EAST WATERWAY OPERABLE UNIT

SUPPLEMENTAL REMEDIAL INVESTIGATION/ FEASIBILITY STUDY

TECHNICAL MEMORANDUM:

FINAL ANTHROPOGENIC BACKGROUND EVALUATION

For submittal to

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

July 2021

Prepared by

ANCHOR QEA

1201 Third Avenue • Suite 2600
Seattle, Washington • 98101

TABLE OF CONTENTS

Executive Summary **ES-1**

1 Introduction **1**

1.1 Background 1

1.2 Problem Definition 1

1.3 AB Estimation Approach 2

2 Physical Conceptual Site Model **3**

2.1 Green River Inputs 4

2.2 Urban Inputs 5

2.3 Lower Duwamish Waterway Bed Input 6

3 Screening of Potentially Applicable Datasets **7**

3.1 Green River Data 7

3.1.1 Green River Investigations 8

3.1.2 Green River Datasets Screening 9

3.2 Urban Input Data 11

4 Green River Suspended Solids Data Assessment **13**

4.1 Sampling Methods 13

4.2 Total PCBs 14

4.2.1 Total PCB Aroclors 14

4.2.2 Total PCB Congener Summing Methods 15

4.3 Dioxins/Furans 15

4.3.1 Congener Selection 15

4.3.2 Non-Detect Treatment 16

4.4 Arsenic 17

4.5 Outlier Evaluation 17

4.5.1 Conceptual Site Model Outlier Evaluation 17

4.5.2 Statistical Distribution Outlier Evaluation 18

4.6 Particle Size Distribution in Suspended Sediment 18

4.6.1 Excluding Samples with Low Fines 19

4.6.2 Fines Normalization 20

4.6.3 Particle Surface Area Adjustments 20

4.6.4 Summary of Particle Size Distribution Adjustments for Organic Contaminants 21

4.7 River Flow and Precipitation Weighting 21

4.8 Selected Data Treatment for the AB Dataset and Calculation 22

5 Uncertainty 23

5.1 Sensitivity Analysis Results Summary 23

5.2 Exclusion of Sediment Trap and Total PCB Aroclor Samples 23

5.3 Non-Detect Treatments 24

5.4 Dioxin/Furan Congener Selection 24

5.5 Changes in Particle Size Distribution Between the Green River and the East Waterway for Organic Contaminants 24

5.6 Green River Flow and Precipitation Conditions 24

5.7 Future Urban Inputs 25

5.8 Arsenic Post-Depositional Processes 25

5.9 Future Inputs to the Green River Watershed 26

5.10 Lower Duwamish Waterway Bedded Sediment 26

5.11 Conclusions 27

6 Summary and Conclusions 28

7 References 29

TABLES

Table 3-1 Sample Counts by Studies for Green River Datasets

Table 3-2 Green River Datasets Screening Summary

Table 3-3 Green River Suspended Solids and Whole Water Datasets Sufficiency Evaluation

Table 4-1 Comparison of Green River Suspended Solids Sampling Methods

Table 4-2 Comparison of Green River Suspended Solids Total PCB Congeners and Aroclors Datasets

Table 4-3 Comparison of PCB Congener Non-detect Treatments for Totals Summing

Table 4-4 Comparison of Dioxin/Furan Congener Non-Detect Treatments Summary Statistics

Table 4-5 Green River Flow and Precipitation Conditions During Sampling of Highest Concentration Values

Table 5-1 Sensitivity Analysis

Table 5-2 Comparison of Arsenic Concentrations in Green River Suspended Solids and East Waterway, Elliott Bay, and Post-Remediation Site Sediments

Table 6-1 Range of Estimated Anthropogenic Background Values for East Waterway Operable Unit

FIGURES

Figure 1-1 East Waterway Operable Unit and Lower Duwamish Waterway Site

Figure 2-1 East Waterway Physical Conceptual Site Model

Figure 2-2 Annual Solids Inputs to the East Waterway

Figure 2-3 Sediment Transport in the Green and Duwamish River by Particle Size Fraction

Figure 2-4 Green River Watershed

Figure 2-5 Green/Duwamish Watershed Land Use

Figure 2-6 EW and LDW Stormwater and CSO Drainage Basins

Figure 2-7 Distribution of Average Daily Flows Below the Howard Hanson Dam (2001–2019; RM 63)

Figure 2-8 Distribution of Rainfall at the Tukwila Rain Gauge (2001–2019; RM 13.8)

Figure 4-1 Comparison of Green River Suspended Solids Results by Sampling Methods

Figure 4-2 Green River Suspended Solids Concentration Distributions

Figure 5-1 Sensitivity Analysis

APPENDICES

Appendix A Supporting Documentation

Appendix B Anthropogenic Background Dataset

ABBREVIATIONS

µg/kg	micrograms per kilogram
AB	anthropogenic background
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	cubic feet per second
cm	centimeter
cm/yr	centimeters per year
COC	contaminant of concern
CSM	conceptual site model
CSO	combined sewer overflow
dw	dry weight
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
EW	East Waterway
EWG	East Waterway Group
FS	Feasibility Study
in/day	inches per day
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
mg/kg	milligrams per kilogram
ng/kg	nanograms per kilogram
PCB	polychlorinated biphenyl
Port	Port of Seattle
PRG	preliminary remediation goal
Q-Q	quantile-quantile
RAO	remedial action objectives
RBTC	risk-based threshold concentration
RI	remedial investigation
RM	river mile
RME	reasonable maximum exposure
ROD	Record of Decision
ROS	regression on order
SRI	Supplemental Remedial Investigation
TEQ	toxic equivalent
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

Executive Summary

This memorandum develops site-specific anthropogenic background (AB) estimates for total polychlorinated biphenyls (PCBs), dioxins/furans, and arsenic for the East Waterway (EW) sediment Operable Unit of the Harbor Island Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Superfund site located in Seattle, Washington. This AB evaluation is part of the EW Supplemental Remedial Investigation and Feasibility Study process to support the U.S. Environmental Protection Agency's (EPA's) development of the Proposed Plan and Record of Decision for the EW sediment Operable Unit.

AB estimates were developed as part of a collaborative process between EPA and East Waterway Group (the Port of Seattle, City of Seattle, and King County), and in coordination with key stakeholders (the Muckleshoot Tribe and the Suquamish Tribe), in meetings held in 2020.

AB estimates were developed based on the EW conceptual site model regarding sediment inputs to the EW, which is predominantly from Green River suspended sediments (approximately 99 percent) and a very small amount from urban inputs (approximately 1 percent).[1] Available datasets representing solids inputs to the EW included upstream Green River suspended solids, surface water, and bedded sediment, as well as storm drain and combined sewer overflow solids in the urban drainage basins to the EW and the Lower Duwamish Waterway (upstream of the EW). Following screening of these datasets, Green River suspended solids data were deemed most acceptable and representative as the AB dataset. These data were further evaluated to support dataset refinement and adjustment, identify potential uncertainties, and develop AB estimates for the EW Superfund site. The selected AB values based on the 95 percent upper confidence level on the mean statistic are as follows:

- Total PCBs: 31 micrograms per kilogram (µg/kg) dry weight (dw)
- Arsenic: 20 milligrams per kilogram (mg/kg) dw
- Dioxins/furans:
  - 1,2,3,7,8-PeCDD (Pentachlorodibenzo-p-dioxin): 2.1 nanograms per kilogram (ng/kg) dw
  - 2,3,4,7,8-PeCDF (Pentachlorodibenzofuran): 1.1 ng/kg dw
  - 2,3,7,8-TCDD (Tetrachlorodibenzo-p-dioxin): 0.71 ng/kg dw
  - 2,3,7,8-TCDF (Tetrachlorodibenzofuran): 1.2 ng/kg dw

[1] Percentages based on the estimates for the future case scenario following source control; see EW Feasibility Study Section 5 (Anchor QEA and Windward 2019).

1 Introduction

This technical memorandum develops site-specific anthropogenic background concentration (AB) estimates for total polychlorinated biphenyls (PCBs), dioxins/furans, and arsenic for the East Waterway (EW) sediment Operable Unit of the Harbor Island Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Superfund site located in Seattle, Washington. Estimation of AB for these contaminants of concern is part of the EW Supplemental Remedial Investigation (SRI) and Feasibility Study (FS) process, and supports the U.S. Environmental Protection Agency's (EPA's) development of the Proposed Plan and Record of Decision (ROD) for the EW sediment Operable Unit. This work was performed under the October 2006 Administrative Settlement Agreement and Order on Consent with the Port of Seattle (Port) and EPA after EPA required this work as part of a supplement to the SRI/FS Work Plan for the Administrative Settlement Agreement and Order on Consent on December 16, 2020. The East Waterway AB values are site-specific for the EW site and are not appropriate for use at other sites.

1.1 Background

The EW is a 1.5-mile-long, 157-acre maintained commercial waterway along the east side of Harbor Island, immediately downstream of the Lower Duwamish Waterway (LDW) Superfund site, which extends for 5 miles upstream (Figure 1-1). In 2006, the Port entered into the Administrative Settlement Agreement and Order on Consent for development of a SRI/FS for the EW. The Port subsequently entered into a Memorandum of Agreement with the City of Seattle and King County to jointly conduct the SRI/FS as the East Waterway Group (EWG). The SRI was approved by EPA in 2014 (Windward and Anchor QEA 2014), and the FS was approved by EPA in 2019 (Anchor QEA and Windward 2019).

1.2 Problem Definition

The FS preliminary remediation goals (PRGs) were established based on natural background[2] for total PCBs, dioxins/furans, and arsenic, because risk-based threshold concentrations (RBTCs) for human health remedial action objectives (RAOs) for these chemicals were less than natural background concentrations. Natural background concentrations and associated RAOs established in the FS are as follows (FS Table 4-3):

- Total PCBs: 2 micrograms per kilogram (µg/kg) dry weight (dw); RAO 1 (human health seafood consumption)
- Dioxins/furans: 2 nanograms per kilogram (ng/kg) toxic equivalent (TEQ) dw; RAO 1 (human health seafood consumption)
- Arsenic: 7 milligrams per kilogram (mg/kg) dw; RAO 2 (human health direct contact)

[2] "**Natural Background**: substances present in the environment in forms that have not been influenced by human activity" (EPA 1989).

FS analyses showed that these PRGs are unlikely to be achieved for any remedial alternatives (e.g., see FS Section 9, Appendix A and Appendix J), due to the urban setting of the EW and sediment inputs from upstream of the LDW. Sediments accumulating in the EW contain concentrations of contaminants of concern (COCs) greater than natural background that are not related to EW sources, including inputs of suspended solids from the upstream Green River, general urban runoff from off-site upland impervious surfaces, storm sewer discharges, combined sewer overflow discharges, and other non-point sources. Therefore, the development of AB[3] values is needed:

> Generally, under CERCLA, cleanup levels are not set at concentrations below natural background levels. Similarly, for anthropogenic contaminant concentrations, the CERCLA program normally does not set cleanup levels below anthropogenic background concentrations (EPA 2002a).

Based on the aforementioned site-specific circumstances, EPA determined it necessary to develop AB estimates for total PCBs, dioxins/furans, and arsenic. These AB values will replace natural background-based PRG values presented in the FS in future EPA decision documents for the EW Operable Unit.

1.3 AB Estimation Approach

In late 2020, EPA and EWG held 13 meetings, with participation from the Muckleshoot Tribe and the Suquamish Tribe, to assemble and evaluate existing data, and then, if sufficient data existed, develop AB estimates for PCBs, dioxins/furans, and arsenic.[4]

The working group first reviewed the EW physical conceptual site model (CSM) with a focus on the relative contribution of different solids inputs to the EW. In the long term, following site remediation, the EW surface sediments will equilibrate to the solids characteristics of material entering the EW. Therefore, the approach used to develop the AB estimate was to identify existing datasets that would be representative of solids entering the EW that are not associated with site releases (Section 2). The assembled datasets were evaluated for acceptable quality and for adequate quantity for statistical evaluation. Ultimately, the working group focused on suspended solids inputs from the Green River based on data collected just upstream of the LDW; the Green River suspended solids data were deemed broadly representative of the upstream solids loading to the EW (Section 3).

Next, the Green River suspended solids dataset was further evaluated through a series of assessments (i.e., comparing different data treatment assumptions) to refine the dataset for use in estimating AB (Section 4). Key uncertainties were also assessed (Section 5). Finally, summary statistics for the selected AB dataset were calculated (Section 6).

[3] "**Anthropogenic Background**: natural and human-made substances present in the environment as a result of human activities (not specifically related to the CERCLA release in question)" (EPA 1989).

[4] The Washington State Department of Ecology attended three meetings only for informational purposes.

2 Physical Conceptual Site Model

This section reviews aspects of the EW physical CSM documented in the FS that are relevant to this AB estimation. The primary sources of sediment to the EW are solids entering from the upstream Green/Duwamish watershed and from storm drain and combined sewer overflow (CSO) lateral[5] inputs (Figure 2-1). Geochronological coring indicates the EW is net depositional, receiving up to 4.2 centimeters (cm) of depositional material per year, with a site-wide average of approximately 1.2 cm per year (cm/yr). This newly deposited sediment is almost entirely (approximately 99 percent) made up of solids from the Green/Duwamish[6] River (Figure 2-2). Smaller portions of suspended sediment originate from the following: 1) lateral inputs, such as storm drains and CSOs, entering the EW along the EW itself (0.43 percent); 2) lateral inputs along the LDW that flow downstream into the EW (0.55 percent); and 3) LDW bed sediments that are resuspended and move downstream into the EW (0.24 percent; Figure 2-2). These estimated percentages of material settling in the EW are based on the future case estimates (FS Appendix J, Table 1, using a site-wide average deposition rate of 1.2 cm/yr),[7] which includes a reduction in solids inputs from EW laterals based on planned CSO control projects and source control actions in stormwater drainage basins. Sediment load into the EW from Elliott Bay is assumed to be very small compared to lateral inputs and was not included in depositional inputs in the CSM (FS Section 2.11.1).

Results from the LDW sediment transport model (QEA 2008) indicate that approximately 99 percent of the incoming upstream load to the EW from the Green River consists of silts and clays, as a result of more coarse fractions settling out in the LDW. This contrasts with the LDW, where coarse-grained particles make up approximately 33 percent of incoming sediment from the Green River, almost all of which deposits in the LDW. Figure 2-3 shows the relative change in grain-size composition during transport and settling in the LDW for the four particle size classes that were modeled in the LDW sediment transport model (QEA 2008).

In the long term (decades), surface sediments in the EW will equilibrate to incoming solids. The sources of solids entering the EW relevant to the AB estimate (Green River, EW/LDW laterals, and resuspended LDW bedded sediment) are discussed in the following sections.

[5] "Lateral inputs" refers to outfall and small urban stream inputs located along the sides of the EW and LDW, consistent with the definition in the EW and LDW FSs. "Urban inputs" is used more generally to refer to EW and LDW laterals plus urban inputs to the Duwamish River upstream of the LDW.

[6] At the confluence of the Green and Black rivers, several miles upstream of the LDW, the name changes to the Duwamish River.

[7] The future case refers to the estimated solids loads to the EW following planned source control actions in lateral load drainage basins. Note that FS Appendix J, Table 1, was based on a site-wide average sedimentation rate of 1.6 cm/yr. However, the EW best-estimate sedimentation rate was later revised to 1.2 cm/yr; therefore, Appendix J, Table 1 values were revised to be based on 1.2 cm/yr for this document, consistent with the best-estimate values in the main body of the Final FS.

2.1 Green River Inputs

The Green River originates in the Central Cascade Mountains and flows through 93 river miles of forested and developed lands, eventually becoming the Duwamish River and discharging into Elliott Bay in downtown Seattle. The Green/Duwamish River watershed is 300,000 acres and can be divided into four main subwatersheds: the Upper Green, the Middle Green, the Lower Green, and the Duwamish (Figure 2-4). The Upper Green and Middle Green are both predominantly forested subwatersheds, consisting of 95 percent and 57 percent forest land, respectively. The Lower Green and Duwamish are predominantly developed subwatersheds, consisting of 85 percent and 91 percent developed land, respectively (Conn et al. 2018a). The Howard Hanson Dam is located within the Upper Green subwatershed and regulates the flow of the Green River, maintaining minimum flows for salmon passage and restricting maximum flows for flood mitigation. Figures 2-5 and 2-6 present the land use and the stormwater and CSO drainage basins for the Green/Duwamish River watershed upstream and downstream of river mile (RM) 10.4, where multiple studies have been focused (Section 3).

Suspended solids in the Green River are from three main inputs, which are important for understanding the Green River component of EW AB. The first input includes solids that have accumulated behind and are released from the Howard Hanson Dam, particularly during large dam releases. The second input is associated with stormwater runoff that enters the Green River during precipitation events downstream of the Howard Hanson Dam, including into tributaries of the Green River. The third input is associated with the erosion of seams of certain geologic formations and resuspended bed sediment of Green River material downstream of the Howard Hanson Dam. These three sources vary over time in their relative contribution to Green River suspended solids inputs and contaminant concentrations due to varying river conditions (varying relative inputs from the Howard Hanson Dam discharges and stormwater runoff over time) (Conn et al. 2018a).

Figure 2-7 presents a histogram of average daily flows from 2001 to 2019 for the U.S. Geological Survey (USGS) flow gauge situated just below the Howard Hanson Dam (USGS station 12105900).[8] The flow discharge distribution shows lower flow conditions the majority of the time (the mode of the distribution is 275 cubic feet per second [cfs]), but with much higher average flows (981 cfs) and upper percentiles (90th percentile = 1,961 cfs). As noted previously, the Howard Hanson Dam maintains minimum flows for the Green River (with a minimum of 157 cfs observed in this dataset).

Figure 2-8 presents precipitation for the same time period based on King County Tukwila rain gauge (ID TUKW). Similar to Howard Hanson Dam discharges, the distribution of precipitation is skewed, with no measurable precipitation the majority of the time. Days with more than 0.36 inch per day (in/day) occur 10 percent of the time (90th percentile of dataset). Figure 2-8 also presents summary

[8] 2001 to 2019 is the period that data were available for King County's Tukwila Rain gauge (ID TUKW), so it was selected for summary statistics.

statistics for days with more than 0.1 in/day to provide resolution on rainfall events at this same rain gauge location.

The sediment transport dynamics in the Green River and the LDW are also important for the EW AB estimate. Beginning at the LDW upper turning basin (RM 4.8),[9] the Duwamish River estuary widens, flow becomes slower, and the saltwater wedge from Elliott Bay becomes more influential. The upstream extent of the saltwater wedge varies over time from RMs 2 to 10 based on tidal and river flow conditions, with the most common extent occurring between RMs 2 to 4. A permanent saltwater wedge exists within the EW and upstream to approximately LDW RM 2.2. Because of these conditions, the LDW turning basin is a trap for depositing Green River suspended sediments and requires dredging every several years to maintain its function of capturing a large portion of the suspended solids to help maintain navigation channel depths further downstream. Coarse-grained suspended solids (sands) settle first, with finer-grained solids progressively settling out as water moves north toward Elliott Bay; thus finer-grained solids are largely what remains in suspension for transport toward the EW (although fine-grained solids do settle in the LDW). Some of the finer-grained solids entering the EW are ultimately transported to Elliott Bay.

Chemical datasets associated with Green River inputs are discussed in Section 3.1.

2.2 Urban Inputs

The Green/Duwamish Watershed becomes gradually more developed and industrialized moving northward toward Elliott Bay. Although the Green/Duwamish River receives stormwater from developed land upstream of the LDW (RM 5.0; Figure 2-5), this discussion is focused on urban inputs directly to the LDW and EW (i.e., EW and LDW lateral inputs), which represent approximately 1 percent of solids entering the EW. The EW and LDW lateral drainage basins are shown in Figure 2-6.

Urban runoff enters the EW/LDW through storm drains and CSOs associated with an extensive system of underground drainage pipes as well as creeks (LDW only). Suspended solids associated with these inputs are referred to collectively as lateral inputs. The drainage basin for the EW laterals, which is described in detail in EW SRI Section 9.4.3 (Windward and Anchor QEA 2014), includes three CSOs (Hinds, Lander, and Hanford No. 2) and 41 storm drain outfalls. CSOs only discharge during large storm events when the amount of water entering the combined sewer pipes exceeds the capacity of the system to transport all the flow to the wastewater treatment plants. The Lander and Hanford No. 2 CSOs share most of the same drainage basin, with the Hanford No. 2 CSO draining slightly more area in South Seattle. The Lander and Hanford No. 2 CSOs combine to drain 5,000 acres, which is approximately 99 percent of the combined sewer drainage basin; the Hinds CSO accounts for the remaining 1 percent. A total of 788 acres around the EW drains through the EW

[9] RMs are measured from the northern extent of the LDW Superfund site at the southern portion of Harbor Island.

storm drains, with the South Lander Street storm drain representing more than half (442 acres) of the total storm drainage basin area.

The LDW drainage basin is described in detail in LDW Remedial Investigation (RI) Section 9.4.4 (Windward 2010) and includes 10 CSOs, 5 emergency overflows, and 188 storm drains. Within the LDW drainage basin, the City of Seattle's municipal storm drain system services 61 percent of the LDW SD drainage basin, which is a separated or partially separated storm drain system, and unincorporated King County and City of Tukwila municipal storm drains service 24 percent of the drainage basin. The remaining 15 percent are serviced by private waterfront storm drain systems services.

The CSO and storm drain systems that discharge to the EW and LDW have been monitored, maintained, and upgraded over decades to reduce the discharge of contaminant inputs to waterways. These source control actions are ongoing, and additional source control is expected to occur.

EW FS Section 2.12 and LDW FS Section 2.4 describe source control activities in detail for these drainage basins. Source control activities include management of stormwater discharge regulated by the National Pollutant Discharge Elimination System, CSO control programs, compliance and inspection programs, EW and LDW source tracing activities and related actions (such as line cleaning), municipal stormwater management (including business inspections), upland site cleanup work, spill response programs, and air quality programs. Line cleaning, long-term infrastructure improvements, and improved maintenance and best management practices gradually reduce the solids mass and chemical concentrations entering the waterways. General urban inputs from permitted discharges will continue to occur. Chemical datasets associated with urban inputs are discussed in Section 3.2.

2.3 Lower Duwamish Waterway Bed Input

Approximately 0.2 percent of solids entering the EW are attributable to resuspended bedded sediments from the LDW (FS Section 5.1.1 [QEA 2008]), a very small fraction of the total solids load entering EW. In addition, cleanup of LDW bedded sediment has not yet been completed. Moreover, in the long term, following source control, sediment cleanup, and natural recovery of the LDW, COC concentrations in LDW surface sediments will become similar to loading inputs from the Green River and urban inputs from LDW laterals. Therefore, LDW bed load is not included in the AB evaluation, and chemical data are not discussed in Section 3.

3 Screening of Potentially Applicable Datasets

This section presents the datasets that were considered in the AB evaluation and provides the rationale for selecting the Green River suspended solids dataset to carry forward for further evaluation in Section 4. Available data were compiled and evaluated for adequacy, acceptability, and representativeness. These data quality categories are based on *Role of Background in the CERCLA Cleanup Program* (EPA 2002a), as adapted for this evaluation.

Adequacy addresses whether enough data are available to provide a reliable estimate of AB and is related to the number of chemical concentration measurements (sample counts).

Acceptability considers the data quality, including documentation, sampling procedures, laboratory procedures, and quality control (e.g., laboratory control samples such as matrix spikes, duplicates, and blanks). An acceptable study provides sufficient detail on field and laboratory methods to prove it is of acceptable quality to be included in the AB estimation. In the field, sampling must be performed using well-documented and well-established field sampling methods. Additionally, quality assurance/quality control samples must be analyzed to evaluate sample integrity and data quality. Each analyte must be measured by an accredited laboratory using EPA-approved methods. These laboratories must present detection limits and relevant data qualifiers. Finally, an appropriate level of data validation must be employed for each analyte considered in the AB estimation.

Representativeness is related to the CSM and considers if the data are characteristic of solids entering the EW. Representativeness was evaluated considering four different factors: geographical, temporal, physical, and land use. Geographical representativeness considers if the sampling location is appropriately selected for representing EW AB. The sampling should be reasonably close upstream of the EW but not be affected by known CERCLA releases. Temporal representativeness considers the age of the data (recent or historical), the time frame in which samples were collected (discrete sample or a time-weighted average), and the flow and precipitation conditions during sampling. Physical representativeness was evaluated by comparing particle size fractions from the samples to expected suspended solid particle size fractions that enter the EW. Land use representativeness considers the land use upstream of the sample compared to the land use upstream of the EW.

3.1 Green River Data

This section describes Green River investigations and screens Green River datasets.

3.1.1 Green River Investigations

The Green River has been the subject of multiple investigations over the past two decades to better understand contaminant loads moving into downstream LDW and EW Superfund sites.[10] These investigations have targeted three media of interest: suspended solids, surface water, and bedded sediment. The studies and the media sampled are listed as follows:

- USGS – Green River Loading Study (Conn et al. 2018a): suspended solids, surface water, and bedded sediment
- King County – Suspended Sediment Study (King County 2016), Green River Watershed Surface Water Data Report (King County 2018a), and Green River PCB Equipment Blank Study Data Report (King County 2018b): suspended solids, surface water
- Ecology – Contaminant Loading from Suspended Sediment (Ecology 2009) and Source Control Sediment Sampling (Ecology and Environment 2009): suspended solids and bedded sediment
- U.S. Army Corps of Engineers (USACE) – Turning Basin Sediment Core Sampling (Summarized in Windward 2020): bedded sediment
- Lower Duwamish Waterway Group (LDWG) – Compilation of Existing Data Report (Windward 2018), LDW Pre-Design Studies Data Evaluation Report (Windward 2020): surface water and bedded sediment from upstream of LDW

For the dataset screening, the reports for these studies were reviewed, and the data from each study were compiled. Some of the data had already been compiled by LDWG for the LDW FS (AECOM 2012), the Compilation of Existing Data Report (Windward 2018), and the Pre-Design Studies Data Evaluation Report (Windward 2020). Data were also acquired from Ecology's Environmental Information Management database and from King County's Environmental Laboratory Information Management System. Table 3-1 presents the sample counts by study for the Green River datasets, Table 3-2 summarizes the dataset screening by medium (suspended solids, surface water, and bedded sediment), and Table 3-3 provides a detailed evaluation of the Green River suspended solids datasets. The studies are summarized in the following paragraphs.

The USGS Green River loading study collected suspended solids, surface water, and bedded surface sediment from 2014 to 2017 at RM 10.4 (at the Foster Links Golf Course). Suspended solids and surface water were collected during 42 discrete sampling periods targeting a variety of flow conditions, as described in Table 3-3. Suspended solids were collected over 24 to 48 hours using centrifugation. In addition, on seven occasions a bedded surface sediment composite sample was collected within 1,000 meters downstream of RM 10.4.

