sampling round 2	2014	16	yes	LDWG	LDWG (2015)
Baseline sampling	2016	18	yes	LDWG	AMEC et al. (2017)
RARE arsenic accumulation study	2015	53	yes	USACE	Kerns et al. (2017b)
Rhone Poulenc					
Rhone Poulenc sediment sampling investigation	2011	40	provisional[b]	Rhodia Inc	Cardno Entrix (2012)
Former Rhone Poulenc sediment characterization	2011–2012	24	yes	Container Properties LLC	AMEC (2012a)
Slip 1 field sampling and data report	2015	65	yes	Manson Construction Co.	Integral (2015b)
Slip 4					
Removal action construction 2012	2011–2012	52	yes	City of Seattle	Integral (2012)
EAA, 8th Ave terminals	2012	5	yes	City of Seattle	Integral (2013)
EAA long-term monitoring year 1	2013	10	yes	City of Seattle	Integral (2014)
EAA long-term monitoring year 3 (2015)	2015	8	yes	City of Seattle	Integral (2015a)
Long-term monitoring year 5	2017	8	yes	City of Seattle	Windward (2018)
South Park Bridge replacement					
2011 (Phase 1)	2011	4	yes	King County	Windward (2012)
2012 (Phase 2)	2012	4	yes	King County	Windward (2012)
2014 (Phase 4)	2014	2	yes	King County	Windward (2014)
South Park Marina 2016 sampling	2016	16	yes	South Park Marina	TIG (2016)

Sampling Event	Sampling Year	No. of Samples	DQOs Met?	Study Client	Reference[a]
South Park slag and sediment results	2017	10	yes	na	Port of Seattle (2017)
Surface sediment sampling at outfalls in the LDW	2011	160	yes	Ecology	SAIC (2011)
T-115					
Post-dredge sediment characterization and sand cover monitoring	2010	4	yes	Port of Seattle	SEE (2010)
Year 1 sand cover monitoring and recontamination study	2011	4	yes	Port of Seattle	SEE and TEC (2012)
Year 3 final sand cover monitoring	2013	4	yes	Port of Seattle	SEE (2013)
T-117					
Cleanup action 2013 - pre-dredge perimeter sediment	2013	5	yes	Port of Seattle	Port of Seattle (2016)
Cleanup action 2013 - post-dredge perimeter sediment	2014	5	yes	Port of Seattle	Port of Seattle (2016)
Outfall post-construction sediment sampling	2015	9	provisional[b]	na	EIM (LDWT117OF PostConSed)
Pre-operation outfall sediment sampling	2016	9	yes	City of Seattle	Integral (2016)
Urban Waters Initiative, sediment quality in Elliott Bay	2013	6	provisional[b]	na	EIM (UWI2013)
Subsurface Sediment (lower depth > 15 cm)					
Crowley Marine Services Inc. 8th Ave S	2014	18	provisional[b]	na	EIM (FS1940187)
Douglas Management dock (AML)	2013	1	provisional[b]	Ecology	EIM (AODE8258)
Duwamish River navigation channel maintenance dredging (DY12)	2011	17	provisional[b]	USACE	EIM (DUW1111)
Duwamish Shipyard, Inc. Phase 1 RI, sediments	2011	65	provisional[b]	Duwamish Shipyard, Inc.	EIM (AQDSI2011Sed)
Duwamish Shipyard, Inc. supplemental (Phase 2) RI	2013	51	provisional[b]	Duwamish Shipyard, Inc.	EIM (DSIP2RI)
Duwamish Waterway, East Waterway, and West Waterway subsurface sediment characterization	2012	44	provisional[b]	USACE	EIM (DUWSU12)
Duwamish Waterway dredged material characterization	2017	16	yes	USACE	USACE (2018)
Former Rhone-Poulenc sediment characterization	2011–2012	82	yes	Container Properties LLC	AMEC (2012a)

Sampling Event	Sampling Year	No. of Samples	DQOs Met?	Study Client	Reference[a]
Glacier Northwest - Reichhold, Inc. RI/FS	2012	62	provisional[b]	na	EIM (FS23881883-RI)
Industrial Container Services WA LLC (EAA 2 - Lower Duwamish)	2012	38	provisional[b]	Industrial Container Services WA LLC	EIM (FS2154)
Isaacson-Thompson RI sediment	2012	53	yes	Boeing	Landau (2014)
LDW ENR/AC pilot study - Candidate Plot Sampling	2014	12	yes	LDWG	LDWG (2015)
LDW ENR/AC pilot study - Candidate Plot Sampling round 2	2014	4	yes	LDWG	LDWG (2015)
South Park Marina 2016 sampling	2016	32	yes	South Park Marina	TIG (2016)
Surface Water					
Douglas Management dock (AML)	2013-2014	3	provisional[b]	Ecology	EIM (AODE8258)
King County NPDES receiving water	2011-2012	12	yes	King County	Mickelson (2013)
LDW groundwater sampling for PCBs	2017	6	yes	Ecology	Leidos (2017)
RARE arsenic accumulation study	2015	2	yes	USACE	Kerns et al. (2017b)
Tissue					
WDFW PSEMP Toxics in Biota Study – toxic contaminants in Dungeness crab and spot prawn from Puget Sound	2011	2	provisional[b]	WDFW	EIM (C1200226)
WDFW PSEMP Toxics in Biota Study – toxic contaminants in juvenile Chinook from Puget Sound	2013	9	provisional[b]	WDFW	EIM (G1300083)
Porewater					
Art Brass Plating, Soil and Groundwater Cleanup	2011	25	provisional[b]	Art Brass Plating	EIM (FS88531932)
Duwamish Shipyard, Inc. Phase 1 RI, sediments	2011	12	provisional[b]	Duwamish Shipyard, Inc.	EIM (AQDSI2011Sed)
Duwamish Shipyard, Inc. supplemental (Phase 2) RI	2013	67	provisional[b]	Duwamish Shipyard, Inc.	EIM (DSIP2RI)
Duwamish Waterway, East Waterway, and West Waterway subsurface sediment characterization	2012	38	provisional[b]	USACE	EIM (DUWSU12)
Glacier Northwest - Reichhold, Inc. RI/FS	2012	20	provisional[b]	na	EIM (FS23881883-RI)

Sampling Event	Sampling Year	No. of Samples	DQOs Met?	Study Client	Reference[a]
LDW ENR/AC Pilot Study baseline sampling	2016–2017	18	yes	LDWG	AMEC et al. (2017)
RARE arsenic accumulation study	2015	15	yes	USACE	Kerns et al. (2017b)
Former Rhone-Poulenc shoreline investigation	2011	7	yes	Container Properties LLC	AMEC (2012b)
Seep					
Crowley Marine Services Inc. 8th Ave S	2013	5	provisional[b]	na	EIM (FS1940187)
Douglas Management dock (AML)	2013-2014	6	provisional[b]	Ecology	EIM (AODE8258)
Duwamish Marine Center	2015	1	provisional[b]	Ecology	EIM (AODE8072)
Duwamish Shipyard, Inc. supplemental (Phase 2) RI	2013	3	provisional[b]	Duwamish Shipyard, Inc.	EIM (DSIP2RI)
Isaacson-Thompson RI Seep	2012	11	yes	Boeing	Landau (2014)

[a] For data obtained from EIM, the study ID is provided. Data were downloaded from EIM between November 15, 2016, and June 15, 2018.

[b] For sampling efforts conducted with agency oversight, it is highly likely that adequate supporting documentation is available; however, such documentation was not readily available for review at the time that this compilation memo was written. These studies have been flagged in the dataset as "conditional use only."

AC – activated carbon
AML – Alaska Marine Lines
Boeing – The Boeing Company
CSO – combined sewer overflow
DQO – data quality objective
EAA – early action area
Ecology – Washington State Department of Ecology
EID – identification
EIM – Environmental Information Management (Ecology database)
ENR – enhanced natural recovery
LDW – Lower Duwamish Waterway
LDWG – Lower Duwamish Waterway Group
na – not applicable or not available
NPDES – National Pollutant Discharge Elimination System
PCB – polychlorinated biphenyl
PSEMP – Puget Sound Ecosystem Monitoring Program
RARE – Regional Applied Research Effort
RI – remedial investigation
RI/FS – remedial investigation/feasibility study
T-115 – Terminal 115
T-117 – Terminal 117
USACE – US Army Corps of Engineers
WDFW – Washington Department of Fish and Wildlife

Five datasets were not included in the Task 2 data compilation because the sampling locations were later dredged or remediated (Table 3-2).[10] Tissue data from the RARE study were not included in the database because they did not represent tissues from clams exposed for their full life cycle in the LDW (mature clams were temporarily exposed as part of an *in situ* bioaccumulation study). Data from MIT studies conducted in 2012, 2014, and 2016 are not yet available for inclusion in the database (Table 3-2).

[10] In cases where samples were collected from a post-remediation or post-capping surface, the associated data were included in the compilation.

