Site Inspection Report
Lower Duwamish River (RK 2.5 to 11.5)
Seattle, Washington

Volume 1—Report and Appendices

CERCLIS NUMBERS
WA0002329803
WA0002329811
WA0002329829
WA0002329837
WA0002329845

EPA REGION 10

Contract No. 68-W9-0046
Work Assignment No. 46-23-0JZZ
Work Order No. 4000-19-38-4100
Document Control No. 4000-19-38-AAAL

April 1999

WESTON.

Dec 2, 1993 11:23 AM

Site Inspection Report

Lower Duwamish River (RK 2.5 to 11.5)
Seattle, Washington

Volume 1—Report and Appendices

SITE INSPECTION REPORT
LOWER DUWAMISH RIVER (RK 2.5 TO 11.5)
SEATTLE, WASHINGTON

VOLUME 1—REPORT AND APPENDICES

Prepared for
U.S. Environmental Protection Agency
Region 10
1200 Sixth Avenue
Seattle, Washington 98101

Contract No. 68-W9-0046
Work Assignment No. 46-23-0JZZ
Work Order No. 4000-19-38-4100
Document Control No. 4000-19-38-AAAL

April 1999

Prepared by
Roy F. Weston, Inc.
700 Fifth Avenue
Suite 5700
Seattle, WA 98104-5057

ARCS QUALITY ASSURANCE CONCURRENCE

Site Inspection Report
Lower Duwamish River (RK 2.5 to 11.5)
Seattle, Washington

Project Name:	Site Inspections—Multiple Sites
Contract Number:	68-W9-0046
Work Assignment Number:	46-23-0JZZ
Responsible Organization:	Roy F. Weston, Inc. 700 Fifth Avenue, Suite 5700 Seattle, Washington 98104

Concurrences:

Name: Keith A. Pine
Title: Project Manager, Roy F. Weston, Inc.

Signature: _____ Date_____

Name: Steve R. Fuller, RG
Title: QA Manager, Roy F. Weston, Inc.

Signature: _____ Date:_____

Name: Frank Monahan
Title: ARCS Program Manager, Roy F. Weston, Inc.

Signature: _____ Date_____

TABLE OF CONTENTS
VOLUME 1

TABLE OF CONTENTS *(Continued)*

Section Page

TABLE OF CONTENTS *(Continued)*

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

SECTION 1

INTRODUCTION

Pursuant to United States Environmental Protection Agency (EPA) Contract No. 68-W9-0046, Multiple Site Inspections, and Work Plan Addenda (WESTON 1994a and 1998a) WESTON conducted a Site Inspection (SI) of sediments in the lower Duwamish River from river kilometer (RK) 2.5 to RK 11.5 (see Figure 1-1).

The EPA (SI) Site Investigation process evaluates actual or potential environmental hazards at a particular site relative to other sites across the nation for the purpose of identifying remedial action priorities. The SI, under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and the Superfund Amendments and Reauthorization Act of 1986 (SARA), is intended to collect sufficient data to determine a site's potential for inclusion on the National Priorities List (NPL) and establish priorities for additional action, if warranted.

The data collection efforts in the lower Duwamish River were also designed to complement and support the other ongoing environmental and beneficial use projects being conducted by various agencies and interested parties to restore and enhance aquatic habitats within the Duwamish River corridor.

This document represents a summary of the objectives, sampling activities, and results of the Duwamish River SI. Included are site background information (Section 2), project description (Section 3), sampling and analysis results (Section 4), and references.

2. BACKGROUND

SECTION 2

BACKGROUND

2.1 SITE LOCATION AND DESCRIPTION

The Duwamish River originates at the confluence of the Green and Black rivers near Tukwila, WA, then flows northwest for approximately 21 kilometers (km), bifurcating at the southern end of Harbor Island to form the East and West waterways prior to discharging into Elliott Bay. The study area for this SI extends from the southern tip of Harbor Island (RK 2.5) to approximately 1.5 kilometers upchannel of the head of navigation (RK 11.5), also referred to as the upper turning basin or Turning Basin #3. The portion of the river that is maintained by the U.S. Army Corps of Engineers (Corps) as a federal navigation channel (i.e., the reach downchannel of Turning Basin #3) is typically referred to as the Duwamish Waterway. Navigation depths maintained by the Corps within the waterway generally range from –15 feet mean lower low water (MLLW) to -30 feet MLLW (WESTON 1994b).

The shorelines along the majority of the Duwamish Waterway have been developed for industrial and commercial operations, as the waterway serves as a major shipping route for containerized and bulk cargo. Common shoreline features within the study area include constructed bulkheads, with manmade structures such as piers, wharves and buildings extending over the water, and steeply sloped banks armored with riprap or other fill materials (e.g., concrete slabs and miscellaneous debris). Intertidal habitats are dispersed in relatively small patches (i.e., generally less than one acre in size), with the exception of Kellogg Island, which represents the largest contiguous area of intertidal habitat remaining in the Duwamish River (Tanner 1991).

The Duwamish River/Green River system drains an area of approximately 483 square miles, with peak runoff occurring during winter rains, and low flow throughout the late summer dry season (WESTON 1994b). Stream flow for most of the Duwamish River is regulated by the Howard-Hanson dam upstream of the junction of the Green and Black rivers. The Corps has limited peak discharges to 12,000 cubic feet per second (cfs) at Tukwila and minimum flows to as low as 200 cfs, with an average flow of 1,500 to 1,800 cfs.