[10] The exception is the LDW upper turning basin core sampling from the U.S. Army Corps of Engineers (USACE), which was sampled for the purpose of evaluating dredge material quality in the upper turning basin of the LDW but which is included in this screening as potentially relevant to AB determination.

The King County suspended sediment study collected suspended solids by filtering surface water (filter solids) or using sediment traps (baffle-style and jar-style) at four locations in the Green River Watershed from 2012 to 2015. Only the samples collected at RM 10.4 were considered for this evaluation, because it is downstream of the other sampling locations and is the same location as the USGS study (totaling 12 filter solids samples and 9 sediment trap samples). Filtered suspended solid samples were collected over 24 to 48 hours, while sediment trap samples were collected following an approximately 3-month deployment period. King County also collected surface water samples from various locations within the Green River Watershed.

Ecology conducted two investigations focused on the collection of suspended solids (Ecology 2009) and bedded sediment (Ecology and Environment 2009). Collection of suspended solids at RM 6.8 occurred approximately monthly over a 7-month period in 2008 and 2009 (seven sampling events). Collection of suspended solids from the water column by continuous-flow centrifugation occurred over 24 or 48 hours. Bedded sediment samples were collected from 104 locations from RM 4.9 to RM 6.5 over a 10-day period in 2008.

USACE performs dredge material characterization testing of sediment in the upper turning basin of the LDW prior to periodic maintenance dredging. Data from sediment core composite samples collected in 2008, 2009, 2011, and 2017 were compiled by the LDWG in the LDW Pre-Design Studies Data Evaluation Report (Windward 2020).

The upper turning basin is located at the upstream end of the LDW Superfund site, but functions as a trap, capturing approximately one-third of the sediment entering the LDW from the Green/Duwamish River.

LDWG has compiled data and performed sampling of surface water and sediment of the Green River upstream of the LDW Superfund site. The LDWG Pre-Design Studies Data Evaluation Report presents surface water samples collected by the LDWG at RM 10.4 for eight sampling events from August 2017 to July 2018. Surface water sampling by King County prior to 2011 are also included in the LDWG compiled data. Additionally, 37 bedded sediment samples upstream of the LDW were compiled by LDWG for the LDW RI (see LDW FS Appendix C, Part 3b; AECOM 2012).

3.1.2 Green River Datasets Screening

Data were aggregated by media (suspended solids, surface water, and bedded sediment) and then evaluated for acceptability, representativeness, and adequacy. As presented below, suspended solids were retained as the applicable Green River dataset, and surface water and bedded sediment were eliminated based on representativeness evaluations for the applicable Green River dataset.

3.1.2.1 Suspended Solids Datasets

The suspended solids datasets were retained based on adequacy (Table 3-1), acceptability (Table 3-2), and representativeness (Table 3-2).

For acceptability, the suspended solids sampling programs by USGS, King County, and Ecology were all performed using well-documented sampling procedures and well-established and validated laboratory procedures. All three sources of data were of acceptable quality to be further evaluated (Table 3-3).

For geographical representativeness,[11] suspended solids data collected from RM 6.8 and RM 10.4 were both considered geographically representative because they are upstream of the EW and LDW Superfund sites. RM 10.4 is upstream of the salt wedge and is therefore representative of Green River suspended solids transporting toward the EW. RM 6.8 has a periodic salt wedge, but Ecology sampling was performed to avoid sampling saltwater (Table 3-3).

For temporal representativeness, all suspended solids data were considered to be sufficiently recent (sampled within the past 15 years) for inclusion. Each suspended sediment sampling program collected samples during a variety of flow and precipitation conditions so that their datasets would be representative of periods with different river conditions within the Green River. This is important because different river conditions can result in different suspended solids chemical concentrations (Table 3-3).

For physical representativeness, suspended solids samples were primarily fine-grained and therefore considered sufficiently representative of fine-grained sediment that deposits in the EW. Sediment trap samples, which are more coarse-grained than centrifuge and filter solids samples, are evaluated further in Section 4.

For land use representativeness, because the Green River Watershed provides roughly 99 percent of solids that enter the EW, the land use upstream of these sampling locations (RM 10.4 and RM 6.8) are considered generally representative. Solids inputs downstream of these sampling locations, particularly from within the LDW and EW Superfund sites, are discussed in Section 3.2.

Based on this evaluation, all suspended solids datasets were considered acceptable and representative and therefore were retained for the AB evaluation, resulting in 59 to 82 samples (depending on the analyte). This number of samples was considered adequate for further AB evaluations in Section 4.

3.1.2.2 Surface Water Datasets

The surface water datasets consisted of whole -water samples for PCBs and dioxins/furans and both whole -water (total) and filtered (dissolved) samples for arsenic. The surface water samples were collected,

[11] Geographical representativeness in this memorandum refers to a physical location that is representative of solids that enter the EW (i.e., upstream solids) rather than a similar environmental setting.

analyzed, and validated using acceptable methods. However, the datasets were not considered representative due to uncertainty in the solids estimate calculation, as described below (Table 3-2).

Surface water data were evaluated using the approach previously employed in the LDW FS Appendix C, Part 3b (AECOM 2012) for estimating Green River inputs to the LDW. Hydrophobic organic compounds, such as PCBs and dioxins/furans, are primarily associated with particulates (through partitioning to organic carbon). Therefore, concentrations in unfiltered whole-water samples can be divided by the sample's total suspended solids concentrations to estimate the particulate concentration in surface water sample. However, because some portion of these compounds can also be associated with colloids[12] as well as exist in freely dissolved fraction, the resulting particulate concentration estimate is biased high.

For arsenic, which includes a larger dissolved component than hydrophobic organics, the filtered water concentrations (dissolved arsenic) were subtracted from unfiltered concentrations (total arsenic) to estimate each sample's particle-bound fraction prior to dividing by the sample's total suspended solids concentration. However, this calculation relies on combining three different analytical results, which compounds variability in the calculated result, reducing representativeness.

In summary, the surface water datasets are of acceptable quality and adequate sample numbers, but the method for calculating suspended solids concentration introduces potential bias and uncertainty. This, combined with the more representative and adequate number of suspended solids samples, resulted in the elimination of the surface water datasets from further AB evaluations.

3.1.2.3 Bedded Sediment Datasets

Green River and LDW turning basin bedded sediment data were collected, analyzed, and validated using acceptable methods. However, these data did not meet representativeness standards (Table 3-2). Bedded surface sediment from the Green River and the LDW Turning Basin has coarser particle sizes compared to that which enters the EW. For this reason, bedded sediment data within the Green River and the LDW turning basin are not considered representative of material that would eventually reach the EW and are not carried forward to Section 4.

3.2 Urban Input Data

This section discusses inputs from urbanized drainage basins that are not captured in the Green River data described in Section 3.1. Urban inputs that are not part of a known CERCLA release are an important component of AB (EPA 2002b). Urban inputs include contributions from the drainage basin to the Duwamish River downstream of RM 10.4 and contributions from the LDW and EW direct drainage basins. These include both general urban inputs that will persist in the long term and

[12] Total suspended solids are typically determined using a 0.45-micrometer filter that does not capture colloids (particulates smaller than filter size).

known CERCLA releases that will be controlled prior to sediment cleanup, which comingle and cannot be easily separated from each other.

Data were not readily available for lateral inputs above the LDW (RM 5.0), but all the urban areas downstream of the Green River sampling locations (at RM 10.4 and RM 6.8) contribute urban runoff that influences AB for the EW.

Section 2.2 describes the EW and LDW lateral drainage basins where lateral input data have been collected. Solids samples collected directly from storm drains or CSOs (catch basin, in-line grab samples, or in-line sediment traps) have been used in the past to estimate urban inputs. The available datasets for lateral solids are presented in the EW SRI (Appendix I) and EW FS (Appendix B, Part 4), and the laterals datasets for the LDW have recently been aggregated in the *Lower Duwamish Waterway Pre-Design Studies Data Evaluation Report* (Windward 2020). These laterals datasets are representative of current conditions (see Appendix A, Part 3, of this document). In addition, these data meet acceptability standards and are of adequate quantity to characterize this input.

As noted in Section 2, the solids mass entering the EW from both EW and LDW drainage basins is low (predicted to be less than 1 percent). However, estimating chemistry concentrations following source control (representing solids inputs not related to CERCLA releases for the drainage basins)[13] is uncertain. Because of the relatively small solids contribution and uncertainty in future chemistry concentrations of urban inputs, the lateral input dataset is not considered further in establishing AB.

[13] Additional source control actions will occur in the future to ensure sources are sufficiently controlled to proceed with sediment cleanup actions.

4 Green River Suspended Solids Data Assessment

The previous section screened potentially relevant datasets, concluding that suspended solids data from samples collected in the Green River at RM 10.4 and RM 6.8 would be retained for further assessment in the AB estimate. The suspended solids dataset is provided in Appendix B. This section discusses the following factors that were assessed in developing a final dataset for estimating AB value:

- Comparison of sampling methods (centrifuge, filter solids, and sediment traps)
- Analyte-specific considerations such as analytical methods (total PCBs congeners versus Aroclors), summing procedures (non-detect treatment), and dioxin/furan congeners selection
- Outlier assessments
- Particle size distribution adjustments
- River flow condition and precipitation weighting

4.1 Sampling Methods

The following three methods were used to sample suspended solids in the Green River.

- 44 samples collected by centrifugation (USGS and Ecology)
- 12 samples collected by filtration (King County)
- 9 samples collected by sediment trap using jar-style or baffle-style traps (King County)

Detailed information on these methods is provided in the source documents for the USGS, King County, and Ecology investigations (see Section 3.1.1).

Centrifuge and filtration sampling methods both rely on pumping river water over a 24-to-48-hour period to collect solids, targeting a range of river conditions over multiple sampling events. The two sediment trap sampling methods both involve the passive collection of solids over a 3-month period. The suspended solids collected by centrifuge and filter methods typically consisted of finer-grained material compared to sediment traps. Sediment traps, which collect solids closer to the sediment bed, retain coarser-grained suspended solids and also sediment bedload. Table 4-1 presents summary statistics for the percent fines for the different sampling methods; the average percent fines is 48 percent for sediment traps, compared to 75 percent for centrifuge and filter solids samples. Fine-grained suspended solids are representative of material that is more likely to reach the EW; coarser-grained suspended solids are representative of material that is more likely to settle in the LDW.

Coarser-grained material generally has lower contaminant concentrations than finer-grained material for all three contaminants of interest. In particular, organic contaminants (total PCBs and dioxins/furans) tend to sorb to the organic carbon on the particle surface. As particle sizes decrease, the surface area-to-mass ratio increases, resulting in higher relative concentrations of organic carbon, and therefore organic contaminants, on smaller particles (Hedges and Kiel 1995; Karickhoff et al. 1979; Wang and Keller 2008). As a result, the sediment trap concentrations are likely biased low

compared to the centrifuge/filter solids concentrations. Mean concentrations for sediment traps are roughly half of the mean centrifuge/filter solids concentrations (sediment traps are 50 percent of centrifuge/filter solids for total PCBs, 36 percent for dioxin/furan TEQ, and 57 percent for arsenic [Figure 4-1 and Table 4-1]).

Sediment trap data were excluded from the dataset used to define AB, due to this systematic higher sand content that is less representative of solids entering EW and results in biased low concentrations of sediment trap samples. The effect this exclusion has on AB calculations is considered as part of the sensitivity analysis in Section 5.

4.2 Total PCBs

4.2.1 Total PCB Aroclors

The 66 centrifuge/filter solids samples were analyzed for PCBs using either EPA Method 8082 (Aroclors), EPA Method 1668A/C (congeners) or, in some cases, both methods, detailed as follows:

- 7 samples: Aroclors only
- 32 samples: congeners only
- 17 samples: both methods

The PCB congener method produces lower detection limits and greater accuracy at low concentrations than the Aroclor method. For example, 8 of the 17 samples analyzed using both methods were non-detect for all Aroclors but contained detectable concentrations of some congeners.[14] For this reason, where both methods were used, only the total PCB congener results were retained.

Seven samples were analyzed for Aroclors only. Although detection limits were relatively low for these samples (2.7 µg/kg or less), no Aroclors were detected in three of seven samples. Furthermore, the mean total PCB concentrations for centrifuged/filtered samples with and without these seven Aroclor samples were essentially the same (Table 4-2). Therefore, the PCB congener dataset (n = 49) was considered adequate without including the seven samples analyzed for Aroclors only.

Based on this assessment, only the congener data were retained for AB estimation. The effect this exclusion has on AB calculations is discussed in the sensitivity analysis in Section 6.

[14] EPA Method 1668A/C analysis includes 209 PCB congeners.

4.2.2 Total PCB Congener Summing Methods

Method EPA 1668A/C analyzes for 209 congeners, which are reported as more than 150 individual and co-eluted PCB congeners. These data are summed to calculate total PCBs. Every sample has some non-detected PCB congeners, so the effect of non-detect value treatment was evaluated for the dataset.

Four non-detect treatments for summing PCB congeners were evaluated. Three consisted of substitution of the non-detected reported value as follows: 1) assuming non-detect values equal 0; 2) assuming non-detect values equal half the reported value; and 3) assuming the non-detect values equal the reported value. The reported value for non-detects is typically equal to the sample specific detection limit for these studies, although a different value can be selected based on the data validation. In each of these three cases, on a sample basis, total PCBs are based on sum of the detected congeners and the non-detect treatment described. The fourth non-detect treatment was based on Kaplan-Meier estimation for the non-detected values for each congener within each sample with Efron's bias correction, based on the method described in the memorandum regarding *Modified Approach for Calculating Total Concentrations of PCBs and PAHs, Bradford Island Remedial Investigation*, *Cascade Locks, Oregon* (URS 2010). The Kaplan-Meier mean was computed for each sample based on the concentrations of detected values and the Kaplan-Meier estimation for non-detects. The sample mean was then multiplied by the number of congener analytical results to calculate the total concentration for each sample.

Different treatments of the non-detects had almost no effect on total PCB congener concentrations (Table 4-3), likely due to the high number of detected congeners in each sample. To remain consistent with the EW SRI and FS, assuming non-detect values equal 0 was selected as the non-detect treatment for the dataset.

4.3 Dioxins/Furans

4.3.1 Congener Selection

Dioxin/furan results consist of 17 congeners. Of these, four were determined to be the primary contributors of the risk associated with seafood consumption (the RAO for which background concentration was used as a PRG in the FS). Specifically, these four congeners make up 86 percent of adult/child tribal seafood consumption dioxin/furan risk and 82 percent of adult Asian Pacific Islander seafood consumption dioxin/furan risk.[15] Therefore, these four congeners were selected for the development of AB values for use in establishing cleanup levels associated with seafood consumption pathway. The four selected congeners are as follows:

[15] These percentages were developed without including the portion of risk from clam/geoduck because of the very low frequency of detection of dioxin/furan congeners in these tissues.

- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 1,2,3,7,8-PeCDD
- 2,3,4,7,8-PeCDF

Dioxin/furan congener concentrations are converted to dioxin/furan TEQ to estimate risk to human health.[16] Dioxin/furan TEQ concentrations are presented in this document as a summary metric to provide continuity with SRI/FS documents and to support risk communication. The dioxin/furan TEQ is also used in evaluations in Section 5 as representing the four dioxin/furan congeners (i.e., the data analysis trends for individual congeners are generally the same as for dioxin/furan TEQ).

4.3.2 Non-Detect Treatment

Dioxin/furan congeners were detected in most of the suspended solids samples. However, because there were a few non-detected congeners for some samples, the effect of the non-detect treatment on congener summary statistics was explored for the AB estimate.

Four non-detect treatments for summing dioxin/furan congeners were evaluated. Three consisted of substitution of the non-detected reported value as follows: 1) assuming non-detect values equal 0; 2) assuming non-detect values equal half the reported value; and 3) assuming the non-detect values equal the reported value. The fourth non-detect treatment was based on a regression on order (ROS) estimation of non-detects for the population.

Out of 54 samples, at least one of the four dioxin/furan congeners were detected in 42 to 46 of the samples. Setting non-detect values to half the reported value resulted in a mean that was similar to the mean calculated using an ROS estimation for all congeners (Table 4-4). Setting non-detect values at 0 times the reported value or at the reported value bracketed these other two methods.

Based on this analysis, both half the reported value and the ROS estimation method of non-detects are reasonable methods for non-detected values for summary statistics because they provide similar results and are in the middle of the lowest and highest possible values. From this analysis, 0 times the reported values would bias the results slightly low, and 1 times the reporting limit would bias the results slightly high.[17] The ROS estimation method for non-detects was carried forward for use in summary statistics for four dioxin/furan congeners in this document.

[16] The TEQ method weighs each congener in a manner proportional to its relative toxicity to 2,3,7,8-TCDD, based on the TEQ for each congener (Van den Berg et al. 2006), as described in the EW Baseline Human Health Risk Assessment (SRI Appendix B).

[17] This is a different result than summing PCB congeners (Section 4.2.2), for which 0 times the detection limit was selected as the appropriate method for summing. The difference is due to the data characteristics and the purpose of the non-detect estimate. Non-detect treatment for PCBs was used for summing many (>150) congeners for each sample with very low detection limits, and the non-detect treatment had almost no impact on sample sums. In contrast, the non-detect treatment for dioxins/furans was used for calculating summary statistics for the population of samples for each congener and had a slight effect on results.

4.4 Arsenic

Arsenic was analyzed in 52 samples by analytical methods EPA 6020 or 200.8. Arsenic was detected in all samples, so evaluation of non-detects was not needed for AB evaluation. However, the AB evaluation dataset indicates a higher arsenic concentration in suspended solids (mean of 17.2 mg/kg for centrifuge/filter solids) than the concentration of bedded sediment in the EW (mean of 11 mg/kg for the FS baseline dataset). Arsenic in Green River suspended solids likely comes from natural and anthropogenic sources such as historical pesticide use.

The arsenic AB value was calculated based on Green River suspended solids (centrifuge/filter solids) because suspended solids are an accurate representation of material entering and settling in the EW. The influence biogeochemical processes may have on arsenic concentrations in EW sediments are discussed in Section 5.8.

4.5 Outlier Evaluation

This section discusses whether any of the analytical data should be qualified as outliers and removed from the dataset. EPA guidance defines outliers as measurements that are unusually larger or smaller than the remaining data. They are not representative of the sample population from which they are drawn (EPA 2002b).

As shown in Figure 4-1, some of the higher centrifuge/filter solids concentrations are well above the median and inner quartiles of the datasets. These data were examined as potential outliers in the following two ways: 1) consideration of whether the data were consistent with the Green River CSM; and 2) consideration of whether the data were consistent with statistical distributions that might underlie the dataset.

4.5.1 Conceptual Site Model Outlier Evaluation

The highest concentrations in the dataset were considered for reasonableness based on flow and precipitation conditions during their collection and the Green River CSM for how these conditions affect contaminant concentrations. As discussed in Section 2.1 and Appendix A, Part 1, of this document, the following three main sources of suspended solids affect concentrations: 1) releases from the Howard Hanson Dam; 2) stormwater runoff; and 3) and erosion from the streambed of the Green River. These three sources vary in concentration of the three contaminants and vary in their relative influence on the suspended solids concentration at any given time, largely based on precipitation and river flow conditions. All three contaminants have lower concentrations associated with substantial dam releases,[18] which results in high flow conditions. The organic contaminants, PCBs, and dioxins/furans have higher concentrations related to stormwater runoff due to diffuse

[18] As adopted by USGS (Conn et al. 2018a) and King County (2016) studies, substantial dam release (termed "significant" dam releases in the reports) is considered 2,000 cfs or greater at the base of the Howard Hanson Dam.

urban sources. In contrast, arsenic concentrations tend to be higher during baseflow[19] conditions without precipitation and runoff. This is likely attributable to less dilution of naturally occurring arsenic associated with Green River bed material, as discussed in Section 4.4.

Table 4-5 presents the five centrifuge/filter solids samples with the highest concentration for each contaminant, the month and season of sampling, the river flow, and the precipitation conditions for each. Consistent with the Green River CSM, the five highest PCBs and dioxins/furans concentrations occurred during high precipitation/runoff and low-flow events. Precipitation for these events was in the upper 77th percentile or higher, and flow was in the 69th percentile and lower.

Also consistent with the CSM, the highest arsenic concentrations occurred during low flow conditions (38th percentile or less). Four of five higher concentrations occurred during no-precipitation events; one sample broke from the pattern and was in the 86th percentile for rainfall. All higher-concentration events were in the later summer and early fall.

Based on this evaluation, the samples with the highest concentrations were consistent with the Green River CSM and are not considered outliers in this context. The highest PCBs and dioxin/furan concentrations occur during low river flow and high precipitation conditions (due to a larger impact of stormwater inputs during these times). The highest arsenic concentrations occur during low river flow and low precipitation conditions (due to a larger impact of natural Green River sources described in Section 4.4 during these times). This analysis does not indicate the presence of any outliers.

4.5.2 Statistical Distribution Outlier Evaluation

The AB dataset was also compared to applicable statistical distributions to assess if high or low concentration samples represent a break with the apparent underlying distribution of the data. Statistical distributions were evaluated graphically using quantile-quantile (Q-Q) plots (Figure 4-2) and mathematically with distribution selection testing.[20] Consistent with the visual evaluation, all three contaminants were identified as log-normally distributed.

If present, high outliers would be located to the upper left of the diagonal line, and low outliers would be located to the lower right of the diagonal line of the Q-Q plots. As shown in Figure 4-2, all values roughly follow the diagonal, indicating the distributions are consistent with the log-normal distribution. This analysis does not indicate the presence of any outliers.

4.6 Particle Size Distribution in Suspended Sediment

A well-established theoretical and empirical relationship exists that shows organic contaminants more strongly associated with finer-grained particulate matter than with coarser-grained sediments

[19] Baseflow is when there are lower river flows without precipitation events.
[20] The Shapiro-Wilk test was implemented in the distChoose function by the EnvStats package for the R software environment.

(Hedges and Kiel 1995; Karickhoff et al. 1979; Wang and Keller 2008). Organic carbon sorbs on the surface of particles and therefore accumulates in proportion to the surface area of particles. Particulate organic matter also occurs in a range of particle sizes. Organic contaminants bind to particulate organic matter as well as the organic carbon sorbed on particle surfaces. Because smaller particles have a larger surface area-to-mass ratio than larger particles, the finer particles also accumulate higher concentrations of organic contaminants. This relationship does not apply to metals.

Empirically, this trend was observed in the suspended solids dataset, with samples with higher fines having higher organic contaminant concentrations on average. This trend was also observed in the USGS bedded sediment samples, which were analyzed for contaminant concentrations in bulk sediment as a whole, as well as in the sieved fines fraction (Conn et al. 2014, 2015).

Centrifuge/filter solids suspended solids samples ranged from 44 percent to 95 percent fines; however, solids entering the EW are predicted to be 99 percent fines in the LDW sediment transport model (QEA 2008). During transport from the Green River through the LDW, the coarser-grained suspended solids settle out first, as seen with sands largely settling in the LDW upper turning basin and finer material progressively settling out as water moves north toward Elliott Bay. The sediments transported through the LDW reaching the EW are essentially the fine-grained sediments (Figure 2-3; QEA 2008). The progressive settlement of more coarse sediments at the south end of the LDW and movement of essentially fine-grained suspended solids into the EW results in a gradual increase, per unit mass, of organic contaminants present in suspension compared to what is present in suspension at RM 10.4, where the AB dataset was sampled. This results in a low bias of the concentrations measurement of suspended solids at RM 10.4 compared to what enters the EW. The following three potential methods to adjust the AB dataset to address this were explored in this analysis:

1. Excluding samples with low fines
2. Fines normalization
3. Particle surface area adjustments

Each of these methods is discussed in the following sections.

4.6.1 Excluding Samples with Low Fines

The first and simplest method for adjusting for the progressive fining (the process whereby coarser material settles out and finer material remains in suspension) of suspended sediment during transport from the Green River to the EW was to exclude suspended solids samples with low-percent fines from the AB calculation. The distribution of samples with percent fines was analyzed to identify potential threshold values for screening the dataset. A threshold value of 60 percent fines was selected to balance the competing needs of excluding samples with the lowest fines content and maintaining a large sample size in the remaining dataset. The 60 percent fines threshold value results in removal of the lower quartile from the dataset (approximately 25 percent of samples were screened out).

Excluding samples with low fines content from the dataset is a simple way to account for the low bias in the dataset. However, the method reduces the total number of samples in the dataset, and the remaining dataset on average still contains a lower percent fines (77 percent on average) than the approximately 99 percent fines entering the EW.

4.6.2 Fines Normalization

Fines normalization retains all samples in the analysis and adjusts each sample concentration in proportion to the percentage of fine-grained material in the sample. Mathematically, fines normalization consists of dividing the concentration by the fraction of fines in each sample as follows:

$$Concentration_{fines-normalized} = \frac{Concentration_{dry-weight}}{Percent\ fines/100}$$

Physically, this equation assumes that all contaminant mass is in the fine-grained fraction of suspended solids, which is the fraction that enters and deposits in the EW.

Fines normalization has the advantage of retaining all the data and adjusting each datapoint according to the characteristics of each sample. The fines normalization approach has a few limitations based on assumptions imposed by the calculation method. The equation may over-adjust for particle size distribution by not attributing any contamination to the sand fraction, which contains a smaller portion of the total contamination of the sample. However, the equation may also under-adjust for particle size distribution because the equation does not account for contaminant concentration differences within the fines category (i.e., the difference between clays and silts). For instance, an increase in the clay fraction entering the EW compared to that measured in the Green River suspended solids will have a larger effect on concentration than an increase in silts.

4.6.3 Particle Surface Area Adjustments

A third method was developed to adjust concentrations based on trends in contaminant concentrations associated with various particle size fractions. This adjustment accounts for the relative particle size distribution between the Green River and the EW, and considers the fact that the area available for organic contaminant binding to a particle is proportional to the surface area of that particle (Hedges and Kiel 1995; Karickhoff et al. 1979; Wang and Keller 2008). As particle size increases, the relative mass (which is directly proportional to the volume of the particle) increases more relative to the increase in surface area. The particle surface area adjustment calculation is provided in Appendix A, Part 2, of this document.

The surface area method is consistent with the physical model for the transport of suspended solids in the Green River, the LDW, and the EW. The method accounts for concentrations in the sand fraction and for changes in concentration between four particle size categories. The drawback of the surface

area method is that it relies on modeling and empirical relationships that are not directly measured in the Green River suspended solids dataset, and would be challenging to measure empirically.