Table 3-2. In-waterway datasets excluded or unavailable for Task 2 data compilation

Study Name	Sampling Year	Media Sampled	Justification	Original Source
Datasets Excluded				
Duwamish Yacht Club maintenance dredging (DY13)	2012	sediment	dredged since sampled	USACE (as part of DMMP)
South Park Bridge DMMP DY11 (phase 1)	2009–2010	sediment, porewater	dredged since sampled	USACE (as part of DMMP)
South Park Bridge DMMP DY11 (phase 2)	2009–2010	sediment, porewater	dredged since sampled	USACE (as part of DMMP)
T-117 cleanup action 2013 - dredge unit sediment	2014	sediment	backfilled since sampling	AECOM
RARE[a]	2013 and 2015	tissue	not representative of LDW clams	USACE and EPA
Datasets Unavailable				
MIT studies	2012, 2014, and 2016	sediment, porewater, surface water, seeps, tissue	final data not yet available	MIT
Slip 4 sediment sampling	2010	sediment	data not obtained[b]	SAIC
WDFW PSEMP Toxics in Biota Study – toxic contaminants in English sole from Puget Sound	2011, 2013, and 2015	tissue (English sole fillet)	data not obtained[c]	WDFW

[a] Mature clams were temporarily exposed as part of an *in situ* bioaccumulation study.

[b] Data could not be obtained; however, due to extensive dredging within Slip 4, it is likely that most, if not all, of these data would be excluded because they represent material that has been removed.

[c] Summary-level data were obtained, but there was insufficient detail to incorporate into the database.

DMMP – Dredged Material Management Program
DY – dredging year
EPA – US Environmental Protection Agency
LDW – Lower Duwamish Waterway
MIT – Massachusetts Institute of Technology
PSEMP – Puget Sound Ecosystem Monitoring Program
RARE – Regional Applied Research Effort
T-117 – Terminal 117
USACE – US Army Corps of Engineers
WDFW – Washington Department of Fish and Wildlife

Datasets that met DQOs are presented in Table 3-3 (including results of the data quality reviews). All data in Table 3-3 are considered acceptable for all uses, with the following exceptions:

- T-117 cleanup action pre-dredge perimeter sediment sampling (2013) – Results for 4-chloroaniline in all five samples were rejected by the data validator due to low laboratory control sample (LCS) recovery.
- Slip 4 EAA long-term monitoring year 3 (2015) – Results for benzyl alcohol data for four of eight samples were rejected by the data validator due to low LCS recovery.
- Surface sediment sampling at outfalls in the LDW (2011) – 71 results for nine semivolatile organic compounds (SVOCs) were rejected by the data validator

because of low (less than 10 percent) LCS / laboratory control sample duplicate (LCSD) and / or matrix spike (MS) / matrix spike duplicate (MSD) recoveries. Rejected results include 25 data points for 2,4-dinitrophenol; 10 each for aniline and 3,3'-dichlorobenzidine; nine for hexachlorocyclopentadiene; seven for 4-chloroaniline; four for 3-nitroaniline; two for 4,6-dinitro-2-methylphenol; and one for 2,4-dimethylphenol.

- Duwamish Waterway dredged material characterization – Results for polybrominated diphenyl ether (PBDE)-010 in three of three samples were rejected by the data validator due to low LCS recovery.

Table 3-3. Summary of in-waterway data that met DQOs

Sampling Area	Sampling Event	Sampling Year	No. of Samples[a]	Analytes	Data Validation Level[b]	Data Quality Conclusion	Reference
Surface Sediment (lower depth ≤ 15 cm)							
Boeing Development Center	South storm drain outlet 2010	2010	3	PCBs (as Aroclors), TOC, total solids	EPA Stage 2A equivalent	acceptable for all uses	CALIBRE (2011)
	South storm drain outlet 2011	2011	3	PCBs (as Aroclors), TOC, total solids	EPA Stage 2A equivalent	acceptable for all uses	CALIBRE (2012)
	South storm drain outlet 2012	2012	3	PCBs (as Aroclors), TOC, total solids	EPA Stage 2A equivalent	acceptable for all uses	CALIBRE (2013)
	South storm drain outlet 2013	2013	3	PCBs (as Aroclors), TOC, total solids	EPA Stage 2A equivalent	acceptable for all uses	CALIBRE (2014)
	South storm drain outlet 2014	2014	3	PCBs (as Aroclors), TOC, total solids	EPA Stage 2A equivalent	acceptable for all uses	CALIBRE (2015)
	South storm drain outlet 2015	2015	3	PCBs (as Aroclors), total solids	EPA Stage 2A equivalent	acceptable for all uses	CALIBRE (2016)
Boeing Plant 2	Perimeter monitoring - pre-dredge 2012 (event 1)	2012	46	metals, PCBs (as Aroclors), TOC, total solids	EPA Stage 2B	acceptable for all uses	AMEC (2013)
	Perimeter monitoring - end of season 2013 (event 2)	2013	43	metals, PCBs (as Aroclors), TOC, total solids	EPA Stage 2B	acceptable for all uses	AMEC (2013)
	Perimeter monitoring - pre-dredge 2013 (event 3)	2013	38	metals, PCBs (as Aroclors), TOC, total solids	EPA Stage 2B	acceptable for all uses	DOF et al. (2014)
	Perimeter monitoring - end of season 2014 (event 4)	2014	38	metals, PCBs (as Aroclors), TOC, total solids	EPA Stage 2B	acceptable for all uses	DOF et al. (2014)
	Perimeter monitoring - pre-SW bank excavation 2014 (event 5)	2014	18	metals, PCBs (as Aroclors), TOC, total solids	EPA Stage 2B	acceptable for all uses	AMEC Foster Wheeler et al. (2016)
	Perimeter monitoring - Pre-dredge 2014 (event 6)	2014	56	metals, PCBs (as Aroclors), TOC, total solids	EPA Stage 2B	acceptable for all uses	AMEC Foster Wheeler et al. (2016)
	Perimeter monitoring - end of season 2015 (event 7)	2015	56	metals, PCBs (as Aroclors), TOC, total solids	EPA Stage 2B	acceptable for all uses	AMEC Foster Wheeler et al. (2016)
	Post-construction surface sediment monitoring Year 0	2015	36	metals, SVOCs, PCBs (as Aroclors), dioxins/furans (subset), grain size (subset), TOC, total solids	EPA Stage 2B; EPA Stage 4 (dioxins/furans only)	acceptable for all uses	AMEC Foster Wheeler et al. (2016)
	Post-construction surface sediment monitoring year 1	2016	36	metals, SVOCs, PCBs (as Aroclors), dioxins/furans (subset), grain size (subset), TOC, total solids	EPA Stage 2B; EPA Stage 4 (dioxins/furans only)	acceptable for all uses	Amec Foster Wheeler (2016)

Table 3-3. Summary of in-waterway data that met DQOs

Sampling Area	Sampling Event	Sampling Year	No. of Samples[a]	Analytes	Data Validation Level[b]	Data Quality Conclusion	Reference
Boeing Plant 2 (cont.)	DSOA backfill additional sampling	2017	97	SVOCs (subset), PAHs (subset), PCBs (as Aroclors) (subset), phthalates (subset), grain size (subset), TOC (subset), total solids (subset)	EPA Stage 2B	acceptable for all uses	Amec Foster Wheeler and DOF (2017)
Duwamish Diagonal	2010 monitoring	2010	23	metals, SVOCs, PCBs (as Aroclors), pesticides, grain size, TOC, total solids	EPA Stage 2A equivalent	acceptable for all uses	King County (2015)
	2011 monitoring	2011	23	metals, SVOCs, PCBs (as Aroclors), pesticides, grain size, TOC, total solids	EPA Stage 2A equivalent	acceptable for all uses	King County (2016a)
	2012 monitoring	2012	22	metals, SVOCs, PCBs (as Aroclors), pesticides, grain size, TOC, total solids	EPA Stage 2A equivalent	acceptable for all uses	King County (2016a)
Former Rhone-Poulenc site	Sediment characterization	2011–2012	24	metals, SVOCs, PAHs, PCBs (as Aroclors), pesticides, phthalates, grain size, pH, TOC, total solids	EPA Stage 2B equivalent	acceptable for all uses	AMEC (2012a)
Isaacson-Thompson	Isaacson-Thompson RI sediment	2012	15	metals, SVOCs, PCBs (as Aroclors), dioxins/furans (subset), TOC, total solids	EPA Stage 2B equivalent	acceptable for all uses	Landau (2014)
Jorgensen	Backfill samples - pre-DSOA dredge	2014	6	metals, PCBs (as Aroclors), TOC, total solids	EPA Stage 2B	acceptable for all uses	AMEC Foster Wheeler et al. (2016)
	Backfill samples - post-DSOA dredge	2015	7	metals, PCBs (as Aroclors), TOC, total solids	EPA Stage 2B	acceptable for all uses	AMEC Foster Wheeler et al. (2016)
LDW ENR/AC Pilot Study[c]	LDW ENR/AC candidate plots	2014	48	PCBs (as Aroclors), TOC, total solids	EPA Stage 2A	acceptable for all uses	LDWG (2015)
	LDW ENR/AC candidate plots round 2	2014	16	PCBs (as Aroclors), TOC, total solids	EPA Stage 2A	acceptable for all uses	LDWG (2015)
	LDW ENR/AC baseline sampling	2016	18	PCBs (as congeners), black carbon, grain size, TOC	EPA Stage 2A; EPA Stage 4 (PCBs only)	acceptable for all uses	AMEC et al. (2017)
RARE study (RM 3.7–RM 3.9)	RARE arsenic accumulation study	2015	53	metals	EPA Stage 4	acceptable for all uses	Kerns et al. (2017b)
Slip 1	Field sampling and data report	2015	65	metals, SVOCs, PAHs including alkylated PAHs, PCBs (as Aroclors), PCBs (as congeners), black carbon, grain size, TOC, total solids	EPA Stage 3 for conventionals and metals; EPA Stage 4 for PAHs and PCBs	acceptable for all uses	Integral (2015b)