Tidal effects have been observed throughout the entire reach of the Duwamish River, resulting in characteristic estuarine stratification of the river: surface water is generally fresh or brackish; bottom water is more saline. This bottom layer (referred to as a “salt wedge”) oscillates with the river based on river flow volume and tidal stage, but tends to be persistent under low flow conditions and high tidal magnitude, being detected as far as 16 km upstream (WESTON 1994b).

Bottom sediment composition is variable throughout the study area. Available historical surface sediment data suggest the presence of coarser sediments (e.g., medium and coarse sands) in nearshore areas adjacent to combined sewer overflow (CSO) and storm drain (SD) discharges

and riprap or similarly constructed banks, as well as in subtidal (scour) areas in the vicinity of the bridges that cross the river (e.g., the First Avenue South and 16th Avenue South bridges). Finer-grained sediments (i.e., silts and clays) have generally been encountered in the remnant mudflats, along channel sideslopes, and within portions of the navigation channel.

2.2 INDUSTRIAL OPERATIONS AND PAST INVESTIGATIONS

Much of the upland areas adjacent to the project area are heavily industrialized, and marine traffic within the Duwamish Waterway is considered to be intensive. Historical or current commercial and industrial operations include cargo handling and storage; marine construction; boat manufacturing; maintenance and repair; marina operations; concrete and other stone material manufacturing and distribution; paper and metals fabrication; food processing; and airplane parts manufacturing. In addition, this reach of the river is the receiving body for discharges from numerous municipal SDs and CSOs, as well as multiple privately held outfalls and drains.

Numerous past investigations within the Duwamish Waterway have been conducted with varying scopes. Some of the historical studies focused on specific properties, while the remaining studies were riverwide and incorporated sediment sampling as only one component of the entire study. These past sediment studies have indicated that polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), metals (e.g., mercury), miscellaneous organic compounds (e.g., phthalate esters and chlorinated benzenes), pesticides, and organotins are present in the river sediments at concentrations that may cause deleterious effects to humans and aquatic organisms. PCBs and bis(2-ethylhexy)phthalate appear to be the most widespread contaminants of potential concern, followed by metals (primarily mercury and zinc) and PAHs. These contaminants may have entered the river via several transport pathways or mechanisms, including spillage during product shipping and handling, direct disposal or discharge, contaminated groundwater discharge, surface water runoff, stormwater discharge, or contaminated soil erosion.

2.3 REGIONAL GEOLOGY

The regional geology of the Seattle area is dominated by recent tectonics and Quaternary glaciations. Drift unconsolidated glacial materials and nonglacial deposits cover structurally deformed Tertiary bedrock comprising marine and estuarine sandstone, shale, and conglomerate, in addition to basalt, andesite, and volcaniclastic rocks. Drift units, separated by nonglacial sediments, from at least five major glaciations are recognized. The last glacier retreated from the Seattle area about 13,500 years before present. Each glaciation is characterized by a complex sequence of lacustrine (lake) deposits, advance outwash (river sediment), glaciomarine drift, till, and recessional outwash. The preservation of these deposits is patchy due to the erosion and deposition during the succeeding nonglacial and glacial intervals. The nonglacial intervals are represented typically by alluvial deposits (Galster and Laprade 1991).

The dominant post-glacial stratigraphy, which occupies relict subglacial meltwater channels scoured into advance outwash and older deposits during recession of the Puget lobe, consists of large, prograding river-mouth deltaic sequences that interfinger with marine embayment deposits. The Duwamish River valley is a relict trough and post-glacial ancient marine embayment, which has been filled with sediment in the past few thousand years by the prograding ancestral Duwamish river-mouth delta (Dragovich et al. 1994).

2.4 CHANNEL DYNAMICS

The original topography of the lower Duwamish River valley has been modified. Prior to development of the Duwamish River valley, the land surface consisted of low-lying floodplains and tidal flats. Prior to 1918, the Duwamish River was widely meandering. The natural slips cutting into the riverbank today are the only evidence of the river's original meandering course. During the period between 1910 and 1920, the lower portion of the river was channelized to create the Duwamish Waterway. The former river channel and surrounding floodplains were filled and graded to form the present-day topography.

2.5 AQUATIC RESOURCES AND CRITICAL HABITATS

The Duwamish River serves as a migratory route, nursery, and osmoregulatory transition zone for several species of Pacific salmon, including coho (*Oncorhynchus kistuch*), chinook (*O. tshawytscha*), chum (*O. keta*), pink (*O. gorbuscha*), as well as steelhead (*O. mykiss*) and cutthroat trout (*O. clarki*) (WESTON 1998b). Chinook and coho utilize Elliot Bay and the Duwamish estuary more extensively than any of the other species (WESTON 1998b). The runs are composed of native and hatchery-reared salmon as a result of the state hatchery program located on the Green River. As part of a continuing effort to protect dwindling Pacific salmon stocks, the Puget Sound chinook salmon has recently been listed as a threatened species under the Endangered Species Act.

The Duwamish River is part of the traditional fishing grounds for the Muckleshoot and Suquamish tribes. During seasonal migration runs, tribal members engage in a gillnet fishery for various commercially important salmonid species (e.g., chinook and coho salmon). The stocks also receive pressure from recreational fishing, which is popular at various public access locations along the lower reaches of the river.