4.6.4 Summary of Particle Size Distribution Adjustments for Organic Contaminants

Three particle size distribution adjustment methods were developed to account for the concentration enrichment expected to occur when coarser material settles out and finer material remains in suspension during transport from the Green River through the LDW to the EW. Excluding data with low (<60 percent) fines reduced the size of the dataset and did not fully account for the change in particle size during transport to the EW. The surface area adjustment method accounts for particulate contaminant concentrations in different grain -size fractions and captures the change in particle size but relies primarily on empirical relationships and modeling. Therefore, it includes additional assumptions that increase the analysis uncertainty. Fines normalization is subject to less uncertainty, as it relies on fewer assumptions while also acknowledging the difference between Green River suspended solids grain sizes compared to the grain sizes that enter the EW. Excluding data with low -percent fines and the surface area adjustment method are included in the sensitivity analysis presented in Section 5.

4.7 River Flow and Precipitation Weighting

As discussed in Sections 2.1 and 4.5.1, the concentrations of contaminants in suspended solids vary with river conditions. River gauge flow measurements from below the Howard Hanson Dam and precipitation gauge measurements near suspended solids sampling locations prior to and during sampling provide a method to assign suspended solids data by the conditions that affect chemical concentrations. Because samples were collected during different flow and precipitation conditions, they may be more or less representative of the overall average conditions in the Green River. Therefore, a flow and precipitation weighting calculation was developed to group and weight samples based on the prevalence of different flow and precipitation conditions in the Green River (Appendix A, Part 1, of this document).

A weighted average concentration was calculated based on the contaminant average concentrations and the amount of time that the Green River is in each of four river flow/precipitation conditions. These four conditions were binned into the following: low flow/low precipitation; high flow/low precipitation; low flow/high precipitation; and high flow/high precipitation (see Appendix A, Part 1). Each sample was placed into one of the four bins based on the conditions during sampling. The average concentration of samples for each of the four conditions was multiplied by the fraction of time each condition occurred over the time period from 2001 to 2019 (the selected time period with available river flow and precipitation data from the gauges) to get a weighted average concentration.

The analysis was not used to establish AB concentrations because of uncertainties and assumptions that are part of the calculation process and flow/precipitation binning methodology. In addition, the methodology effectively reduces the sample size to what is present in each individual bin. However, the river flow and precipitation weighting method was retained as a sensitivity run in Section 5 in order to evaluate the effects of adjusting the suspended solids concentrations following the Green River CSM.

4.8 Selected Data Treatment for the AB Dataset and Calculation

Sections 4.1 through 4.7 detail a number of assessments that help understand the effects of different data treatments on the AB dataset. From these assessments, the following data treatments were selected for AB estimation:

- Use centrifuge and filter solid samples only (exclude sediment traps)
- Use PCB congener data only (exclude all Aroclor data)
- Use only detected PCB congeners in summing (non-detected congeners equal to 0)
- Calculate AB for the four dioxin/furan congeners that are primary contributors to human health seafood consumption risk (while also presenting the dioxin/furan TEQ for informational purposes) and use ROS for non-detects summary statistics for non-detected results
- Perform fines normalization for organic contaminants to account for particle size differences between Green River samples and suspended solids flowing into the EW
- All centrifuged and filtered solids sample data used without any adjustment for arsenic

Section 5 presents the sensitivity analysis associated with these analyses, and Section 6 presents the statistics for the AB dataset.

5 Uncertainty

Multiple assessments of the Green River suspended solids dataset were explored in the development of the AB dataset and calculation methods. This section compares the results of those assessments and their effect on AB estimates in a sensitivity analysis and discusses additional uncertainties related to the AB evaluation. Sections 5.1 through 5.5 discuss uncertainty factors that were quantitatively evaluated in the sensitivity analysis, and Sections 5.6 through 5.8 discuss uncertainty factors that were evaluated qualitatively.

5.1 Sensitivity Analysis Results Summary

The sensitivity analysis identifies the magnitude of changes to the AB estimate when changing a single component of data selection or data treatment, while keeping all other variables constant.

Figure 5-1 provides a graphical depiction of the sensitivity analysis. The mean concentrations resulting from each sensitivity component are compared to the mean concentration of the unadjusted AB dataset.[21] Negative percentages on the figure indicate a reduction in the mean concentration, and positive percentages indicate an increase in mean concentration. Zero denotes no change from the mean concentration.

The results range from a reduction in concentration of up to approximately 20 percent (using river flow/precipitation conditions weighting for total PCBs) to an increase of approximately 66 percent (using the surface area method of particle size adjustment for both total PCBs and dioxins/furans). Table 5-1 provides the numerical results. The sensitivity analysis results are discussed further in the context of uncertainty discussions in the following sections.

5.2 Exclusion of Sediment Trap and Total PCB Aroclor Samples

This section documents the impact of excluding sediment trap or PCB Aroclor samples as described in Sections 4.1 and 4.2.1. Including sediment trap data would decrease average concentration of the dataset by 8 percent (total PCBs), 5 percent (dioxins/furans), and 6 percent (arsenic). Concentrations in sediment trap data are low compared to the centrifuge and filter solids samples, because sediment traps contain a higher percentage of coarse-grained solids that are associated with lower chemical concentrations (Section 4.1; Figure 4-1 and Table 4-1). The sensitivity calculations also show that including the samples with Aroclor-only data results in a 2 percent decrease in average concentration in the dataset. This small change is due to the small number of samples (n = 7), and the similar mean concentration in the Aroclor-only dataset compared to the mean of the congeners-only dataset (Table 4-2).

[21] The sensitivity analysis varies one component at a time compared to the AB dataset without grain size adjustment, consistent with the sensitivity analysis methodology.

5.3 Non-Detect Treatments

Non-detect treatments for total PCB summing and dioxin/furan summary statistics were evaluated in Sections 4.2.2 and 4.3.2. AB concentrations are not sensitive to non-detect treatment. The effect of non-detect treatment can be further minimized by applying identical treatments to EW site samples during comparisons to AB.

5.4 Dioxin/Furan Congener Selection

AB estimates are established for four of 17 dioxin/furan congeners. These four congeners contribute the majority of the dioxin/furan seafood consumption risk (82 percent to 86 percent; Section 4.3.1). The other congeners each represented 7 percent to <1 percent of the risk (based on TEQ contribution to fish and crab tissues). This small contribution of each indicates AB for the four congeners will be representative of most of AB contribution to risk. Thus, only a small uncertainty exists for developing AB for four of 17 dioxin/furan congeners. In addition, all 17 dioxin/furan congeners will be monitored at the EW site to evaluate risk reductions achieved by the sediment cleanup.

5.5 Changes in Particle Size Distribution Between the Green River and the East Waterway for Organic Contaminants

The sensitivity analysis evaluates particle size distribution using three methods; all of which account for the difference in particle size of organic contaminants between suspended solids data in the Green River compared to the fine-grained sediment that enters the EW (Section 4.6).

Each of the three methods to adjust for the effects of particle size for organic chemicals increased concentrations as expected, but the magnitude of the impacts varied across methods (Figure 5-1 and Table 5-1). Excluding samples with less than 60 percent fines only resulted in small increases of the overall PCB and dioxin/furan concentrations (6 percent for total PCBs and 3 percent for dioxins/furans), because the remaining samples still contained a measurable quantity of coarse-grained material(Section 4.6.1). Fines normalizing, where all samples are included but normalized based on fines content, increased concentrations by 28 percent (total PCBs) and 27 percent (dioxins/furans). Finally, the surface area method of fines adjustment (which accounts for variations in particle size distribution within the fines category and for changes in particle size distribution during transport from the Green River to the EW [Section 4.6.3]) resulted in the largest increase (approximately 65 percent) in concentration.

5.6 Green River Flow and Precipitation Conditions

As discussed in Sections 2.1, 4.5.1, and 4.7, COC concentrations in Green River suspended solids vary over time with changing flow and precipitation conditions, which affects the solids introduced into the river, stormwater inputs, dam releases , and erosion of Green River bed material.

Weighting for river flow and precipitation resulted in different outcomes, depending on the contaminant (Figure 5-1 and Table 5-1); total PCB concentrations declined 20 percent, dioxins/furans showed a slight increase, and arsenic concentration increased 28 percent. These changes are due to the large proportion of time that the Green River is in the baseflow condition with low flow and low precipitation. As discussed in Section 4.5.1, arsenic concentrations tend to be higher during baseflow conditions without precipitation and runoff diluting naturally occurring arsenic associated with Green River bed material. PCB concentrations tend to be lower during baseflow when the influence of stormwater runoff is reduced. As discussed in Section 4.7, river flow/precipitation weighting was not used to establish AB concentrations because of uncertainties and assumptions that are part of the calculation process and flow/precipitation binning methodology. In addition, the methodology effectively reduces the sample size to that which remains in each of the four individual river condition bins, further increasing uncertainty in this estimating method.

5.7 Future Urban Inputs

Diffuse inputs from urbanized drainage basins (i.e., inputs related to general urban activity rather than a specific contaminant source) will be an ongoing contributor of chemicals to the EW; therefore, it is important to consider potential influence these sources may have on the sediment concentrations in the EW. The sensitivity analysis includes an evaluation of the effects of EW and LDW lateral inputs on the average concentration in the AB dataset, as described in Appendix A, Part 3, of this document. The chemical concentrations used in this analysis were derived using the current lateral dataset and applying best professional judgment to estimate the concentrations of chemicals in discharges following future source control actions. Including estimated future EW and LDW lateral inputs results in an increase in organics concentrations by 5 percent (total PCBs) and 4 percent (dioxins/furans) compared to the AB dataset without EW and LDW lateral inputs (Figure 5-1). There is no change in average arsenic concentrations.

As discussed in Sections 2.2 and 3.2, the average mass and contaminant levels from lateral inputs to the EW and LDW are likely to change due to the influence of ongoing and future source control measures implemented as part of discharge permits, municipal stormwater permits, upland contaminated site cleanups, and CERCLA activities.

5.8 Arsenic Post-Depositional Processes

Arsenic sediment contaminant concentrations can change following deposition due to biological, chemical, and physical processes, which contribute uncertainty to expectations for future sediment concentrations regardless of incoming AB concentrations. This AB evaluation only assessed sediment concentrations entering the EW and did not assess changes to bedded sediment concentrations of PCBs, dioxins/furans, or arsenic following deposition. The Green River suspended solids arsenic concentrations are higher than observed bedded sediment concentrations within EW and post-remediation cleanup

sites proximate to the EW. This difference likely stems from biogeochemical processes that modulate the concentration of arsenic in bedded sediment. Table 5-2 compares the arsenic concentrations in the AB dataset (Green River suspended sediment centrifuge/filter solids samples) with arsenic concentrations in bedded sediment in the EW, and in two completed sediment cleanup sites in West Waterway and LDW (post-remediation conditions evaluated during long-term monitoring).

Concentrations associated with bedded sediment can be influenced by biogeochemical conditions that affect the partitioning behavior and mobility of arsenic, both in the water column and in sediment (Fendorf et al. 2010; Campbell and Nordstrom 2014). Arsenic partitioning from particles to water is enhanced by increasing pH and salinity in the water column. Arsenic can also be mobilized from deposited sediment particles under reducing conditions. These complex biogeochemical processes can result in the release of arsenic into the dissolved phase both from suspended particles in the water column and from deposited sediment. PCBs and dioxins/furans are comparatively inert to these mechanisms. The effects of post-depositional biogeochemical processes are difficult to predict and therefore were not incorporated into the AB estimate for arsenic.

5.9 Future Inputs to the Green River Watershed

The AB evaluation is based on recent data and is considered representative of current conditions in the Green River Watershed. Inputs to the Green River Watershed could change over time. For example, stormwater regulations and improvements could lead to a reduction in the amount of stormwater or improvements in contaminant levels into the Green River Watershed over time. Alternatively, new development within the watershed could result in land use changes that increase stormwater contributions in the watershed.

5.10 Lower Duwamish Waterway Bedded Sediment

As discussed in Section 2.3, a small portion of bedded sediment within the LDW Superfund site resuspends and moves downstream into the EW. This is not considered part of AB and is not accounted for in the AB dataset or sensitivity analyses.

The impact of omitting the contribution of resuspended LDW bedded sediment to AB is small for a couple of reasons. First, current modeling indicates that sediment load to the EW from LDW bed is minimal (0.24 percent of the total load; Figure 2-2). Second, in the long term, LDW bedded sediment concentrations following completion of the CERCLA cleanup are expected to equilibrate with incoming concentrations from the Green River and urban inputs from LDW lateral inputs. Following remediation of LDW, monitoring data will be available to better understand LDW site-wide concentrations.

5.11 Conclusions

The Green River suspended solids dataset was assessed to understand potential uncertainties in the data and to select a final AB dataset. Although uncertainties are inherent to the AB estimating process, the overall conclusion is that data are suitable for representing AB for the EW.

Most of the evaluated uncertainties had a minor impact on average AB concentrations. However, adjusting organics data based on percent fines was considered a meaningful adjustment to accurately reflect the sediment transport CSM between the Green River and the EW (Section 4.6.2). Therefore, fines normalization was selected as the method for particle size adjustment for the final estimate of AB for PCBs and dioxins/furans. Arsenic AB is estimated without particle size adjustment and may be higher than what ultimately becomes the EW bedded sediment concentration over time due to influence of biogeochemical processes.

6 Summary and Conclusions

A collaborative process between EPA, EWG, and key stakeholders was used to evaluate available data to develop an AB estimate for the EW. A logical step-wise approach was followed to understand sediment transport into the EW, screen potentially applicable datasets, evaluate the remaining data, and select a data treatment approach. This section presents the final AB values from the selected AB dataset.

As described in Section 4.8, the following data refinements were made:

- Use centrifuge and filter solid samples only (exclude sediment traps)
- Use PCB congener data only (exclude all Aroclor data)
- Use only detected PCB congeners in summing
- Calculate AB for the four dioxin/furan congeners that are primary contributors to human health seafood consumption risk (while also presenting the dioxin/furan TEQ for informational purposes) and use ROS to account for non-detected results when calculating summary statistics
- Perform fines normalization for organic contaminants to account for particle size differences between Green River samples and suspended solids flowing into the EW
- All centrifuged and filtered solids sample data used without any adjustment for arsenic

Based on the above data refinements, various summary statistics for the AB dataset are presented in Table 6-1.[22] The UCL95 on the mean will be used in future EW decision documents in place of the natural background-based PRG values presented in the EW FS. Mean, median, and two upper tolerance limits (90/90 UTL and 95/95 UTL) are also presented in the table for informational purposes.

The AB values presented in the following bullets are based on the 95 percent upper confidence level on the mean (UCL95) and rounded to two digits:

- Total PCBs 31 µg/kg dw
- Arsenic 20 mg/kg dw
- 1,2,3,7,8-PeCDD 2.1 ng/kg dw
- 2,3,4,7,8-PeCDF 1.1 ng/kg dw
- 2,3,7,8-TCDD 0.71 ng/kg dw
- 2,3,7,8-TCDF 1.2 ng/kg dw

[22] Dioxin/furan TEQ values are presented in Table 6-1 for informational purposes.

7 References

AECOM, 2012. *Feasibility Study, Lower Duwamish Waterway, Seattle, Washington*. Final Report. Prepared for Lower Duwamish Waterway Group. October 2012.

Anchor QEA (Anchor QEA, LLC), [in preparation]. *Factors Affecting East Waterway Site Performance Following Remediation*.

Anchor QEA and Windward (Anchor QEA, LLC, and Windward Environmental, LLC), 2019. *East Waterway Operable Unit Supplemental Remedial Investigation/Feasibility Study – Final Feasibility Study*. Prepared for Port of Seattle. June 2019.

Campbell, K.M., and D.K. Nordstrom, 2014. "Arsenic Speciation and Sorption in Natural Environments." *Reviews in Mineralogy and Geochemistry* 79:185–216.

Conn, K.E., and R.W. Black, 2014. *Data Compilation for Assessing Sediment and Toxic Chemical Loads from the Green River to the Lower Duwamish Waterway, Washington*. U.S. Geological Survey Data Series 880. 46 p. Available at: http://dx.doi.org/10.3133/ds880.

Conn, K.E., R.W. Black, A.M. Vanderpool-Kimura, J.R. Foreman, N.T. Peterson, C.A. Senter, and S.K. Sissel, 2015. *Chemical Concentrations and Instantaneous Loads, Green River to the Lower Duwamish Waterway near Seattle, Washington, 2013–15*. U.S. Geological Survey Data Series 973. 46 p. Available at: http://dx.doi.org/10.3133/ds973.

Conn, K.E., R.W. Black, C.A. Senter, N.T. Peterson, and A. Vanderpool-Kimura, 2018a. *Hydrology-Driven Chemical Loads Transported by the Green River to the Lower Duwamish Waterway near Seattle, Washington, 2013–17*. U.S. Geological Survey Scientific Investigations Report 2018-5133. 37 p. Available at: https://doi.org/10.3133/sir20185133.

Conn, K.E., R.W. Black, N.T. Peterson, C.A. Senter, and E.A. Chapman, 2018b. *Chemical Concentrations in Water and Suspended Sediment, Green River to Lower Duwamish Waterway near Seattle, Washington, 2016–17*. U.S. Geological Survey Data Series 1073. 17 pp. 2018.

Ecology (Washington State Department of Ecology), 2009. *Contaminant Loading to the Lower Duwamish Waterway from Suspended Sediment in the Green River*. Publication No. 09-03-028. November 2009.

Ecology and Environment (Ecology and Environment, Inc.), 2009. Memorandum to: Washington State Department of Ecology. Regarding: Final Report, Duwamish River Sediment Sampling and Analysis. June 30, 2009.

EPA (U.S. Environmental Protection Agency), 1989. *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A), Interim Final*. Office of Emergency and Remedial Response. EPA/540/1-89/002.

EPA, 2002a. *Role of Background in the CERCLA Cleanup Program.* Office of Solid Waste and Emergency Response Office of Emergency and Remedial Response, OSWER 9285.6-07P. April 26, 2002.

EPA, 2002b. *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites*. Office of Emergency and Remedial Response. OSWER 9285.7-41, EPA 40-R-01-003. 2002.

EPA, 2018. *Frequently Asked Questions About the Development and Use of Background Concentrations at Superfund Sites: Part One, General Concepts*. OLEM Directive 9200.2-141 A. March 2018.

Fendorf, S., P.S. Nico, B.D. Kocar, Y. Masue, and K.J. Tufano, 2010. "Chapter 12: Arsenic Chemistry in Soils and Sediments." *Developments in Soil Science.* Editors, B. Singh and M. Gräfe. DOI: 10.1016/S0166-2481(10)34012-8.

Hedges, J.I., and R.G. Keil, 1995. "Sedimentary Organic Matter Preservation: An Assessment and Speculative Synthesis." *Marine Chemistry* 49:81–115.

Karickhoff, S.W., D.S. Brown, and T.A. Scott, 1979. "Sorption of Hydrophobic Pollutants on Natural Sediments." *Water Research* 13:241–248.

King County, 2016. *Lower Duwamish Waterway Source Control: Green River Watershed Suspended Solids Data Report*. Prepared by Carly Greyell and Debra Williston, Water and Land Resources Division. Seattle, Washington. December 2016.

King County, 2018a. *Lower Duwamish Waterway Source Control: Green River Watershed Surface Water Data Report*. March 2014; revised February 2018.

King County, 2018b. *Green River PCB Equipment Blank Study Data Report*. Prepared by Carly Greyell and Debra Williston, King County Water and Land Resources Division, Science and Technical Support Section. Seattle, Washington. 2018.

QEA (Quantitative Environmental Analysis), 2008. *Lower Duwamish Waterway Sediment Transport Modeling (STM) Report, Final*. Prepared for U.S. Environmental Protection Agency, Region 10, and the Washington State Department of Ecology. October 2008.

URS (URS Corporation), 2010. Memorandum to: Mike Gross, PE, U.S. Army Corps of Engineers, Portland District. From: Mike Powell, Laura McWilliams, and Chi-Wah Wong. Regarding:

Modified Approach for Calculating Total Concentrations of PCBs and PAHs Bradford Island Remedial Investigation Cascade Locks, Oregon. September 30, 2010.

Van den Berg, M., L.S. Birnbaum, M. Denison, M. De Vito, W. Farland, M. Feeley, H. Fiedler, H. Hakansson, A. Hanberg, L. Haws, M. Rose, S. Safe, V. Schrenk, C. Tohyama, A. Tritscher, J. Tuomisto, M. Tysklind, N. Walker, and R.E. Peterson, 2006. "The 2005 World Health Organization Reevaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-Like Compounds." *Toxicology Science* 93(2): 223–241.

Wang, P., and A.A. Keller, 2008. "Particle-Size Dependent Sorption and Desorption of Pesticides within a Water-Soil-Nonionic Surfactant System." *Environmental Science & Technology* 42:3381–3387.

Windward, 2018. Technical memorandum to: Lower Duwamish Waterway Group. Regarding: Compilation of Existing Data. November 18, 2018.

Windward, 2020. *Lower Duwamish Waterway Pre-Design Studies Data Evaluation Report*. Prepared for Lower Duwamish Waterway Group. June 26, 2020.

Windward and Anchor QEA (Windward Environmental, LLC, and Anchor QEA, LLC), 2014. *Supplemental Remedial Investigation*. East Waterway Operable Unit Supplemental Remedial Investigation/Feasibility Study. Final. January 2014.

Tables

Table 3-1
Sample Counts by Studies for Green River Datasets

Medium	Dataset	Sample Year(s)	Sample Counts		
			PCBs	Dioxins/Furans	Arsenic
Suspended Solids	USGS Centrifuged Solids[a]	2013–2017	37	38	35
	King County Filtered Solids[b]	2013–2015	12	10	10
	Ecology Centrifuged Solids[c]	2008–2009	7	6	7
	King County Sediment Traps[b]	2013–2015	9	5	7
Surface Water	LDWG Surface Water[d]	2017–2018	8	3	n/a
	King County Surface Water[e]	2000–2017	45	n/a	121
	USGS Surface Water[a]	2013–2017	37	37	32
Bedded Sediment	USGS Bedded Sediment[a]	2013–2015	7	7	7
	Ecology Upstream Bedded Sediment[c]	2008	30	31	31
	USACE Turning Basin Cores[d]	2008–2017	17	12	18
	LDW RI Bedded Sediment[f]	1994-2006	37	4	24

Notes:

a. Suspended solid, surface water, and bedded sediment data source: Conn et al. (2015, 2016, 2018a, 2018b); Conn and Black (2014); and Senter et al. (2018)

b. Filter solids and sediment trap data source: King County (2016)

c. Centrifuged solids and bedded sediments data source: Gries and Sloan (2009)

d. Surface water, sediment cores, and bedded sediment data source: Windward (2020)

e. Surface water data source: King County (2018a, 2018b); AECOM (2012)

f. Bedded sediment data source: AECOM (2012)

Ecology: Washington State Department of Ecology

LDWG: Lower Duwamish Waterway Group

n/a: not applicable

PCB: polychlorinated biphenyl

USACE: U.S. Army Corps of Engineers

USGS: U.S. Geological Survey

Table 3-2
Green River Datasets Screening Summary

Media Type	Screening Criteria			
	Acceptability		Representativeness	
	Determination	Lines of Evidence	Determination	Lines of Evidence
Suspended Solids	Acceptable	• Performed using well-documented or well-established field sampling methods • Performed using acceptable laboratory analyses and QA/QC procedures • See Table 3-3 for additional information	Representative	• Geographical Representativeness: Samples collected upstream of the LDW • Temporal Representativeness: Recent data representative of current conditions and represent all flow regimes in the Green River • Physical Representativeness: Primarily fine grained, most similar to that in the EW • Land Use Representativeness: Land use is less urban than the EW, but representative of the Green River • See Table 3-3 for additional information
Surface Water	Acceptable	• Performed using well-documented or well-established field sampling methods • Performed using acceptable laboratory analyses and QA/QC procedures • Uncertainty is associated with assumptions around dissolved contaminant fractions	Not Representative	• Geographical Representativeness: Samples collected upstream of the LDW • Temporal Representativeness: Recent data representative of current conditions and represent all flow regimes in the Green River • Physical Representativeness: Whole water captures freely dissolved, particulates, and colloids; requires normalizing whole water samples by TSS to estimate particulate concentrations, causing uncertainty. For example, whole water data dioxins/furans appeared to be biased high compared to suspended solids. Because surface water is less representative than the suspended solids dataset and the suspended solids dataset is acceptable, representative, and adequate, surface water is considered not representative for this analysis. • Land Use Representativeness: Land use is less urban than the EW, but representative of the Green River
Bedded Sediment	Acceptable	• Performed using well-documented or well-established field sampling methods • Performed using acceptable laboratory analyses and QA/QC procedures	Not Representative	• Physical Representativeness: the Green River is more energetic than the EW; therefore, bedded surface sediment had coarser grain sizes compared to that which enters settles in the EW

Table 3-2
Green River Datasets Screening Summary

Notes:
EW: East Waterway
LDW: Lower Duwamish Waterway
QA/QC: quality assurance/quality control
TSS: total suspended solids

Table 3-3
Green River Suspended Solids and Whole Water Datasets Sufficiency Evaluation

Study	Acceptability						Representativeness			
	Documentation (Report; Data Availability)	Field		Analytical			Geographical	Temporal	Physical (Grain Size)	Land Use
		Methods	QA/QC, Sampling Comparability	Laboratory/Methods	Detection Limits	QA/QC Samples, Data Validation				
Suspended Solids										
USGS Green River Loading Study	Conn et al. 2015, 2016, 2018a, 2018b; Conn and Black 2014; Senter et al. 2018; EIM Study IDs: GRNRVLD13, GRNRVLD14, GRNRVLD16	Pump water from 3 feet above bed and 30 feet from shore into Teflon-lined drum before laboratory centrifugation of 1,000 to 2,000 liters (Phase 1) or continuous flow field centrifugation (Phases 2 and 3) (Conn et al. 2016)	Field replicates, equipment blanks, and trip blanks included.	Washington State-accredited laboratories and EPA-approved methods *PCB:* Congeners, AXYS; EPA 1668A/C DF: Congeners, AXYS; EPA 1613B *As:* ARI/MEL EPA 200.8/6020 *Grain Size:* Guy 1969 *TOC:* PLUMB81TC, PSEP-TOC	*PCB and DF:* Congener data include some non-detected and estimated values (J flag) consistent with low concentrations analyzed by the analysis method. Aroclor split samples have been screened out because they had high percentages of non-detects and the same samples were also analyzed for congeners. *As:* All detected.	Standard USGS QA procedures (i.e., employee review of chemistry QA/QC). QA/QC samples included trip blank, lab blank, and matrix spike, as applicable.	RM 10.4: Upstream of EW/LDW and salt wedge.	*Age:* 2014 to 2017. *Sampling Time Frame:* Centrifuge solids represent a ~24- to 48-hour snapshot. *Flow Conditions:* The samples characterize Green River flow categories over several seasons: significant dam release, storm event with and without significant dam release, and baseline.	Suspended solids are primarily fine-grained. *Suspended sediment fines:* 40% to 95%; mean 73.5%.	Green River solids at RM 10.4 reflect upstream and local land use (natural resource/agriculture 68%; commercial/industrial 13%; and residential 19%). The commercial/industrial development is newer, relative to these land use inputs from more urban land within the LDW and EW basins (downstream of RM 5).
King County Green River Watershed Suspended Solids Data Report	King County 2016; King County data request	Filter solids and sediment traps (baffle- and jar-style traps) • Baffle intake 11 inches from the bed • Jar intake 9 inches from the bed • Filter solids intake ~2 feet from bed; water pumped through 5-µm polypropylene felt filter	Comparison of three sampling methods built into the study. Equipment blank was included for both baffle and filtered solids; no field replicates, due to limited field equipment and sample volume.	Washington State-accredited laboratories and EPA-approved methods *PCB:* Congeners, AXYS and PRL; EPA 1668C *DF*: Congeners, AXYS and PRL; EPA 1613B *As*: KCEL EPA Method 3050B/6020A *PSD:* ASTM Method D422 or ASTM D422/ D3977-97 and laser diffraction by ISO 13320:2009E *TOC:* EPA 9060	*PCB and DF*: congener data include some non-detected and estimated values (J flag) consistent with low concentrations analyzed by the analysis method. Aroclor split samples have been screened out because had high percentage of non-detects and same Green River samples also analyzed for congeners. *As*: all detected	QA/QC samples included for each sample batch (e.g., laboratory blank, laboratory duplicate, matrix spike, as applicable). PCB and DF Congeners validated by LDC; As and conventional data validated by King County WLRD Science Section.	RM 10.4: Upstream of EW/LDW and salt wedge. Additional study locations/samples[a] from farther upstream within the Green River and from four major tributaries are available but are screened out because downstream at RM 10.4 is most representative of all upstream inputs.	*Age*: 2012 to 2015. *Sampling Time Frame*: Filter solids represent a ~24- to 48-hour snapshot. Sediment traps represent a 3-month time-weighted average. *Flow Conditions*: The samples characterize Green River flow categories over several seasons: significant dam release, storm event with significant dam	Suspended solids are primarily fine grained. *Sediment trap fines:* 18% to 85%; mean 47.8%. Filtered solids fines: 49% to 80%; mean 63%. Note that some sediment trap samples have lower percent fines that would not be representative of material depositing in EW.	Same as USGS Green River Loading Study.