Table 3-3. Summary of in-waterway data that met DQOs

Sampling Area	Sampling Event	Sampling Year	No. of Samples[a]	Analytes	Data Validation Level[b]	Data Quality Conclusion	Reference
Slip 4	Early Action Area long-term monitoring year 1	2013	10	metals (subset), SVOCs (subset), PCBs (as Aroclors), grain size (subset), TOC (subset), total solids (subset)	EPA Stage 4	acceptable for all uses	Integral (2014)
	Early Action Area long-term monitoring year 3 (2015)	2015	8	metals, SVOCs, PCBs (as Aroclors), grain size, TOC, total solids	EPA Stage 4	acceptable for all uses, except for four non-detected benzyl alcohol results "R" qualified due to low LCS recovery	Integral (2015a)
	Removal action construction 2012	2011-2012	52	metals (subset), SVOCs (subset), PCBs (as Aroclors), TOC, total solids	EPA Stage 4	acceptable for all uses	Integral (2012)
	Early Action Area, 8th Ave Terminals	2012	5	PCBs (as Aroclors), grain size, TOC, total solids	EPA Stage 4	acceptable for all uses	Integral (2013)
	Long-term monitoring year 5	2017	8	metals, SVOCs, PAHs, PCBs (as Aroclors), phthalates, grain size, TOC, total solids	EPA Stage 2B for SVOCs; EPA Stage 3 for conventionals and metals; EPA Stage 4 for PCBs	acceptable for all uses	Windward (2018)
South Park Bridge replacement	2011 (Phase 1)	2011	4	PCBs (as Aroclors), grain size, TOC, total solids	EPA Stage 2B	acceptable for all uses	Windward (2012)
	2012 (Phase 2)	2012	4	PCBs (as Aroclors), grain size, TOC, total solids	EPA Stage 2B	acceptable for all uses	Windward (2012)
	2014 (Phase 4)	2014	2	PCBs (as Aroclors), grain size, TOC, total solids	EPA Stage 2B	acceptable for all uses	Windward (2014)
South Park Marina	2016 sampling	2016	16	PCBs (as Aroclors), PCBs (as congeners), TOC	EPA Stage 2B for 90% of the data; EPA Stage 4 for 10% of the data	acceptable for all uses	TIG (2016)
South Park	Slag and sediment results	2017	10	metals, total solids	EPA Stage 2A	acceptable for all uses	Port of Seattle (2017)
T-115	Post-dredge sediment characterization and sand cover monitoring	2010	4	dioxins/furans, SVOCs, PAHs, phthalates, grain size, TOC	EPA Stage 4 equivalent	acceptable for all uses	SEE (2010)
	Year 1 sand cover monitoring and recontamination study	2011	4	dioxins/furans, PAHs, grain size, TOC, total solids	EPA Stage 4 equivalent	acceptable for all uses	SEE and TEC (2012)
	Year 3 final sand cover monitoring	2013	4	dioxins/furans, PAHs, grain size, TOC, total solids, total volatile solids	EPA Stage 4 equivalent	acceptable for all uses	SEE (2013)

Table 3-3. Summary of in-waterway data that met DQOs

Sampling Area	Sampling Event	Sampling Year	No. of Samples[a]	Analytes	Data Validation Level[b]	Data Quality Conclusion	Reference
T-117	Cleanup action 2013 - pre-dredge perimeter sediment	2013	5	metals, SVOCs, PCBs (as Aroclors), dioxins/furans, TOC	EPA Stage 2B; EPA Stage 4 for dioxins/furans	acceptable for all uses, except for five 4-chloroaniline results "R" qualified due to very low LCS recovery	Port of Seattle (2016)
	Cleanup action 2013 - post-dredge perimeter sediment	2014	5	metals, SVOCs, PCBs (as Aroclors), dioxins/furans, TOC	EPA Stage 2B; EPA Stage 4 for dioxins/furans	acceptable for all uses	Port of Seattle (2016)
	Pre-operation outfall sediment sampling	2016	9	PCBs (as Aroclors), grain size, TOC, total solids	EPA Stage 4	acceptable for all uses	Integral (2016)
Throughout the LDW	Surface sediment sampling at outfalls in the Lower Duwamish Waterway	2011	160	metals, SVOCs, PCBs (as Aroclors), dioxins/furans (subset), grain size, TOC, total solids	EPA Stage 2B, EPA Stage 4 for dioxins/furans	acceptable for all uses, except for 71 results for 9 SVOCs rejected for extremely low LCS/LCSD and/or MS/MSD recoveries (less than 10%)[d]	SAIC (2011)
South Brandon St.	King County CSO 2011 sediment characterization	2011	6	metals, SVOCs, PCBs (as Aroclors), grain size, TOC, total solids	EPA Stage 2A equivalent	acceptable for all uses	(King County 2012)
Subsurface Sediment (lower depth > 15 cm)							
Isaacson-Thompson	Isaacson-Thompson RI sediment	2012	53	metals (subset), SVOCs (subset), PCBs (as Aroclors), dioxins/furans (subset), TOC, total solids	EPA Stage 2B equivalent	acceptable for all uses	Landau (2014)
LDW ENR/AC Pilot Study[c]	LDW ENR/AC candidate plots	2014	12	PCBs (as Aroclors), TOC, total solids	EPA Stage 2A	acceptable for all uses	LDWG (2015)
	LDW ENR/AC candidate plots round 2	2014	4	PCBs (as Aroclors), TOC, total solids	EPA Stage 2A	acceptable for all uses	LDWG (2015)
Former Rhone-Poulenc site	Sediment characterization	2011-2012	82	metals (subset), SVOCs (subset), PAHs (subset), PCBs (as Aroclors) (subset), pesticides (subset), phthalates (subset), grain size (subset), TOC (subset), total solids (subset)	EPA Stage 2B equivalent	acceptable for all uses	AMEC (2012a)
South Park Marina	2016 sampling	2016	32	PCBs (as Aroclors), PCBs (as congeners), TOC	EPA Stage 2B for 90% of the data; EPA Stage 4 for 10% of the data	acceptable for all uses	TIG (2016)

Table 3-3. Summary of in-waterway data that met DQOs

Sampling Area	Sampling Event	Sampling Year	No. of Samples[a]	Analytes	Data Validation Level[b]	Data Quality Conclusion	Reference
Turning Basin[e]	Duwamish Waterway dredged material characterization	2017	16	dioxins/furans (subset), metals (subset), PAHs (subset), PBDEs (subset), PCBs (Aroclors) (subset), pesticides (subset), phthalates, SVOCs (subset), ammonia as nitrogen (subset), grain size (subset), sulfide (subset), TOC (subset), total volatile solids (subset)	EPA Stage 2B; EPA Stage 4 for 10% of dioxin/furan data	acceptable for all uses, except for 3 PBDE-010 results rejected for low LCS recovery	USACE (2018)
Surface Water							
Near the MLK/ Henderson-Norfolk CSO	King County NPDES receiving water	2011-2012	12	metals, hardness, pH, salinity	EPA Stage 2A equivalent	acceptable for all uses	Mickelson (2013)
LDW	LDW groundwater sampling for PCBs	2017	6	PCBs (as Aroclors), PCBs (as congeners)	EPA Stage 2B for Aroclors; EPA Stage 4 for congeners	acceptable for all uses	Leidos (2017)
RARE study (RM 3.7 – RM 3.9)	RARE arsenic accumulation study	2015	2	metals, hardness	EPA Stage 4	acceptable for all uses	Kerns et al. (2017b)
Porewater							
ENR/AC Plots[c]	LDW ENR/AC baseline sampling	2016-2017	18	PCBs (as congeners)	EPA Stage 4	acceptable for all uses	AMEC et al. (2017)
RARE study (RM 3.7– RM 3.9)	RARE arsenic accumulation study	2015	15	arsenic	EPA Stage 4	acceptable for all uses	Kerns et al. (2017b)
Former Rhone-Poulenc site	Shoreline investigation	2011	7	metals, PAHs, VOCs, pH	EPA Stage 2B equivalent	acceptable for all uses	AMEC (2012b)
Seep							
Isaacson-Thompson	Isaacson-Thompson RI seep	2012	11	metals (subset), SVOCs (subset), PAHs (subset), VOCs (subset), PCBs (as Aroclors), petroleum hydrocarbons, chloride, nitrate, sulfate, total dissolved solids	EPA Stage 2B equivalent	acceptable for all uses	Landau (2014)

Note: The term "(subset)" in the Analytes column indicates that a subset of samples from the study were analyzed for the analyte group noted.

[a] Number of samples does not include field duplicates.

[b] As discussed in Section 2.2.2.2, if the reports for a particular dataset did not specify an EPA stage of data validation, Windward reviewed the methods and identified an equivalent stage.

[c] ENR/AC plots were placed at various locations in the LDW (see Map 5-1).

[d] Rejected results include 25 results for 2,4-dinitrophenol; 10 results each for aniline and 3,3'-dichlorobenzidine; 9 results for hexachlorocyclopentadiene; 7 results for 4-chloroaniline; 4 results for 3-nitroaniline; 2 results for 4,6-dinitro-2-methylphenol; and 1 result for 2,4-dimethylphenol.

[e] A portion of the samples collected for this study (those from Section A and the Turning Basin) are from areas that were dredged in 2017/2018. Nevertheless, the data have been included in order to provide the most current information (from within the LDW) on upstream inputs.