There is a diverse assemblage of avian species present within the lower Duwamish River estuary. Both migratory and resident species of shorebirds, waterfowl, seabirds, songbirds, and raptors can be observed throughout much of the year. Piscivorous species recorded in the lower estuary include kingfisher and great blue heron. Raptors, such as hawks, bald eagles, and ospreys also reside and/or frequent the Duwamish corridor (WESTON 1994b). An active osprey nest located on the Birmingham Steel property was observed during the SI site reconnaissance, as well as during the field sampling program. It is also not uncommon to find bald eagles nesting in the

underdeveloped open spaces or parks in West Seattle. The type of habitat use is not well documented for any of these species, but at a minimum, the lower Duwamish estuary serves as an adult and juvenile forage area.

Mammals such as otters and muskrats have been observed along the Duwamish River corridor. Marine mammals, including harbor seals (*Phoca vitulina*), and California sea lions (*Zalophus californianus*) are known to frequently forage in Elliott Bay and have been sighted in the Duwamish Waterway (WESTON 1994b). Both harbor seals and California sea lions are classified by the Washington Department of Fish and Wildlife as state monitor species (WESTON 1998b).

2.6 POTENTIAL CONTAMINANT TRANSPORT PATHWAYS AND RECEPTORS

2.6.1 Sediment

Sediments located in areas of direct deposition of waste materials or receiving contaminated surface water or groundwater drainage may act as a receptor, and, in turn, also act as a source, because the sediments can retain contaminants. In addition, sediments can act as a source of contaminants to locations distal from the original source materials because they can be transported by tides, currents, and wave action. Aquatic organisms represent additional receptors that may be impacted by sediment-bound contaminants due to exposure via dermal contact, respiration, or direct ingestion. Exposed lower trophic-order organisms also provide a pathway for exposure of higher trophic-order organisms via ingestion of contaminated prey. The potential for sediments to act as a receptor and a source was evaluated through the collection and chemical analysis of surface and subsurface sediments and sediment porewater from locations throughout the 9-kilometer study area.

2.6.2 Surface Water

The surface waters of the Duwamish River represent the principal surface water receptor. The primary and secondary ecological receptors associated with this aquatic habitat include anadromous and resident populations of fish, and numerous piscivorous birds, migratory waterfowl, raptors, and mammals. As described above, in addition to direct deposition, transport of contaminants to the surface waters of the Duwamish River may have occurred via stormwater runoff, direct discharge (i.e., storm drains and CSO discharges), tidal flushing, or groundwater transport. However, water quality was not directly evaluated as a part of this project.

2.6.3 Soil

Although this medium may represent a source of contamination or an exposure mechanism to terrestrial receptors, soil conditions associated with adjacent upland areas were not evaluated as part of this investigation. However, soil that may have been eroded and transported to nearshore

sediment by stormwater flow was evaluated as part of the sediment pathway through collection of nearshore surface and subsurface sediment samples.

2.6.4 Groundwater

The groundwater pathway was not directly evaluated for this site, but the investigation of the sediment pathway would likely have captured areas of significant groundwater contamination that impacted sediment quality.

2.6.5 Air

The air pathway was not directly evaluated for this site, but the investigation of the sediment pathway would likely have captured potential impacts to riverine areas receiving significant particulate matter from the upland properties adjacent to the Duwamish River.

3. PROJECT DESCRIPTION

SECTION 3

PROJECT DESCRIPTION

3.1 SAMPLING OBJECTIVES

The EPA SI process is used to determine actual or potential environmental hazards at a particular site relative to other sites across the nation for the purposes of identifying remedial action priorities. This project was designed to collect sufficient data to support an SI evaluation for a 9-kilometer section of the Duwamish River, as well as other ongoing environmental efforts being conducted by various agencies and interested parties.

The purpose of this investigation was to provide a screening level evaluation of sediment quality in the Duwamish River. Accordingly, the following sampling objectives were identified for this investigation:

- Characterize the nature and areal extent of contaminant distribution in surface (0-10 cm) sediments.
- Preliminarily characterize the nature and vertical extent of sediment contaminant distribution in shallow (up to 1.21 m below mudline) subsurface sediments in localized areas.
- Obtain sediment porewater samples to evaluate the potential bioavailability of organotins and metals to aquatic receptors.

3.2 SAMPLE TYPES, NUMBERS LOCATIONS AND RATIONALE

In total, 300 stations were sampled and analyzed for various contaminants as part of this SI effort. The following is a breakdown of the number of stations and samples collected for each media. A graphical representation of station location and identification is depicted in Maps 3-1 through 3-3.

3.2.1 Surface (300 stations)

- 312 surface sediment samples
- 300 primary surface (0 to 10 cm) sediment samples
- 12 duplicate surface (0 to 10 cm) sediment samples

3.2.2 Subsurface (17 stations co-located with selected surface sediment sample station)

- 35 subsurface sediment samples
- 17 primary subsurface (0 to 0.6 m) sediment samples
- 1 duplicate subsurface (0 to 0.6 m) sediment samples

- 16 primary subsurface (0.6 to 1.2 m) sediment samples
- 1 duplicate subsurface (0.6 to 1.2 m) sediment sample

3.2.3 Porewater (15 stations co-located with selected surface sediment sample station)

- 16 surface sediment porewater samples
- 15 primary surface (0 to 10 cm) sediment porewater
- 1 duplicate surface (0 to 10 cm) sediment porewater

Surface, subsurface, and sediment porewater analyses performed at each station are depicted in Maps 3-4 through 3-6.

Split samples were provided to two interested parties owning properties adjacent to the study area. Information detailing interested parties and split sampling locations is provided in Table 3-1.