Table 3-3
Green River Suspended Solids and Whole Water Datasets Sufficiency Evaluation

Study	Acceptability						Representativeness			
	Documentation (Report; Data Availability)	Field		Analytical			Geographical	Temporal	Physical (Grain Size)	Land Use
		Methods	QA/QC, Sampling Comparability	Laboratory/Methods	Detection Limits	QA/QC Samples, Data Validation				
								release, and baseline.		
Ecology Contaminant Loading Study	Gries and Sloan 2009; EIM Study ID LDW_08	Field centrifuge • Intake targeted 0.6 times the mid-channel depth, with modifications based on stage height, tidal phase, salinity, and the maximum water depth	Sample replicates; comparison to sieved samples; field blanks.	Washington State-accredited laboratories and EPA-approved methods *PCB:* Aroclors, MEL; EPA8082 *DF*: Congeners, PRL; EPA1613B *As*: MEL EPA Method 3050B/200.8 TOC: PSEP-TOC	*PCB:* Three of seven samples, all Aroclors, are non-detect at ~2.5 µg/kg. *DF*: Congener data include some non-detected and estimated values (J flag) consistent with low concentrations analyzed by the analysis method. *As*: All detected.	QAPP referenced but source document not found to confirm QA/QC laboratory requirements. Validated by EPA.	RM 6.8: Upstream of EW/LDW; some impact from salt wedge.	*Age*: January to July 2009. *Sampling Time Frame*: Centrifuge solids represent a ~24-hour snapshot. *Flow Conditions*: Green River flow categories: four baseline, one storm event, and two significant dam releases (as assessed by EWG using available storm and flow data).	Suspended solids are primarily fine-grained. *Sample fines:* 79% to 94% estimated based on TSS data.	Generally similar to USGS Green River Loading Study, approximately 3.5 miles farther downstream. Location farther downstream increases commercial/industrial land use percentage slightly.

Notes:

a. Additional locations include Green River Flaming Geyser, Newaukum Creek, Soos Creek, Mill Creek, Black River, and Springbrook Creek.

µg/kg: micrograms per kilogram
µm: micron
ARI: Analytical Resources, Inc.
As: Arsenic
ASTM: ASTM International
DF: dioxin/furan
Ecology: Washington State Department of Ecology
EIM: Environmental Information Management database
EPA: U.S. Environmental Protection Agency
EW: East Waterway
KCEL: King County Environmental Laboratory
LDC: Laboratory Data Consultants, Inc.
LDW: Lower Duwamish Waterway
LDWG: Lower Duwamish Waterway Group
MEL: Manchester Environmental Laboratory
N/A: not available
NJ: non-detect estimated
PCB: polychlorinated biphenyl
PRL: Pacific Rim Laboratories
PSD: Particle size distribution
PSEP: Puget Sound Estuary Protocols
QA/QC: quality assurance/quality control
QAPP: Quality Assurance Project Plan
RM: river mile
SM: Standard Method
TOC: total organic carbon
TSS: total suspended solids
USGS: U.S. Geological Survey
WLRD: Water and Land Resources Division

Table 4-1

Comparison of Green River Suspended Solids Sampling Methods

Sampling Method	Total PCB Congeners (µg/kg)				Dioxin/Furan TEQ (ng/kg)				Arsenic (mg/kg)				Fines (pct)			
	Count	Mean	Med	90th Pctl	Count	Mean	Med	90th Pctl	Count	Mean	Med	90th Pctl	Count	Mean	Med	90th Pctl
Centrifuge/Filter																
Centrifuge	37	15	11	32	44	6.3	4.2	14	42	16	14	26	46	77	81	93
Filter Solids	12	24	8.2	70	10	5.4	3.5	9.1	10	22	16	38	12	67	66	80
All	49	17	8.8	46	54	6.1	4.1	14	52	17	14	26	58	75	78	93
Sediment Trap																
Baffle	5	5.3	1.1	12	3	1.7	0.5	3.5	5	8.9	5.1	15	5	46	47	66
Jar	4	13	9.2	26	2	2.9	2.9	4.9	4	11	9.8	18	4	51	50	82
All	9	8.6	3.6	18	5	2.2	0.5	4.9	9	9.8	5.9	18	9	48	47	78

Notes:
Colored bars provide a visual representation of the numerical value compared to other values for each analyte.
Colored bars provide a visual representation of the numerical value compared to other values for each analyte.
Includes all Green River suspended solids data.
Total PCB Aroclors are excluded; see Table 4-2 for Aroclor results.

µg/kg: micrograms per kilogram dry-weight
ng/kg: nanograms per kilogram dry-weight
med: median
mg/kg: milligrams per kilogram dry-weight
PCB: polychlorinated biphenyl
pct: percent
pctl: percentile

Table 4-2

Comparison of Green River Suspended Solids Total PCB Congeners and Aroclors Datasets

Data Subset	Total PCBs (µg/kg)			
	Count	Mean	Median	90th Pctl
Congeners	49	17	8.8	46
Aroclors (Ecology Samples)	7	14	7.5	32
Congeners + Ecology Aroclor Samples	56	17	8.6	48
All Aroclor Samples	24	18	13	45

Notes:

Colored bars provide a visual representation of the value compared to other values in the table.

Sediment traps are not included; see Table 4-1 for sediment trap results.

µg/kg: micrograms per kilogram dry-weight

Ecology: Washington State Department of Ecology

PCB: polychlorinated biphenyl

pctl: percentile

Table 4-3

Comparison of PCB Congener Non-Detect Treatments for Totals Summing

Non-Detect Treatment	Total PCBs (µg/kg)			
	Count	Mean	Median	Pct 90
ND = 0.0	49	17.0	8.8	46.5
ND = 0.5 * RV	49	17.1	9.2	46.5
ND = 1.0 * RV	49	17.2	9.5	46.5
Kaplan Meier Sum	49	17.1	8.9	46.5

Notes:

The blue bars are a visual representation of the mean, median, or 90 pct value compared to the other values of the same type with different non-detect treatments.

The median number of congener detections per sample was 81%.

Dataset includes centrifuge and filter solids samples.

UCL95 based on bootstrap with replacement for the n presented with the exception of the Kaplan Meier-Sum method (next note).

Kaplan Meier Sum method based on ProUCL Kaplan Meier non-detect treatment on each sample (i.e., across congeners) with Efron's bias correction. The Kaplan Meier mean or UCL is then multiplied by the number of congeners. The mean, median, and 90th percentile summary statistics are on the (Kaplan Meier mean*# of congeners) for samples. The UCL is the mean of (UCL*# of congeners) for all samples. The lognormal ROS with 95% BCa bootstrap was used to calculate the UCL.

µg/kg: micrograms per kilogram dry-weight

BCa: bias-corrected and accelerated

ND: non-detected result

ROS: regression on order statistics

RV: Reported value for the non-detected result; summary statistics based on the sample- and congener-specific non-detected reported value

UCL: upper confidence level

UCL95: 95% upper confidence level on the mean

Table 4-4

Comparison of Dioxin/Furan Congener Non-Detect Treatments Summary Statistics

Chemical	TEF	n	Det	Mean Concentration (ng/kg)			
				nd=0*RV	nd=0.5*RV	nd=1.0*RV	nd=statistical treatment[a]
Dioxin/Furan Congeners							
1,2,3,7,8-PeCDD	1	54	46	1.27	1.32	1.37	1.33
2,3,4,7,8-PeCDF	0.3	54	45	0.68	0.77	0.86	0.73
2,3,7,8-TCDD	1	54	42	0.43	0.47	0.51	0.47
2,3,7,8-TCDF	0.1	54	46	0.67	0.73	0.78	0.71
Dioxin/Furan TEQ[b]							
TEQ Calculated from Congener Statistics	n/a	54	54	5.9	6.1	6.3	6.1
TEQ Calculated from Samples	n/a	54	54	5.9	6.1	6.3	n/a

Notes:

a. Non-detected values were estimated by ROS statistics with an assumed log-normal distribution for non-detect estimation. ROS was selected because it supports the UCL and UTL statistics selected for use in the final dataset (Section 6).

b. Dioxin/furan TEQs were calculated using TEFs for mammals presented in Van den Berg et al. (2006).

Det: detected
n: sample size
nd: non-detect
ng/kg: nanograms per kilogram dry-weight
RV: reported value
ROS: regression on order
TEF: toxic equivalency factor
TEQ: toxic equivalent
UCL: upper confidence level
UTL: upper tolerance limit

Table 4-5

Green River Flow and Precipitation Conditions During Sampling of Highest Concentration Values

Chemical	Concentration	Month	Season	Flow Below Howard Hanson Dam		Precipitation	
				cfs	pctl	inches/day	pctl
Total PCB (µg/kg)	100	October 2015	Fall	468	32	0.9	98
	84	July 2014	Summer	310	16	1.2	99
	72	October 2014	Fall	1,031	69	1.0	98
	59	February 2013	Winter	1,012	68	0.23	84
	56	August 2008	Summer	323	18	0.14	77
Dioxin/Furan TEQ (ng/kg)	22	January 2017	Winter	604	44	1.7	100
	22	February 2013	Winter	1,012	68	0.23	84
	20	February 2017	Winter	808	58	2.2	100
	19	July 2014	Summer	310	16	1.2	99
	19	August 2008	Summer	323	18	0.14	77
Arsenic (mg/kg)	51	September 2015	Fall	357	23	0	27
	37	June 2015	Summer	228	3	0	27
	32	August 2013	Summer	327	19	0	27
	28	October 2014	Fall	536	38	0	27
	27	September 2016	Summer	393	26	0.28	86

Notes:

Percentiles are based on the 2001 to 2019 calendar year datasets.

µg/kg: micrograms per kilogram dry-weight

cfs: cubic feet per second

mg/kg: milligrams per kilogram dry-weight

ng/kg: nanograms per kilogram dry-weight

PCB: polychlorinated biphenyl

pctl: percentile

TEQ: toxic equivalent

Table 5-1
Sensitivity Analysis

Chemical	Calculation	Mean Concentration
Total PCBs (µg/kg)	AB Dataset Without Fines Adjustment	17.0
	Include Ecology Aroclor Samples	16.6
	Include Sediment Trap Samples	15.7
	Exclude Samples with <60% Fines	18.0
	Fines Normalize	21.9
	Fines Adjustment Based on Particle Surface Area	28.2
	Weight Samples Based on Flow and Precipitation Conditions	13.6
	Include Adjustment for EW and LDW Laterals	17.8
Dioxin/furan TEQ (ng/kg)[a]	AB Dataset Without Fines Adjustment	6.1
	Include Sediment Trap Samples	5.8
	Exclude Samples with <60% Fines	6.3
	Fines Normalize	7.8
	Fines Adjustment Based on Particle Surface Area	10.1
	Weight Samples Based on Flow and Precipitation Conditions	6.2
	Include Adjustment for EW and LDW Laterals	6.4
Arsenic (mg/kg)	AB Dataset Without Fines Adjustment	17.2
	Include Sediment Trap Samples	16.2
	Weight Samples Based on Flow and Precipitation Conditions	22.0
	Include Adjustment for EW and LDW Laterals	17.2

Notes:
Shade: Method selected for AB estimate
The colored bars are a visual representation of the magnitude of the concentration or percent change compared to other values of the same chemical.
a. Dioxin/furan TEQ is representative of the trends for the four dioxin/furan congeners with calculated AB values.

µg/kg: micrograms per kilogram
AB: anthropogenic background
EW: East Waterway
LDW: Lower Duwamish Waterway
mg/kg: milligrams per kilogram
ng/kg: nanograms per kilogram
PCB: polychlorinated biphenyl
TEQ: toxic equivalent

Table 5-2

Comparison of Arsenic Concentrations in Green River Suspended Solids and EW and Post-Remediation Site Sediments

Location and Description	Mean (mg/kg)	n	Sample Year(s)
AB Evaluation			
Green River Suspended Solids (Centrifuge/Filter Solids)	17.2	52	2008–2017
EW Sediments (per Feasibility Study)			
EW Samples	11.0	239	1995–2009
Sediment Remediation Sites			
Lockheed, Shipyard No. 1 - West Waterway: Open channel remediation areas (dredge with/without ENR)	8.2	10	2012–2014
Duwamish Diagonal - Lower Duwamish Waterway: Caps A and B	9.6	32	2009–2012

Notes:

References:

AECOM, 2012. *Feasibility Study, Lower Duwamish Waterway, Seattle, Washington, Final Report* . Prepared for: Lower Duwamish Waterway Group. October 2012.

Anchor QEA and Windward (Anchor QEA, LLC, and Windward Environmental, LLC), 2019. *East Waterway Operable Unit Supplemental Remedial Investigation/Feasibility Study – Final Feasibility Study* . Prepared for Port of Seattle. June 2019.

EPA 2015. *Five-Year Review Report for Harbor Island Superfund Site Seattle, Washington* . Prepared by USEPA Region 10, Seattle Washington. September 23, 2015.

King County, 2016. *Duwamish Diagonal Sediment Remediation Project: 2011 and 2012 Monitoring Report* . Prepared by Jenée Colton, Water and Land Resources Division. Seattle, Washington.

Tetra Tech, 2012. *Lockheed Shipyard No. 1, Sediments Operable Unit (LSSOU) Harbor Island, Seattle, Washington, 2012 Operations, Monitoring and Maintenance Report* . Prepared for: Lockheed Martin Corporation. September 2012.

The red bars are a visual representation of the magnitude of the mean value compared to the other locations.

AB: anthropogenic background
ENR: enhanced natural recovery
EW: East Waterway
mg/kg: milligrams per kilogram dry-weight
n: sample count

Table 6-1

Range of Estimated Anthropogenic Background Values for East Waterway Operable Unit

Chemical	Unit	Sample Count / Detected Count	Median	Mean	95% UCL[a]	90_90_UTL[b]	95_95_UTL[b]
Total PCBs	µg/kg-fines normalized	49/49	12	22	31	90	115
Arsenic	mg/kg	52/52	14	17	20	28	40
1,2,3,7,8-PeCDD[c]	ng/kg-fines normalized	46/54	1.0	1.7	2.1	4.7	6.9
2,3,4,7,8-PeCDF[c]	ng/kg-fines normalized	45/54	0.68	0.90	1.1	2.9	3.1
2,3,7,8-TCDD[c]	ng/kg-fines normalized	42/54	0.39	0.58	0.71	1.5	1.8
2,3,7,8-TCDF[c]	ng/kg-fines normalized	46/54	0.64	0.91	1.2	2.5	4.5
Dioxin/Furan TEQ[d]	ng/kg-fines normalized	54/54	5.8	7.8	9.6	20	26

Notes:

a. 95% UCLs calculated in ProUCL based on the 95% bootstrap-t UCL, to minimize assumptions in the calculation (i.e., distribution selection). The bootstrap-t distribution was selected due to applicability for skewed datasets (e.g., lognormal) as suggested by Singh and Singh 2013. 95% bootstrap-t UCL values were similar to UCLs calculated by other methods, indicating calculation stability.

b. UTLs calculated in ProUCL based on the percentile bootstrap method, to minimize assumptions in the calculation (i.e., distribution selection). UTL values were similar to UTLs calculated by other methods, indicating calculation stability.

c. Non-detected values were estimated by ROS statistics with an assumed log-normal distribution for non-detect estimation. ROS was selected because it supports the UCL and UTL statistics selected (i.e., bootstrap).

d. TEQ presented for comparison to RI/FS values.

µg/kg: micrograms per kilogram
mg/kg: milligrams per kilogram dry-weight
ng/kg: nanograms per kilogram
PCB: polychlorinated biphenyl
ROS: regression on order
TEQ: toxic equivalent
UCL: upper confidence level
UTL: upper tolerance limit

Figures

East Waterway Operable Unit of Harbor Island Superfund Site

Lower Duwamish Waterway Superfund Site

River Mile 10.4

Green River

LEGEND:

- East Waterway Operable Unit Study Area Boundary
- Lower Duwamish Waterway Superfund Site

NOTES:

0 4,000
Feet

Publish Date: 2021/02/15, 4:15 PM | User: adowell
Filepath: \\orcas\gis\Jobs\060003-01 East Waterway SRI-FS\Maps\2020_01\AQ_fig1-1_East_Waterway_Operable_Unit.mxd

ANCHOR QEA

Figure 1-1
East Waterway Operable Unit and Lower Duwamish Waterway Site
Final Anthropogenic Background Evaluation
East Waterway Operable Unit SRI/FS

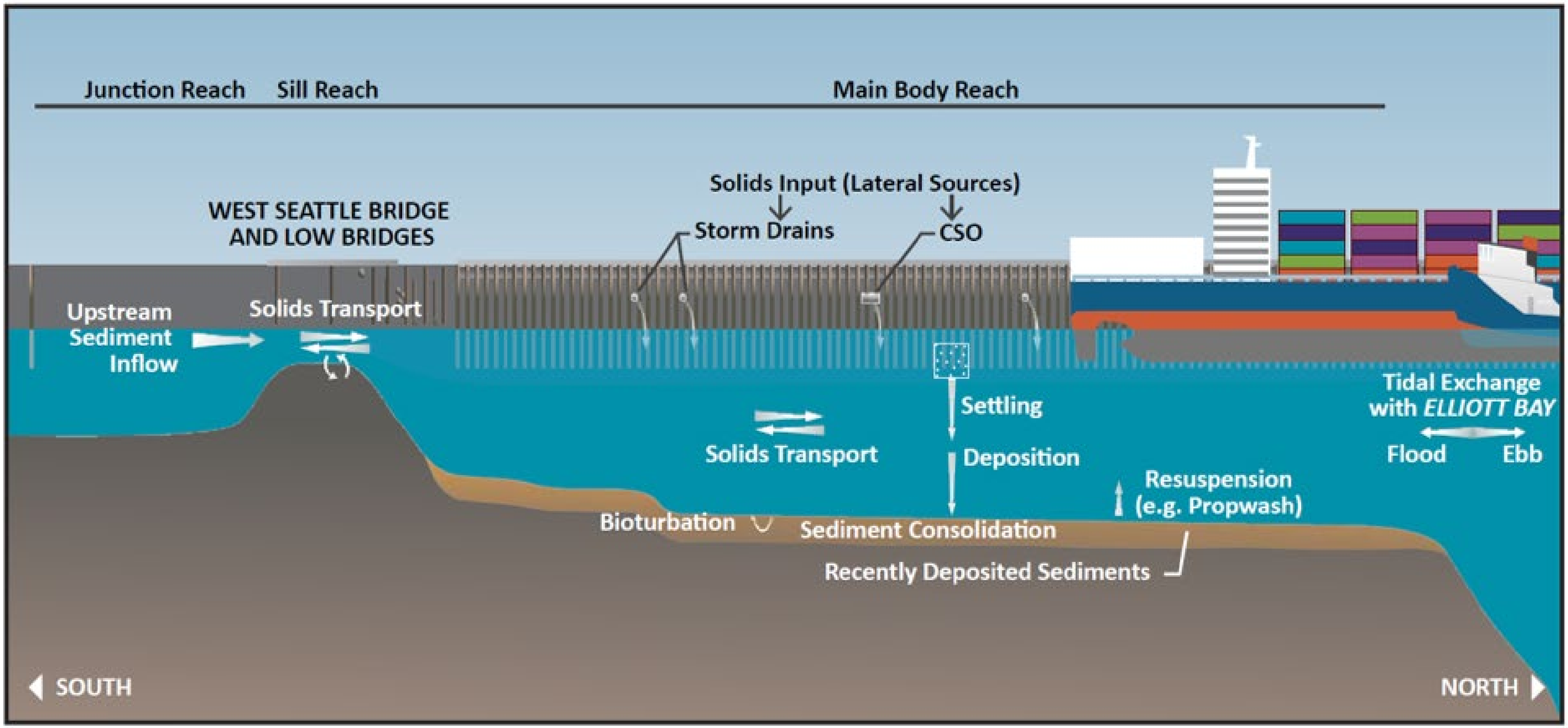
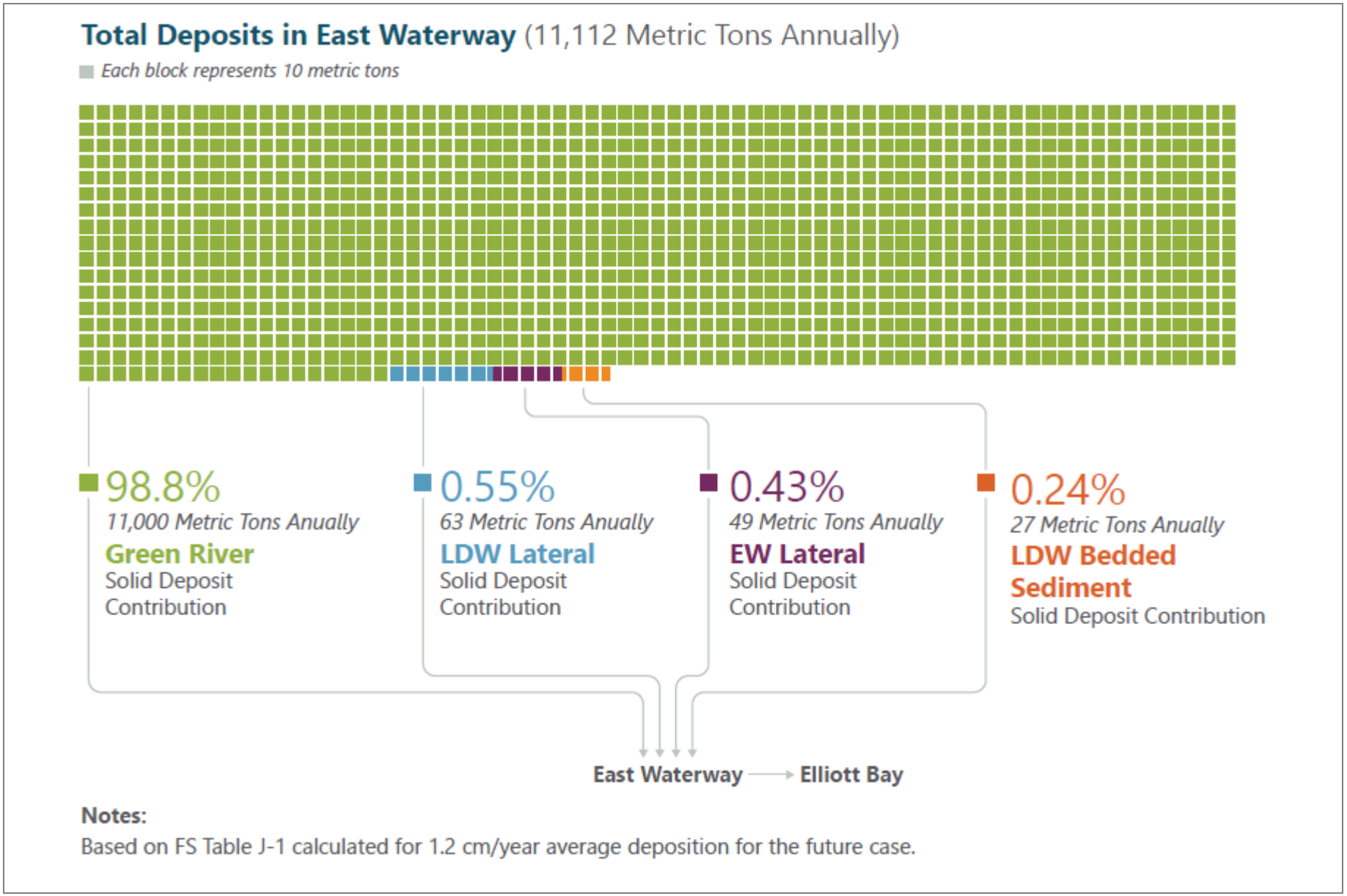


Figure 2-1
East Waterway Physical Conceptual Site Model
Final Anthropogenic Background Evaluation
East Waterway Operable Unit SRI/FS

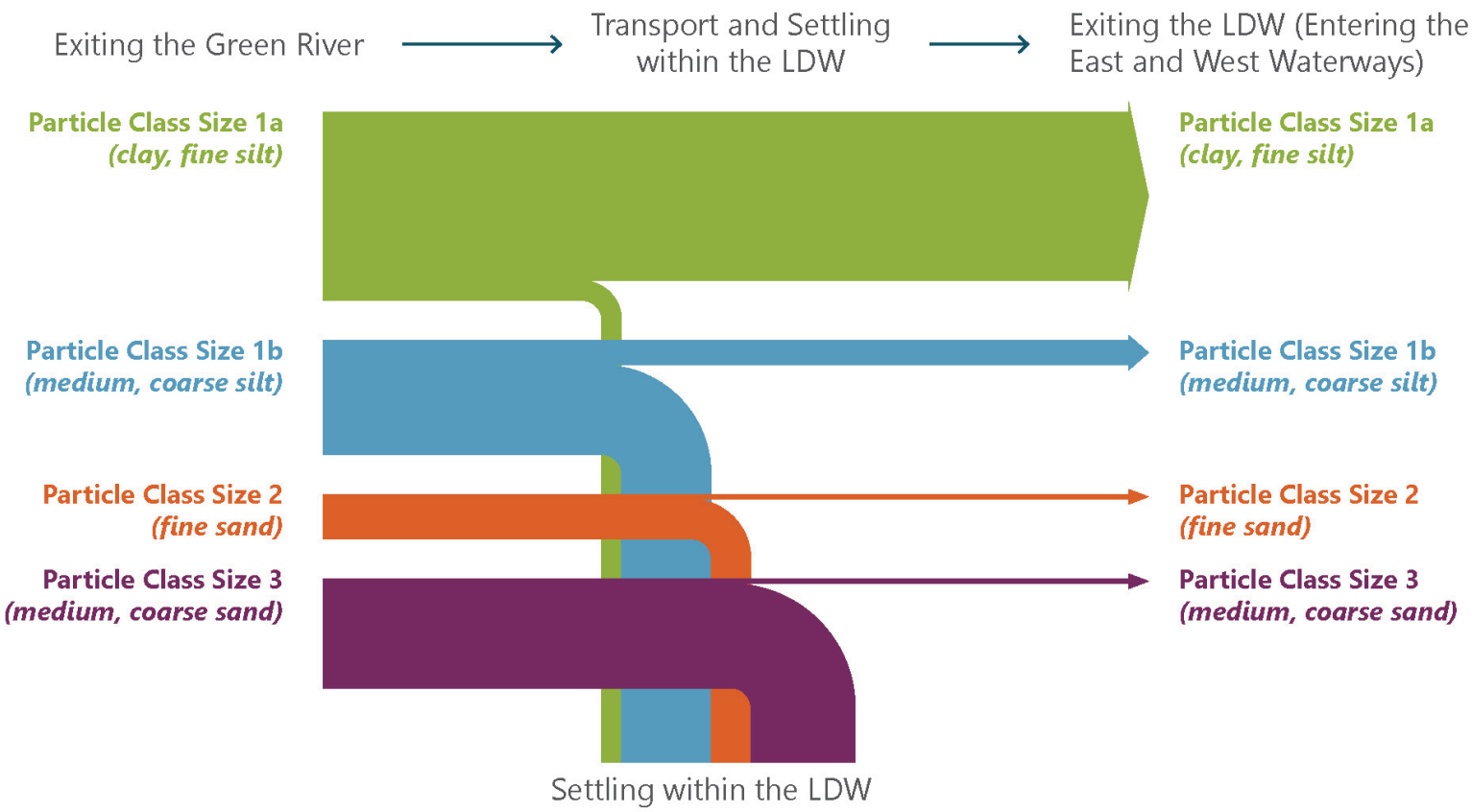


Filepath: \\fuji\anchor\Projects\Port of Seattle\060003-01 East WW SRI_FS\PP ROD\Anthropogenic\EPA Memo\Figures\Fig_2-2, 4-1, 4-2_EW_07-15-2021.docx

ANCHOR QEA

Figure 2-2
Annual Solids Inputs to the East Waterway
Final Anthropogenic Background Evaluation
East Waterway Operable Unit SRI/FS

Sediment Transport in the Green and Duwamish River



Notes:

QEA (Quantitative Environmental Analysis), 2008. Lower Duwamish Waterway Sediment Transport Modeling (STM) Report, Final. Prepared for USEPA, Region 10, and the Washington State Department of Ecology. Quantitative Environmental Analysis, Montvale, NJ. October 2008.