AC – activated carbon
CSO – combined sewer overflow
DQO – data quality objective
DSOA – Duwamish sediment other area
ENR – enhanced natural recovery
EPA – US Environmental Protection Agency
LCS – laboratory control sample
LDW – Lower Duwamish Waterway
MLK – Martin Luther King
MS – matrix spike
MSD – matrix spike duplicate
NPDES – National Pollutant Discharge Elimination System
PAH – polycyclic aromatic hydrocarbon
PBDE – polybrominated diphenyl ether
PCB – polychlorinated biphenyl
RARE – Regional Applied Research Effort
RI – remedial investigation
RM – river mile
SRM – standard reference material
SVOC – semivolatile organic compound
T-115 – Terminal 115
T-117 – Terminal 117
TOC – total organic carbon
VOC – volatile organic compound

Rejected results were excluded from the exported datasets presented in the user-ready data tables (Appendix C). Additional details from the data quality reviews for in-waterway data (i.e., sampling objectives, sampling dates, sample collection methods, sampling depth for sediment samples, number of field duplicates, analytical methods, analytical laboratory, and data validator) are included in Table B-1 in Appendix B.

Datasets that only provisionally meet DQOs are listed in Table 3-4. All of these datasets were downloaded from EIM (except one for which a data report was available), and supporting documentation describing data quality was incomplete or unavailable to Windward at the time this memorandum was prepared.[11] EIM provides certain qualitative information regarding the level of data quality for each study, identified as a study quality assessment (QA) level, as presented in Table 3-4. However, because all of the necessary supporting documentation (i.e., laboratory Form 1s and data validation reports) was not available for review within the timeline of this memorandum, it was determined for the purpose of this data compilation task that DQOs were only provisionally met. These data are flagged in the database as "conditional use only."

A number of studies downloaded from EIM include data gathered under Model Toxics Control Act (MTCA) authority, which requires data validation and qualifiers comparable to those used by EPA. It is highly likely that adequate supporting documentation exists for these datasets, and the "conditional use only" flag could be removed in the future if the responsible party provides documentation that fulfills the DQOs.

To date, those data flagged as "conditional use only" have been used in preparation of pre-design studies QAPPs and data evaluation reports. Other potential uses for these data, such as in support of design sampling, will be discussed on a case-by-case basis with the relevant regulatory party for which the work was done.

[11] Source documents were requested from Ecology and EPA for the EIM studies in Table 3-4. In addition, online searches were conducted to identify any publicly available source documents. Work plans and draft RI reports were located for a number of studies, providing confirmation of some details, such as sampling locations and methodology. However, none of the reports obtained were sufficient to satisfy all DQOs because laboratory Form 1s and validation reports were not available for review.

Table 3-4. Summary of in-waterway data that provisionally met all DQOs (flagged for conditional use)

Sampling Event	Sampling Year	No. of Samples	Analytes	EPA Validation Level or EIM Study QA Level[a]	Reference[b]
Surface Sediment (lower depth ≤ 15 cm)					
Alaska Marine Lines under-pier sampling	2015	3	metals, SVOCs, PCBs (as Aroclors), dioxin/furans, tributyltin, grain size, TOC, percent moisture, total solids	EIM Level 3	EIM (AMLPFM15)
Crowley Marine Services Inc. 8th Ave S	2013-2014	23	metals, semivolatile petroleum products (subset), SVOCs, PCBs (as Aroclors), dioxin/furans (subset), grain size, TOC, total solids	EIM Level 4	EIM (FS1940187)
Duwamish Shipyard, Inc. Phase 1 RI, sediments	2011	12	metals, SVOCs, PCBs (as Aroclors), pesticides, VOCs, dioxin/furans (subset), tributyltin, pentachlorophenol, TOC, percent moisture, total solids, total volatile solids	EIM Level 4	EIM (AQDSI2011Sed)
Duwamish Shipyard, Inc. supplemental (Phase 2) RI	2013	18	metals, SVOCs, PCBs (as Aroclors), pesticides, VOCs, dioxin/furans, tributyltin, TOC, grain size, moisture, total solids, total volatile solids	EIM Level 4	EIM (DSIP2RI)
Glacier Northwest - Reichhold, Inc. RI/FS	2012	20	metals, SVOCs, PCBs (as Aroclors), dioxin/furans, grain size, TOC, total solids	EIM Level 4	EIM (FS23881883-RI)
Industrial Container Services WA LLC (Early Action Area 2 - Lower Duwamish)	2012, 2014	38	metals (subset), TCLP metals (subset), semivolatile petroleum products (subset), SVOCs (subset), PCBs (as Aroclors) (subset), pesticides (subset), tributyltin (subset), grain size (subset), TOC, percent moisture (subset), specific gravity (subset)	EIM Level 2	EIM (FS2154)
Rhone Poulenc sediment sampling investigation	2011	40	metals (subset), SVOCs (subset), resin acids (subset), PCBs (as Aroclors) (subset), pesticides (subset), dioxins/furans (subset), butyltins (subset), ammonia (subset), grain size (subset), TOC (subset), total solids, total volatile solids (subset), sulfide (subset)	EPA stages 3 and 4 (subset of samples)	Cardno Entrix (2012)

Table 3-4. Summary of in-waterway data that provisionally met all DQOs (flagged for conditional use)

Sampling Event	Sampling Year	No. of Samples	Analytes	EPA Validation Level or EIM Study QA Level[a]	Reference[b]
Terminal 117 Outfall Post-construction Sediment Sampling	2015	9	PCBs (as Aroclors), grain size, TOC, total solids	EIM Level 4	EIM (LDWT117OFPostConSed)
Urban Waters Initiative, in Elliott Bay	2013	6	metals (subset), SVOCs (subset), PCBs (as Aroclors) (subset), PCBs (as congeners) (subset), pesticides (subset), PBDEs (subset), dioxins/furans (subset), pharmaceuticals (subset), grain size (subset), TOC (subset), total solids (subset)	EIM Level 5	EIM (UWI2013)
Subsurface Sediment (lower depth > 15 cm)					
Crowley Marine Services Inc. 8th Ave S	2014	18	metals, SVOCs, PCBs (as Aroclors), VOCs, dioxin/furans, grain size, TOC, total solids	EIM Level 4	EIM (FS1940187)
Douglas Management dock (Alaska Marine Lines)	2013	1	metals, SVOCs, PCBs (as Aroclors), pesticides, volatile petroleum products, VOCs, dioxin/furans, grain size, TOC, total solids	EIM Level 3	EIM (AODE8258)
Duwamish River navigation channel maintenance dredging (DY12)	2011	17	metals, SVOCs, PCBs (as Aroclors), PBDEs (subset), pesticides, VOCs, ammonia, dioxin/furans (subset), grain size, TOC, total solids, total volatile solids, sulfide	EIM Level 4	EIM (DUW1111)
Duwamish Shipyard, Inc. Phase 1 RI, sediments	2011	65	metals (subset), SVOCs (subset), PCBs (as Aroclors) (subset), pesticides (subset), VOCs (subset), dioxin/furans (subset), tributyltins (subset), TOC, total solids, total volatile solids (subset)	EIM Level 4	EIM (AQDSI2011Sed)
Duwamish Shipyard, Inc. supplemental (Phase 2) RI	2013	67	metals, SVOCs, PCBs (as Aroclors), pesticides, VOCs, dioxin/furans, tributyltin, percent moisture, TOC, total solids, total volatile solids	EIM Level 4	EIM (DSIP2RI)

Table 3-4. Summary of in-waterway data that provisionally met all DQOs (flagged for conditional use)

Sampling Event	Sampling Year	No. of Samples	Analytes	EPA Validation Level or EIM Study QA Level[a]	Reference[b]
Duwamish Waterway, East Waterway and West Waterway subsurface sediment characterization	2012	38	metals, SVOCs, PCBs (as Aroclors), PCBs (as congeners) (subset), pesticides, dioxin/furans, ammonia, grain size, TOC, total solids, total solids (preserved), sulfide	QA1[c]	EIM (DUWSU12)
Glacier Northwest - Reichhold, Inc. RI/FS	2012	62	metals (subset), SVOCs (subset), PCBs (as Aroclors) (subset), dioxin/furans (subset), tributyltin (subset), grain size (subset), TOC (subset), total solids (subset)	EIM Level 4	EIM (FS23881883-RI)
Industrial Container Services WA LLC (Early Action Area 2 - Lower Duwamish)	2012	38	metals (subset), semivolatile petroleum products (subset), SVOCs (subset), PCBs (as Aroclors) (subset), pesticides (subset), tributyltin (subset), grain size (subset), TOC (subset), percent moisture (subset), total solids (subset)	EIM Level 2	EIM (FS2154)
Surface Water					
Douglas Management Dock (Alaska Marine Lines)	2013-2014	3	metals, semivolatile petroleum products, SVOCs, PCBs (as Aroclors), pesticides, volatile petroleum products, VOCs, TDS, chloride	EIM Level 3	EIM (AODE8258)
Tissue					
WDFW PSEMP toxics in biota study- toxic contaminants in Dungeness crab and spot prawn from Puget Sound	2011	2	metals (subset), SVOCs (subset), PCBs (as congeners) (subset), pesticides (subset), PBDEs (subset), dioxins/furans (subset), lipids (subset), total solids	EIM Level 4	EIM (C1200226)

Table 3-4. Summary of in-waterway data that provisionally met all DQOs (flagged for conditional use)