3.3 SAMPLING METHODS, ANALYTICAL REQUIREMENTS, AND STATION LOCATIONS

3.3.1 Sampling Methods

3.3.1.1 Surface Sediment Sampling

Subtidal surface sediments were collected using a stainless-steel modified 0.1 m^2 van Veen grab sampler in accordance with the procedures outlined in the sampling and analysis plan (SAP; WESTON 1998a). Up to eleven grabs were required at each station to achieve sufficient sediment volumes for bulk chemical and porewater analyses. Penetration depths for acceptable grabs ranged from 5 to 17 cm, depending on sediment type.

Observations of sediment composition were made for each sample and recorded on the appropriate field sample record forms (see Appendix A). Samples were placed in a stainless-steel container for homogenization; homogenized samples were placed in labeled precleaned sample jars or decontaminated high-density polyethylene (HDPE) buckets in the case of porewater samples. All sample containers were subsequently packed in coolers with ice for shipment.

3.3.1.2 Subsurface Sediment Sampling

Subsurface sediment samples were generally collected in accordance with the SAP (WESTON 1998a), with the exception of the size of the gravity corer selected for use. Based on past experience with coring in the Duwamish River, it was recommended that a 10.2 cm corer configured with a 1.52 m stainless-steel core barrel and a 317 kg weight stand be used, (Eaton 1998). Core recovery lengths varied throughout the study area depending on sediment type, and

ranged from 0.7 to 1.4 (m), with an average recovery of 1.3 (m). A summary of the actual recovery lengths is provided in Table 3-2.

Core processing was conducted aboard the sampling vessel. Sediment from each core was extruded onto a decontaminated 1.5 (m) stainless-steel tray by elevating the tube at an angle. When necessary, the core was tapped with a rubber mallet to loosen the sediment from the core barrel. Care was taken to ensure that samples were extruded slowly to maintain the integrity of the core. Once the core was extruded onto the tray, observations of sediment composition were made and recorded on the appropriate field sample record forms (see Appendix B). Samples were then placed in stainless-steel bowls for homogenization; homogenized samples were subsequently placed in labeled precleaned sample jars. All sample containers were packed in coolers with ice for shipment.

3.3.2 Analytical Requirements

In general, all samples were analyzed in accordance with the methods and procedures specified in the SAP (WESTON 1998a). A few minor deviations from the proposed sample analytical requirements occurred, as follows:

- Surface sediment organotin analyses were inadvertently omitted during the field sample collection effort at stations DR013, DR109, DR139, DR190, and DR228.
- Physical conditions encountered in the field, including the presence of obstructions (e.g., overhead lines, moorage lines, moored vessels, shallow water, and impenetrable substrates composed of gravel, large rocks, and wood debris prohibited the collection of surface and subsurface sediment samples at several originally proposed sampling locations. As a result, some stations were deleted from the sampling effort, and alternate locations were evaluated as substitutes and sampled when appropriate conditions permitted. Where necessary, subsurface sediment analyses were also modified to coincide with that of the co-located surface sediments. A list of the samples affected, analytical changes, and justification for deviation is provided in Table 3-3.

Chemical analyses conducted at each surface sediment sampling location (including porewater stations) are presented in Tables 3-4 through 3-7. Chemical analyses conducted at each subsurface sediment sampling location are presented in Table 3-8.

3.3.3 Station Locations

3.3.3.1 Surface Sediment Stations

Considerable effort was made to collect surface sediment at or within close proximity of the sampling locations identified in the SAP. However, as described in Section 3.3.2, sampling locations had to be relocated due to physical obstructions or poor substrate conditions in several instances. Under the latter condition, multiple attempts were made before the given station was abandoned. In some cases, an appropriate alternate site was established and sampled

accordingly. A description of the sites affected and the corrective action taken is provided in Table 3-3. Complete station coordinates are provided in Appendix C.

3.3.3.2 Subsurface Sediment Stations

Considerable effort was made to co-locate subsurface sediment sampling locations within 3 meters of the previously occupied surface sediment sampling locations. However, in several instances, subsurface sediment conditions prohibited adequate recovery of subsurface sediment. If an adequate sample could not be obtained after numerous attempts, then the station was abandoned or moved to an area of more favorable sampling conditions that had previously been sampled for surface (0 to 10 cm) sediment. Station-positioning modifications are detailed in Table 3-3. Complete station coordinates are provided in Appendix C.

3.4 SAMPLE HANDLING, PACKAGING, AND SHIPPING

Samples were handled, packaged, and shipped in accordance with the procedures specified in the SAP (WESTON 1998a).

3.5 DOCUMENTATION

All field documentation, sample designation and labeling, and chain of custody procedures were followed in accordance with the procedures specified in the SAP (WESTON 1998a).

3.6 EQUIPMENT DECONTAMINATION AND INVESTIGATION-DERIVED WASTE

Procedures specified in the SAP (WESTON, 1998a) for decontaminating equipment and disposing of investigation-derived wastes (IDW) were followed during field activities.

4. SAMPLING RESULTS

SECTION 4

SAMPLING RESULTS

The following sections present analytical data generated during this SI. A log summarizing individuals and affiliated agencies contacted during the course of this SI is provided in Appendix D. Chain-of-custody forms and data validation reports can be provided by EPA Region 10 upon request.

4.1 DATA PRESENTATION

Analytical data tables for surface, subsurface, and surface sediment porewater are presented in Appendix E, along with a list of data qualifiers. Analytical data are reported as follows:

- Sediment inorganic concentrations are expressed in units of milligram per kilogram (mg/kg) dry-weight
- Sediment organic concentrations are expressed in units of microgram per kilogram (µg/kg) dry-weight; sediment nonionic/nonpolar organics are also expressed in units of µg/kg-organic carbon (i.e., the dry-weight concentration was normalized to the organic carbon content of the sample by dividing the chemical concentration by the sample-specific decimal fraction of organic carbon).
- Sediment porewater inorganic concentration and organotin compound concentration are expressed in units of microgram per liter (µg/L).
- Sediment organotin concentrations are expressed in units of µg-ion/kg-dry weight and µg-ion/kg-organic carbon
- Sediment total organic carbon (TOC) content and grain size fractions are expressed as percentages.