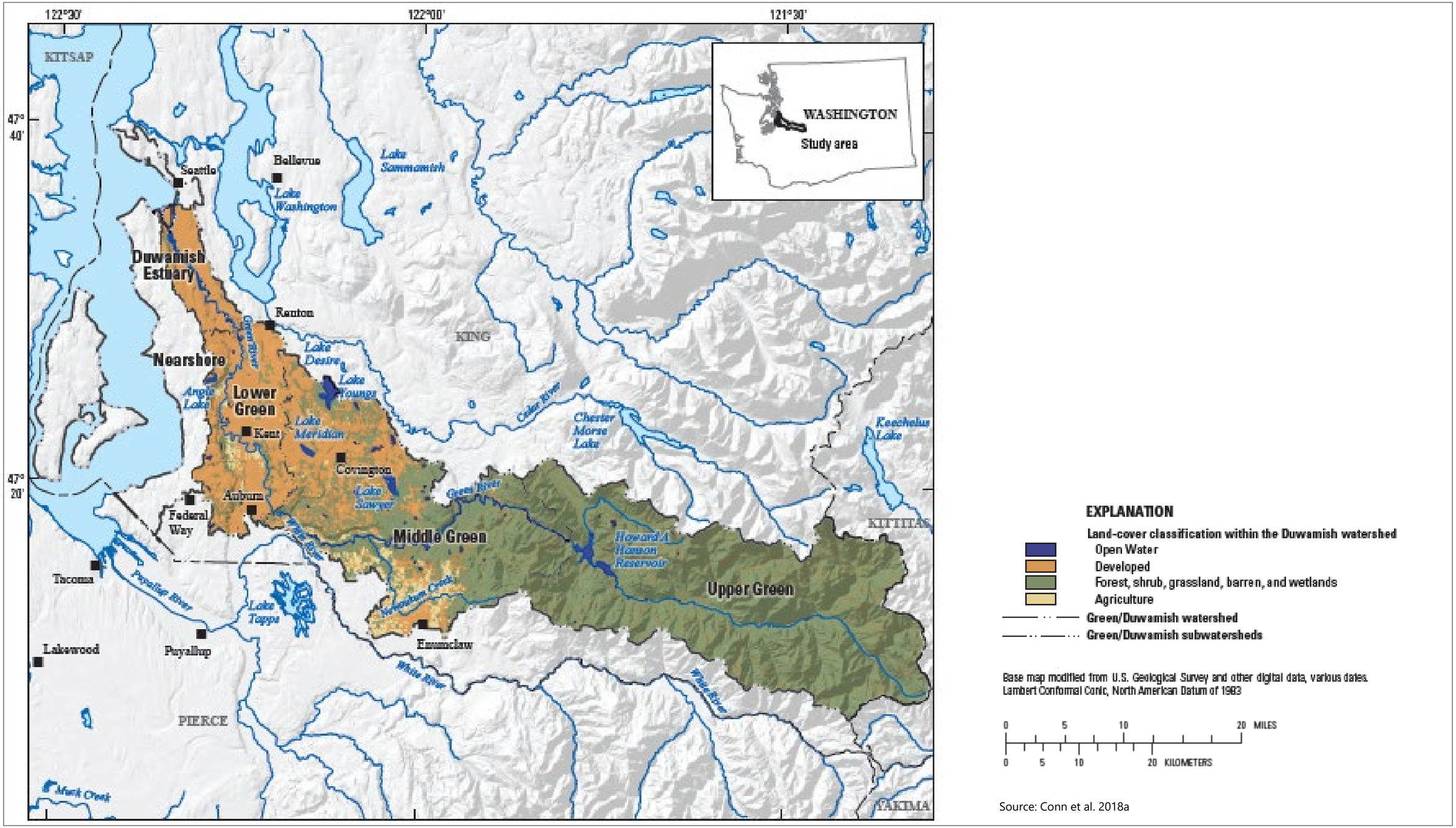
LDW: Lower Duwamish Waterway

STM: sediment transport modeling

Filepath: \\fuji\anchor\Projects\Port of Seattle\060003-01 East WW SRI_FS\PP ROD\Anthropogenic\EPA Memo\Figures\Fig_2-3_EW_Particle_Size_07-15-2021.docx

ANCHOR QEA

Figure 2-3
Sediment Transport in the Green and Duwamish River by Particle Size Fraction
Final Anthropogenic Background Evaluation
East Waterway Operable Unit SRI/FS

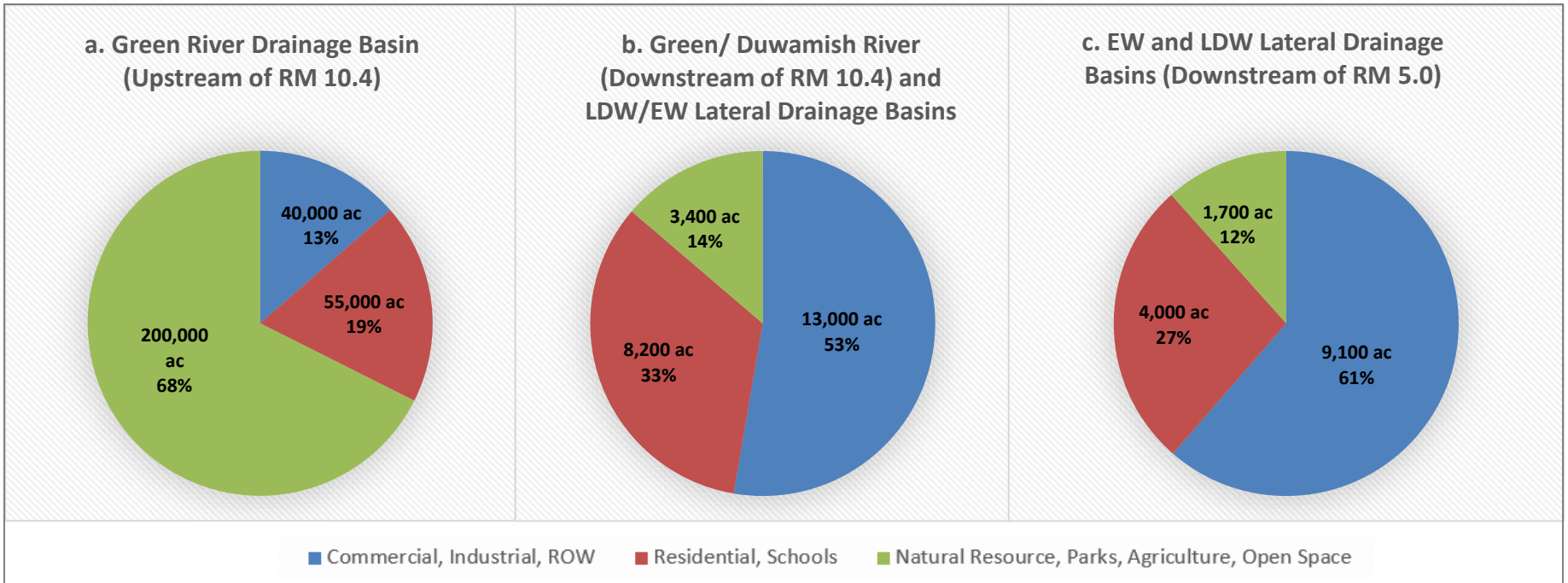


Source: Conn et al. 2018a

Filepath: \\fuji\anchor\Projects\Port of Seattle\060003-01 East WW SRI_FS\PP ROD\Anthropogenic\EPA Memo\Figures\Fig_2-4_EW_Green_Riv_and_Land_Use_07-15-2021.docx

ANCHOR QEA

Figure 2-4
Green River Watershed
Final Anthropogenic Background Evaluation
East Waterway Operable Unit SRI/FS



Notes:

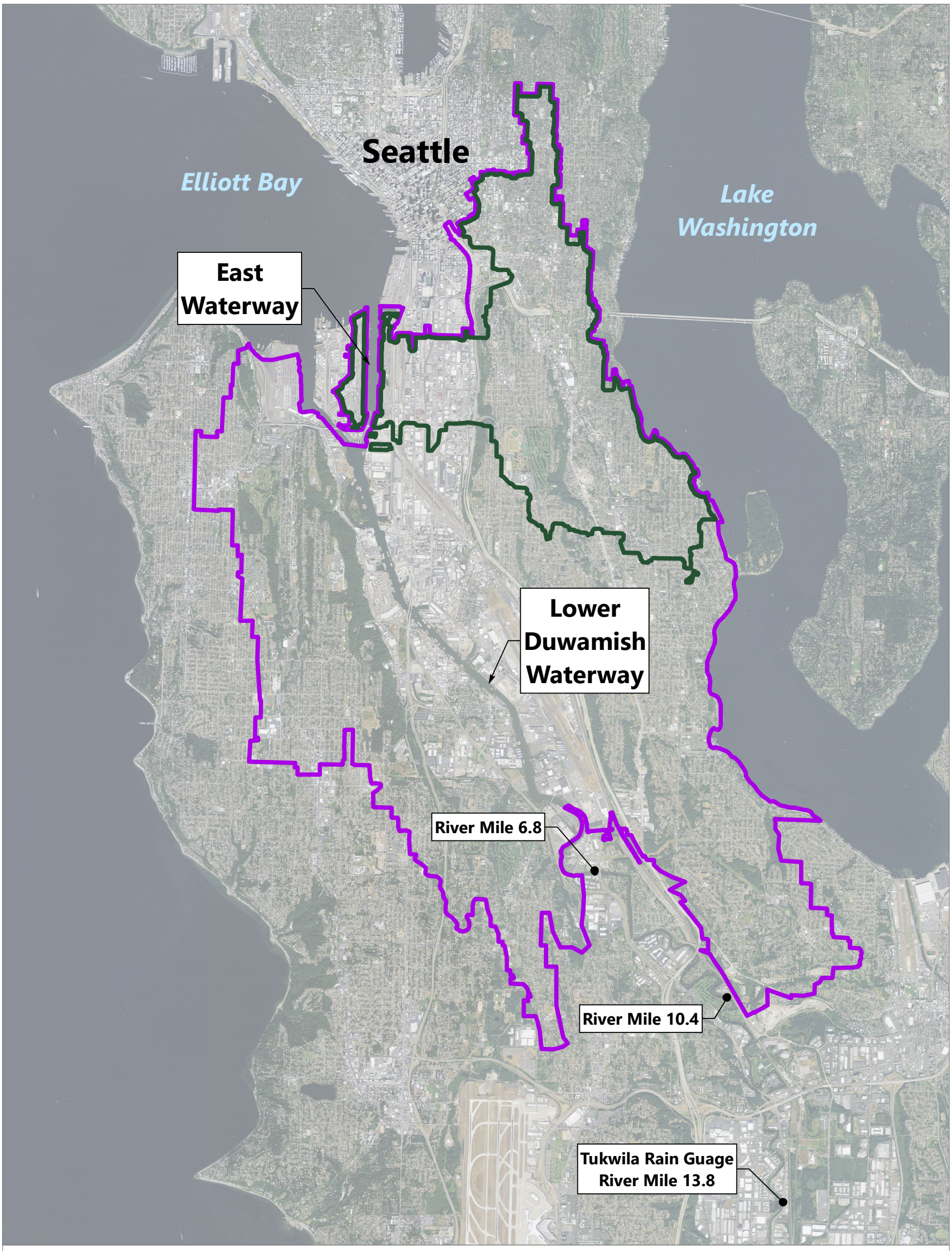
1. Green River Drainage Basin (Upstream of RM 10.4) data source: Green River Watershed Surface Water Data Report Figure 3 (King County 2018)
2. Green/ Duwamish River and LDW/EW Drainage Basin (Downstream of RM 10.4) data source: Provided by King County
3. EW drainage basin land use data source: SRI Tables 9-8 and 9-9 (Windward and Anchor QEA 2014)
4. LDW drainage basin land use data source: LDW FS Table 9-8 (Anchor QEA and Windward 2019)
5. Figures a and b together cover the entire Green/Duwamish watershed; Figure c represents a subset of the area depicted in Figure b

ac: acre
RM: river mile
EW: East Waterway
LDW: Lower Duwamish Waterway
ROW: right-of-way

Filepath: \\fuji\anchor\Projects\Port of Seattle\060003-01 East WW SRI_FS\PP ROD\Anthropogenic\EPA Memo\Figures\Fig_2-5_EW_Land_Use_Pies_07-15-2021.docx

ANCHOR QEA

Figure 2-5
Green/Duwamish Watershed Land Use
Final Anthropogenic Background Evaluation
East Waterway Operable Unit SRI/FS



LEGEND:

- EW Lateral Drainage Basin
- LDW Lateral Drainage Basin

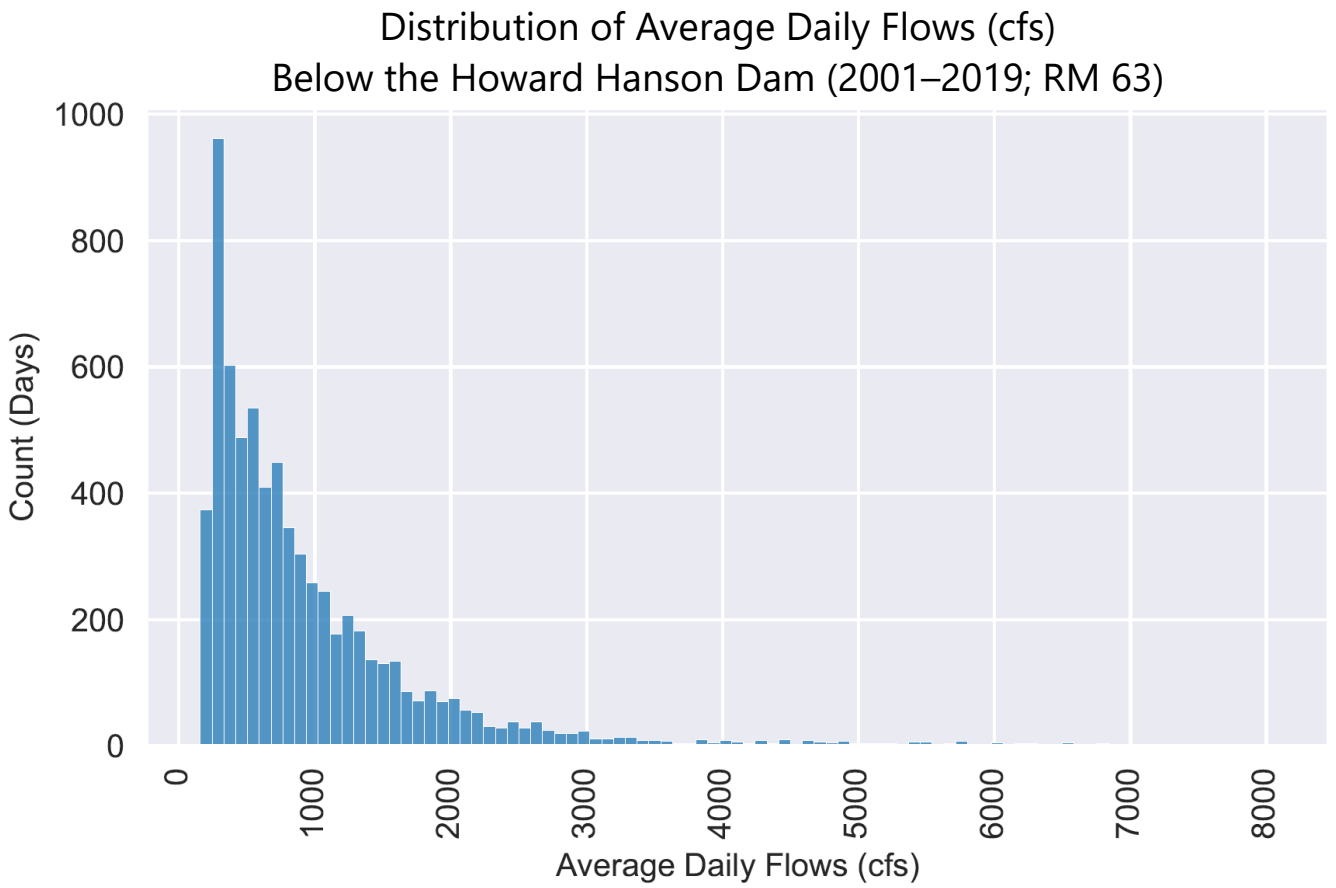
NOTES:

0 4,000
Feet

Publish Date: 2021/02/15, 4:15 PM | User: adowell
Filepath: \\orcas\gis\Jobs\060003-01 East Waterway SRI-FS\Maps\2020_01\AQ_fig2-5_EW_and_LDW_Drainage_Basins.mxd

ANCHOR QEA

Figure 2-6
EW and LDW Stormwater and CSO Drainage Basins
Final Anthropogenic Background Evaluation
East Waterway Operable Unit SRI/FS



Daily Average Flow (cfs)

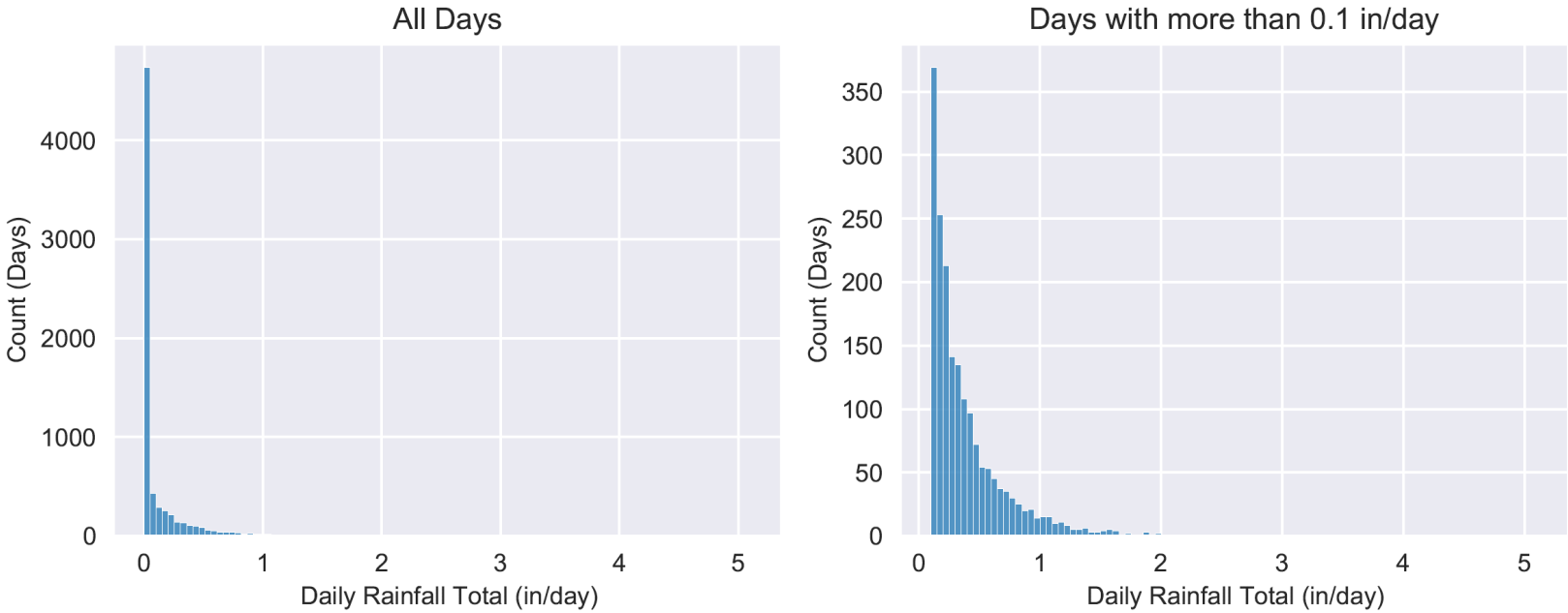
n	Min	Mean	Median	Mode	90th Percentile
6,939	157	981	694	275	1961

Filepath: \\fuji\anchor\Projects\Port of Seattle\060003-01 East WW SRI_FS\PP ROD\Anthropogenic\EPA Memo\Figures\Fig_2-7_EW_Distr_of_Avg_Daily_Flows_HH Dam_07-15-2021.docx

ANCHOR QEA

Figure 2-7
Distribution of Average Daily Flows Below the Howard Hanson Dam (2001–2019; RM 63)

Distribution of Rainfall Tukwila Rain Gauge (2001–2019; RM 13.8)



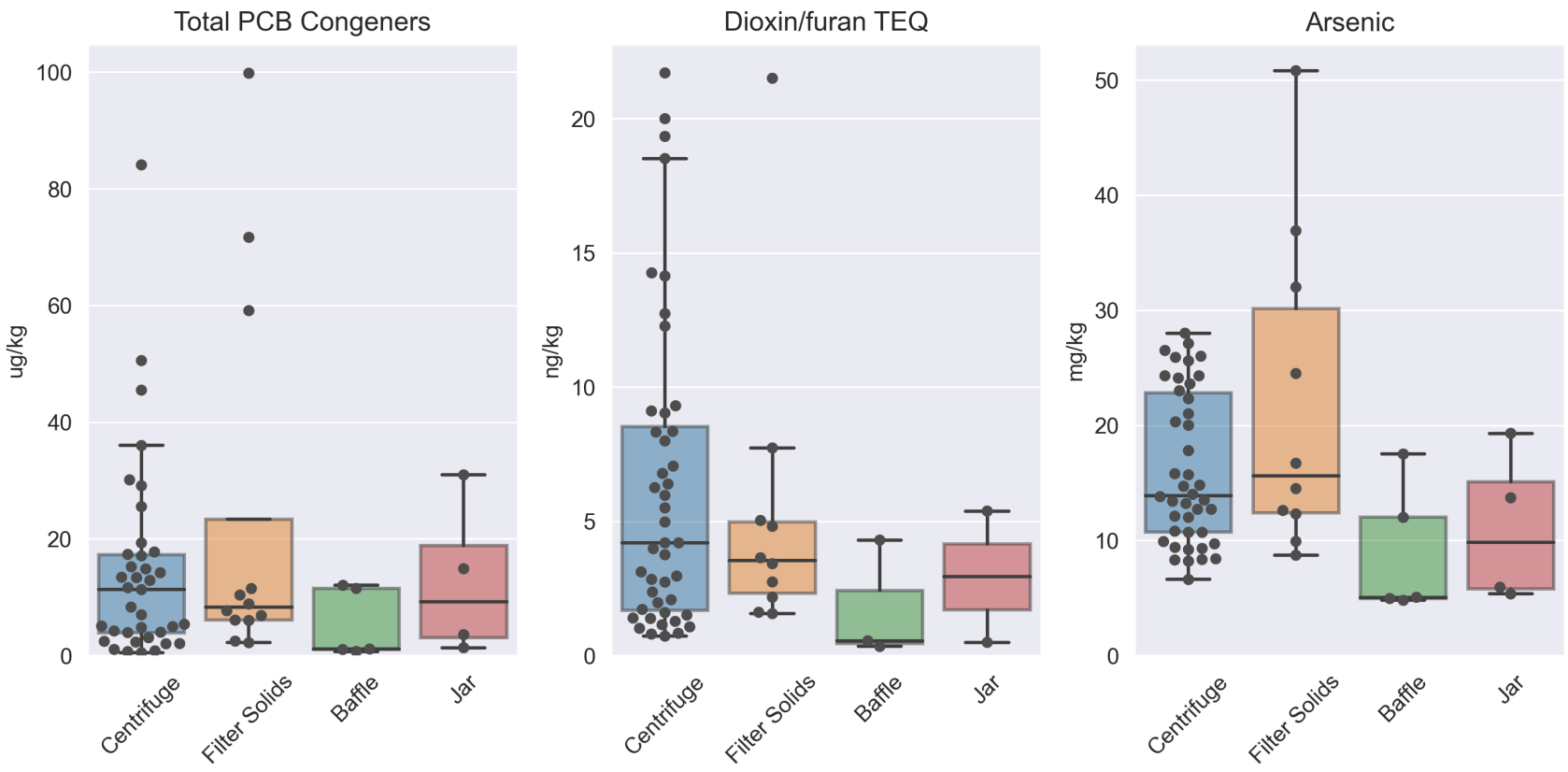
Daily Precipitation (in)

	n	Mean	Median	90th Percentile
All Days	6921	0.11	0.0	0.36
Days with more the 0.1 in	1834	0.40	0.28	0.82