Sampling Event	Sampling Year	No. of Samples	Analytes	EPA Validation Level or EIM Study QA Level[a]	Reference[b]
WDFW PSEMP toxics in biota study- toxic contaminants in juvenile Chinook from Puget Sound	2013	9	metals (subset), SVOCs (subset), PAHs (as subset), PCBs (as congeners) (subset), pesticides (subset), PBDEs (subset), lipids (subset)	EIM Level 4	EIM (G1300083)
Porewater					
Art Brass Plating, Soil and Groundwater Cleanup	2011	25	VOCs	EIM Level 4	EIM (FS88531932)
Duwamish Shipyard, Inc. Phase 1 RI, sediments	2011	12	tributyltin	EIM Level 4	EIM (AQDSI2011Sed)
Duwamish Shipyard, Inc. supplemental (Phase 2) RI	2013	67	tributyltin	EIM Level 4	EIM (DSIP2RI)
Duwamish Waterway, East Waterway and West Waterway subsurface sediment characterization	2012	38	butyltin	EIM QA1[c]	EIM (DUWSU12)
Glacier Northwest - Reichhold, Inc. RI/FS	2012	20	tributyltin	EIM Level 4	EIM (FS23881883-RI)

Table 3-4. Summary of in-waterway data that provisionally met all DQOs (flagged for conditional use)

Sampling Event	Sampling Year	No. of Samples	Analytes	EPA Validation Level or EIM Study QA Level[a]	Reference[b]
Seep					
Crowley Marine Services Inc. 8th Ave S	2013	5	metals, semivolatile petroleum products, SVOCs, PCBs (as Aroclors), volatile petroleum products, VOCs, dioxins/furans, TOC, TSS, chloride	EIM Level 4	EIM (FS1940187)
Douglas Management Dock (Alaska Marine Lines)	2013-2014	6	metals, semivolatile petroleum products, SVOCs, PCBs (as Aroclors), pesticides, volatile petroleum products, VOCs, dioxins/furans, TDS, chloride	EIM Level 3	EIM (AODE8258)
Duwamish Marine Center	2015	1	metals, semivolatile petroleum products, SVOCs, PCBs (as Aroclors), VOCs, volatile petroleum products	EIM Level 2	EIM (AODE8072)
Duwamish Shipyard, Inc. supplemental (Phase 2) RI	2013	3	metals, semivolatile petroleum products (subset), SVOCs, PCBs (as Aroclors), pesticides (subset), volatile petroleum products (subset), VOCs (subset), dioxin/furans, tributyltins, TDS (subset), TSS (subset)	EIM Level 4	EIM (DSIP2RI)

Notes:

The term "(subset)" in the Analytes column indicates that a subset of samples from the study were analyzed for the analyte group noted.

It was determined that data in this table provisionally meet DQOs because laboratory Form 1s or data validation reports were not available. Also, in many cases, data reports to determine whether other DQOs had been met were not available to Windward at the time this memo was prepared.

[a] EIM Study QA levels provide some indication of data quality, as described by Ecology (2017):

Level 1: Data neither verified nor assessed for usability.

Level 2: Data verified (study quality control results have been examined for compliance with acceptance criteria specified in the QAPP, SAP or field/analytical method).

Level 3: Level 2 plus data assessed for usability (study data package has at a minimum been evaluated for precision, bias, representativeness, comparability, and completeness as specified in the QAPP or SAP.

Level 4: Level 3 plus formal study report (document describing study objectives, procedures, results, conclusions, and assessment of the quality of the data).

Level 5: Level 4 plus peer-reviewed study report (report was checked or reviewed for accuracy and completeness by a supervisor or colleague with appropriate experience; does not require independent, outside scientific review, as for juried publications).

[b] Data were downloaded from EIM between November 15 2016 and June 15, 2018. The EIM study ID is provided in parentheses.

[c] The EIM Study QA Level was identified as QA1, although this level is not consistent with those defined by Ecology (2017) for EIM.

Ecology – Washington State Department of Ecology

PBDE – polybrominated diphenyl ether

PCB – polychlorinated biphenyl

SVOC – semivolatile organic compound

TCLP – toxicity characteristic leaching procedure

EIM – Environmental Information Management (Ecology database)
EPA – US Environmental Protection Agency
FS – feasibility study
ID – identification
na – not applicable
PAH – polycyclic aromatic hydrocarbon
PSEMP – Puget Sound Ecosystem Monitoring Program
QA – quality assurance
QAPP – quality assurance project plan
RI – remedial investigation
RI/FS – remedial investigation and feasibility study
SAP – sampling and analysis plan
TDS – total dissolved solids
TOC – total organic carbon
TSS – total suspended solids
VOC – volatile organic compound
WDFW – Washington Department of Fish and Wildlife
Windward – Windward Environmental LLC

4 Data Compilation Summary – Source Control-related and Upstream Data

This section summarizes data compiled (i.e., imported into EQuIS™) that are source control-related (i.e., combined sewer system / storm drain solids, bank soils, and groundwater) and upstream (i.e., Green / Duwamish River suspended solids and surface water). Data quality reviews were not required for source control-related and upstream data as part of Task 2 (EPA 2016d), and therefore these data are flagged in the database for conditional use only. It should be noted that regardless of the conditional use flag, the majority of source control-related data are known to have been validated or were assumed to have been validated based on an EIM study QA level higher than Level 1, indicating that some level of validation has been performed. For example, data collected under a MTCA agreed order or EPA authority are required to undergo data validation, and all of the upstream solids and water data have been validated and are well documented with respect to sampling locations and methodology. Note, however, that not all data are representative of current discharges, because samples may have been collected prior to upland cleanup or treatment system implementation.

The remainder of the source control-related data were obtained from EIM, which provides less contextual detail. EIM provides some qualitative information regarding the level of data quality for each study, identified as a Study QA Assessment Level (Table 4-1). Before the source control-related data are used, the parties that generated the data should be consulted for additional information regarding the location of the combined sewer system / storm drain solids samples within a particular system (e.g., prior to or after any treatment process) and the condition which samples represent (e.g., pre- or post-line cleaning or other source control action).

Groundwater data from the Terminal 117 (T-117) EAA (Terminal 117 Early Action Area Non-Time-Critical Removal Action data from sampling in 2011; EIM Study G0800557) were excluded because the area was remediated after the data had been collected.[12] Similarly, groundwater data from Boeing properties on the east side of the LDW along the shoreline were excluded if they had been collected from wells in areas that have since been remediated (Map 2-5).[13]

[12] The COCs and site-specific removal action levels for groundwater at the T-117 EAA are as follows: arsenic – 5 µg / L, silver – 1.9 µg / L, carcinogenic polycyclic aromatic hydrocarbon (cPAH) toxic equivalents – 0.15 µg / L, diesel- and lube-oil-range total petroleum hydrocarbons – 500 µg / L, bis(2-ethylhexyl)phthalate – 1.7 µg / L, and total PCBs – 0.01 µg / L (Port of Seattle 2016).

[13] Soil and / or groundwater have been remediated in a number of areas as a result of or during operations involving sheet pile remediation, LDW bank cutback and dredging, 16th Avenue Bridge excavation, soil removal, and LDW habitat construction. The primary COCs are volatile organic compounds (VOCs); groundwater cleanup goals have not yet been established.

Overall, the following datasets were compiled in the database (Table 4-1):

- Nineteen combined sewer system / storm drain solids datasets
- Three bank soil datasets
- Thirty-one groundwater datasets
- Three upstream suspended solids datasets
- Three upstream surface water datasets

User-ready tables with exported data are included in Appendix C.

Table 4-1. Summary of source control related and upstream data

Sampling Event	Sampling Year	No. of Samples	Chemicals Analyzed	Validation status or EIM Study QA Level[a]	Reference[b]
Combined Sewer System/Storm Drain Solids					
Boeing Development Center south storm drain outlet solids 2010-2015	2010–2015	26	PCBs (as Aroclors), TOC (subset), total solids (subset)	validated[c]	CALIBRE (2011, 2012, 2013, 2014, 2015, 2016)
Boeing Isaacson-Thompson storm drain sampling	2011	37	metals, SVOCs (subset), PAHs (subset), PCBs (as Aroclors), VOCs (subset), dioxin/furans (subset), petroleum products (subset), TOC, total solids	EIM Level 3	EIM (AODE7088)
Crowley Marine Services Inc., 8th Ave S	2012–2014	20	metals (subset), petroleum products (subset), SVOCs (subset), PCBs (as Aroclors) (subset), VOCs (subset), dioxins/furans (subset), grain size (subset), TOC (subset), total solids (subset)	EIM Level 4	EIM (FS1940187)
Duwamish Marine Center	2015–2016	7	metals, semivolatile petroleum products, SVOCs, PCBs (as Aroclors), volatile petroleum products, VOCs, TOC	EIM Level 2	EIM (AODE8072)
Duwamish Shipyard, Inc. supplemental (Phase 2) RI	2013	1	metals, semivolatile petroleum products, SVOCs, PCBs (as Aroclors and congeners), volatile petroleum products, VOCs, dioxins/furans, tributyltin, TOC, total solids	EIM Level 4	EIM (DSIP2RI)
Glacier Northwest - Reichhold, Inc. RI/FS	2012, 2014	6	metals, semivolatile petroleum products (subset), SVOCs, PCBs (as Aroclors), dioxins/furans, grain size, pH, TOC, total solids	EIM Level 4	EIM (FS23881883-RI)
Industrial Container Services WA LLC (Early Action Area 2 - Lower Duwamish)	2012	1	metals, semivolatile petroleum products, SVOCs, PCBs (as Aroclors), pesticides, volatile petroleum products, VOCs, dioxins/furans, grain size, TOC, total solids	EIM Level 2	EIM (FS2154)
Insurance Auto Auctions Stormwater System Investigation	2010–2011	15	metals (subset), tributyltin (subset), SVOCs (subset), PAHs (subset), PCBs (as Aroclors) (subset), dioxins/furans (subset), grain size, TOC (subset), total solids (subset)	validated[c]	(Windward 2011)