4.2 DATA EVALUATION METHODS

4.2.1 Comparisons with Effects-Based Screening Values

Average and range of concentrations have been provided in the analytical results section of this report for selected analytes found to be at elevated concentrations and/or possess a wide distribution throughout the study area. Because information collected as part of this investigation may be used by various regulatory agencies, including the National Oceanic and Atmospheric Administration (NOAA), Washington State Department of Ecology (Ecology), and the EPA, the sediment and porewater data were also compared to several effects-based screening guidelines to assist in the interpretation of potential risks associated with exposures to these media at the site. The screening guidelines used for such comparisons include:

4.2.1.1 Sediment Screening Guidelines

- Washington State Sediment Management Standards (SMS) Sediment Quality Standard (SQS) and Cleanup Screening Level (CSL) (WAC 173-204). SQS are long-term cleanup goals that correspond to a sediment quality that will not result in adverse effects to biological resources. CSL are less stringent standards that correspond to minor adverse effects to biological resources; they are typically used to determine if remediation is required in a specific area.
- The SMS include TOC-normalized criteria for nonionic/nonpolar organic compounds. However, these criteria are generally only effective at predicting adverse effects in sediments with TOC content greater than 0.5 percent (Michelsen 1997). Also, in cases where high TOC (greater than 3 to 4 percent) may be due to some anthropogenic contribution (e.g., oils and wood debris), TOC normalization may not be appropriate. Where TOC exceeded 4 percent, concentrations of nonionic/nonpolar organic chemicals for these samples were compared with the Apparent Effects Threshold (AET) values (Barrick et al. 1988). The AET values are the functional equivalent of the SQS and CSL values, only they are expressed on a dry-weight basis. The lowest AET (LAET) was used as the equivalent of the SQS, and the second lowest AET (2LAET) was used in place of the CSL.

4.2.1.2 Porewater Screening Guidelines

- Federal marine chronic and acute Ambient Water Quality Criteria (AWQC; EPA 1995). As a requirement of the Clean Water Act (CWA), ambient water quality criteria have been published for the protection of aquatic organisms and human health (40 CFR 131). Acute values are designed to protect for short-term exposures to higher concentration, whereas chronic criteria address long-term exposures. While not promulgated standards, states and tribes are expected to adopt these criteria as their standards or develop criteria affording a similar degree of protectiveness.
- Washington State marine acute and chronic AWQC (WAC 173-201A). State water quality standards have been promulgated and incorporate the federal criteria in large measure.
- EPA proposed marine acute and chronic AWQC for tributyltin (TBT; EPA 1997). These guidelines are based on protection of most invertebrates and fishes, but do not protect for the most sensitive life stages or taxa.

These comparisons are only depicted in the graphical representations contained within Volume 2 of this report and are not discussed in the analytical results section. Summaries of the above screening guidelines, as well as other potentially applicable effects-based screening values, are provided in Appendix F.

4.2.2 Additional Evaluations of TBT Data

No standards are available for evaluating tributyltin in sediment. However, screening guidelines have been proposed for evaluation of TBT for use in several Puget Sound sediment management

programs. The guidelines are based on partitioning theory and estimate a threshold sediment concentration based on an effects concentration in water. The following formula is used to calculate the sediment concentration of TBT:

$$[TBT]_{sed\ oc} = [TBT]_{pw} * K_{oc}$$

Where:

$[TBT]_{pw}$ = Concentration of TBT in porewater (µg/L)

$[TBT]_{sed\ oc}$ = Concentration of TBT in sediment (µg/kg oc)

K_{oc} = Organic carbon partition coefficient (L/kg)

For the purpose of this study, the PSDDA porewater screening guideline of 0.15 µg TBT/L was used to calculate a lower-end sediment screening concentration of 3,765 µg/kg oc, based on a K_{oc} of 25,100 (Meador et al. 1997). An upper-end sediment screening value was derived based on the marine acute water quality criterion and resulted in a concentration of 9,287 µg/kg oc. A TOC of 1 percent was used to calculate the dry weight equivalents for these screening concentrations.

4.3 ANALYTICAL RESULTS

4.3.1 Surface Sediment

4.3.1.1 Polychlorinated Biphenyls (PCBs)

PCBs were analyzed at all surface sediment sampling stations. Total PCBs were detected at 91 percent of these stations. Total PCB concentration averaged 334 µg/kg and ranged from 20 to 12,000 µg/kg dry-weight (DW). The highest measured total PCB concentration occurred in Reach C at station DR207. Aroclors 1254, 1260, and 1242 were the only PCB Aroclors detected. Aroclor 1254 was detected at 89 percent of the stations at concentrations ranging from 20 to 9,400 µg/kg DW. Aroclor 1260 was also frequently detected at 85 percent of the surface sediment stations. The highest measured concentration for Aroclors 1254 and 1260 occurred at station DR271 and DR207, respectively. Aroclor 1242 was infrequently detected at 13 percent of the stations. A statistical summary and complete listing of the PCB and PCB congener data are presented, as dry-weight concentrations, in Appendix E-1. A statistical summary and complete data listing of the TOC-normalized data can also be found in Appendix E-1. Map series 4-1 provides a graphical representation of the total PCB results for the entire waterway.