Filepath: \\fuji\anchor\Projects\Port of Seattle\060003-01 East WW SRI_FS\PP ROD\Anthropogenic\EPA Memo\Figures\Fig_2-8_EW_Distr_of_Rain_Tukwila_07-15-2021.docx

ANCHOR QEA

Figure 2-8
Distribution of Rainfall at the Tukwila Rain Gauge (2001–2009; RM 13.8)



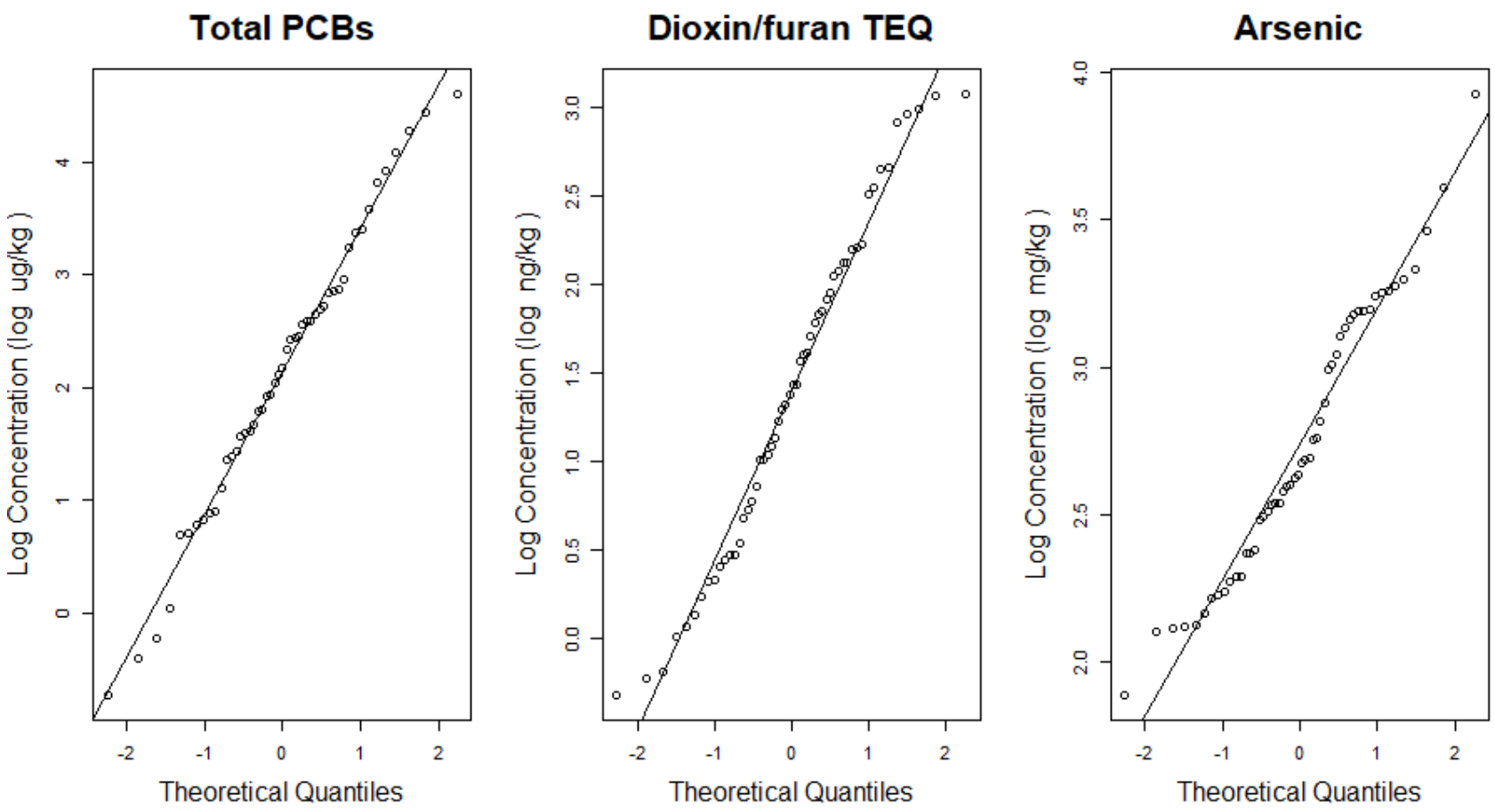
Notes:

1. Data includes suspended solids samples from the USGS, King County, and Ecology datasets (Section 3.1.3)
2. Colored boxes represent the upper and lower inner quartiles. Whiskers are set at the closest data point within 1.5 * the inner quartile. Dots represent sample concentrations in the datasets.

Filepath: \\fuji\anchor\Projects\Port of Seattle\060003-01 East WW SRI_FS\PP ROD\Anthropogenic\EPA Memo\Figures\Fig_2-2, 4-1, 4-2_EW_07-15-2021.docx

ANCHOR QEA

Figure 4-1
Comparison of Green River Suspended Solids Results by Sampling Methods



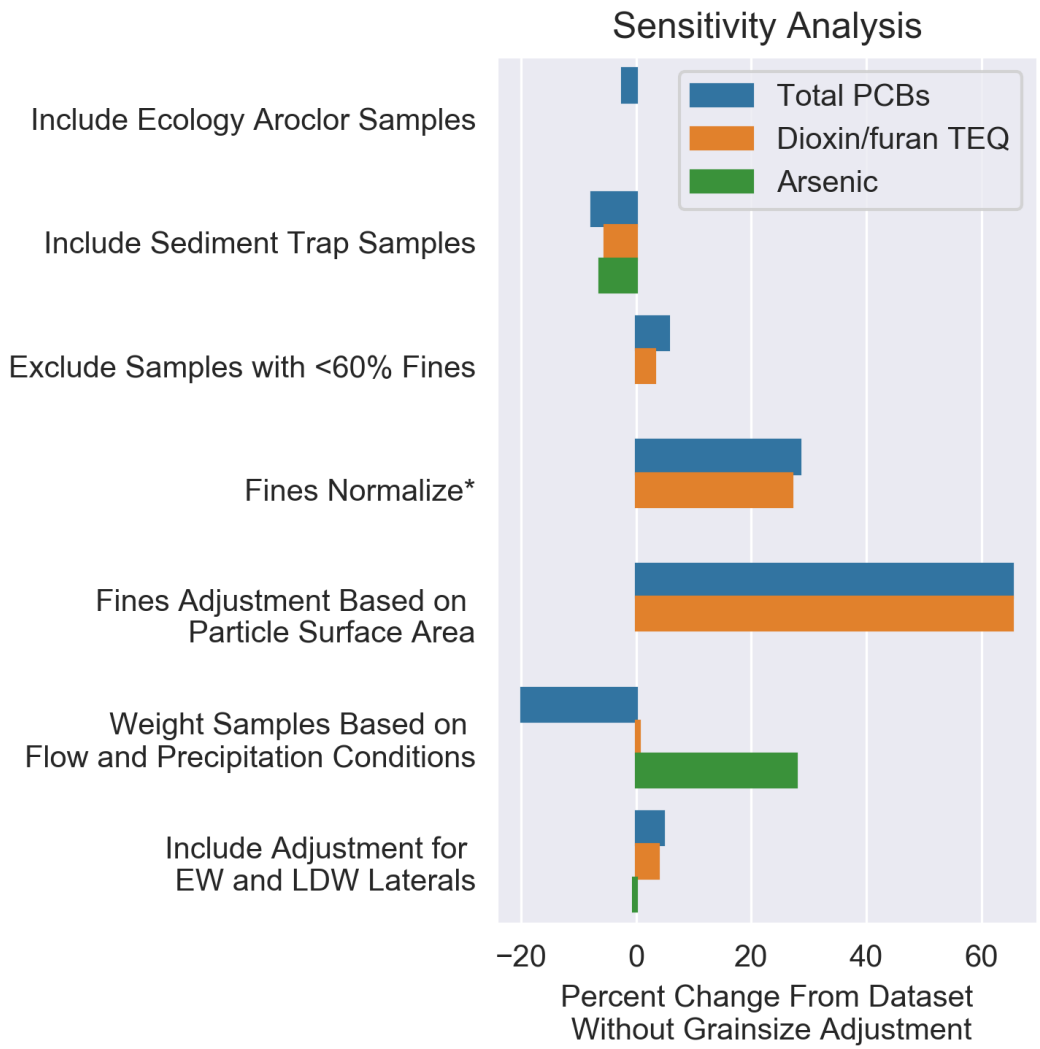
Notes

1. Total PCBs are based on congener data (no Aroclors)
2. Data includes centrifuge and filter solids (no sediment traps)
3. All COCs fit a log normal distribution based on statistical evaluation (Section 4.5)

Filepath: \\fuji\anchor\Projects\Port of Seattle\060003-01 East WW SRI_FS\PP ROD\Anthropogenic\EPA Memo\Figures\Fig_2-2, 4-1, 4-2_EW_07-15-2021.docx

ANCHOR QEA

Figure 4-2
Green River Suspended Solids Concentration Distributions



Notes

1. The sensitivity analysis values are based on the methods described in Section 4.
2. Percent change is based on a comparison to the dataset without fines normalization (17.0 µg/kg, 6.1 ng/kg, and 17.2 mg/kg for total PCBs, dioxin/furan TEQ, and arsenic, respectively).
3. Negative percent changes represent a lower concentration, and positive percent changes represent higher concentrations.

* The fines normalized concentrations were selected for the AB estimate for total PCBs and dioxins/furans.

Filepath: \\fuji\anchor\Projects\Port of Seattle\060003-01 East WW SRI_FS\PP ROD\Anthropogenic\EPA Memo\Figures\Fig_5-1_EW_Sensitivity_Analysis_07-15-2021.docx

ANCHOR QEA

Figure 5-1
Sensitivity Analysis
Final Anthropogenic Background Evaluation
East Waterway Operable Unit SRI/FS

Appendix A
Supporting Documentation

APPENDIX A – SUPPORTING DOCUMENTATION
FINAL ANTHROPOGENIC BACKGROUND EVALUATION

For submittal to

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

July 2021

Prepared by

1201 Third Avenue • Suite 2600
Seattle, Washington • 98101

TABLE OF CONTENTS

Introduction 1

Part 1 – River Flow and Precipitation Weighting 2

Part 2 – Particle Grain Size Surface Area Adjustment 4

Part 3 – Urban Inputs 5

References 7

TABLE

Table A-1 Surface Area Particle Size Adjustment Calculation

FIGURES

Figure A-1 Green River Suspended Solids Total PCBs Concentrations with Flow and Precipitation Conditions

Figure A-2 Green River Suspended Solids Dioxin/Furan TEQ Concentrations with Flow and Precipitation Conditions

Figure A-3 Green River Suspended Solids Arsenic Concentrations with Flow and Precipitation Conditions

Introduction

This appendix presents detail on three sensitivity assessments completed to support the East Waterway (EW) anthropogenic background (AB) evaluation. The results of these assessments are discussed in the main body of this document. This appendix includes the following three parts:

- Part 1 – River Flow and Precipitation Weighting
- Part 2 – Particle Grain Size Surface Area Adjustment
- Part 3 – Urban Inputs

Part 1 – River Flow and Precipitation Weighting

Green River suspended solids characteristics are largely influenced by two factors: the volume of water being released by the Howard Hanson Dam and the amount of recent precipitation. Both the U.S. Geological Survey (USGS) suspended solids study (Conn et al. 2018) and the King County suspended solids study (King County 2016) categorized flow conditions within the Green River based on the volume of dam release and precipitation conditions during and just before sampling. The two studies differed slightly in the details of their approach (i.e., which precipitation gauge was used) but used the same general methodology. Low dam flow with low (or no) precipitation was categorized as "baseflow"; high dam flow with low or no precipitation was categorized as "dam"; low dam flow with high precipitation was categorized as "storm"; and high dam flow with high precipitation was categorized as "storm+dam." Figures 2-6 and 2-7 of the main text provide flow and precipitation histograms for years 2001 to 2019. Figures A-1, A-2, and A-3 present contaminant concentrations under different flow and precipitation conditions, with flow below the dam (average from USGS station 12105900 during sampling) on the x-axis, and precipitation during and 12 hours before sampling (Tukwila rain gauge) on the y-axis, with the size of the markers scaled to show chemical concentration. The color indicates the season during which the sample was collected. All three contaminants have lower concentrations (smaller circles) at higher flows, due to significant dam release[1] (to the right on the graph). Toward the origin (to the left on the graph), the data show higher concentrations and more variation, with higher concentrations for organics during higher precipitation events (up on the graph; Figures A-1 and A-2), and higher concentrations for arsenic during lower precipitation events representative of baseflow (down on the graph; Figure A-3).

This information was used for the conceptual site model outlier evaluation (Section 4.5.1 of the main text) and for the river flow and precipitation weighting sensitivity analysis (Section 4.6 of the main text). Additional details on the river flow and precipitation weighting sensitivity analysis are provided in the following paragraphs.

To apply river flow and precipitation weighting, the data depicted in Figures A-1 through A-3 were binned into four quadrants along the x- and y-axes in the figures. The binning thresholds were selected based on trends in the distribution of the data across the flow and precipitation conditions (i.e., to more evenly distribute sample counts within each bin). The dam flow threshold was set at 2,000 cubic feet per second (average during sampling), reflecting higher flows associated with a significant dam release, and the precipitation threshold was set at 0.25 inch per day for the analysis, reflecting precipitation events that contribute to stormwater runoff. Both thresholds are generally consistent with the USGS and King County evaluations (Conn et al. 2018; King County 2016). The data were then binned into the four quadrants created from these two thresholds based on the

[1] As adopted by USGS and King County studies, a significant dam release is considered 2,000 cubic feet per second or greater at the base on the Howard Hanson Dam.

conditions during sampling: low flow, low precipitation; low flow, high precipitation; high flow, low precipitation; and high flow, high precipitation.

A weighted average concentration was calculated based on the time that the Green River is in each of the four river flow/precipitation conditions. The number of days that the river is in each condition was calculated based on the data from 2001 to 2019 (calendar years for which data was available for the selected flow and precipitation gauges). The number of days in each of the four river flow/ precipitation conditions was divided by the total duration from 2001 through 2019 to estimate the percentage that the river is in each river flow/precipitation condition. Then, the average concentration for each quadrant was multiplied by the percentage for each to calculate a weighted average concentration. The results of this weighting calculation are presented in Section 6 of the main text.

Part 2 – Particle Grain Size Surface Area Adjustment

This section provides additional details related to Section 4.6.3 of the main text. This adjustment assumes that organic contaminant mass is distributed to the organic carbon that is proportional to the surface area of particles (e.g., Hedges and Kiel 1995; Karickhoff et al. 1979; Wang and Keller 2008), then calculates the concentration of suspended solids entering the EW considering the changes in the particle size distribution between the Green River and the EW. The components of the calculation are shown in Table A-1 and described by the following steps:

1. Extract the average particle size distribution by mass from the Lower Duwamish Waterway (LDW) sediment transport model data for suspended solids entering the LDW (i.e., in the Green River).
2. Calculate the surface area-to-mass ratio for each particle size category for particles based on the effective particle diameter for each category, assuming a spherical shape and a typical particle density for each category.
3. Multiply the surface area-to-mass ratio (from Step No. 2) times the mass for the particle size category (from Step No. 1) to calculate the total surface area for each particle size category.
4. Calculate the average contaminant concentration without particle size adjustments for organic contaminants from the AB dataset.
5. Calculate the contaminant mass associated with each particle size category for a unit contaminant mass by multiplying the average concentration (from Step No. 4) times the surface area for each particle size category and dividing by the total surface area for all the categories (from Step No. 3).
6. Divide the contaminant mass associated with each particle size category by the total mass associated with each particle size category (from Step No. 1) to get the concentration for each particle size category.
7. Extract the average particle size distribution by mass from the LDW sediment transport model data for suspended solids exiting the LDW (i.e., entering the EW).
8. Multiply the contaminant concentrations for each particle size category (from Step No. 6) by the percent of mass entering the EW for each particle size category (from Step No. 7) to calculate the weighted average concentration of all particulate entering the EW.

The results shown in Table A-1 are discussed in Section 5 of the main text.

Part 3 – Urban Inputs

This section provides additional details related to the urban inputs discussed in Section 5.5 of the main text. The available datasets for the EW lateral solids samples are presented in the EW Supplemental Remedial Investigation Appendix I and EW Feasibility Study Appendix B, Part 4, and the laterals datasets for the LDW have recently been aggregated in the *Lower Duwamish Waterway Pre-Design Studies Data Evaluation Report* (Windward 2020). Lateral input data were aggregated using a sample-by-sample evaluation that considers the sample location in the context of the pipe network and the age of the data to identify samples that are most representative of current conditions. The general rules for aggregating lateral input data are as follows:

- Prioritize data to be the most representative of what is entering the waterway by including only the in-line samples closest to the end of the pipe.
  - If end-of-pipe in-line samples are not available, include other in-line samples collected further up the pipe, plus catch basin samples collected downstream of the in-line samples.
  - If no other in-line samples are available, use catch basin samples collected throughout the system.
- If an area has had line cleaning or significant remedial or source control actions, only use data following the action(s). If no significant source control actions have been conducted, include all available data for that location.

The most recent application of this approach for LDW laterals resulted in 379 samples for PCBs, 351 samples for arsenic, and 57 samples for dioxins/furans (Windward 2020). The EW FS laterals data aggregation resulted in 261 samples for PCBs, 255 samples for arsenic, and 20 samples for dioxins/furans. These laterals datasets have an adequate number of samples that meet sample acceptability standards and are representative of current conditions.

As described in Section 3.2 of the main text, urban inputs from downstream of the Green River river mile (RM) 10.4 were not included in AB estimates because of challenges in estimating concentrations when source control actions are not complete and because of the relatively small contribution of solids mass entering the EW compared to Green River. Urban inputs that are not captured by the AB dataset include lateral inputs to the EW, lateral inputs to the LDW, and lateral inputs to the Duwamish River between the LDW (RM 5.0) and the sampling location (RM 10.4). However, urban inputs (that not associated with Comprehensive Environmental Response, Compensation, and Liability Act releases) are part of background that will affect the EW in the future. Therefore, the effect of future urban input on AB was estimated in a sensitivity evaluation.

The sensitivity evaluation was performed by calculating a weighted average concentration of Green River suspended solids (i.e., the AB dataset) with EW and LDW lateral inputs (i.e., lateral

datasets). The calculation does not account for LDW bedded sediment that can resuspend and travel downstream into the EW or lateral inputs to the Green River upstream of the LDW, which would increase the mass of the laterals input. The mass inputs are based on EW FS modeling estimates for anticipated future conditions, which assigns 11,000 metric tons a year from the Green River and 110 metric tons a year from EW and LDW lateral inputs (based on EW FS Table J-1 calculated for 1.2 cm/year average deposition for the future case; see Figure 2-2 of the main text). The concentration in Green River suspended solids for this analysis was estimated based on the dataset without fines adjustment, consistent with the other sensitivity analysis (Section 5.1 of the main text). The lateral inputs concentrations following future source control actions were estimated based on best professional judgment of the source control implementation leads. The lateral loads were estimated based on the recently compiled LDW lateral dataset presented in Table 8-1 of the *Lower Duwamish Waterway Pre-Design Studies Data Evaluation Report* (Windward 2020). In addition to the screening steps outlined in bullets above, additional adjustments to the LDW laterals dataset were made to exclude values that are expected to be controlled by source control actions[2]:

- PCBs: excluding all samples above 2,000 micrograms per kilogram (µg/kg)
- Dioxin/furan toxic equivalent (TEQ): excluding three extreme values
- Arsenic: excluding all samples above 57 milligrams per kilogram (mg/kg)

The median values from Table 8-1 were used to represent both the EW and LDW lateral inputs as follows: PCBs: 97 µg/kg dw; dioxin/furan TEQ: 26 nanograms per kilogram dw; arsenic: 10 mg/kg dw. The median was selected as representative of post-source control concentrations.

The results of the analysis are discussed in Section 5 of the main text.

[2] There was one outlier concentration from dioxin/furan dataset that was also removed.

References

Conn, K.E., R.W. Black, C.A. Senter, N.T. Peterson, and A. Vanderpool-Kimura, 2018. *Hydrology-Driven Chemical Loads Transported by the Green River to the Lower Duwamish Waterway near Seattle, Washington, 2013–17*. U.S. Geological Survey Scientific Investigations Report 2018-5133. 2018. Available at https://doi.org/10.3133/sir20185133.

Hedges, J.I., and R.G. Keil, 1995. "Sedimentary Organic Matter Preservation: An Assessment and Speculative Synthesis." *Marine Chemistry* 49:81–115.

Karickhoff, S.W., D.S. Brown, and T.A. Scott, 1979. "Sorption of Hydrophobic Pollutants on Natural Sediments." *Water Research* 13:241–248.

King County, 2016. *Lower Duwamish Waterway Source Control: Green River Watershed Suspended Solids Data Report*. Prepared by Carly Greyell and Debra Williston, Water and Land Resources Division. Seattle, Washington. December 2016.

Windward (Windward Environmental, LLC), 2020. *Lower Duwamish Waterway Pre-Design Studies Data Evaluation Report*. Prepared for Lower Duwamish Waterway Group. June 26, 2020.

Wang, P., and A.A. Keller, 2008. "Particle-Size Dependent Sorption and Desorption of Pesticides within a Water-Soil-Nonionic Surfactant System." *Environmental Science & Technology* 42:3381–3387.

Table

Table A-1
Surface Area Particle Size Adjustment Calculation

Parameter		Unit	Values by Particle Size Class				Total	Notes
Particle Parameters								
Particle Parameters	**Size Class**	**n/a**	**1a**	**1b**	**2**	**3**	n/a	LDW STM bins (QEA 2008[a])
	Designation	**n/a**	Clay	Silt	Fine Sand	Sand		Approximate correspondence between sediment classes and STM classes.
	Diameter	**µm**	5	20	130	540		Effective particle diameter STM Table 2-3 (QEA 2008[a])
	Surface Area	**m^2**	7.9E-11	1.3E-09	5.3E-08	9.2E-07		Calculated from particle diameter assuming spherical geometry
	Volume	**m^3**	6.5E-17	4.2E-15	1.1E-12	8.2E-11		
	Density	**kg/m^3**	2,650	2,650	2,650	2,650		Typical particle density for sands and clays
	Mass	**g**	1.7E-10	1.1E-08	3.0E-06	2.2E-04		Calculated (density * volume)
	Unit Area per Mass	**m^2/g**	0.453	0.113	0.017	0.004		Calculated (area/mass)
Suspended Sediment - Mass and Surface Area Parameters								
Green River Suspended Solids	**Mass**	**MT**	3,340,800	835,300	575,900	1,515,200	6,267,200	STM modeled values entering the LDW (QEA 2009[b])
		%	53%	13%	9%	24%	100%	
	Surface Area	**km^2**	1,512,815	94,562	10,030	6,353	1,623,761	Calculated (Green River Mass * Unit Area per Mass)
		%	93%	6%	1%	0.4%	100%	
Suspended Solids Exiting the LDW (entering the East and West Waterways)	**Mass**	**MT**	3,013,100	198,100	24,000	1,600	3,236,800	STM modeled values exiting the LDW (QEA 2009[b])
		%	93%	6%	1%	0.05%	100%	
	Surface Area	**km^2**	1,364,423	22,426	418	7	1,387,274	Calculated (Exiting the LDW Mass * Unit Area per Mass)
		%	98%	2%	0.03%	0.0005%	100%	
Suspended Sediment - Concentration Parameters								
Green River Suspended Solids	**Total PCBs**	**µg/kg**	29.7	7.4	1.1	0.3	17.0	Total concentration is input (17 µg/kg) from the average of Green River suspended solids in the dataset. Concentration by size class was calculated from the concentration times the percent volume divided by the percent mass for that size class.
Suspended Solids Entering the EW							**28.2**	Concentration by size class is assumed to be unchanged from the Green River suspended solids. The total concentration is the mass-weighted average of size class concentrations entering the EW.
Green River Suspended Solids	**Dioxins/Furan TEQ**	**ng/kg**	10.7	2.7	0.4	0.1	6.1	Same methodology as for Total PCBs but with a different input (6.1 ng/kg).
Suspended Solids Entering the EW							**10.1**	Same methodology as for Total PCBs but with a different value.

Table A-1
Surface Area Particle Size Adjustment Calculation

Notes:

a. QEA (Quantitative Environmental Analysis), 2008. *Lower Duwamish Waterway Sediment Transport Modeling (STM) Report, Final* . Prepared for USEPA, Region 10, and the Washington State Department of Ecology. Quantitative Environmental Analysis, Montvale, NJ. October 2008.

b. QEA 2009. LDW STM Group Meeting Comparison of Original and Re-Calibrated STM Presentation. September 28, 2009.