Table 4-1. Summary of source control related and upstream data

Sampling Event	Sampling Year	No. of Samples	Chemicals Analyzed	Validation status or EIM Study QA Level[a]	Reference[b]
King County combined sewer system source tracing solids	2010–2015	48	metals (subset), SVOCs (subset), PAHs (subset), PCBs (as Aroclors) (subset), petroleum products (subset), grain size (subset), TOC (subset), TVS (subset), total solids	validated[c]	(King County 2016b)
King County storm drain source tracing solids	2016	10	metals (subset), SVOCs (subset), PAHs (subset), PCBs (as Aroclors) (subset), dioxins/furans (subset), grain size (subset), TOC (subset), total solids	validated[c]	(King County 2016b)
North Boeing Field/Georgetown Steam Plant source control solids	2010–2012	340	metals (subset), SVOCs (subset), PAHs (subset), PCBs (as Aroclors) (subset), petroleum products (subset), grain size (subset), TOC (subset), total solids (subset)	validated[c]	(Landau 2018)
North Boeing Field lift station solids	2013	30	metals (subset), PAHs (subset), PCBs (as Aroclors), total solids	validated[c]	(Landau 2016)
NPDES inspection sampling support	2013–2015	59	metals, semivolatile petroleum products (subset), SVOCs, PCBs (as Aroclors), PCBs (as congeners) (subset), pesticides (subset), volatile petroleum products (subset), VOCs (subset), dioxins/furans (subset), grain size (subset), TOC (subset), total solids (subset)	EPA 2A, 3, 4[d]	EIM (LDWISS)
Port of Seattle stormwater line cleanout: T-102, -103, -104, -106, -108, -115	2015	12	metals, SVOCs (subset), PCBs (as Aroclors), dioxins/furans (subset), grain size (subset), percent moisture, total solids	validated[c]	Port of Seattle (2015a)
Port of Seattle T-108W, -108E, and -106W source control data evaluation	2013	5	metals (subset), PAHs (subset), PCBs (as Aroclors) (subset), TOC (subset), total solids (subset)	validated[c]	AECOM (2014)
Port of Seattle T-115N RI	2014	5	metals, semivolatile petroleum products (subset), SVOCs, PCBs (as Aroclors), volatile petroleum products (subset), VOCs (subset), dioxins/furans (subset)	EIM Level 3	EIM (AODE8099)

Table 4-1. Summary of source control related and upstream data

Sampling Event	Sampling Year	No. of Samples	Chemicals Analyzed	Validation status or EIM Study QA Level[a]	Reference[b]
Seattle Public Utilities source tracing for LDW	2010–2017	559	metals (subset), semivolatile petroleum products (subset), SVOCs (subset), PAHs (subset), PCBs (as Aroclors) (subset), grain size (subset), TOC (subset), total solids (subset)	validated[c]	Seattle Public Utilities (2016), EIM (C1100067)
South Park Marina 2016 sampling	2016	9	PCBs (as Aroclors and as congeners), TOC	validated[c]	(TIG 2016)
Washington State Liquor Control Board site characterization	2011	4	metals, SVOCs, PAHs, PCBs (as Aroclors), pesticides, VOCs, dioxins/furans, petroleum products, PBDEs, TOC, total solids	EIM Level 4	EIM (WSLCB)
Bank Soils					
Lower Duwamish Waterway bank sampling	2011	45	metals, semivolatile petroleum products, SVOCs, PCBs (as Aroclors), pesticides, volatile petroleum products, VOCs (subset), dioxins/furans, PBDEs, tributyltin, TOC, total solids	EIM Level 4	EIM (LDWBS)
Port of Seattle T-108 bank stabilization	2015	3	metals, SVOCs, PCBs (as Aroclors), TOC (subset)	not validated	(Port of Seattle 2015b)
Port of Seattle T-108W, -108E, and -106W source control data evaluation	2012	5	metals, SVOCs, PCBs (as Aroclors), TOC, total solids	validated[c]	AECOM (2014)
Upstream Suspended Solids					
Green River loading study - Phases 1 and 2	2013–2015	27	metals (subset), SVOCs (subset), PCBs (as Aroclors) (subset), PBCs (as congeners) (subset), pesticides (subset), VOCs (subset), dioxins/furans (subset), butyltins (subset), grain size (subset), TOC (subset), total solids (subset)	EIM Level 5	EIM (GRNRVLD13, GRNRVLD14)
King County Green River watershed suspended solids	2013–2015	21	metals (subset), SVOCs (subset), PCBs (as Aroclors) (subset), PCBs (as congeners), pesticides (subset), dioxins/furans, grain size, TOC (subset), total solids	validated[c]	King County (2016c)

Table 4-1. Summary of source control related and upstream data

Sampling Event	Sampling Year	No. of Samples	Chemicals Analyzed	Validation status or EIM Study QA Level[a]	Reference[b]
PBT trend monitoring: measuring lead in suspended particulate matter	2010–2014	20	metals (lead only)	EIM Level 5	EIM (PbTrends10 through PbTrends14)
Upstream Surface Water					
Green River loading study - Phases 1 and 2	2013–2015	28	metals (subset), SVOCs (subset), PCBs (as Aroclors) (subset), PCBs (as congeners) (subset), pesticides (subset), VOCs (subset), dioxins/furans (subset), butyltins (subset), DOC (subset), TOC (subset)	EIM Level 5	EIM (GRNRVLD13, GRNRVLD14)
King County Green River watershed surface water 2011–2012	2011–2012	13	metals (arsenic only), SVOCs, PCBs (as congeners), dioxins/furans, DOC, TOC, TSS	validated[c]	King County (2018b)
King County Green River PCB Equipment Blank Study	2015–2017	8	PCBs (as congeners), DOC, TOC, TSS	validated[c]	King County (2018a)

Notes:

The term "(subset)" in the Analytes column indicates that a subset of samples from the study were analyzed for the chemical group noted.

[a] EIM Study QA levels provide some indication of data quality, as described by Ecology (2017):

Level 1: Data neither verified nor assessed for usability.

Level 2: Data verified (study quality control results have been examined for compliance with acceptance criteria specified in the QAPP, SAP or field/analytical method).

Level 3: Level 2 plus data assessed for usability (study data package has at a minimum been evaluated for precision, bias, representativeness, comparability, and completeness as specified in the QAPP or SAP.

Level 4: Level 3 plus formal study report (document describing study objectives, procedures, results, conclusions, and assessment of the quality of the data).

Level 5: Level 4 plus peer-reviewed study report (report was checked or reviewed for accuracy and completeness by a supervisor or colleague with appropriate experience; does not require independent, outside scientific review, as for juried publications).

[b] Data were downloaded from EIM between November 15 2016 and June 15, 2018. The EIM study ID is provided in parentheses.

[c] Source documents indicate that data were validated. Since DQO reviews were not performed on source control-related or upstream data, no validation level was determined.

[d] The EIM Study QA Assessment Level was identified as EPA 2A, 3, 4, although this level is not consistent with those defined by Ecology (2017) for EIM.

DOC – dissolved organic carbon
Ecology – Washington State Department of Ecology
EIM – Environmental Information Management (Ecology database)
EMF – Electronics Manufacturing Facility
FS – feasibility study
ID – identification
LDW – Lower Duwamish Waterway
na – not applicable
NPDES – National Pollutant Discharge Elimination System
PAH – polycyclic aromatic hydrocarbon
PBDE – polybrominated diphenyl ether
PBT – persistent, bioaccumulative, toxic
PCB – polychlorinated biphenyl
QA – quality assurance
QAPP – quality assurance project plan
QC – quality control
RI/FS – remedial investigation/feasibility study
RM – river mile
SAP – sampling and analysis plan
SPU – Seattle Public Utilities
SVOC – semivolatile organic compound
T – terminal
TDS – total dissolved solids
TOC – total organic carbon
TSS – total suspended solids
TVS – total volatile solids
VOC – volatile organic compound
Windward – Windward Environmental LLC

Eleven source control-related datasets could not be obtained or final data were not available (Table 4-2). One dataset was not included in the Task 2 data compilation because the sampling locations were later remediated (Table 4-2).

Table 4-2. Source control-related datasets not included in the Task 2 data compilation

Study Name	Sampling Year	Media Sampled	Justification	Original Source
Source Control-related Data Not Obtained				
Ecology Accelerated Source Tracing Study	2011	solids	data not obtained[a]	SAIC and Newfields
Ecology Stormwater Lateral Loading Study	2010-2011	solids	data not obtained[a]	SAIC and Newfields
EPA Sediment Sampling S 96th Street Rounds 1 and 2	2012[b]	solids	data not obtained[a]	KTA Associates
EPA Sediment Sampling Tukwila, Rounds 1, 2, and 3	2012[b]	solids	data not obtained[a]	KTA Associates
Jorgensen Forge Outfall Site source control action	2011[b]	solids	data not obtained[a]	Floyd/Snider
King County International Airport Slip 4 Source Control	2011	solids	final data not yet available	King County Department of Transportation
King County International Airport source tracing solids	2005–2016	solids	final data not yet available	King County Department of Transportation
North Boeing Field/Georgetown Steam Plant - 2010–2011 Stormwater Sampling Data Report (Leidos Study ID N0235)	2010-2011	solids	data not obtained[a]	SAIC
North Boeing Field/Georgetown Steam Plant - NBF 2011-2012 SW Sampling Data Tables 090512 Final (Leidos Study ID N0259)	2011-2012	solids	data not obtained[a]	SAIC
North Boeing Field/Georgetown Steam Plant - NBF/GTSP RI/FS Preliminary Stormwater Sampling Interim Data Report (Leidos Study ID N1782)	2009-2010	solids	data not obtained[a]	SAIC
North Boeing Field/Georgetown Steam Plant - Expanded Stormwater Sampling Interim Data Report (Updated) (Leidos Study ID N1815)	2010	solids	data not obtained[a]	SAIC
Bank Soil Data Excluded				
T-117 cleanup action 2013 - bank soil/sediment	2013	bank soil	backfilled/regraded since sampling	AECOM

[a] LDWG was unable to obtain these datasets.