4.3.1.2 Base-Neutral Acid Extractables (BNAs)

BNAs were analyzed and detected at all surface sediment stations collected for this study. PAHs were most prevalent. Total high molecular weight PAHs (HPAHs) were encountered in

98 percent of the samples collected. Total HPAH concentration averaged 4,356 µg/kg and ranged from 20 to 50,840 µg/kg DW. The highest measured HPAH concentration was observed in Reach A at station DR044. Fluoranthene, chrysene, and indeno(1,2,3-cd)pyrene were also ubiquitous throughout the waterway.

Total low molecular weight PAHs (LPAHs) and phenanthrene were detected at 97 percent of the surface sediment stations sampled. Total LPAH concentration averaged 791 µg/kg and ranged from 30 to 20,030 µg/kg DW. Phenanthrene averaged 514 µg/kg DW and ranged from 30 to 16,000 µg/kg DW. The highest measured concentration for LPAHs and phenanthrene occurred in Reach C at station DR175. Acenaphthene, fluorene, phenol, and hexachlorobenzene were also encountered in the waterway.

Bis(2-ethylhexyl) phthalate and butyl benzyl phthalate were detected at 74 and 64 percent of the surface sediment sampling stations, respectively. Bis(2-ethylhexyl) phthalate averaged 568 µg/kg, and ranged from 20 to 11,000 µg/kg DW. Butyl benzyl phthalate concentration averaged 47 µg/kg, with a range of 20 to 940 µg/kg DW. The highest concentrations of both analytes occurred at station DR008. A statistical summary and a complete listing of the BNA data are presented, as dry-weight concentrations, in Appendix E-2. A statistical summary and complete data listing of the TOC-normalized data can also be found in Appendix E-2. Map series 4-2 through 4-13 provides a graphical representation of these BNA results for the entire waterway.

4.3.1.3 Total Inorganics

Analytical results indicate that total inorganics were detected at all surface sediment sampling stations. Mercury was detected in 96 percent of the surface sediment samples collected for this study. The average mercury concentration was 0.18 mg/kg and ranged from 0.02 to 1.6 mg/kg DW. The highest mercury concentration occurred in Reach B at station DR157. Arsenic and zinc were also detected at all surface sediment stations. Maximum concentrations for both analytes occurred in Reach A at station DR020. The highest lead concentration was recorded in Reach D at station DR254. Appendix E-3 provides a statistical summary of the data and a complete data listing. Map series 4-14 through 4-17 provides a graphical representation of mercury, arsenic, lead, and zinc at selected reaches.

4.3.1.4 Pesticides

Pesticides were analyzed at 47 of the surface sediment sampling stations. Pesticides were infrequently detected with exception to 4,4'-dichloro-diphenyl-trichloroethene (4,4'-DDT) and its associated metabolites (i.e., 4,4'-DDD and 4,4'-DDE). 4,4'-DDT was detected in approximately 11 percent of those samples analyzed for this analyte. 4,4'-DDT had a mean concentration of 42 µg/kg and ranged from 2 to 1,670 µg/kg DW. The highest concentrations of 4,4'-DDT, 4,4'-DDD, and 4,4'-DDE were detected in Reach C at station DR178. Appendix E-1 provides a statistical summary of pesticide data and a complete listing of the data. Map series

4-18 through 4-20 provides a graphical representation of the 4,4'-DDT, 4,4'-DDD, and 4,4'-DDE results at selected reaches.

4.3.1.5 Dioxins/Furans

Analyses for dioxins/furans were conducted at 30 surface sediment sampling stations. Analytical results indicate that dioxins/furans were detected at all stations. For this study, total 2,3,7,8-TCDD (equivalence) was used as a measure of the relative toxicity of the various congeners identified. Total 2,3,7,8-TCDD (equivalence) had a mean concentration of 16 ng/kg, and ranged from below the method detection limit to 218 ng/kg DW. The highest concentration occurred in Reach B at DR123. Appendix E-4 provides a statistical summary and a complete listing of the data. Map series 4-21 provides a graphical representation of the total 2,3,7,8-TCDD results throughout the waterway.

4.3.1.6 Organotins

Organotins (reported as Organotin-ion) were analyzed at 92 of the surface sediment sampling stations. The most commonly detected organotin constituent was tri-n-butyltin (TBT), occurring in 92 percent of the samples analyzed for this analyte. TBT concentration averaged 70 µg/kg and ranged from 1 to 320 µg/kg DW, with the highest concentration identified at station DR002. Appendix E-5 provides a statistical summary of organotin data and a complete data listing. Map series 4-22 provides a graphical representation of the TBT results throughout the waterway.

4.3.1.7 Volatile Organic Compounds (VOCs)

VOCs were analyzed at 47 surface sediment sampling stations. VOCs were infrequently detected, with exception of 2-butanone. 2-Butanone was detected at 26 percent of the surface sediment stations sampled for this analyte. 2-Butanone concentrations averaged 30 µg/kg and ranged from 5 µg/kg to 35µg/kg DW. The highest measured concentration occurred at station DR154. Appendix E-6 provides a statistical summary and complete listing of the VOC data, as dry-weight concentrations.

4.3.1.8 Total Organic Carbon (TOC)

TOC analysis was performed at all surface sediment sampling stations. Analytical results indicate that TOC averaged 2.2 percent. TOC ranged from 0.1 to 9.2 percent, with the highest concentration measured at DR042. Appendix E-7 provides a statistical summary and a complete listing of the TOC data. Map series 4-23 provides a graphical representation of TOC results for the entire waterway.