Light blue shading indicates calculated surface area adjusted value
µg/kg: micrograms per kilogram
µm: micron
EW: East Waterway
g: gram
kg: kilogram
km^2: square kilometer
LDW: Lower Duwamish Waterway
m^2: square meter
m^3: cubic meter
MT: metric ton
n/a: not applicable
ng/kg: nanograms per kilogram
PCB: polychlorinated biphenyl
STM: sediment transport modeling

Figures

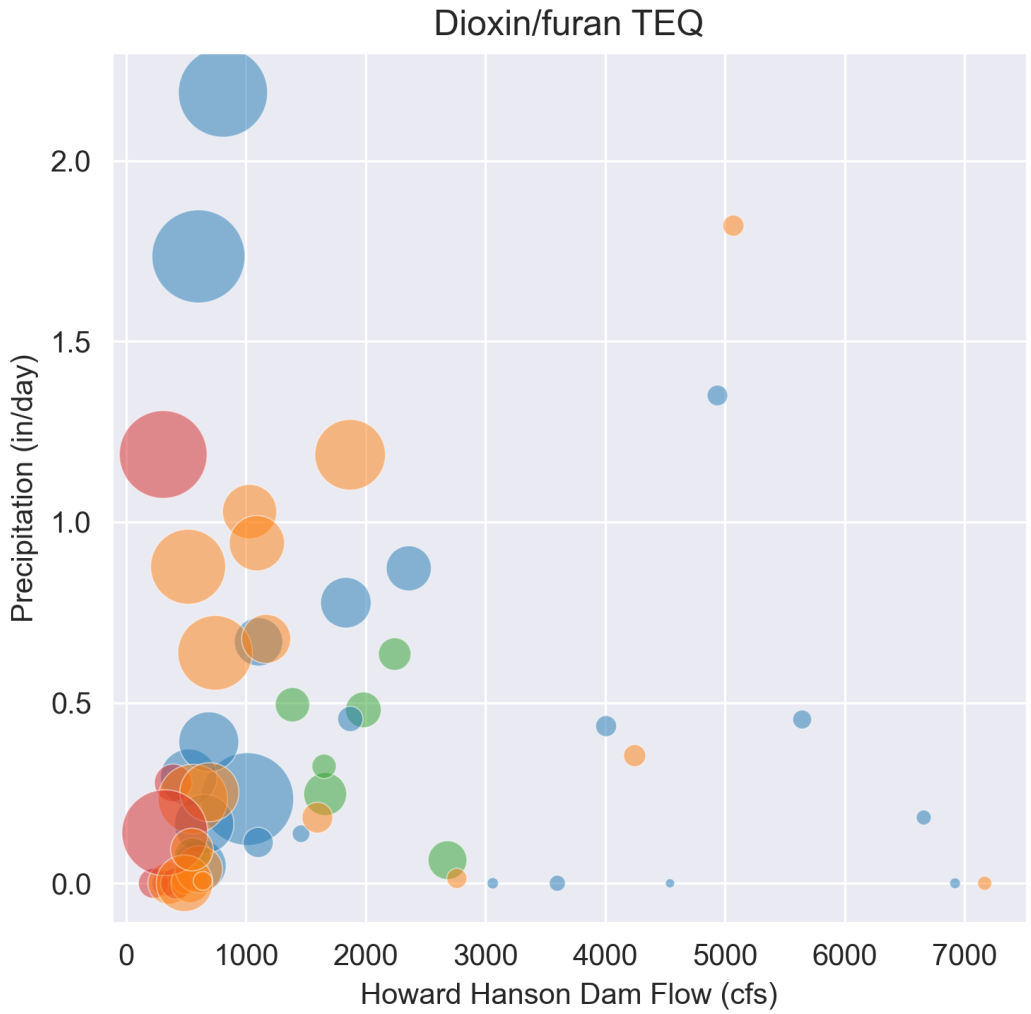
Notes

1. Total PCBs are based on congener data (no Aroclors)
2. Data includes centrifuge and filter solids (no sediment traps).
3. Precipitation is the average during and 8 hours before the start of sampling from the King County Tukwila rainfall gauge, (ID TUKW; RM 13.8)
4. Howard Hanson Dam flow is based on the flow at USGS station 12105900 below the Howard Hanson dam (RM 63).

Filepath: \\fuji\anchor\Projects\Port of Seattle\060003-01 East WW SRI_FS\PP ROD\Anthropogenic\EPA Memo\Appdx A - Supporting Evaluations\Figures\Figure_A-1 thru A-3_07-15-2021.docx

ANCHOR QEA

Figure A-1
Green River Suspended Solids Total PCBs Concentrations with Flow and Precipitation Conditions



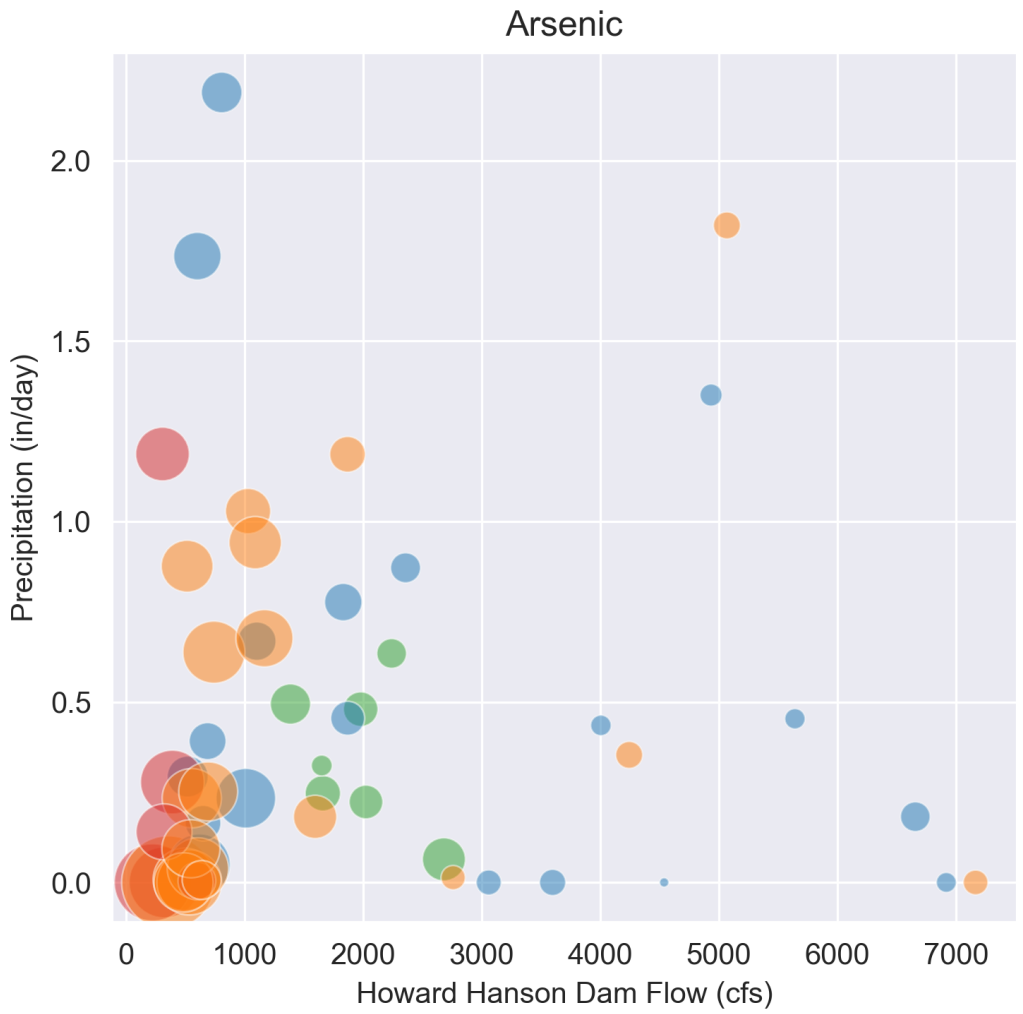
Notes

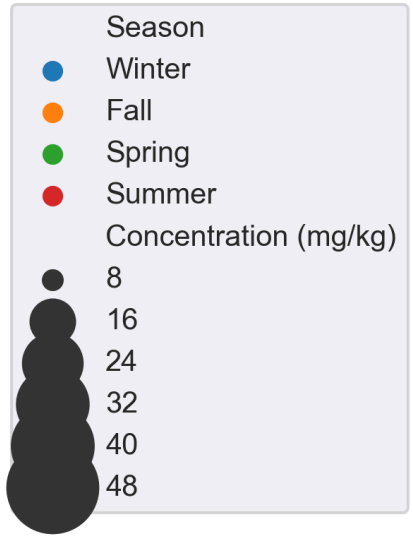
1. Data includes centrifuge and filter solids (no sediment traps)
2. Precipitation is the average during and 8 hours before the start of sampling from the King County Tukwila rainfall gauge, (ID TUKW; RM 13.8)
3. Howard Hanson Dam flow is based on the flow at USGS station 12105900 below the Howard Hanson dam (RM 63).

Filepath: \\fuji\anchor\Projects\Port of Seattle\060003-01 East WW SRI_FS\PP ROD\Anthropogenic\EPA Memo\Appdx A - Supporting Evaluations\Figures\Figure_A-1 thru A-3_07-15-2021.docx

ANCHOR QEA

Figure A-2
Green River Suspended Solids Dioxin/Furan TEQ Concentrations with Flow and Precipitation Conditions





Notes

1. Data includes centrifuge and filter solids (no sediment traps)
2. Precipitation is the average during and 8 hours before the start of sampling from the King County Tukwila rainfall gauge, (ID TUKW; RM 13.8)
3. Howard Hanson Dam flow is based on the flow at USGS station 12105900 below the Howard Hanson dam (RM 63).

Filepath: \\fuji\anchor\Projects\Port of Seattle\060003-01 East WW SRI_FS\PP ROD\Anthropogenic\EPA Memo\Appdx A - Supporting Evaluations\Figures\Figure_A-1 thru A-3_07-15-2021.docx

ANCHOR QEA

Figure A-3
Green River Suspended Solids Arsenic Concentrations with Flow and Precipitation Conditions

Final Anthropogenic Background Evaluation
East Waterway Operable Unit SRI/FS

Appendix B
Anthropogenic Background Dataset

Table B-1
Anthropogenic Background Data Set

Research Lead	Sample Name	Sampling Method	Chemical	Value	Unit	Detected
USGS	201501061230SS	Centrifuge	1,2,3,7,8-PeCDD	0.252	ng/kg fines norm	Yes
USGS	201501081130SS	Centrifuge	1,2,3,7,8-PeCDD	0.319	ng/kg fines norm	Yes
USGS	201501052200SS	Centrifuge	1,2,3,7,8-PeCDD	0.371	ng/kg fines norm	Yes
USGS	201411260930SS	Centrifuge	1,2,3,7,8-PeCDD	0.372	ng/kg fines norm	Yes
USGS	201703141130SS	Centrifuge	1,2,3,7,8-PeCDD	0.379	ng/kg fines norm	Yes
USGS	201412221230SS	Centrifuge	1,2,3,7,8-PeCDD	0.435	ng/kg fines norm	Yes
USGS	201403061400SS	Centrifuge	1,2,3,7,8-PeCDD	0.447	ng/kg fines norm	Yes
USGS	201302070930SS	Centrifuge	1,2,3,7,8-PeCDD	0.474	ng/kg fines norm	Yes
USGS	201402141230SS	Centrifuge	1,2,3,7,8-PeCDD	0.555	ng/kg fines norm	Yes
ECY	8414183-Centrifuge_Sediment	Centrifuge	1,2,3,7,8-PeCDD	0.573	ng/kg fines norm	No
USGS	201609271130SS	Centrifuge	1,2,3,7,8-PeCDD	0.623	ng/kg fines norm	Yes
ECY	8474280-Centrifuge_Sediment	Centrifuge	1,2,3,7,8-PeCDD	0.632	ng/kg fines norm	No
KC	L58537-2	Filter Solids	1,2,3,7,8-PeCDD	0.632	ng/kg fines norm	Yes
USGS	201411251300SS	Centrifuge	1,2,3,7,8-PeCDD	0.643	ng/kg fines norm	Yes
USGS	201404151500SS	Centrifuge	1,2,3,7,8-PeCDD	0.651	ng/kg fines norm	Yes
ECY	0901022-16-Centrifuge_Sediment	Centrifuge	1,2,3,7,8-PeCDD	0.653	ng/kg fines norm	No
ECY	8514030-Centrifuge_Sediment	Centrifuge	1,2,3,7,8-PeCDD	0.664	ng/kg fines norm	No
KC	L59919-1	Filter Solids	1,2,3,7,8-PeCDD	0.664	ng/kg fines norm	Yes
KC	L61568-1	Filter Solids	1,2,3,7,8-PeCDD	0.719	ng/kg fines norm	No
USGS	201303131400SS	Centrifuge	1,2,3,7,8-PeCDD	0.774	ng/kg fines norm	Yes
USGS	201410261000SS	Centrifuge	1,2,3,7,8-PeCDD	0.816	ng/kg fines norm	Yes
KC	L63181-1	Filter Solids	1,2,3,7,8-PeCDD	0.847	ng/kg fines norm	No
USGS	201304051100SS	Centrifuge	1,2,3,7,8-PeCDD	0.946	ng/kg fines norm	Yes
USGS	201608301200SS	Centrifuge	1,2,3,7,8-PeCDD	0.948	ng/kg fines norm	Yes
USGS	201609170900SS	Centrifuge	1,2,3,7,8-PeCDD	0.955	ng/kg fines norm	Yes
KC	L64265-1	Filter Solids	1,2,3,7,8-PeCDD	0.984	ng/kg fines norm	Yes
USGS	201406091430SS	Centrifuge	1,2,3,7,8-PeCDD	1.03	ng/kg fines norm	Yes
KC	L57792-1	Filter Solids	1,2,3,7,8-PeCDD	1.21	ng/kg fines norm	No

Table B-1
Anthropogenic Background Data Set

Research Lead	Sample Name	Sampling Method	Chemical	Value	Unit	Detected
USGS	201410081100SS	Centrifuge	1,2,3,7,8-PeCDD	1.23	ng/kg fines norm	Yes
KC	L57732-1	Filter Solids	1,2,3,7,8-PeCDD	1.38	ng/kg fines norm	Yes
USGS	201401111230SS	Centrifuge	1,2,3,7,8-PeCDD	1.40	ng/kg fines norm	Yes
USGS	201502051430SS	Centrifuge	1,2,3,7,8-PeCDD	1.50	ng/kg fines norm	Yes
USGS	201701111030SS	Centrifuge	1,2,3,7,8-PeCDD	1.57	ng/kg fines norm	Yes
KC	L63858-1	Filter Solids	1,2,3,7,8-PeCDD	1.78	ng/kg fines norm	Yes
USGS	201411201030SS	Centrifuge	1,2,3,7,8-PeCDD	1.88	ng/kg fines norm	Yes
USGS	201410231430SS	Centrifuge	1,2,3,7,8-PeCDD	1.90	ng/kg fines norm	Yes
USGS	201304081300SS	Centrifuge	1,2,3,7,8-PeCDD	1.92	ng/kg fines norm	Yes
USGS	201703071130SS	Centrifuge	1,2,3,7,8-PeCDD	2.02	ng/kg fines norm	Yes
USGS	201502261330SS	Centrifuge	1,2,3,7,8-PeCDD	2.06	ng/kg fines norm	Yes
USGS	201612201200SS	Centrifuge	1,2,3,7,8-PeCDD	2.12	ng/kg fines norm	Yes
USGS	201703031030SS	Centrifuge	1,2,3,7,8-PeCDD	2.42	ng/kg fines norm	Yes
USGS	201610131130SS	Centrifuge	1,2,3,7,8-PeCDD	2.46	ng/kg fines norm	Yes
USGS	201402181230SS	Centrifuge	1,2,3,7,8-PeCDD	2.66	ng/kg fines norm	Yes
ECY	8404073-Centrifuge_Sediment	Centrifuge	1,2,3,7,8-PeCDD	2.67	ng/kg fines norm	Yes
USGS	201610070930SS	Centrifuge	1,2,3,7,8-PeCDD	2.76	ng/kg fines norm	Yes
KC	L57634-1	Filter Solids	1,2,3,7,8-PeCDD	2.96	ng/kg fines norm	No
USGS	201410221300SS	Centrifuge	1,2,3,7,8-PeCDD	3.20	ng/kg fines norm	Yes
ECY	8354130-Centrifuge_Sediment	Centrifuge	1,2,3,7,8-PeCDD	3.55	ng/kg fines norm	Yes
USGS	201409241230SS	Centrifuge	1,2,3,7,8-PeCDD	3.80	ng/kg fines norm	Yes
USGS	201407231230SS	Centrifuge	1,2,3,7,8-PeCDD	4.29	ng/kg fines norm	Yes
USGS	201701181330SS	Centrifuge	1,2,3,7,8-PeCDD	4.65	ng/kg fines norm	Yes
USGS	201702091145SS	Centrifuge	1,2,3,7,8-PeCDD	4.77	ng/kg fines norm	Yes
USGS	201410311100SS	Centrifuge	1,2,3,7,8-PeCDD	6.40	ng/kg fines norm	Yes
KC	L57495-1	Filter Solids	1,2,3,7,8-PeCDD	7.83	ng/kg fines norm	Yes
USGS	201501081130SS	Centrifuge	2,3,4,7,8-PeCDF	0.111	ng/kg fines norm	Yes
USGS	201501061230SS	Centrifuge	2,3,4,7,8-PeCDF	0.206	ng/kg fines norm	Yes

Table B-1
Anthropogenic Background Data Set

Research Lead	Sample Name	Sampling Method	Chemical	Value	Unit	Detected
USGS	201501052200SS	Centrifuge	2,3,4,7,8-PeCDF	0.210	ng/kg fines norm	Yes
USGS	201412221230SS	Centrifuge	2,3,4,7,8-PeCDF	0.225	ng/kg fines norm	Yes
USGS	201703141130SS	Centrifuge	2,3,4,7,8-PeCDF	0.231	ng/kg fines norm	Yes
USGS	201302070930SS	Centrifuge	2,3,4,7,8-PeCDF	0.292	ng/kg fines norm	Yes
USGS	201411260930SS	Centrifuge	2,3,4,7,8-PeCDF	0.301	ng/kg fines norm	Yes
USGS	201609271130SS	Centrifuge	2,3,4,7,8-PeCDF	0.316	ng/kg fines norm	Yes
USGS	201402141230SS	Centrifuge	2,3,4,7,8-PeCDF	0.321	ng/kg fines norm	Yes
USGS	201403061400SS	Centrifuge	2,3,4,7,8-PeCDF	0.331	ng/kg fines norm	Yes
USGS	201404151500SS	Centrifuge	2,3,4,7,8-PeCDF	0.374	ng/kg fines norm	Yes
USGS	201411251300SS	Centrifuge	2,3,4,7,8-PeCDF	0.391	ng/kg fines norm	Yes
KC	L59919-1	Filter Solids	2,3,4,7,8-PeCDF	0.410	ng/kg fines norm	Yes
USGS	201406091430SS	Centrifuge	2,3,4,7,8-PeCDF	0.446	ng/kg fines norm	Yes
USGS	201303131400SS	Centrifuge	2,3,4,7,8-PeCDF	0.456	ng/kg fines norm	Yes
USGS	201608301200SS	Centrifuge	2,3,4,7,8-PeCDF	0.481	ng/kg fines norm	Yes
KC	L58537-2	Filter Solids	2,3,4,7,8-PeCDF	0.533	ng/kg fines norm	No
USGS	201410261000SS	Centrifuge	2,3,4,7,8-PeCDF	0.552	ng/kg fines norm	Yes
KC	L64265-1	Filter Solids	2,3,4,7,8-PeCDF	0.557	ng/kg fines norm	Yes
USGS	201304051100SS	Centrifuge	2,3,4,7,8-PeCDF	0.564	ng/kg fines norm	Yes
ECY	8414183-Centrifuge_Sediment	Centrifuge	2,3,4,7,8-PeCDF	0.596	ng/kg fines norm	Yes
ECY	8474280-Centrifuge_Sediment	Centrifuge	2,3,4,7,8-PeCDF	0.632	ng/kg fines norm	No
ECY	0901022-16-Centrifuge_Sediment	Centrifuge	2,3,4,7,8-PeCDF	0.653	ng/kg fines norm	No
USGS	201401111230SS	Centrifuge	2,3,4,7,8-PeCDF	0.653	ng/kg fines norm	Yes
ECY	8514030-Centrifuge_Sediment	Centrifuge	2,3,4,7,8-PeCDF	0.664	ng/kg fines norm	No
USGS	201502051430SS	Centrifuge	2,3,4,7,8-PeCDF	0.713	ng/kg fines norm	Yes
KC	L63181-1	Filter Solids	2,3,4,7,8-PeCDF	0.749	ng/kg fines norm	Yes
ECY	8404073-Centrifuge_Sediment	Centrifuge	2,3,4,7,8-PeCDF	0.809	ng/kg fines norm	Yes
USGS	201411201030SS	Centrifuge	2,3,4,7,8-PeCDF	0.861	ng/kg fines norm	Yes
USGS	201701111030SS	Centrifuge	2,3,4,7,8-PeCDF	0.911	ng/kg fines norm	Yes

Table B-1
Anthropogenic Background Data Set

Research Lead	Sample Name	Sampling Method	Chemical	Value	Unit	Detected
KC	L63858-1	Filter Solids	2,3,4,7,8-PeCDF	0.917	ng/kg fines norm	Yes
USGS	2016091709005S	Centrifuge	2,3,4,7,8-PeCDF	0.924	ng/kg fines norm	Yes
USGS	2013040813005S	Centrifuge	2,3,4,7,8-PeCDF	0.991	ng/kg fines norm	Yes
KC	L57634-1	Filter Solids	2,3,4,7,8-PeCDF	1.00	ng/kg fines norm	No
USGS	2014103111005S	Centrifuge	2,3,4,7,8-PeCDF	1.07	ng/kg fines norm	Yes
USGS	2014102314305S	Centrifuge	2,3,4,7,8-PeCDF	1.10	ng/kg fines norm	Yes
USGS	2014100811005S	Centrifuge	2,3,4,7,8-PeCDF	1.10	ng/kg fines norm	Yes
KC	L57732-1	Filter Solids	2,3,4,7,8-PeCDF	1.12	ng/kg fines norm	No
USGS	2017030310305S	Centrifuge	2,3,4,7,8-PeCDF	1.15	ng/kg fines norm	Yes
USGS	2016101311305S	Centrifuge	2,3,4,7,8-PeCDF	1.20	ng/kg fines norm	Yes
USGS	2015022613305S	Centrifuge	2,3,4,7,8-PeCDF	1.39	ng/kg fines norm	Yes
USGS	2016122012005S	Centrifuge	2,3,4,7,8-PeCDF	1.45	ng/kg fines norm	Yes
USGS	2014021812305S	Centrifuge	2,3,4,7,8-PeCDF	1.49	ng/kg fines norm	Yes
USGS	2017030711305S	Centrifuge	2,3,4,7,8-PeCDF	1.49	ng/kg fines norm	Yes
KC	L61568-1	Filter Solids	2,3,4,7,8-PeCDF	1.54	ng/kg fines norm	No
KC	L57792-1	Filter Solids	2,3,4,7,8-PeCDF	1.61	ng/kg fines norm	No
ECY	8354130-Centrifuge_Sediment	Centrifuge	2,3,4,7,8-PeCDF	1.77	ng/kg fines norm	Yes
USGS	2016100709305S	Centrifuge	2,3,4,7,8-PeCDF	1.96	ng/kg fines norm	Yes
USGS	2014102213005S	Centrifuge	2,3,4,7,8-PeCDF	2.23	ng/kg fines norm	Yes
USGS	2017020911455S	Centrifuge	2,3,4,7,8-PeCDF	2.92	ng/kg fines norm	Yes
USGS	2014092412305S	Centrifuge	2,3,4,7,8-PeCDF	3.00	ng/kg fines norm	Yes
USGS	2014072312305S	Centrifuge	2,3,4,7,8-PeCDF	3.14	ng/kg fines norm	Yes
USGS	2017011813305S	Centrifuge	2,3,4,7,8-PeCDF	3.16	ng/kg fines norm	Yes
KC	L57495-1	Filter Solids	2,3,4,7,8-PeCDF	7.52	ng/kg fines norm	No
KC	L61568-1	Filter Solids	2,3,7,8-TCDD	0.0423	ng/kg fines norm	No
USGS	2013020709305S	Centrifuge	2,3,7,8-TCDD	0.200	ng/kg fines norm	Yes
USGS	2015010811305S	Centrifuge	2,3,7,8-TCDD	0.206	ng/kg fines norm	Yes
USGS	2014112609305S	Centrifuge	2,3,7,8-TCDD	0.213	ng/kg fines norm	Yes

Table B-1
Anthropogenic Background Data Set

Research Lead	Sample Name	Sampling Method	Chemical	Value	Unit	Detected
USGS	201412221230SS	Centrifuge	2,3,7,8-TCDD	0.222	ng/kg fines norm	Yes
USGS	20150105220OSS	Centrifuge	2,3,7,8-TCDD	0.238	ng/kg fines norm	Yes
ECY	0901022-16-Centrifuge_Sediment	Centrifuge	2,3,7,8-TCDD	0.261	ng/kg fines norm	No
ECY	8514030-Centrifuge_Sediment	Centrifuge	2,3,7,8-TCDD	0.265	ng/kg fines norm	No
USGS	201703141130SS	Centrifuge	2,3,7,8-TCDD	0.280	ng/kg fines norm	Yes
USGS	201411251300SS	Centrifuge	2,3,7,8-TCDD	0.294	ng/kg fines norm	Yes
USGS	201608301200SS	Centrifuge	2,3,7,8-TCDD	0.310	ng/kg fines norm	No
USGS	201403061400SS	Centrifuge	2,3,7,8-TCDD	0.310	ng/kg fines norm	Yes
KC	L58537-2	Filter Solids	2,3,7,8-TCDD	0.314	ng/kg fines norm	Yes
USGS	201304051100SS	Centrifuge	2,3,7,8-TCDD	0.315	ng/kg fines norm	No
USGS	201501061230SS	Centrifuge	2,3,7,8-TCDD	0.317	ng/kg fines norm	Yes
KC	L63181-1	Filter Solids	2,3,7,8-TCDD	0.319	ng/kg fines norm	No
KC	L63858-1	Filter Solids	2,3,7,8-TCDD	0.320	ng/kg fines norm	No
USGS	201402141230SS	Centrifuge	2,3,7,8-TCDD	0.323	ng/kg fines norm	Yes
USGS	201410261000SS	Centrifuge	2,3,7,8-TCDD	0.330	ng/kg fines norm	Yes
USGS	201303131400SS	Centrifuge	2,3,7,8-TCDD	0.333	ng/kg fines norm	Yes
KC	L59919-1	Filter Solids	2,3,7,8-TCDD	0.339	ng/kg fines norm	Yes
USGS	201404151500SS	Centrifuge	2,3,7,8-TCDD	0.349	ng/kg fines norm	Yes
USGS	201502051430SS	Centrifuge	2,3,7,8-TCDD	0.382	ng/kg fines norm	Yes
USGS	201401111230SS	Centrifuge	2,3,7,8-TCDD	0.383	ng/kg fines norm	Yes
KC	L64265-1	Filter Solids	2,3,7,8-TCDD	0.388	ng/kg fines norm	No
USGS	201609271130SS	Centrifuge	2,3,7,8-TCDD	0.392	ng/kg fines norm	Yes
USGS	201612201200SS	Centrifuge	2,3,7,8-TCDD	0.404	ng/kg fines norm	No
USGS	201406091430SS	Centrifuge	2,3,7,8-TCDD	0.407	ng/kg fines norm	Yes
KC	L57732-1	Filter Solids	2,3,7,8-TCDD	0.461	ng/kg fines norm	No
USGS	201609170900SS	Centrifuge	2,3,7,8-TCDD	0.488	ng/kg fines norm	Yes
USGS	201411201030SS	Centrifuge	2,3,7,8-TCDD	0.496	ng/kg fines norm	Yes
USGS	201410231430SS	Centrifuge	2,3,7,8-TCDD	0.528	ng/kg fines norm	Yes