[b] Information in these reports was presented to LDWG by EPA. The sampling dates were not provided so the date shown is the report date.

Ecology – Washington State Department of Ecology
EIM – Environmental Information Management (Ecology database)
EPA – US Environmental Protection Agency
LDWG – Lower Duwamish Waterway Group
T-117 – Terminal 117

5 Assessment of RARE, MIT, and ENR/AC Studies

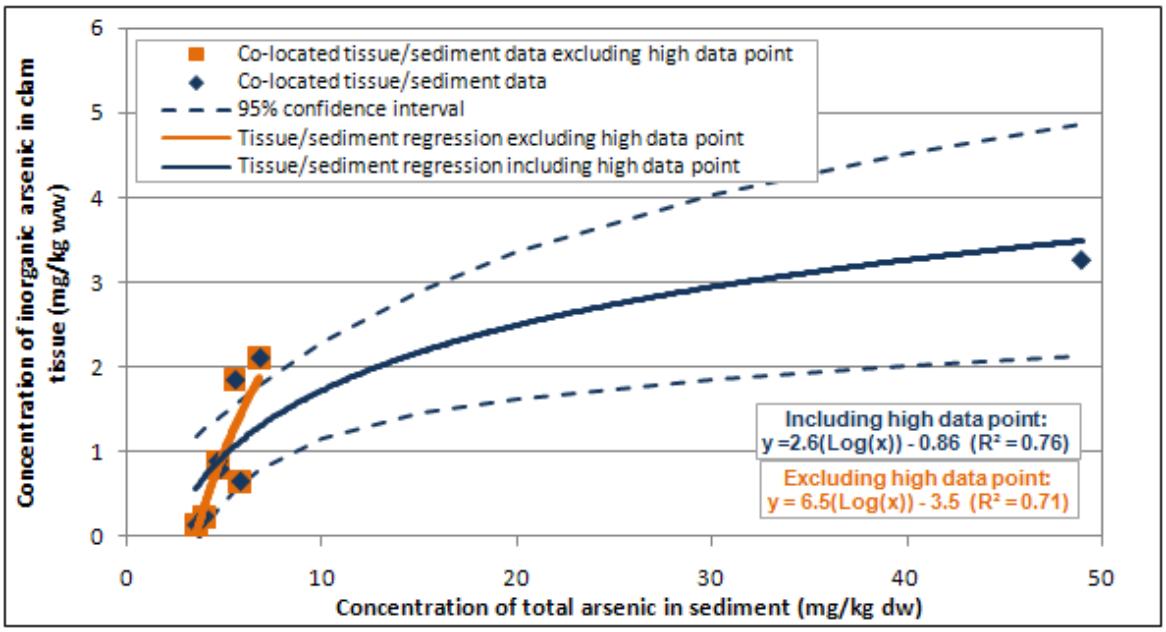
This section describes LDW studies that have or will provide information regarding relationships between chemical concentrations in different media in the waterway. These studies include the EPA regional applied research effort conducted by the US Army Corps of Engineers (USACE) and EPA, porewater studies led by MIT, and the ENR/AC pilot study being conducted by LDWG. Much of the data being collected as part of these efforts are not yet available. Data that become available from these studies will be assessed as part of Task 6 (Data Evaluation Report), together with the data collected from the RI/FS and datasets obtained during the Task 4 sampling effort, to determine if additional information is needed regarding the relationships among contaminant concentrations in clam tissue, sediment, and porewater. An overview of these ongoing studies is provided below.

5.1 RARE STUDY

The USACE and EPA have completed the second part of their RARE study entitled *Elucidating arsenic bioaccumulation pathways in* Mya arenaria *to improve remedy decision making and protection of Tribal fishers for Lower Duwamish Waterway Superfund Site* (USACE 2015). The primary objective of this study was to improve the current understanding of the relationship between arsenic concentrations in LDW sediment and inorganic arsenic bioaccumulation in clam tissue (*Mya arenaria*). Arsenic concentrations in porewater were also analyzed as part of this study. Understanding how and from which media *M. arenaria* bioaccumulate arsenic is important in making science-based sediment remediation decisions (USACE 2015).

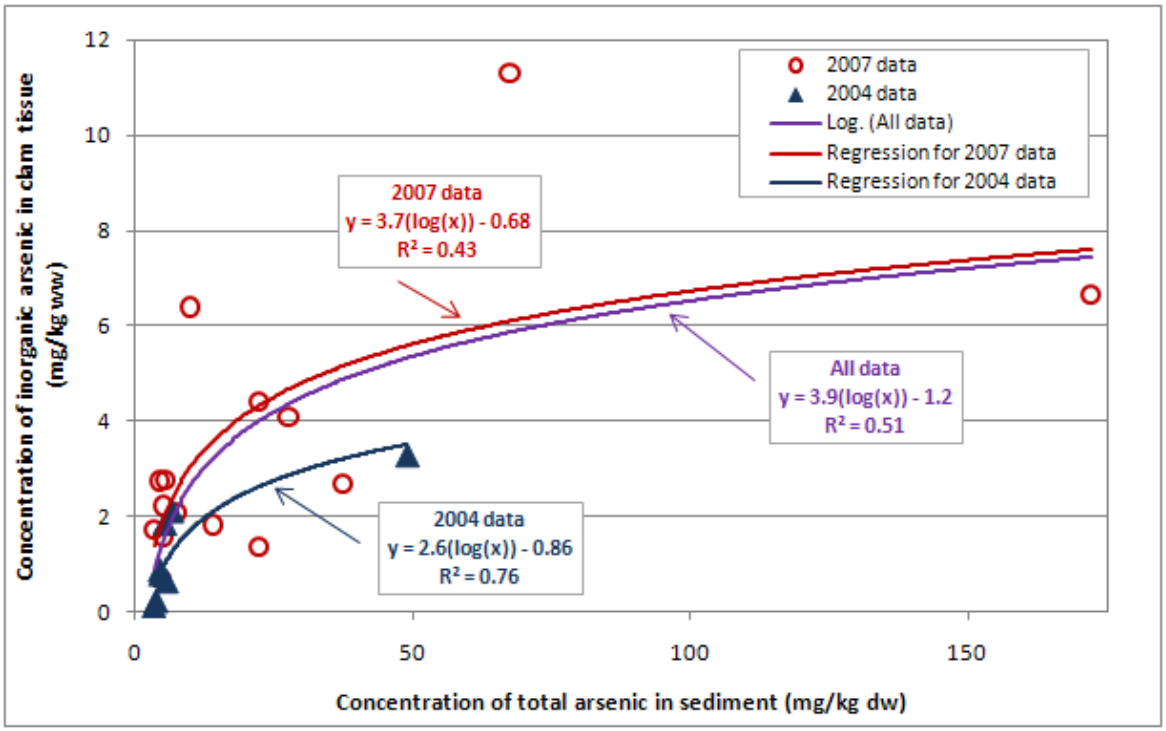
The LDW RI found an uncertain relationship between total arsenic in sediments and inorganic arsenic in *M. arenaria* (Windward 2010).[14] Regression equations developed using co-located sediment and clam tissue data collected in 2004 had wide confidence intervals, and the regressions were highly influenced by a single high data point (Figure 5-1). The collection of additional data in 2007 did not improve the fit of the relationship as evidenced by the lower R^2 values (Figure 5-2), suggesting the relationship between total arsenic in sediment and inorganic arsenic in clam tissue should not be relied upon for remedial decision-making (Windward 2010). The uncertainty in these relationships was part of the motivation behind the two-phase RARE study described below. The first phase was a laboratory mesocosm study conducted using LDW sediments (Lotufo et al. 2014), and the second phase was an *in situ* field study conducted in two plots within the LDW (USACE 2015).

[14] In addition to co-located sediment concentrations, spatially weighted average sediment concentrations in tidal areas alone and in tidal areas including a buffer area were evaluated for arsenic sediment-clam relationships, with similar uncertainty observed (Windward 2010). In an additional evaluation of the relationship between arsenic concentrations in surface water and clam tissue in the LDW, no clear relationship was found (Windward 2010).



Source: Windward (2010)

Figure 5-1. Logarithmic regression of inorganic arsenic concentrations in LDW clam tissue relative to total arsenic concentrations in co-located sediment samples collected in 2004



Source: Windward (2010)

Figure 5-2. Logarithmic regression of inorganic arsenic concentrations in LDW clam tissue relative to total arsenic concentrations in co-located sediment using 2004 and 2007 data

5.1.1 RARE study part 1: laboratory exposures

The initial laboratory study assessed arsenic bioaccumulation in *M. arenaria* from two potential exposure pathways: uptake from suspended solids and uptake from bedded sediments (Lotufo et al. 2014). The bedded sediment exposures were conducted by placing adult clams purchased from Aquatic Research Organisms (in New Hampshire)[15] in undisturbed LDW sediments[16] for 60 days. Exposures to suspended sediments were conducted by first wet-sieving LDW sediments through a 250-µm sieve, and then circulating the fine sediments (total suspended solids concentration of approximately 30 mg/L) in a flow-through exposure system containing the clams for 60 days.