4.3.1.9 Grain Size

Grain size analysis was performed at all surface sediment sampling stations. Sediments were characterized as coarse if the total fines fraction was less than 55 percent fines. Sediments

identified as having 55 percent fines or greater were labeled as fine-grain sediments. As a result, the majority of stations sampled for this study were characterized as having fine-grain sediments. Analytical results indicate that stations averaged 65 percent total fines and 33 percent total sand. Total fines ranged from 1 to 97 percent, with the greatest percentage of fines occurring at station DR244. Total sands ranged from 3 to 99 percent. Station DR297 was identified as the station with the highest percentage of sands. Appendix E-7 provides a statistical summary and a complete listing of the grain size data. Map series 4-24 provides a graphical representation of grain size results for the entire waterway.

4.3.2 Subsurface Sediment

4.3.2.1 Polychlorinated Biphenyls

PCBs were analyzed at all of the subsurface sediment sampling stations. Total PCBs were detected at 76 percent of the subsurface stations analyzed and averaged 583 µg/kg, with a range of 37 to 4,043 µg/kg DW. The highest concentration was detected in Reach A at the 2- to 4-foot interval of station DR021. Aroclors 1254, 1260, and 1242 were the only PCB Aroclors detected. Aroclor 1254 was most frequently detected at 76 percent of the stations sampled. Concentrations of Aroclor 1254 ranged from 37 to 2,200 µg/kg, with the highest concentration measured at Reach A in the 0- to 2-foot interval of station DR068. Aroclor 1260 was also detected at many of the stations (73 percent) and ranged from 22 to 678 µg/kg DW. The maximum concentration of Aroclor 1260 was identified at the surface interval of station DR206 in Reach C. Aroclor 1242 was detected in 58 percent of the samples analyzed for this analyte. A statistical summary and complete listing of the PCB and PCB congener data are presented, as dry-weight concentrations, in Appendix E-8. A statistical summary and complete data listing of the TOC-normalized data can also be found in Appendix E-8. Map series 4-25 provides a graphical representation of total PCB results throughout the entire waterway.

4.3.2.2 Base-Neutral Acid Extractables

BNAs were analyzed at all subsurface sediment sampling stations and were frequently detected. Subsurface sediment results were similar to that of the surface, due to the prevalence of PAHs. Total HPAH and LPAH were detected in every core sampled. Total HPAH concentration averaged 3,095 µg/kg DW, with a range of 80 to 15,080 µg/kg. The highest total HPAH concentration was measured at the 2- to 4-foot interval of station DR054. Fluoranthene, chrysene, and indeno(1,2,3-cd)pyrene were detected at this same station and interval.

Total LPAH and phenanthrene were detected at 100 percent of the subsurface samples collected. The total LPAH concentration averaged 411 µg/kg and ranged from 20 to 2,310 µg/kg DW. Phenanthrene averaged 252 µg/kg DW and ranged from 20 to 1,500 µg/kg. The highest measured concentration for LPAHs and phenanthrene occurred in Reach A at the 2- to 4-foot interval of station DR054. Acenaphthene, fluorene, phenol, and hexachlorobenzene were also encountered in the waterway.

Phthalates were frequently detected at subsurface stations, as well. Bis(2-ethylhexyl)phthalate and butyl benzyl phthalate were detected at 88 and 61 percent of the subsurface samples, respectively. Bis(2-ethylhexyl) averaged 741 µg/kg and ranged from 30 to 6,900 µg/kg DW. The maximum concentration was measured at the 0- to 2-foot interval of station DR008. Butyl benzyl phthalate ranged from 20 to 670 µg/kg, with an average concentration of 70 µg/kg DW. The highest measured concentration of butyl benzyl phthalate was observed at station DR008, 2 to 4 feet below the surface. A statistical summary and a complete listing of the BNA data are presented, as dry-weight concentrations, in Appendix E-9. A statistical summary and complete data listing of the TOC-normalized data can also be found in Appendix E-9. Map series 4-26 through 4-37 provides a graphical representation of these BNA results throughout the waterway and selected reaches.

4.3.2.3 Total Inorganics

Total inorganics were analyzed at all subsurface sediment sampling stations. Analytical results indicate that total inorganics were detected at all stations. Mercury was detected at 100 percent of the subsurface sediment samples collected for this study. The average mercury concentration was 0.30 mg/kg and ranged from 0.06 to 1.44 mg/kg DW. The highest measured concentration occurred at the 2- to 4-foot interval of station DR054 in Reach A. The highest concentrations of arsenic, lead, and zinc were also measured at DR054. Appendix E-10 provides a statistical summary and a complete listing of the total inorganic data. Map series 4-38 through 4-41 provides a graphical representation of mercury, arsenic, lead, and zinc at selected reaches.

4.3.2.4 Pesticides

Pesticides were analyzed at 8 of the subsurface sediment sampling stations. Pesticides were infrequently detected, with the exception of 4,4'-DDD and 4,4'-DDE. 4,4'-DDD was detected in 44 percent of the samples analyzed for this metabolite and ranged from 2 to 14 µg/kg DW. The highest concentration occurred at station DR008, 2 to 4 feet below the surface. 4,4'-DDE was detected at a frequency of 63 percent, with a range of 1 to 18 µg/kg DW. The highest 4,4'-DDE concentration was detected in Reach A at the 2- to 4-foot interval of station DR021. A statistical summary and complete data listing of the pesticide data, as dry-weight concentrations, are presented in Appendix E-8. Map series 4-42 through 4-44 provides a graphical representation of the 4,4'-DDT, 4,4'-DDD and 4,4'-DDE results at selected reaches.