Table B-1
Anthropogenic Background Data Set

Research Lead	Sample Name	Sampling Method	Chemical	Value	Unit	Detected
USGS	201703031030SS	Centrifuge	2,3,7,8-TCDD	0.548	ng/kg fines norm	Yes
USGS	201304081300SS	Centrifuge	2,3,7,8-TCDD	0.591	ng/kg fines norm	Yes
USGS	201701111030SS	Centrifuge	2,3,7,8-TCDD	0.629	ng/kg fines norm	Yes
USGS	201410081100SS	Centrifuge	2,3,7,8-TCDD	0.639	ng/kg fines norm	Yes
USGS	201610131130SS	Centrifuge	2,3,7,8-TCDD	0.660	ng/kg fines norm	Yes
USGS	201402181230SS	Centrifuge	2,3,7,8-TCDD	0.682	ng/kg fines norm	Yes
USGS	201502261330SS	Centrifuge	2,3,7,8-TCDD	0.690	ng/kg fines norm	Yes
USGS	201703071130SS	Centrifuge	2,3,7,8-TCDD	0.804	ng/kg fines norm	Yes
USGS	201702091145SS	Centrifuge	2,3,7,8-TCDD	0.927	ng/kg fines norm	Yes
KC	L57634-1	Filter Solids	2,3,7,8-TCDD	0.929	ng/kg fines norm	No
ECY	8474280-Centrifuge_Sediment	Centrifuge	2,3,7,8-TCDD	0.973	ng/kg fines norm	Yes
USGS	201610070930SS	Centrifuge	2,3,7,8-TCDD	1.02	ng/kg fines norm	Yes
USGS	201410311100SS	Centrifuge	2,3,7,8-TCDD	1.15	ng/kg fines norm	Yes
USGS	201407231230SS	Centrifuge	2,3,7,8-TCDD	1.15	ng/kg fines norm	Yes
ECY	8404073-Centrifuge_Sediment	Centrifuge	2,3,7,8-TCDD	1.30	ng/kg fines norm	Yes
USGS	201701181330SS	Centrifuge	2,3,7,8-TCDD	1.32	ng/kg fines norm	Yes
USGS	201410221300SS	Centrifuge	2,3,7,8-TCDD	1.35	ng/kg fines norm	Yes
USGS	201409241230SS	Centrifuge	2,3,7,8-TCDD	1.54	ng/kg fines norm	Yes
KC	L57792-1	Filter Solids	2,3,7,8-TCDD	1.60	ng/kg fines norm	Yes
ECY	8354130-Centrifuge_Sediment	Centrifuge	2,3,7,8-TCDD	1.75	ng/kg fines norm	Yes
ECY	8414183-Centrifuge_Sediment	Centrifuge	2,3,7,8-TCDD	1.93	ng/kg fines norm	Yes
KC	L57495-1	Filter Solids	2,3,7,8-TCDD	2.53	ng/kg fines norm	No
USGS	201501081130SS	Centrifuge	2,3,7,8-TCDF	0.100	ng/kg fines norm	Yes
USGS	201501061230SS	Centrifuge	2,3,7,8-TCDF	0.119	ng/kg fines norm	Yes
USGS	201412221230SS	Centrifuge	2,3,7,8-TCDF	0.134	ng/kg fines norm	Yes
USGS	201501052200SS	Centrifuge	2,3,7,8-TCDF	0.149	ng/kg fines norm	Yes
USGS	201411260930SS	Centrifuge	2,3,7,8-TCDF	0.185	ng/kg fines norm	Yes
USGS	201703141130SS	Centrifuge	2,3,7,8-TCDF	0.196	ng/kg fines norm	Yes

Table B-1
Anthropogenic Background Data Set

Research Lead	Sample Name	Sampling Method	Chemical	Value	Unit	Detected
ECY	8404073-Centrifuge_Sediment	Centrifuge	2,3,7,8-TCDF	0.228	ng/kg fines norm	No
USGS	2013020709305S	Centrifuge	2,3,7,8-TCDF	0.251	ng/kg fines norm	Yes
ECY	8514030-Centrifuge_Sediment	Centrifuge	2,3,7,8-TCDF	0.265	ng/kg fines norm	No
USGS	2014030614005S	Centrifuge	2,3,7,8-TCDF	0.278	ng/kg fines norm	Yes
USGS	2014021412305S	Centrifuge	2,3,7,8-TCDF	0.288	ng/kg fines norm	Yes
USGS	2014112513005S	Centrifuge	2,3,7,8-TCDF	0.293	ng/kg fines norm	Yes
ECY	8474280-Centrifuge_Sediment	Centrifuge	2,3,7,8-TCDF	0.316	ng/kg fines norm	Yes
USGS	2014102610005S	Centrifuge	2,3,7,8-TCDF	0.323	ng/kg fines norm	Yes
USGS	2014041515005S	Centrifuge	2,3,7,8-TCDF	0.386	ng/kg fines norm	Yes
USGS	2013040511005S	Centrifuge	2,3,7,8-TCDF	0.387	ng/kg fines norm	Yes
KC	L59919-1	Filter Solids	2,3,7,8-TCDF	0.417	ng/kg fines norm	Yes
KC	L64265-1	Filter Solids	2,3,7,8-TCDF	0.431	ng/kg fines norm	Yes
USGS	2013031314005S	Centrifuge	2,3,7,8-TCDF	0.433	ng/kg fines norm	Yes
USGS	2016092711305S	Centrifuge	2,3,7,8-TCDF	0.455	ng/kg fines norm	Yes
ECY	0901022-16-Centrifuge_Sediment	Centrifuge	2,3,7,8-TCDF	0.562	ng/kg fines norm	Yes
USGS	2016083012005S	Centrifuge	2,3,7,8-TCDF	0.570	ng/kg fines norm	Yes
USGS	2014011112305S	Centrifuge	2,3,7,8-TCDF	0.587	ng/kg fines norm	Yes
KC	L58537-2	Filter Solids	2,3,7,8-TCDF	0.588	ng/kg fines norm	Yes
USGS	2017011110305S	Centrifuge	2,3,7,8-TCDF	0.736	ng/kg fines norm	Yes
USGS	2015020514305S	Centrifuge	2,3,7,8-TCDF	0.737	ng/kg fines norm	Yes
USGS	2016091709005S	Centrifuge	2,3,7,8-TCDF	0.749	ng/kg fines norm	Yes
ECY	8354130-Centrifuge_Sediment	Centrifuge	2,3,7,8-TCDF	0.769	ng/kg fines norm	Yes
USGS	2014112010305S	Centrifuge	2,3,7,8-TCDF	0.785	ng/kg fines norm	Yes
USGS	2014102314305S	Centrifuge	2,3,7,8-TCDF	0.806	ng/kg fines norm	Yes
USGS	2013040813005S	Centrifuge	2,3,7,8-TCDF	0.830	ng/kg fines norm	Yes
KC	L57732-1	Filter Solids	2,3,7,8-TCDF	0.833	ng/kg fines norm	No
USGS	2017030310305S	Centrifuge	2,3,7,8-TCDF	0.845	ng/kg fines norm	Yes
USGS	2017030711305S	Centrifuge	2,3,7,8-TCDF	0.980	ng/kg fines norm	Yes

Table B-1
Anthropogenic Background Data Set

Research Lead	Sample Name	Sampling Method	Chemical	Value	Unit	Detected
USGS	201410311100SS	Centrifuge	2,3,7,8-TCDF	1.03	ng/kg fines norm	Yes
KC	L63858-1	Filter Solids	2,3,7,8-TCDF	1.10	ng/kg fines norm	No
USGS	201406091430SS	Centrifuge	2,3,7,8-TCDF	1.13	ng/kg fines norm	No
USGS	201502261330SS	Centrifuge	2,3,7,8-TCDF	1.16	ng/kg fines norm	Yes
USGS	201612201200SS	Centrifuge	2,3,7,8-TCDF	1.20	ng/kg fines norm	Yes
USGS	201402181230SS	Centrifuge	2,3,7,8-TCDF	1.21	ng/kg fines norm	Yes
USGS	201610131130SS	Centrifuge	2,3,7,8-TCDF	1.27	ng/kg fines norm	Yes
KC	L63181-1	Filter Solids	2,3,7,8-TCDF	1.32	ng/kg fines norm	Yes
USGS	201410221300SS	Centrifuge	2,3,7,8-TCDF	1.32	ng/kg fines norm	Yes
KC	L57634-1	Filter Solids	2,3,7,8-TCDF	1.39	ng/kg fines norm	No
KC	L57792-1	Filter Solids	2,3,7,8-TCDF	1.51	ng/kg fines norm	No
USGS	201610070930SS	Centrifuge	2,3,7,8-TCDF	1.64	ng/kg fines norm	Yes
USGS	201410081100SS	Centrifuge	2,3,7,8-TCDF	1.86	ng/kg fines norm	No
KC	L61568-1	Filter Solids	2,3,7,8-TCDF	2.13	ng/kg fines norm	Yes
USGS	201702091145SS	Centrifuge	2,3,7,8-TCDF	2.15	ng/kg fines norm	Yes
ECY	8414183-Centrifuge_Sediment	Centrifuge	2,3,7,8-TCDF	2.20	ng/kg fines norm	Yes
USGS	201701181330SS	Centrifuge	2,3,7,8-TCDF	2.51	ng/kg fines norm	Yes
USGS	201407231230SS	Centrifuge	2,3,7,8-TCDF	2.63	ng/kg fines norm	Yes
USGS	201409241230SS	Centrifuge	2,3,7,8-TCDF	3.78	ng/kg fines norm	Yes
KC	L57495-1	Filter Solids	2,3,7,8-TCDF	5.96	ng/kg fines norm	Yes
USGS	201501081130SS	Centrifuge	Arsenic	6.60	mg/kg	Yes
USGS	201501061230SS	Centrifuge	Arsenic	8.20	mg/kg	Yes
USGS	201403061400SS	Centrifuge	Arsenic	8.30	mg/kg	Yes
USGS	201703141130SS	Centrifuge	Arsenic	8.34	mg/kg	Yes
USGS	201404151500SS	Centrifuge	Arsenic	8.40	mg/kg	Yes
KC	L59919-1	Filter Solids	Arsenic	8.71	mg/kg	Yes
ECY	8474280-Centrifuge_Sediment	Centrifuge	Arsenic	9.20	mg/kg	Yes
USGS	201411260930SS	Centrifuge	Arsenic	9.30	mg/kg	Yes

Table B-1
Anthropogenic Background Data Set

Research Lead	Sample Name	Sampling Method	Chemical	Value	Unit	Detected
ECY	0901022-16-Centrifuge_Sediment	Centrifuge	Arsenic	9.39	mg/kg	Yes
USGS	201412221230SS	Centrifuge	Arsenic	9.70	mg/kg	Yes
USGS	201411251300SS	Centrifuge	Arsenic	9.90	mg/kg	Yes
KC	L64265-1	Filter Solids	Arsenic	9.91	mg/kg	Yes
USGS	201501052200SS	Centrifuge	Arsenic	10.7	mg/kg	Yes
USGS	201304051100SS	Centrifuge	Arsenic	10.7	mg/kg	Yes
USGS	201401111230SS	Centrifuge	Arsenic	10.8	mg/kg	Yes
USGS	201305131400SS	Centrifuge	Arsenic	12.0	mg/kg	Yes
USGS	201402141230SS	Centrifuge	Arsenic	12.1	mg/kg	Yes
KC	L57732-1	Filter Solids	Arsenic	12.3	mg/kg	Yes
KC	L57634-1	Filter Solids	Arsenic	12.6	mg/kg	Yes
USGS	201703031030SS	Centrifuge	Arsenic	12.7	mg/kg	Yes
USGS	201410311100SS	Centrifuge	Arsenic	12.7	mg/kg	Yes
USGS	201703071130SS	Centrifuge	Arsenic	13.2	mg/kg	Yes
USGS	201402181230SS	Centrifuge	Arsenic	13.4	mg/kg	Yes
ECY	8354143-Centrifuge_Sediment	Centrifuge	Arsenic	13.5	mg/kg	Yes
USGS	201502051430SS	Centrifuge	Arsenic	13.8	mg/kg	Yes
ECY	8514030-Centrifuge_Sediment	Centrifuge	Arsenic	14.0	mg/kg	Yes
KC	L57792-1	Filter Solids	Arsenic	14.5	mg/kg	Yes
USGS	201702091145SS	Centrifuge	Arsenic	14.7	mg/kg	Yes
USGS	201502261330SS	Centrifuge	Arsenic	14.8	mg/kg	Yes
USGS	201304081300SS	Centrifuge	Arsenic	15.7	mg/kg	Yes
USGS	201410261000SS	Centrifuge	Arsenic	15.8	mg/kg	Yes
KC	L61568-1	Filter Solids	Arsenic	16.7	mg/kg	Yes
USGS	201701181330SS	Centrifuge	Arsenic	17.8	mg/kg	Yes
USGS	201409241230SS	Centrifuge	Arsenic	20.0	mg/kg	Yes
USGS	201610131130SS	Centrifuge	Arsenic	20.3	mg/kg	Yes
USGS	201407231230SS	Centrifuge	Arsenic	21.0	mg/kg	Yes

Table B-1
Anthropogenic Background Data Set

Research Lead	Sample Name	Sampling Method	Chemical	Value	Unit	Detected
ECY	8354130-Centrifuge_Sediment	Centrifuge	Arsenic	22.3	mg/kg	Yes
USGS	201410231430SS	Centrifuge	Arsenic	23.0	mg/kg	Yes
ECY	8414183-Centrifuge_Sediment	Centrifuge	Arsenic	23.6	mg/kg	Yes
USGS	201612201200SS	Centrifuge	Arsenic	24.1	mg/kg	Yes
USGS	201610070930SS	Centrifuge	Arsenic	24.3	mg/kg	Yes
ECY	8404073-Centrifuge_Sediment	Centrifuge	Arsenic	24.3	mg/kg	Yes
KC	L57495-1	Filter Solids	Arsenic	24.5	mg/kg	Yes
USGS	201411201030SS	Centrifuge	Arsenic	25.6	mg/kg	Yes
USGS	201701111030SS	Centrifuge	Arsenic	25.9	mg/kg	Yes
USGS	201410221300SS	Centrifuge	Arsenic	26.0	mg/kg	Yes
USGS	201609271130SS	Centrifuge	Arsenic	26.5	mg/kg	Yes
USGS	201609170900SS	Centrifuge	Arsenic	27.1	mg/kg	Yes
USGS	201410081100SS	Centrifuge	Arsenic	28.0	mg/kg	Yes
KC	L58537-2	Filter Solids	Arsenic	32.0	mg/kg	Yes
KC	L63181-1	Filter Solids	Arsenic	36.9	mg/kg	Yes
KC	L63858-1	Filter Solids	Arsenic	50.8	mg/kg	Yes
USGS	201501081130SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	1.00	ng/kg fines norm	Yes
ECY	0901022-16-Centrifuge_Sediment	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	1.08	ng/kg fines norm	Yes
USGS	201501061230SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	1.16	ng/kg fines norm	Yes
USGS	201412221230SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	1.45	ng/kg fines norm	Yes
USGS	201411260930SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	1.51	ng/kg fines norm	Yes
USGS	201501052200SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	1.55	ng/kg fines norm	Yes
USGS	201703141130SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	1.68	ng/kg fines norm	Yes
ECY	8514030-Centrifuge_Sediment	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	1.83	ng/kg fines norm	Yes
ECY	8474280-Centrifuge_Sediment	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	1.90	ng/kg fines norm	Yes
USGS	201403061400SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	2.05	ng/kg fines norm	Yes
USGS	201302070930SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	2.09	ng/kg fines norm	Yes
USGS	201404151500SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	2.52	ng/kg fines norm	Yes

Table B-1
Anthropogenic Background Data Set

Research Lead	Sample Name	Sampling Method	Chemical	Value	Unit	Detected
USGS	201402141230SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	2.53	ng/kg fines norm	Yes
KC	L59919-1	Filter Solids	Dioxin/furan TEQ - mammal (half DL)	2.54	ng/kg fines norm	Yes
USGS	201411251300SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	2.56	ng/kg fines norm	Yes
USGS	201609271130SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	2.75	ng/kg fines norm	Yes
KC	L58537-2	Filter Solids	Dioxin/furan TEQ - mammal (half DL)	2.81	ng/kg fines norm	Yes
KC	L64265-1	Filter Solids	Dioxin/furan TEQ - mammal (half DL)	3.27	ng/kg fines norm	Yes
USGS	201303131400SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	3.42	ng/kg fines norm	Yes
KC	L63181-1	Filter Solids	Dioxin/furan TEQ - mammal (half DL)	3.47	ng/kg fines norm	Yes
USGS	201410261000SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	3.50	ng/kg fines norm	Yes
USGS	201608301200SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	3.52	ng/kg fines norm	Yes
USGS	201406091430SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	4.47	ng/kg fines norm	Yes
USGS	201609170900SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	4.63	ng/kg fines norm	Yes
USGS	201410081100SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	5.05	ng/kg fines norm	Yes
USGS	201304051100SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	5.11	ng/kg fines norm	Yes
ECY	8414183-Centrifuge_Sediment	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	5.70	ng/kg fines norm	Yes
KC	L63858-1	Filter Solids	Dioxin/furan TEQ - mammal (half DL)	5.91	ng/kg fines norm	Yes
KC	L57792-1	Filter Solids	Dioxin/furan TEQ - mammal (half DL)	5.94	ng/kg fines norm	Yes
KC	L57732-1	Filter Solids	Dioxin/furan TEQ - mammal (half DL)	5.97	ng/kg fines norm	Yes
USGS	201401111230SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	6.40	ng/kg fines norm	Yes
USGS	201411201030SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	6.48	ng/kg fines norm	Yes
USGS	201502051430SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	6.65	ng/kg fines norm	Yes
USGS	201701111030SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	7.75	ng/kg fines norm	Yes
USGS	201410231430SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	7.88	ng/kg fines norm	Yes
KC	L57634-1	Filter Solids	Dioxin/furan TEQ - mammal (half DL)	9.42	ng/kg fines norm	Yes
ECY	8404073-Centrifuge_Sediment	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	9.51	ng/kg fines norm	Yes
USGS	201304081300SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	9.54	ng/kg fines norm	Yes
USGS	201703031030SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	9.59	ng/kg fines norm	Yes
USGS	201612201200SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	9.71	ng/kg fines norm	Yes

Table B-1
Anthropogenic Background Data Set

Research Lead	Sample Name	Sampling Method	Chemical	Value	Unit	Detected
USGS	201703071130SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	9.79	ng/kg fines norm	Yes
USGS	201502261330SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	10.4	ng/kg fines norm	Yes
KC	L61568-1	Filter Solids	Dioxin/furan TEQ - mammal (half DL)	10.9	ng/kg fines norm	Yes
USGS	201610131130SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	11.9	ng/kg fines norm	Yes
USGS	201402181230SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	12.1	ng/kg fines norm	Yes
USGS	201410311100SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	15.7	ng/kg fines norm	Yes
USGS	201410221300SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	17.4	ng/kg fines norm	Yes
USGS	201610070930SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	18.3	ng/kg fines norm	Yes
USGS	201409241230SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	18.8	ng/kg fines norm	Yes
ECY	8354130-Centrifuge_Sediment	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	19.8	ng/kg fines norm	Yes
USGS	201407231230SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	20.4	ng/kg fines norm	Yes
USGS	201702091145SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	21.0	ng/kg fines norm	Yes
USGS	201701181330SS	Centrifuge	Dioxin/furan TEQ - mammal (half DL)	22.8	ng/kg fines norm	Yes
KC	L57495-1	Filter Solids	Dioxin/furan TEQ - mammal (half DL)	34.8	ng/kg fines norm	Yes
USGS	201501081130SS	Centrifuge	Total PCB Congeners	0.669	µg/kg fines norm	Yes
USGS	201501061230SS	Centrifuge	Total PCB Congeners	0.970	µg/kg fines norm	Yes
USGS	201501052200SS	Centrifuge	Total PCB Congeners	1.16	µg/kg fines norm	Yes
USGS	201412221230SS	Centrifuge	Total PCB Congeners	1.31	µg/kg fines norm	Yes
USGS	201703141130SS	Centrifuge	Total PCB Congeners	2.12	µg/kg fines norm	Yes
USGS	201403061400SS	Centrifuge	Total PCB Congeners	3.01	µg/kg fines norm	Yes
USGS	201411251300SS	Centrifuge	Total PCB Congeners	3.43	µg/kg fines norm	Yes
USGS	201402141230SS	Centrifuge	Total PCB Congeners	3.72	µg/kg fines norm	Yes
USGS	201302070930SS	Centrifuge	Total PCB Congeners	3.98	µg/kg fines norm	Yes
KC	L59919-1	Filter Solids	Total PCB Congeners	4.01	µg/kg fines norm	Yes
KC	L64265-1	Filter Solids	Total PCB Congeners	4.47	µg/kg fines norm	Yes
USGS	201303131400SS	Centrifuge	Total PCB Congeners	4.91	µg/kg fines norm	Yes
USGS	201410261000SS	Centrifuge	Total PCB Congeners	4.93	µg/kg fines norm	Yes
USGS	201410081100SS	Centrifuge	Total PCB Congeners	6.08	µg/kg fines norm	Yes

Table B-1
Anthropogenic Background Data Set

Research Lead	Sample Name	Sampling Method	Chemical	Value	Unit	Detected
USGS	201404151500SS	Centrifuge	Total PCB Congeners	6.15	µg/kg fines norm	Yes
USGS	2013040511100SS	Centrifuge	Total PCB Congeners	6.90	µg/kg fines norm	Yes
USGS	20141126093OSS	Centrifuge	Total PCB Congeners	7.40	µg/kg fines norm	Yes
KC	L58537-2	Filter Solids	Total PCB Congeners	7.78	µg/kg fines norm	Yes
USGS	201608301200SS	Centrifuge	Total PCB Congeners	8.31	µg/kg fines norm	Yes
KC	L63181-1	Filter Solids	Total PCB Congeners	8.67	µg/kg fines norm	Yes
USGS	201701111030SS	Centrifuge	Total PCB Congeners	9.12	µg/kg fines norm	Yes
KC	L57792-1	Filter Solids	Total PCB Congeners	10.5	µg/kg fines norm	Yes
KC	L62291-1	Filter Solids	Total PCB Congeners	12.1	µg/kg fines norm	Yes
USGS	201304081300SS	Centrifuge	Total PCB Congeners	12.2	µg/kg fines norm	Yes
USGS	20141120103OSS	Centrifuge	Total PCB Congeners	12.3	µg/kg fines norm	Yes
KC	L57732-1	Filter Solids	Total PCB Congeners	12.6	µg/kg fines norm	Yes
KC	L63858-1	Filter Solids	Total PCB Congeners	12.7	µg/kg fines norm	Yes
USGS	201703031030SS	Centrifuge	Total PCB Congeners	13.6	µg/kg fines norm	Yes
USGS	201406091430SS	Centrifuge	Total PCB Congeners	13.8	µg/kg fines norm	Yes
USGS	201703071130SS	Centrifuge	Total PCB Congeners	14.9	µg/kg fines norm	Yes
USGS	201401111230SS	Centrifuge	Total PCB Congeners	15.6	µg/kg fines norm	Yes
USGS	201502051430SS	Centrifuge	Total PCB Congeners	15.8	µg/kg fines norm	Yes
USGS	201410311100SS	Centrifuge	Total PCB Congeners	16.5	µg/kg fines norm	Yes
USGS	201609170900SS	Centrifuge	Total PCB Congeners	17.7	µg/kg fines norm	Yes
USGS	201612201200SS	Centrifuge	Total PCB Congeners	18.4	µg/kg fines norm	Yes
KC	L57634-1	Filter Solids	Total PCB Congeners	21.5	µg/kg fines norm	Yes
USGS	201502261330SS	Centrifuge	Total PCB Congeners	21.7	µg/kg fines norm	Yes
USGS	201610131130SS	Centrifuge	Total PCB Congeners	28.8	µg/kg fines norm	Yes
USGS	201410231430SS	Centrifuge	Total PCB Congeners	31.5	µg/kg fines norm	Yes
USGS	201402181230SS	Centrifuge	Total PCB Congeners	31.7	µg/kg fines norm	Yes
USGS	201410221300SS	Centrifuge	Total PCB Congeners	37.2	µg/kg fines norm	Yes
USGS	201610070930SS	Centrifuge	Total PCB Congeners	43.4	µg/kg fines norm	Yes

Table B-1
Anthropogenic Background Data Set

Research Lead	Sample Name	Sampling Method	Chemical	Value	Unit	Detected
USGS	201409241230SS	Centrifuge	Total PCB Congeners	47.3	µg/kg fines norm	Yes
USGS	201701181330SS	Centrifuge	Total PCB Congeners	47.9	µg/kg fines norm	Yes
USGS	201702091145SS	Centrifuge	Total PCB Congeners	53.2	µg/kg fines norm	Yes
USGS	201407231230SS	Centrifuge	Total PCB Congeners	88.5	µg/kg fines norm	Yes
KC	L57495-1	Filter Solids	Total PCB Congeners	95.8	µg/kg fines norm	Yes
KC	L61568-1	Filter Solids	Total PCB Congeners	101	µg/kg fines norm	Yes
KC	L63997-1	Filter Solids	Total PCB Congeners	124	µg/kg fines norm	Yes

Notes:
µg/kg: micrograms per kilogram
ECY: Washington State Department of Ecology
KC: King County
mg/kg: milligrams per kilogram
ng/kg: nanograms per kilogram
USGS: U.S. Geological Survey
TEQ: toxic equivalent
PCB: polychlorinated biphenyl
DL: detection limit