[15] Clams were field-collected from a site considered to be pristine site in Maine. However, based on some variability in initial tissue concentrations, the clams were held for 30 days in clean water to lower the arsenic concentration in their tissues.

[16] Sediment used for the laboratory exposures was collected from intertidal areas north of Kellogg Island and Slip 1, combined, and homogenized. The arsenic concentration of the homogenized sediment was 191 mg/kg.

5.1.2 RARE study part 2: field exposures

The second part of the RARE study was conducted by exposing *M. arenaria* in the LDW *in situ*, where clams would be exposed through all potential LDW pathways. In addition to evaluating the relationship between total arsenic in sediment and inorganic arsenic in clam tissue, study objectives included assessing the potential relationship between arsenic concentrations in porewater and clam tissue.

Adult clams from Aquatic Research Organisms were deployed in bottomless buckets in two separate test plots within the LDW, one location with high anticipated arsenic concentrations in sediment (RM 3.75), and one with lower anticipated arsenic concentrations in sediment (RM 3.9) (Map 5-1). The clams were exposed to different treatments within each plot, with six replicates per treatment, as follows:

- Plot 1 (low arsenic concentration)
  - Undisturbed sediment
  - Homogenized sediment (sediment excavated, homogenized, and returned to bucket)
- Plot 2 (high arsenic concentration)
  - Homogenized sediment (sediment excavated, homogenized, and returned to bucket)
  - Sand treatment (sediment excavated, discarded, and replaced with clean sand)
  - Ferric hydroxide amendment (sediment excavated, amended with 15 percent granular ferric hydroxide by weight of dry sediment, homogenized, and returned to bucket)

Total and inorganic arsenic concentrations in clam tissue were analyzed following 180 days of exposure for every treatment. Total arsenic concentrations in sediment were analyzed in all buckets, except for the sand treatment. Total arsenic concentrations in porewater were analyzed in all treatments; porewater was obtained from the sediment sample by centrifuging the sediment and then filtering (< 45 µm) the supernatant. Total arsenic concentrations in porewater were also estimated using Diffusive Gradient in Thin-Film samplers in all buckets, except for the sand and ferric hydroxide treatments. The results from this study (Kerns et al. 2017a, b) were discussed in Appendix E of the pre-design studies work plan (Windward and Integral 2017) and will be summarized in the data evaluation report.

5.2 MIT POREWATER SAMPLING STUDIES

Starting in 2012, researchers from Dr. Philip Gschwend's group at MIT have used polyethylene (PE) passive samplers to estimate freely dissolved PCB concentrations in LDW surface water and porewater. These data may be useful in better understanding

the relationship between PCB concentrations in surface water, surface sediment, and porewater. In addition, clam tissue and co-located sediment were collected from five beaches in 2016, and fish tissue collection from the four RI tissue sampling areas is planned in 2017 (Kerns 2017).

The majority of this work has been conducted as part of a research project funded by the Strategic Environmental Research and Development Program (SERDP), a US Department of Defense funding program. The project is entitled *Combining Mass Balance Modeling with Passive Sampling at Contaminated Sediment Sites to Evaluate Continuing Inputs and Food Web Responses to Remedial Actions.* Project objectives include the use of PE passive samplers to evaluate ongoing PCB inputs into the LDW from upstream contaminant sources, groundwater, and site sediments (SERDP 2016). Data gathered as part of this study will be incorporated into mass balance and food web models being developed by MIT to evaluate whether passive sampling data can improve exposure characterization and predict future exposure.

The SERDP-funded work follows a previous study that was recently published comparing *in situ* and *ex situ* passive sampling approaches using LDW sediments (Apell and Gschwend 2016). Both of these studies are summarized below, focusing on aspects particularly relevant to the LDW pre-design studies.

5.2.1 *In situ* and *ex situ* passive sampling comparison

In November 2016, MIT researchers published a peer-reviewed journal article presenting concentrations of 35 PCB congeners (or co-eluting congener groups) in LDW porewater (Apell and Gschwend 2016). As part of this effort, PE passive samplers were deployed *in situ* at five sites in the LDW in November 2012 (Map 5-1). Samplers were retrieved in January 2013. Freely dissolved PCB concentrations in porewater were estimated by analyzing PCB congener concentrations in the samplers and using the congeners' polymer-water partition coefficients to calculate freely dissolved concentrations (Apell and Gschwend 2016).

For the *ex situ* evaluation, divers collected sediment cores in the vicinity of the porewater samplers when the porewater samplers were deployed. Sediments from the 0- to 10-cm interval of these cores were homogenized in the laboratory and tumbled in flasks containing PE strips. Concentrations in PE strips were then used to estimate freely dissolved PCB porewater concentrations.

Subsamples of the bulk sediments were also analyzed for the same PCB congeners as analyzed in the PE strips. Bulk sediment was also analyzed for total organic carbon and black carbon content. The bulk sediment PCB concentrations and organic carbon concentrations enabled a third estimation of dissolved porewater concentrations using equilibrium partitioning (EqP) theory (USEPA 2003).

As has been reported in the scientific literature, porewater concentrations estimated using EqP overestimate porewater concentrations measured using passive samplers

(Cornelissen et al. 2005). PCB porewater concentrations based on *in situ* and *ex situ* porewater sampling generally agreed within a factor of 2 (Apell and Gschwend 2016). *Ex situ* concentrations (based on the PE strips tumbled with the bulk sediment) were consistently higher than *in situ* porewater concentrations, suggesting this method provides a reasonable conservative estimate while reducing costs, risk of passive sampler loss, and risk to divers during sampler deployment and retrieval.

5.2.2 SERDP study

As part of the SERDP-funded study, MIT deployed PE samplers throughout the LDW in the summer / fall of 2014 to characterize PCB concentrations in porewater and overlying surface water and to evaluate PCB fluxes between sediment and surface water. The passive samplers were partially inserted into the sediment to enable sampling of the surface water immediately overlying the sediment bed as well as the sediment porewater. Co-located sediment samples were not collected as part of this 2014 effort. Of the 52 PE passive samplers deployed, only 20 could be found at the time of retrieval (approximately 2 months after deployment). The approximate locations of the retrieved passive samplers are shown in Map 5-1. The release date for these data will depend upon the timing of the manuscript preparation and SERDP reporting requirements.

5.3 ENHANCED NATURAL RECOVERY/ACTIVATED CARBON PILOT STUDY

LDWG is currently conducting a pilot study to evaluate the potential effectiveness of granular activated carbon in combination with an enhanced natural recovery sand layer to reduce the bioavailability of PCBs in sediment in the LDW (AMEC et al. 2015). The study will evaluate the effectiveness of ENR amended with AC (ENR+AC) compared to ENR alone. The study locations include an intertidal plot, a subtidal plot, and a scour plot to enable the relative evaluation of the two technologies over a range of conditions. Each of the study plots has been divided into two subplots of approximately 0.5 acre each: one ENR-only subplot and one ENR+AC subplot (Map 5-1).

The pilot study has a number of objectives, including evaluating the physical placement and stability of the ENR+AC in the different plots, evaluating the performance of ENR+AC relative to ENR alone with a range of PCB sediment concentrations, assessing the potential effects of the ENR+AC layer relative to ENR alone on the benthic community, and assessing the changes in PCB bioavailability in ENR+AC and in ENR alone.

In this study, freely dissolved PCB congener concentrations in porewater are being estimated using solid-phase microextraction (SPME) fibers placed in the sediment for approximately 28 days. Co-located sediment samples were analyzed for PCB congeners in each of the subplots as part of a baseline monitoring event conducted in fall 2016. Porewater sampling will be used to monitor changes in PCB bioavailability annually for 3 years after placement (spring 2018, 2019, and 2020). Each subplot will be sampled at

multiple locations, with at least three composite samples created for both sediment and SPME fibers from each location (AMEC et al. 2016).

Porewater and sediment results from the baseline monitoring effort are available. A laboratory bioaccumulation study for PCBs using sediments from a pilot test plot will also be conducted as part of this pilot study; however, this element will not be conducted until 2020. The results of the baseline effort will be discussed in the data evaluation report as part of the porewater analysis.

6 Summary

In summary, 59 datasets were exported from the Task 2 database into user-ready data tables with data considered acceptable for all uses, and 89 datasets were exported with data flagged for "conditional use only" (Table 6-1). The sampling locations associated with the in-waterway data are shown on Maps 3-1 through 3-6. Groundwater sampling locations are shown on Maps 2-1 through 2-6.

Table 6-1. Summary of data included in Task 2 user-ready data tables

Dataset Category	Data Identified as Acceptable for All Uses		Data Identified for "Conditional Use Only"	
	No. of Datasets	No. of Samples	No. of Datasets	No. of Samples
In-waterway				
Surface sediment	46	1,118	9	169
Subsurface sediment	6	199	8	306
Surface water	3	20	1	3
Tissue	0	0	2	11
Porewater	3	40	5	162
Seep	1	11	4	15
Source Control-related				
Combined sewer system/storm drain solids	na	na	20	1,194
Bank soils	na	na	3	53
Groundwater	na	na	31	468
Upstream				
Suspended solids	na	na	3	68
Surface water	na	na	3	49

na – not applicable; data quality reviews were not conducted

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