4.3.2.5 Organotins

Organotins (reported as organotin-ion) were analyzed at 13 of the subsurface sediment sampling stations. The most commonly detected organotin was TBT, occurring in 80 percent of the samples analyzed for this analyte. TBT concentration averaged 235 µg/kg DW, and ranged from 3 to 2,500 µg/kg. The highest TBT concentration was measured at the surface interval of station DR054. Appendix E-11 provides a statistical summary and complete data listing of organotin data in subsurface sediments. Map series 4-45 provides a graphical representation of the TBT results throughout the waterway.

4.3.2.6 Total Organic Carbon

TOC analysis was performed at all subsurface sediment sampling stations. Analytical results indicate that TOC averaged 2.2 percent. TOC ranged from 0.8 to 3.6 percent, with the highest concentration measured at DR008. Appendix E-12 provides a statistical summary and complete data listing of the TOC data.

4.3.2.7 Grain Size

Grain size analysis was performed at all subsurface sediment sampling stations. Analytical results indicate that subsurface stations averaged 76 percent total fines and 23 percent total sand. Total fines ranged from 30 to 94 percent, with the greatest percentage of fines occurring at the 2- to 4-foot interval of stations DR044. Total sands ranged from 6 to 69 percent. The highest percentage of sands was identified at the 2- to 4-foot fraction of station DR269. Appendix E-12 provides a statistical summary and complete data listing of the grain size data.

4.3.3 Sediment Porewater Analysis

4.3.3.1 Total Inorganics

Total inorganics were analyzed at all surface sediment porewater stations. Analytical results indicate that total inorganics were detected at all stations. Arsenic was detected at 80 percent of the surface sediment porewater stations. Arsenic concentration averaged 53 µg/L and ranged from 26 to 114 µg/L. The highest measured concentration occurred at station DR244. Appendix E-13 provides a statistical summary and a complete data listing of the surface sediment porewater data. Map series 4-46 provides a graphical representation of surface sediment porewater results for arsenic throughout the entire waterway.

4.3.3.2 Organotins

Organotins were analyzed at all surface sediment porewater sampling stations. The most commonly detected organotin constituent was TBT; occurring in 53 percent of the samples analyzed for this analyte. Detected TBT concentrations ranged from less than the method detection limit to 0.08 µg/L, with the highest concentration measured at station DR055. Appendix E-14 provides a statistical summary and a complete data listing of organotin data in surface sediment porewater. Map series 4-47 provides a graphical representation of surface sediment porewater results for TBT throughout the entire waterway.

5. REFERENCES

SECTION 5

REFERENCES

Barrick, R., S. Becker, L. Brown, H. Beller, and R. Pastorak. 1988. Sediment Quality Values Refinement: 1988 Update and Evaluation of Puget Sound AET. Prepared for the Office of Puget Sound Estuary Program, U.S. Environmental Protection Agency, Region 10, Seattle, WA. PTI Environmental Services, Bellevue, WA.

Dragovich, J.D., P.T. Pringel, and T.J. Walsh, 1994. Extent and Geometry of the mid-Holocene Osceola Mudflow in the Puget Lowland-Implications for Halocene Sedimentation and Paleogeography, Washington Geology, Vol. 22, No. 3.

Eaton, C. 1998. Research Contractor, Seattle, WA. Personal communication with D. Hughes, Roy F. Weston, Inc., Seattle, WA.

Galster, RW, and WT Laprade. 1991. Geology of Seattle, Washington, United States of America. *Bulletin of the Association of Engineering Geologists.* Vol. XXVIII, No., 3. August 1991.

Meador, J.P., C.A. Krone, D.W. Dyer, and V. Varanasi. 1997. Toxicity of Sediment-Associated Tributyltin to Infaunal Invertebrates; Species Comparison and the Role of Organic Carbon. Marine Environmental Research. 43(3):219-241.

Michelsen, T. 1997. Washington Department of Ecology, Bellevue, Washington. Personal communication with N. Musgrove, Roy F., Weston, Inc., Seattle, WA.

Tanner, C.D. 1991. Potential Intertidal Habitat Restoration Sites in the Duwamish River Estuary. Prepared for Port of Seattle Engineering Department, Seattle, WA and U.S. EPA, Environmental Evaluation Branch, Seattle, WA. December.

U.S. EPA. (U.S. Environmental Protection Agency). 1997. Draft Ambient Water Quality Criteria for Tributyltin.

U.S. EPA. 1995. Interim Draft Water Quality Criteria Summary Concentrations.

WESTON (Roy F. Weston, Inc.). 1998a. Sampling and Analysis Plan, Duwamish River Site Inspection, Seattle, WA. Prepared for U.S. Environmental Protection Agency, Region 10, Seattle, WA. July 1998.

WESTON. 1998b. Pacific Sound Resources (PSR) Marine Sediments Unit Remedial Investigation Report-Appendix K, Technical Memorandum, Ecological and Human Health Risk Assessments. Prepared for U.S. EPA, Region 10, Seattle, WA. April.

WESTON. 1996. Recommendations for Screening Values for Tributyltin in Sediments at Superfund Sites in Puget Sound. Prepared for U.S. EPA, Region 10, Seattle, WA. October.

WESTON. 1994a. Site Inspections-Multiple Sites, Quality Assurance Program Plan. March.

WESTON. 1994b. Harbor Island Remedial Investigation Report (Part 2-Sediment). Prepared for U.S. EPA, Region 10, Seattle, WA. September.